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Research on the Structure of Urban Innovation Network Based on Sichuan Science and Technology Progress Award

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Abstract: Innovation is the inner core driving force of urban and regional development, and urban innovation network is an important support to enhance regional innovation capacity. This paper constructs an urban innovation network based on the data of the 2020 Sichuan Science and Technology Progress Award, and analyses the innovation network using social network analysis and GIS spatial analysis. The spatial pattern of the innovation network is based on Chengdu as the core and radiates across the province, with a low degree of inter-city connectivity and uneven distribution of innovation links.

1. Introduction

Today's world economy has stepped into the era of knowledge economy, and with the rapid development of new technologies represented by information technology, international competition is becoming increasingly fierce. Innovation is the internal core driving force for the socio-economic development of cities and regions. In the context of the innovation-driven development strategy, the establishment of a good urban innovation network is conducive to inter-regional innovation linkages and to the advantages of regional innovation factor clustering. As a spatial carrier of innovation development, the regional innovation network formed by the conclusion of collaborative innovation among citiescan promote the flow of innovation factors in the region, which plays an important role in promoting the transformation of scientific and technological achievements and enhancing regional innovation capacity. The British evolutionary economist Freeman. C[1] proposed the concepts of "innovator networks" and "innovation networks", and since then, innovation networks have been extensively researched[2], from descriptive research on the concept of innovation networks to the introduction of social network analysis[3]. The paradigm has been developed with in-depth research on network attributes and network spatial structure[4]; the research scale covers a wide range, from micro innovation subjects represented by enterprises and organizations to macro spatial units in cities, regions, countries and the world; the research methods are based on social network analysis theory, complex network theory and spatial econometric models to dig into network characteristics[5]

As one of the fastest growing regions in China's western regional integration, the Chengdu-

Chongqing region has gathered a number of strong higher education institutions and research institutes in the cities in the region, which is a highland where scientific resources such as talents, knowledge, information and technology are concentrated. In the context of implementing the innovation-driven strategy, it is of practical significance to explore the urban innovation cooperation network in Sichuan Province, to study the structural characteristics and spatial pattern of its innovation network, to explore the different roles and functions played by different cities in the urban innovation network, and to provide references and lessons for promoting sustainable development in various regions of Sichuan Province.

2. Data Sources and Research Methodology

2.1. Data Sources

This paper is based on the 2020 Sichuan Science and Technology Progress Award (https://www.sc.gov.cn/) as the research data and 21 cities in Sichuan Province as the research objects, with more than two cooperative institutions representing inter-city collaborative innovation links, and the counting rules are as follows: if cooperative institution A and institution B are both in Chengdu, the cooperative project is not counted; if cooperative institution A is in Chengdu and institution C is in If partner institution A is Chengdu and institution C is Mianyang, it will be counted as Chengdu-Mianyang innovation linkage; using research institutions with common research results, the technological exchange relationship and cooperation relationship between cities will be determined through the cities to which the research institutions belong, and the innovation network of the city will be constructed[6]

2.2. Social Network Analysis

Social network analysis (SNA) is a method of modelling the relationships between social actors, describing the structure of group relations, the interaction between actors in a social network and the structural characteristics of their cooperative network. In this paper, we use social network analysis to measure network indicators such as network density, average distance, clustering coefficient[7], network centrality and cohesive subgroups of urban innovation networks using Ucinet software.

2.2.1 Overall Network Analysis

The overall network analysis uses indicators such as network density, average distance and clustering coefficient to reflect the characteristics of the overall network in terms of size, interactivity and strength of ties. Network density is the ratio of the actual number of relationships between cities in the network to the maximum possible number of relationships in the whole network. In general, the larger the value of network density, the better the network as a whole and the stronger the connections within the network. The calculation formula is as follows:

$$D = \sum_{i=1}^{k} \sum_{j=1}^{k} \frac{r_{ij}}{k(k-1)} \tag{1}$$

The average distance is the average of the distances between two different nodes. A small average distance indicates good accessibility within the network. The calculation formula is as follows:

$$L = \frac{2}{n(n-1)} \sum_{i \neq j} l_{ij} \tag{2}$$

The clustering factor is the aggregation of nodes in a network, i.e. how tightly packed the network is. The larger the clustering coefficient, the more efficient the network. The calculation formula is as follows:

$$C = \frac{2E_i}{k_i(k_i - 1)} \tag{3}$$

2.2.2 Network Centrality

Social network analysis measures the position and relationship of the network nodes and the individual networks they form within the overall network and is called centrality. Degree centrality refers to the number of other nodes directly connected to the node in the network and measures the degree of centrality of the node in the network. The higher the degree of centrality, the more important the node is in the network, and the formula is:

$$C_{D_i} = \frac{r_{ij}}{(n-1)} \tag{4}$$

Closeness centrality is a measure of the shortest path from a node to other nodes. The higher the centrality, the greater the independence and autonomy, and the closer the connection between the node and other cities, the easier it is to transfer resources, and the formula is:

$$C_{C_i} = \sum_{j=1}^{n} \frac{r_{ij}}{n-1} \tag{5}$$

Betweenness centrality is the number of times a node helps any two other nodes in the network to connect with each other on the shortest path, the more times the node acts as a "middleman" in the network, the greater the betweenness centrality, the formula is:

$$C_{B_i} = \frac{\sum_{j \neq k} \frac{g_{jk}(c_j)}{g_{jk}}}{(n-1)(n-2)} \tag{6}$$

2.2.3 Cohesive Subgroup Analysis

In social network analysis, cohesive subgroups (factions) are subsets of actors with relatively strong, direct, close, regular or active relationships or shared characteristics. The division into small groups with strong ties formed within the network indicates the existence of groups with strong innovative ties within urban agglomerations and allows for an overall grasp of the state of development within the network.

3. Structural Analysis of Urban Innovation Networks

3.1. Structural Characteristics of Innovation Networks

3.1.1 Overall Network Characteristics

This paper uses Ucinet 6.0 software to calculate the network density, average distance, clustering

coefficient and other network structure characteristics indicators of this from innovation network, the calculation results are shown in Table 1 below:

Table 1: Results of knowledge innovation network indicators calculation

Index	Value
Density	0.352
NO.Ties	148
Diameter	2
Average distance	1.648
Compactness	0.676
Avg Degree	7.048

The density of the innovation network in this city is 0.352, which is less than half of the theoretical value of "1". The low value of network density reflects the loose structure of the network, which is spatially connected and not dense, and the future development of the innovation network requires the node cities to strengthen their connections and improve the density of the network[8]. The average distance is 1.648 and the clustering coefficient is 0.676. The innovation network has a high clustering coefficient and a short average distance, and has the characteristics of a small world in the future.

3.1.2 Network Centrality Analysis

In this paper, three indicators are selected to measure the location, independence and degree of control of node cities in the innovation network: degree centrality, proximity centrality and intermediate centrality, and the results are shown in Table 2.

Table 2: Results of urban innovation network centrality calculations

City	Degree	Closeness	Betweenness
Chengdu	100	100	41.921
Yaan	80	83.333	14.754
Deyang	45	64.516	1.158
Mianyang	45	64.516	3.175
Leshan	40	62.5	1.167
Dazhou	40	62.5	1.035
Bazhong	40	62.5	0.667
Liangshan Yi Autonomous Prefecture	40	62.5	1.904
Luzhou	35	60.606	1.184
Guangyuan	35	60.606	1.404
Neijiang	35	60.606	0.325
Yibin	35	60.606	0.965
Panzhihua	30	58.824	0.263
Ganzi Tibetan Autonomous Prefecture	30	58.824	0.833
Nanchong	25	57.143	0.307
Meishan	25	57.143	0.211
Aba Tibetan and Qiang Autonomous Prefecture	20	55.556	0.307
Zigong	15	54.054	0
Suining	15	54.054	0
Guangan	5	51.282	0
Ziyang	5	51.282	0

