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Original Research Article

Assessment of the resilience of urban tourism flow network structure based on the impact of COVID-19: A case of Chongqing

Zhangjun Wang[1], Xiaoman Zhou[2], Zhongquan Fang[3*]

[1] *School of Culture and Tourism, Chongqing City Management College, Chongqing 401331, China.*

[2] *School of geography and Tourism, Chongqing Normal University, Chongqing 401331, China.*

[*3] *Department of Tourism Management, Tourism college, Beijing Union University, Beijing 100101, China. E-mail: fzq33@sina.com*

ABSTRACT

Based on the change data of network comments of tourist attractions in the central urban area of Chongqing from 2019 to 2021, the urban tourism flow network of Chongqing before and after the epidemic was constructed in stages based on the gravity model. And from the three dimensions of resistance, resilience and adaptability, the six measurement indicators of network load, stability, growth, hierarchy, matching and transmission are evaluated. The results show that: 1) Although the comprehensive indicator of network load of urban tourism flow in Chongqing is seriously impacted by the COVID-19 pandemic, the network structure of tourism flow has obvious resilience in the indicators of stability and growth. 2) COVID-19 helps to force the optimization of tourism flow network structure. The hierarchy of the urban tourism flow network structure in Chongqing tends to be flat, and the indicator of assortative shows obvious heterogeneity characteristics. 3) Transmission is a weak link in the network structure of urban tourism flow in Chongqing, which needs to be further optimized.

Keywords: tourism flow; network structure; resilience evaluation; COVID-19 pandemic; Chongqing

1. Introduction

Resilience originated from the Latin word "resilio", meaning to jump back to the original state. Holling introduced it into ecological research as a core introduction in 1973, and gradually attracted the attention of the academic community[1]. Since then, the concept of toughness has been widely used in sociology, economics, engineering, materials science and other fields[2–5]. As the concept of resilience emphasizes actively accepting external environmental challenges and improving the ability to respond to crises, resilience thinking provides a new perspective for regional economic research in the context of increasing global economic uncertainty[6,7], and also provides an important theoretical basis for the country's macro policy formulation of "transforming the mode and adjusting the structure". Since the COVID-19, the global tourism industry has suffered a severe setback, and

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urban tourism has shown a continuous adjustment process from resistance to recovery to active adaptation, which is highly consistent with the "process" advocated by the concept of "resilience"[8]. Assessing the urban tourism flow network structure based on the resilience theory is helpful to insight into the vulnerable links in the urban tourism flow network structure, and is of great significance for urban tourism destinations to formulate tourism policies scientifically, allocate tourism resources reasonably, and promote the sustainable and healthy development of urban tourism.

At present, toughness research is mostly at the theoretical level, and quantitative research is not yet mature[9]. In terms of quantitative measurement, it can be divided into two categories: Resilience surrogates and indicator system[10]. The toughness proxy method indirectly characterizes the system toughness by the change of the system core variables[11]. For example, Martin took the composition of the employed population as a proxy indicator to measure the resilience of the regional economy, and assessed the economic resilience of various regions in the UK by measuring the changes in the composition of the employed population in nine British industrial sectors[12]. The advantage of the flexible proxy method is that the proxy indicators are sensitive to the crisis response, emphasizing the process analysis based on time data, and the research results have strong practical significance. The index system method refers to the comprehensive assessment of toughness by establishing a series of measurement indexes. For example, the toughness analysis framework proposed by Rockefeller Foundation and the toughness index system proposed by Arup Engineering Consultants[13]. The indicator system method is more comprehensive than the flexible proxy method in terms of evaluation indicators, and the cross-sectional data is easier to obtain, so this method is more widely used in the research of regional economy and urban development. However, the indicator system approach focuses on the research of current characteristics, does not include the real external environment changes into the analysis framework, and is unable to assess the resilience of the system in response to specific impact events, such as resistance, recovery and adaptation. Because different research fields have different understanding of the connotation of toughness, there are obvious differences in the selection of indicators.

In recent years, network structure resilience has become a new research hotspot[14–17]. At present, the popular research paradigm includes two typical steps: Firstly, based on the concept of "flow", we use gravity model and other methods to measure the connection strength between space nodes and build the network structure of flow space. Secondly, with the help of social network analysis tools and measurement indicators, the network structure resilience of regional economic subsystems is evaluated. Common measurement indicators include hierarchy, matching, transmission, aggregation, diversity, etc. Generally, the flatter the hierarchy of the network structure, the higher the heterogeneity, the shorter the transmission path, the higher the compactness of aggregation, and the more diverse the contact methods between nodes, the stronger the anti-interference ability and the higher the toughness of the network[18,19]. This research paradigm abstracts complex economic activities into a network structure, which is intuitive and easy to understand and measure. However, there are two limitations. The research paradigm is essentially an indicator system approach, and the measurement indicators are mostly static indicators based on network topology, which is difficult to reflect the "process" advocated by resilience. At present, most of the research indicators mainly focus on the resilience or resilience of the network structure, less on the dimension of adaptability. The connotation of resilience is rich, including not only the ability to resist shocks in the short term, but also the ability to recover from lock-in effects after a period of time, and even the ability to adapt to new growth paths in the long run[20].

Based on this, this paper takes the central urban area of Chongqing, a typical urban tourism destination in China, as an example, and based on the change data of the network comments of tourist attractions in 2019 and 2021, builds the urban tourism flow network of Chongqing before and after the impact of the COVID-19 in stages, and comprehensively uses the resilience proxy method and the indicator system method to assess the resilience of multiple measurement indicators of the urban tourism flow network structure from the three dimensions of resistance, resilience and adaptability. It is expected to correctly grasp the resilience pattern of Chongqing's tourism industry under the impact of the COVID-19, and provide new ideas for optimizing the spatial layout of urban tourism resources and combating the impact of crisis events.

2. Materials and research methods

2.1. Data source

Phase division

The precursor effect of network attention is obvious, which is helpful to identify the development and evolution stages of events[21,22]. This paper combs the typical events that affect the development of urban tourism in Chongqing after the COVID-19, analyzes the coupling process of network attention about "epidemic" and "Chongqing tourism" in combination with Baidu index, and finally divides the urban tourism in Chongqing after the COVID-19 into three development stages with the same length, obvious characteristics and easy comparison (**Figure 1**). The resistance period is January 13, April 12, 2020, a total of 60 days. In this stage, the attention to the epidemic has increased sharply, and the willingness to travel has decreased sharply. The recovery period is from April 13 to July 11, 2020, a total of 60 days. At this stage, Wuhan has ended its "closure", and tourists' confidence in traveling has gradually recovered. The adaptation period is July 5, 2021 and October 3, 2021, totaling 60 days. In this stage, the sporadic outbreaks of COVID-19 cases and the continuous accompanying of tourism and the epidemic are the stages of fluctuating development of tourism under the background of normalization of epidemic prevention and control. The resistance period is recorded as T^1, the recovery period as T^2, and the adaptation period as T^3. In order to facilitate comparison, the same period of 2019 of the three stages is set as the reference period, which is respectively recorded as T^{1*}, T^{2*} and T^{3*}. The following indicators at different stages are also distinguished by the same superscript.

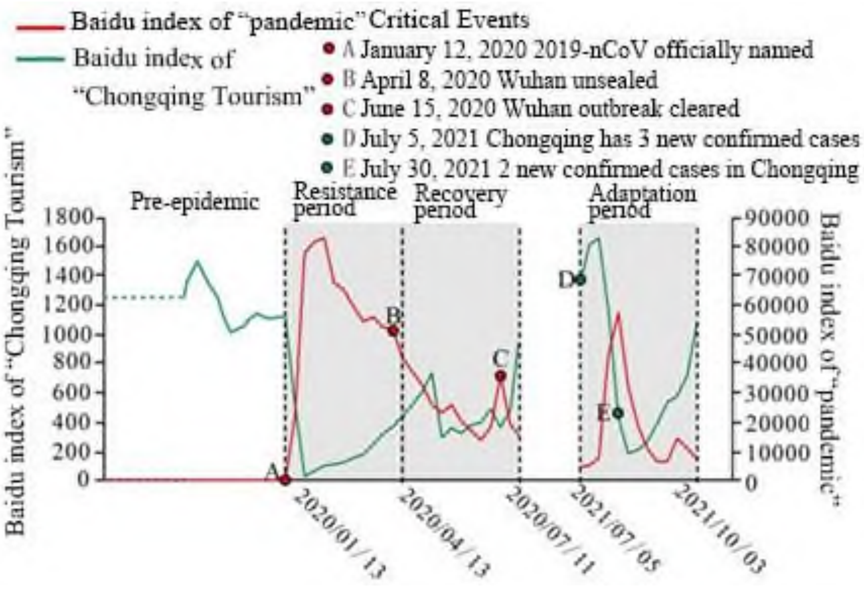

Figure 1. The coupling process between internet attention of COVID-19 pandemic and tourism for Chongqing.

Study area

The central urban area of Chongqing is selected as the study area (**Figure 2**) Chongqing's tourism economy is developed. Before the COVID-19, the total tourism revenue reached RMB 573,907 billion, ranking the second in China among cities above prefecture level. The central urban area of Chongqing, including Yuzhong District, Dadukou District, Jiangbei District, Shapingba District, Jiulongpo District, Nan'an District, Beibei District, Yubei District and Banan District, is the core space of urban tourism in Chongqing. Taking the central urban area of Chongqing as the research area has typical research significance.