In terms of the centrality of this city's innovation network, Chengdu has a degree centrality value of 100, reaching the level of an innovation pole and always at the centre of the network, with Ya'an City, Deyang City and Mianyang City following in the second tier of the network; in terms of proximity to the centre, Chengdu has the highest proximity centrality value of 100, indicating that Chengdu, as the capital city of the province, has more resources and advantages, and is in the second tier of the network. Chengdu, as the capital city of the province, has more resources and advantages, and has a strong ability to transmit innovation information within the network, and an outstanding ability to innovate independently. Ya'an, Deyang and Mianyang, being geographically close to each other, also have a high degree of proximity to the centre. The intermediate centrality of a node is the degree of control it has over the network. Chengdu has a high degree of intermediate centrality, indicating that the cities in the region are indirectly connected to each other through the 'middleman' bridge of Chengdu for innovation. Ziyang City has a low degree of network centrality, indicating a weak position in the innovation network and a relatively poor command of network resources.

3.1.3 Cohesive Subgroup Analysis

Using the iterative correlation convergence method of Roles&Positions in the Network module of the Ucinet software, cohesive subgroup analysis was carried out, resulting in the cohesive subgroup clustering distribution in Figure 1.

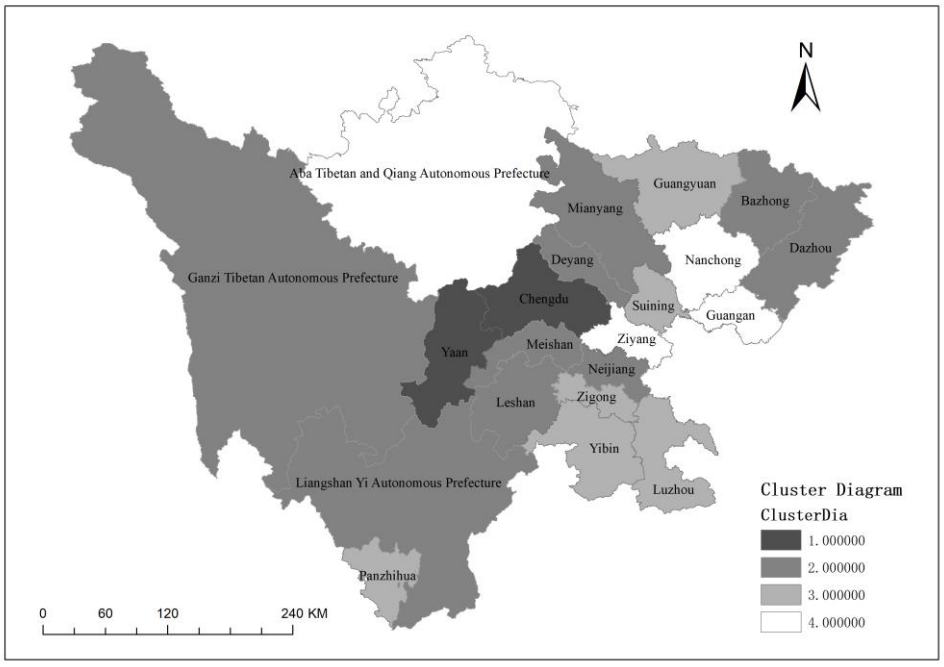

Figure 1: Distribution of cohesive subgroups of urban innovation networks

The innovation network of the study area can be divided into 4 subgroups. Among them, the first cohesive subgroup is composed of 2 cities, Chengdu and Ya'an, which, as geographically adjacent cities to Chengdu, are more likely to receive Chengdu's innovation polarisation effect; the second cohesive subgroup contains 9 cities[9], Deyang, Mianyang, Neijiang, Leshan, Meishan, Dazhou, Bazhong, Ganzi Tibetan Autonomous Prefecture and Liangshan Yi Autonomous Prefecture, which mostly receive Chengdu's innovation polarisation-trickle-down influence; the third cohesive subgroup contains Zigong, Panzhihua, Luzhou, Guangyuan, Suining, and Yibin, six cities that show little geographic proximity to Chengdu; the fourth cohesive subgroup is Ziyang, Guang'an, and Aba

Tibetan and Qiang Autonomous Prefecture, three cities that are in the innovation periphery.

3.2. Innovative Cyberspace Patterns

This paper uses GIS10.8 to measure the city's innovation network linkages, using the natural breakpoint method to represent the strength of the city's innovation linkages by the thickness of the connecting lines, resulting in the following Figure 2.