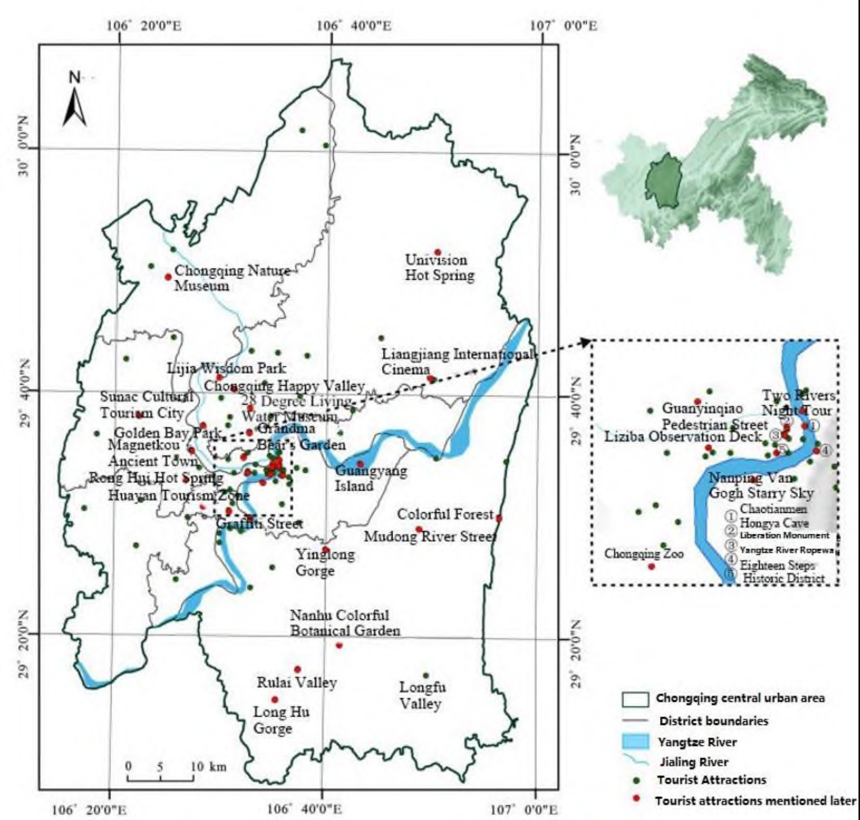

Figure 2. Location of the main urban area of Chongqing and the distribution of tourist attractions.

Research data

As the evidence of tourists' digital footprints, online reviews are an important indicator of tourist reception in tourist attractions and are widely used in tourism research[23–25]. The change in the number of comments indirectly reflects the change in the development pattern of tourist attractions. For example, Wei Haiyan and others built the Shanghai urban tourism flow network before and after the opening of Disney based on the tourists' comments on Donkey Mum's website, and then analyzed the impact of Disney's opening on Shanghai urban tourism[26]. Dianping.com has a large number of comments and high data quality, covering all scenic spots in the central city of Chongqing. In view of the high similarity between the data structure of Dianping.com and that of Mommy Donkey, Ctrip, Qunar, and the significantly higher number of comments than other platforms, the paper takes the rating of Dianping.com as the proxy index for the evaluation of the resilience of the urban tourism flow network structure, and uses technical means to obtain the online rating data of each tourist attraction in the central urban area of Chongqing in the resistance period, recovery period and adaptation period in 2019 and the same period in 2019. Considering that the rating of some small scenic spots is too low, their data changes are greatly interfered by random factors, and their statistical significance is insufficient, the scenic spots with rating less than 500 will be excluded. Finally, 292,963 comments from 97 scenic spots in downtown Chongqing were selected as the basic data for subsequent analysis (**Figure 2**).

2.2. Research methods

Construction of tourism flow network structure

The closer the tourist destination is and the more tourists are received, the easier it is to generate passenger flow exchange and form tourism flow[27]. Therefore, Newton's law of universal gravitation is widely used in the study of tourist flows[28–30]. Based on the comments of the public comment network of 97 scenic spots, this paper calculates the intensity of tourism flow among scenic spots before and after the impact of COVID-19 in the central city of Chongqing by stages based on the gravity model, to build a tourism flow network. The formula is as follows:

$$F_{ij} = \frac{(C_i \times C_j)}{D_{ij}^2} \quad (1)$$

Where F_{ij} is the intensity of tourism flow between scenic spot i and scenic spot j, reflecting the degree of tourism connection between the two scenic spots. C_i and C_j are the network comments of scenic spot i and j respectively. D_{ij} refers to the straight-line distance between two scenic spots.

Measurement index

The index system of network structure resilience is not unified yet, among which hierarchy, matching, transmission, aggregation, diversity and other indicators are relatively used. However, transmission, aggregation and diversity are all strongly related to the network density, and transmission is selected as the representative in this paper. As most indicators currently used are static indicators based on network topology, it is difficult to reflect the "process" advocated by resilience. Therefore, two dynamic indicators, stability and growth, are added on the basis of selecting hierarchy, matching and transmissibility as static indicators, and the network load is used as a comprehensive indicator to build a measurement index system of network structure toughness. **Table 1** shows the spatial significance of each measurement index.

Table 1. Indexes for measurement of network structure resilience

Evaluation indicators	Measurement index	Spatial meaning
Comprehensive	Network load (tourist flow intensity F)	Reflect the total passenger flow carried by the network
Dynamic indicators	Stability (QPA correlation coefficient r)	Reflect whether the network form has changed significantly
	Growth (number of non-empty nodes N)	Reflect the expansion or contraction of the network scale
Static indicators	Hierarchy (slope of degree distribution a)	Reflect the difference or balance degree between network nodes
	Matching (slope of degree correlation b)	Reflect the difference or similarity between network nodes and
	Transmissibility (average path length L)	Reflect the closeness of connection between network nodes

(1) Network load. The comment amount of tourist attractions is regarded as the load amount of network nodes, and the network load amount is the sum of the load amount of all nodes on the network. By comparing the size of the network load in different periods, it can reflect the change of the passenger flow carrying capacity of the tourism flow network. The network load is expressed in F.

$$F = \sum_{i=1}^{n} C_i \quad (2)$$

Where: F is the network load and C_i is the load of the ith node.

(2) Stability. Stability is an indicator to reflect whether the network structure changes significantly at different stages after the crisis. It can be checked by the secondary assignment procedure (QPA). QPA is a matrix based correlation analysis method, which can perform parameter estimation and statistical test for cross correlated values in the matrix[31]. The results of QPA correlation analysis can be calculated by Ucinet software. The stability was finally judged by the correlation coefficient r and the significance

level *p* value.

(3) Growth. Growth is an indicator of the expansion or contraction of the network scale. Affected by the epidemic, tourist attractions may be temporarily closed or closed, or may be added against the trend. When the scenic spots die out or the passenger flow is small enough to lose the connection with other scenic spots, we can judge such scenic spots as invalid nodes or empty nodes. The growth is represented by the number of non-empty nodes N.

(4) Hierarchy. Hierarchy is an indicator reflecting the degree of disparity between network nodes. We can draw a power curve, that is, the degree distribution curve, and calculate the slope by referring to the position scale rule. The higher the absolute value of the slope a of the degree distribution, the higher the hierarchy. Generally, the lower the hierarchy of the network structure, the stronger the network toughness. In the high-level network structure, a small number of nodes gather most of the traffic, which leads to obvious heterogeneity and serious polarization. Once the high-energy nodes are impacted, the network traffic will be seriously lost. Degree distribution formula:

$$\ln(K_i) = \ln(c) + a\ln(K_i^*) \tag{3}$$

Where: K_i is the centrality of node i, that is, the number of directly connected edges of node i; C is a constant; A is the slope of the degree distribution curve.

(5) Matching. Matching is an indicator that reflects the difference or similarity between network nodes and adjacent nodes. The closer the mean value of centrality between nodes and adjacent nodes is, the stronger the network structure homogeneity is. On the contrary, the stronger the histocompatibility is. In general, the network structure tends to be homogeneous, which will lead to regional locking and homogeneity, and is not conducive to the effective connection between core nodes and edge nodes. The stronger the homogeneity is, the worse the network structure toughness is. The measure of matching is usually expressed by the slope b of the degree correlation curve. Estimation formula of degree correlation curve:

$$\overline{K_i} = d + bK_i \tag{4}$$

Where: K_i is the centrality of node i; $\overline{K_i}$ is the average centrality of all nodes directly connected to node i; d is a constant; b is the slope of the degree correlation curve. If b>0, the network structure tends to be homozygous, and vice versa. The larger the absolute value, the stronger the property.

(6) Transmissibility. Transmissibility is an indicator reflecting the tightness of network nodes, expressed by the average path length of the network. The shorter the average path length of the network is, the closer the network nodes are connected and the higher the operation efficiency is. On the contrary, in the network with low transmission, if the intermediate node is impacted, the contact between the nodes at both ends will be interrupted. The formula of average path length is:

$$L = \frac{1}{N(N-1)} \sum_{i \neq j} d_{ij} \tag{5}$$

Where: L is the average path length; N is the number of points; d_{ij} is the distance between node i and node j.

Evaluation Dimension

Resilience is commonly used dimensions to study the resilience of regional economy, reflecting the process of recession and recovery of regional economy in the short term after the impact of the crisis. Considering the continuous fluctuation of the impact of the epidemic on the tourism industry, on this basis, adaptability is included in the assessment dimension above to reflect the continuous performance of the tourism industry accompanied by the epidemic. Since the values of static indicators in the measurement indicators are of realistic interpretation significance and do not require cross stage longitudinal comparison calculation, the resistance, resilience and adaptability of static indicators are represented by the actual values of the three stages respectively. Comprehensive indicators and dynamic indicators need cross stage comparative calculation, and the calculation formula is:

(1) The resistance of index i can be expressed as:

$$Res_i = \frac{X_i^1}{X_i^{1^*}} \times 100\% \tag{6}$$

Where: Res_i is the resistance of the ith measurement index; X_i^1 is the value of the ith measurement index in the resistance period; X_i^{1*} is the value of the ith measurement index in the resistance period in 2019. Generally, $0 \leq Res_i \leq 1$; The greater the Res_i the stronger the resistance. Resistance reflects the degree of risk resistance of measurement indicators.

(2) The resilience of the i-th index can be expressed as:

$$Rec_i = \frac{X_i^2}{X_i^{2^*}} \times 100\% \tag{7}$$

Where: Rec_i is the resilience of the ith measurement index; X_i^2 is the value of the ith measurement index in the recovery period; X_i^{2*} is the same period value of the ith measurement index in 2019 during the recovery period, and generally, $Rec_i \geq Res_i$ The greater the Rec_i the stronger the resilience. The resilience reflects the degree of recovery of the measurement index relative to the reference period.

(3) The adaptability of index i can be expressed as:

$$Adp_i = \frac{X_i^3}{X_i^{3^*}} / \frac{X_i^2}{X_i^{2^*}} \times 100\% \tag{8}$$

Where: Adp_i is the adaptability of the ith measurement index; X_i^3 is the value of the ith measurement index in the adaptation period; X_i^{3*} is the same period value in 2019 of the ith measurement index in the adaptation period. The larger the Adp_i, the stronger the adaptability. When $Adp_i < 1$, it indicates that the measurement index cannot continue to maintain the trend of recovery period, and the sustainable development ability is weak. On the contrary, the ability of sustainable development is strong. Adaptability reflects the degree to which the measurement indicators continue to get better or worse in the adaptation period compared with the recovery period.

In addition, the stability index reflects whether the network form has changed significantly in different stages compared with the same period in 2019. Therefore, the resistance, resilience and adaptability of the stability index are measured by the significance level of the three stages relative to the QAP analysis results in the same period of 2019.