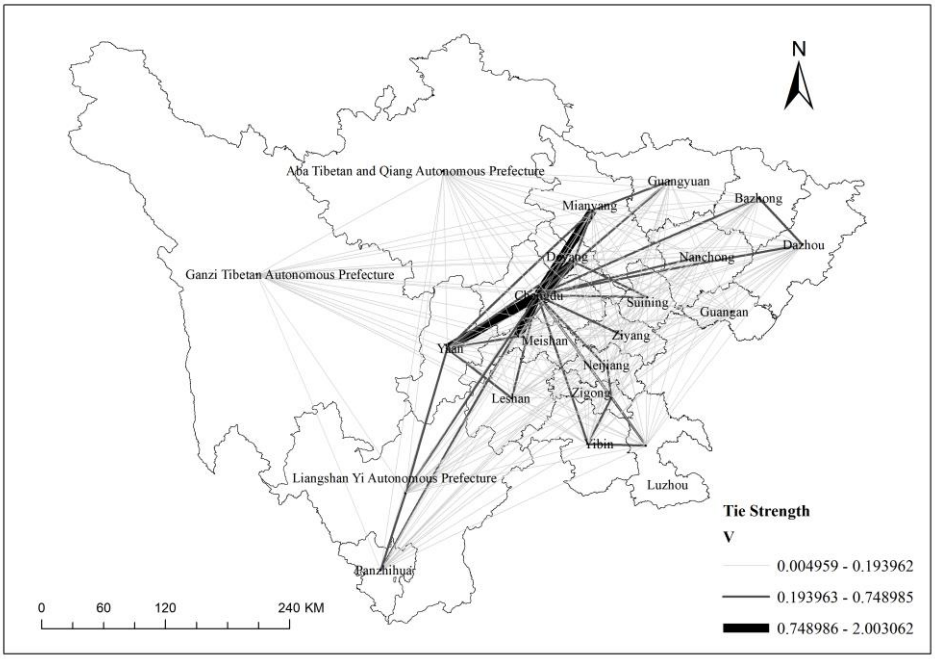

Figure 2: Map of innovation links in urban innovation networks

The urban innovation network has Chengdu as its core, with the cities of Ya'an, Mianyang and Deyang as its fulcrum, and the Chengdu-Ya-Mian city cluster as the innovation development belt, radiating the province's innovation linkages. The innovation pole with Chengdu as the core has a polarisation-trickle-down effect, with most cities in the province receiving innovation overflow from Chengdu and forming vertical innovation links, but with insufficient horizontal links between them[10]; the weak innovation links in the west are restricted by the special geographical environment of Ganzi Tibetan Autonomous Prefecture and Liangshan Yi Autonomous Prefecture, with low levels of urban innovation and insufficient innovation capacity to develop effective innovation links. Chengdu is the core of the innovation network, with Chengdu-Ya-Mian as the development belt, and the spatial pattern of close innovation links in the east and sparse in the west.

4. Conclusions and Recommendations

The Sichuan Science and Technology Progress Award is an important manifestation of Sichuan's scientific and technological achievements, and plays a very important role in promoting the development of the regional economy. This paper constructs an urban innovation network based on the 2020 Sichuan Science and Technology Progress Award, and the results show that: the urban innovation network is in the development stage, with low network density and small-world characteristics; the urban innovation network has Chengdu as its core, with geographically adjacent cities such as Ya'an and Mianyang receiving the polarisation-trickle-down effect and forming multi-polar development in the future; the innovation network is spatially not densely connected, with uneven innovation distribution, with Chengdu is the core, and Chengyamian is the development belt,

with a spatial pattern of close innovation links in the east and sparse in the west.

From the results of this paper, the scope of cooperation between the award cities in Sichuan province is small and the exchange is low, which is not conducive to the full use of innovation resources. It is therefore recommended that: links and communication should be strengthened between the award cities of the Sichuan Science and Technology Progress Award; enterprises with comparative and scale advantages in the field of science and technology innovation should be encouraged to actively engage in technical cooperation and exchange with other non-award-winning units; non-award-winning units should be encouraged to strengthen cooperation with other enterprises that have won the Science and Technology Progress Award for innovation achievements.

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