3. Evaluation on the resilience of Chongqing urban tourism flow network structure

The premise of network structure resilience assessment is to build a tourism flow network. Based on the evaluation of 97 scenic spots in the downtown of Chongqing, the tourist flow network is constructed by stages based on the gravity model (**Figure 3**). Based on building the network, Ucinet software is used to extract the network topology, and six measurement indicators are evaluated from the three dimensions of resistance, resilience and adaptability.

3.1. Sub indicator characteristics

Network load

In the resistance period after the impact of the COVID-19 epidemic, the load of Chongqing's urban tourism flow network was only 9,982 comments, 31.36% of the same period in 2019. Chongqing's tourism industry is greatly impacted by the COVID-19, and its resistance is not strong. Among them, the network load of high-level tourist attractions located in the core area of the city, such as Liangjiang Night Tour, Chaotianmen Square, Hongya Cave, has decreased most significantly. Despite the huge impact of the epidemic, Chongqing's urban tourism rebounded rapidly. During the recovery period, the load of the tourist flow network reached 21,212, more than twice that of the resistance period, and recovered to 55.53% in the same period of 2019. Among them, the resilience of some tourism nodes, such as Grandma Xiong's Garden, Golden Bay Park, Huayan Tourist Area and Mudonghe Street, which are located outside the city and mainly serve local tourists, has exceeded 100%, and the network load is higher than the level of the same period before the epidemic. With the normalization of epidemic prevention and control, Chongqing's tourism has entered the adaptation period of fluctuation adjustment. The network load during the adaptation period is 13,686, 45.21% of the same period in 2019. At this stage, Chongqing's urban tourism did not maintain the rebound trend in the recovery period, but the decline was not obvious, and the adaptability was moderate, 82.19%.

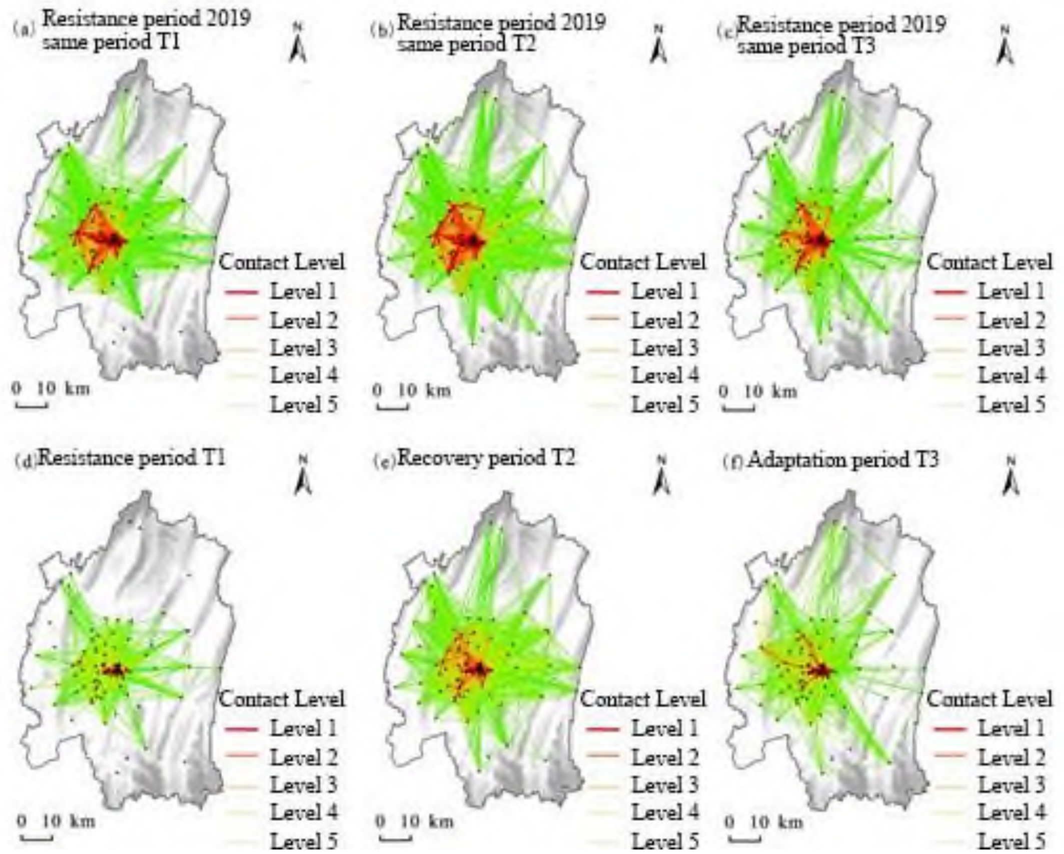

Figure 3. Distribution of network connection intensity of urban tourism flow in Chongqing for different stages.

Table 2. Correlation coefficients of network of urban tourism flow in Chongqing among different stages

	The same period	**Resistance period**	**Convalescence**	**Adaptation period**
The same period in 2019	-	0.589***	0.621***	0.334***

Resistance period	0.589***	-	0.578***	0.509***
convalescence	0.621***	0.578***	-	0.411***
Adaptation period	0.334***	0.509***	0.411***	-

Note: *** means passing 0.01 significance level test

Stability

Through the QAP correlation analysis (**Table 2**), it is found that the urban tourism flow network structure in Chongqing is highly similar to that in the same period of 2019 in the resistance period, recovery period and adaptation period, with the lowest correlation of 0.334 ($P < 0.01$), indicating that the stability of urban tourism flow network structure in Chongqing is high. Furthermore, from the changes in the correlation coefficients of the three stages and the same period in 2019, it can be found that the structure of Chongqing's urban tourism flow network shows a process from variation to recovery to further intensification of variation. This means that Chongqing's urban tourism structure has been adjusted repeatedly in the process of constantly adapting to the COVID-19, which is more and more different from that before the epidemic.

Growth

The number of non empty nodes in the network is extracted from the binary matrix of urban tourism flow in Chongqing at different stages. The results show that the number of non empty nodes in the network is 85, 93 and 95 in the resistance period, recovery period and adaptation period, respectively, which changes greatly compared with 91, 92 and 91 in the same period of 2019. During the resistance period, Huayan Tourist Area, Guangyang Island, Tongjing Hot Spring and other scenic spots actively responded to the epidemic prevention policy and closed the park continuously. Yinglong Gorge, Longhu Gorge, Colorful Forest and other scenic spots have a small passenger flow, which is even worse under the impact of the epidemic. The number of non empty nodes in the network is only 93.41% of the same period in 2019. During the recovery period, Huayan Tourist Area was reopened. A large number of scenic spots, such as Laigu, were revitalized. The 28 degree Living Water Pavilion and Lijia Smart Park were built and opened in the recovery period from scratch. The recovery of growth indicators was 101.09%. During the adaptation period, the network structure of urban tourism flow in Chongqing was dramatically adjusted. Nanping Van Gogh starry sky has never recovered, and the passenger flow of South Lake. Colorful Botanical Garden has declined sharply, but at the same time, Rongchuang Cultural Tourism City has been built and opened, and the traditional landscape area of the 18th Stairway and Guangyang Island have been renovated and upgraded to welcome guests at the time of the epidemic. Although urban tourism in Chongqing failed to maintain the rebound trend in the growth period during the adaptation period, the number of non empty nodes in the network was still increasing, with a recovery capacity of 103.27%.

Hierarchy

Under the influence of the epidemic, the hierarchy of Chongqing's urban tourism flow network structure has rapidly decreased. Even though the hierarchy of the adaptation period has recovered, it is still lower than the level before the COVID-19, and the network structure toughness tends to be optimized. Before the COVID-19 epidemic, the network degree distribution slope remained between 1.21 and 1.17. In the resistance period, the recovery period and the adaptation period, the obvious changes were 1.06, 0.92 and 1.13, respectively (**Figure 4**). From the change of the centrality of the network nodes, it can be seen that the centrality of the core nodes with large tourist reception, such as Ciqikou Ancient Town, Hongya Cave, Chaotianmen Square, Yangtze River Cableway, Liziba Viewing Platform, has a large change, while the centrality of the edge nodes with small tourist reception is less affected by the pandemic. This change can also be confirmed by the comparison of the changes in the network connection intensity of Chongqing's urban tourism flows before and after the COVID-19 pandemic (**Figure 3**). This shows that the COVID-19 pandemic has significantly reduced the status of core nodes, especially in the recovery phase, the core nodes' resilience is lower than that of edge nodes, which further reduces the hierarchical difference between "core edge". The lower level is conducive to reducing the path dependence of the edge scenic spots on the core scenic spots. Even if the core scenic spots are accidentally impacted, other nodes can become stronger and resist external disturbances.

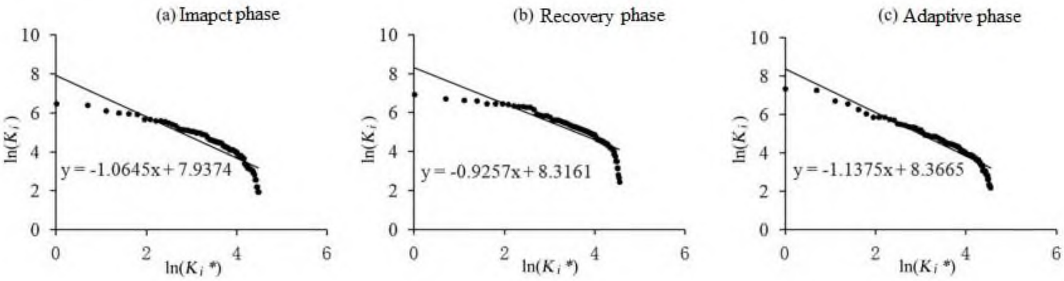

Figure 4. Distribution of degrees of urban tourism flow network in Chongqing for different stages.

Matching

The slope of the degree correlation curve of the nodes of Chongqing urban tourism flow network is always negative. The node relationship shows the characteristics of heterogeneity. The node connection tends to be diversified and heterogeneous, and the structure is relatively reasonable. After the COVID-19, the heterogeneity of Chongqing's urban tourism flow network structure rebounded rapidly from 0.24 to 0.18 in the resistance period, and it was 0.22 in the recovery period and 0.32 in the adaptation period (**Figure 5**), and the heterogeneity continued to rise. Specifically, the sudden COVID-19 epidemic has a huge impact on high-level nodes. At the initial stage of the impact, many edge nodes and core nodes were disconnected. Small and medium-sized scenic spots tend to develop in groups nearby, and urban tourism has shifted to the local tourist source market, enhancing the compatibility. With the improvement of the epidemic situation, the attraction of the core nodes is restored, and the node connections show a trend of heterozygosity. Some scenic spots focusing on the local tourism market, such as Chongqing Zoo, Ronghui Hot Spring, 28 degree Living Water Museum, Rongchuang Cultural Tourism City, Chongqing Happy Valley, have strong adaptability and become new regional cores. The urban tourism flow network structure shows a trend of multi center development. After the improvement of heterogamy, even if the large-scale scenic spots dominated by tourists from outside the city are impacted by the epidemic, the introverted scenic spots with different energy levels can still make adaptive adjustments and develop in groups.

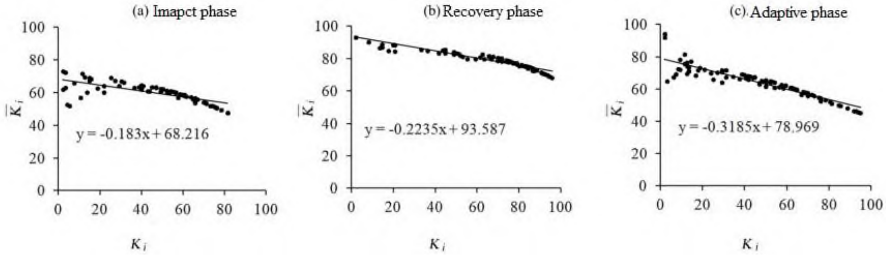

Figure 5. Degree correlation of urban tourism flow networks in Chongqing for different stages.

Transmissibility

The transmission of urban tourism flow network structure in Chongqing continued to decline after the COVID-19, but the overall transmission level is still high. Before the

COVID-19, the average path length of Chongqing's urban tourism flow network fluctuated slightly between 1.16 and 1.17, increased to 1.19 in the resistance period, and then rapidly increased to 1.28 and 1.56 in the recovery and adaptation periods. Although the transmission of the network structure seems to be declining continuously, the reasons for the change are different at different stages. During the resistance period, the number of network nodes decreased from 91 in the same period of 2019 to 85, and some nodes were disconnected, affecting the transmission. The recovery period and adaptation period are due to the rapid recovery of the local tourism market in the peripheral areas of the city, the development of inward oriented scenic spots and their growing strength, and the weakening of the connection between the edge scenic spots and the traditional core scenic spots, which leads to a further decline in transmission. Although the rapid development of the local tourism market is behind the decline in transmissibility, it will ultimately be detrimental to the interactive exchange of host and guest tourism space and the sharing of passenger flow.

2.2. Evaluation results

At present, there is no unified evaluation standard for the resilience of tourism flow network structure. In combination with the actual influence of the COVID-19, this paper proposes a set of evaluation criteria for the resistance, resilience and adaptability of each measurement index, and evaluates the structural resilience of Chongqing's urban tourism flow network (**Table 3**).

Table 3. Evaluation of network structure resilience of urban tourism flow in Chongqing

	Resistance		**Resilience**		**Adaptability**	
	Evaluation criteria	**Evaluation**	**Evaluation criteria**	**Evaluation**	**Evaluation criteria**	**Evaluation**
Network load	[70%, +∞): High [35%, 70%): [0, 35%): Low	Low 31.36%	[85%, +∞): High [50%, 85%): [0, 50%): Low	Medium 55.53%	[100%, +∞): High [75%, 100%): [0, 75%): Low	Medium 82.19%
Stability	QAP analysis p [0, 0.01): High [0.01, 0.05): [0.05, 1): Low	High P<0.01	QAP analysis p [0, 0.01): High [0.01, 0.05): [0.05, 1): Low	High P<0.01	QAP analysis p [0, 0.01): High [0.01, 0.05): [0.05, 1): Low	High P<0.01
Growth	[100%, +∞): High [90%, 100%): [0, 90%): Low	Medium 93.41%	[100%, +∞): High [90%, 100%): [0, 90%): Low	High 101.09%	[100%, +∞): High [90%, 100%): [0, 90%): Low	High 103.27%
Hierarchical	[0, 1): High [1, 1.5%): Medium [1.5, +∞): Low	Medium -1.06	[0, 1): High [1, 1.5%): Medium [1.5, +∞): Low	High -0.93-	[0, 1): High [1, 1.5%): Medium [1.5, +∞): Low	Medium -1.14-
Matching	(∞, 0.3]: high (0.3, 0.3): Medium [0.3, +∞): Low	Medium -0.18	(∞, 0.3]: High (0.3, 0.3): Medium [0.3, +∞): Low	In -0.22	(∞, 0.3]: High (0.3, 0.3): Medium [0.3, +∞): Low	High -0.32
Transmissibility	[1, 1.5): High [1.5, 2): Medium [2, +∞): Low	High One point	[1, 1.5): High [1.5, 2): Medium [2, +∞): Low	High One point	[1, 1.5): High [1.5, 2): Medium [2, +∞): Low	Medium One point

The load of urban tourism flow network in Chongqing was greatly impacted by the COVID-19, and the resistance, resilience and adaptability were 31.36%, 55.53% and 82.19% respectively. Low resistance, moderate resilience and adaptability. From the stability index, Chongqing urban tourism flow network structure showed significant stability under the impact of the epidemic situation. The QAP analysis p value was always less than 0.01, and the resistance, resilience and adaptability were high. In the growth index, although the resistance was 93.41%, which was moderate, its resilience and adaptability exceeded 100% and continued to increase. The hierarchical indicators of Chongqing's urban tourism flow network have high resilience and moderate resistance and adaptability. Although the hierarchical indicators show a fluctuating state, they are better than the pre pandemic levels in the resistance period, recovery period and adaptation period. The matching indicators were continuously optimized after the outbreak of the epidemic, from 0.18 to 0.32, with moderate resistance and resilience and high adaptability. The transmission index resistance and resilience of Chongqing urban tourism flow network are high, respectively 1.19 and 1.28, but the adaptability is moderate, only 1.56. Transmission showed a downward trend after the COVID-19.

The assessment result of the resilience of Chongqing's urban tourism flow network structure is generally excellent. Although the COVID-19 has a great impact on Chongqing's urban tourism in terms of tourist reception, it has also forced the optimization and adjustment of its network structure. Chongqing's urban tourism flow network transmission shows an obvious downward trend, which needs further optimization.

3. Discussion

The COVID-19 is not only an impact and challenge to China's tourism industry, but also an important opportunity to "transform the mode and adjust the structure". Since the outbreak of the epidemic, China's tourism industry has been severely shocked and deeply adjusted, and the development level is still extremely unstable[32]. Despite the severe situation, departments at all levels actively responded to the epidemic challenge by constantly adjusting the supply of tourism products, upgrading tourism marketing means, and optimizing tourism spatial pattern through government assistance, industry guidance, enterprise self-help and other forms[32,33]. Taking the downtown area of Chongqing as an example, this paper quantitatively evaluates the network structure resilience of tourism flows, which confirms the resilience process of China's tourism industry after the pandemic from resistance to recovery to constant adjustment and adaptation. It is also worth affirming that although Chongqing's urban tourism has been greatly impacted by the COVID-19 in terms of "quantity", with weak resistance, moderate resilience and adaptability, several network structure indicators reflecting "quality" still perform well, and the COVID-19 has forced the optimization and adjustment of Chongqing's urban tourism flow network structure.

Actively responding to the evolution of tourists' behavior rules is the key to enhance the resilience of tourist destinations. Influenced by multiple factors such as epidemic prevention and control policies, residents' travel confidence, tourists' risk perception, and tourism environmental capacity, cross regional tourism activities nationwide are severely suppressed[32,34]. Tourists tend to choose short distance tourism or urban micro vacations with administrative regions as activity units[35]. Intra provincial tourism, rural tourism, ecological tourism and self driving tourism have become important tourism products under the epidemic situation[36]. It can be seen from the case of Chongqing that although the epidemic has restrained the tourist flow of export-oriented tourist attractions in the core areas of the city, the peripheral areas of the city have benefited significantly. Not only that, the change of passenger flow has changed the spatial connection between scenic spots, the multi center pattern has begun to appear, the hierarchy between the "core edge" areas has shrunk, and the heterogeneity between nodes has increased, and the scenic spots have formed a new flexible spatial pattern during the epidemic period in the spontaneous adjustment.

It is a new research idea to introduce resilience theory into the study of tourism flow network structure. It is helpful to quantitatively evaluate the risk response ability of tourist destinations, understand the weak links in the tourism flow network, and then provide optimization strategies. In future research, the tourism flow network structure resilience evaluation system can be further optimized and adjusted in terms of measurement indicators and evaluation dimensions, applied to multiple geographic spatial scales, and carried out network structure resilience evaluation from the perspective of evolution.

4. Conclusions

In this paper, the network structure of tourism flow is regarded as the projection of tourism industry development in geographical space. Based on the digital footprints left by tourists on www.dianping.com in 2019 and 2021, Chongqing urban tourism flow network at different stages before and after the impact of COVID-19 is constructed, and a resilience assessment system is established to assess the resilience of Chongqing urban tourism flow network structure.

Although the "network load" of urban tourism flow in Chongqing is seriously impacted by the epidemic, with weak resistance, moderate resilience and adaptability, the network structure is highly like the same period in 2019. In addition, since the COVID-19, the number of non empty nodes in Chongqing's urban tourism flow network has increased rather than decreased, with strong growth. Therefore, Chongqing's urban tourism flow network structure has obvious resilience in terms of "stability" and "growth" indicators.

The COVID-19 helps to force the optimization and adjustment of urban tourism flow network structure. Under the influence of the epidemic situation, the status of urban tourism core nodes has been significantly reduced, and the resilience and adaptability are far less than those of edge nodes. The "hierarchical" indicators of the tourism flow network structure tend to be flat, which is conducive to reducing the path dependence of edge scenic spots on traditional core scenic spots. Some scenic spots dominated by the local tourism market have strong adaptability and become new regional cores. Even though the scenic spots with different levels are impacted by risks, they can still make adaptive adjustments and develop in groups.

The transmission of urban tourism flow network structure in Chongqing has continued to decline after the COVID-19. The reason is that the rapid development of inward looking scenic spots dominated by the local tourism market has weakened the connection with the traditional core scenic spots, which will not be conducive to the interaction and exchange of host and guest tourism space and the sharing of passenger flow, and it is necessary to further optimize.

Conflict of interest

The authors declare no conflict of interest.

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