How Networks Shape the Spatial Structure of the Less Developed Areas? —A Case Study of South-Central Yunnan, China

Jing-Xin Nie and He-Lin Liu

***Abstract*—Since networking has become a recent trend across the globe, scientifically measuring the characters of the network structure is the main task of the regional study. The existing literature is concentrated more on developed areas, while less on the formation of the urban networking characters in less developed areas. Taking the south-central Yunnan in China as an example, this paper analyzed the extent and features of the connection among cities and towns within the region. The regional network was developed through passenger flow, express logistics and capital flow data, and analyzed by the Social Network Analysis (SNA) method. The result shows that the spatial structure of the south-central Yunnan emerges to a low-degree networking. There are several key nodes surrounding the core – Kunming. Their gathering and interaction foster several town clusters and the north-south corridor. The conclusion is that the network makes the regional structure more open and efficient, so that the resources can be well configured in the region. However, the backward geographical environment and infrastructure are still important factors restricting the evolution of the urban structure in less developed areas. We suggest that the coordinated development of undeveloped areas should be promoted through more investment in infrastructure, clustering the local industries, creating regional dialogue organizations, and facilitating cross-border trade.**

Index Terms—Urban network, social network analysis, the less developed area, networking, south-central Yunnan.

I. Introduction

The construction of infrastructures is rapidly boosting with the swift development of information technologies. The world has been shaped by the flow of people, logistics, information and other elements. Therefore, not only between countries, the organizational model between regions within the State also significantly changed. Urban agglomeration, city-region and other forms have become the inevitable choices of accelerating the free circulation of elements in developed areas and continuously facilitating their competitive power [1]. For example, the top ten Urban agglomeration was selected in *America 2050*, which was the most developed and high-density areas in the United States. The Chinese government adhering to the overall thinking of regional development has drawn up many regional plans for its world-class regions, including Beijing-Tianjin-Hebei, Yangtze River Delta and Pearl River Delta.

In the 40 years' reform and opening up, China's economy has achieved a worldwide success, resulting in great improvements in cities and towns and huge leaps in the economic, population and land use. The expansion of cities boosted the tightness of links within them, and loosened the original hierarchical urban system. Moreover, the flow of resource elements has obviously promoted the spatial reorganization of regions [1], following which, studies on the urban and regional network are on the rise [2].

In fact, since Castells first proposed the network society, the large-scale rapid flow of information and capital has reshaped the globe [3]. The global city network continuously emerged, and further compressed space and time, bringing about the faster flow of factors. Nodes' roles of cities and towns in this network differ. Mage cities and regions with strong connection ability occupy the core position of the network, while most of the small and medium-sized nodes are difficult to enter the core club to some extent. This "start effort" makes the big cities become the focus of research. For example, the GaWC research group established the network among major cities relying on the global urban network theory, which rated the high-level nodes in the world every year and measured the reshaping effect of productive service sectors [4]–[7]. Other studies also paid attention to how big cities compete with each other in the global network [8]–[10]. Furthermore, some researchers demonstrated the changes in the urban organization through international air networks and infrastructure networks [11]–[16]. However, these studies mainly focused on the interaction between large cities, while the marginal urban nodes were often ignored [17]. From the perspective of coordinated development, the development of small and medium-sized cities will be more beneficial to the overall promotion within a country. Therefore, for regional progress, consideration of the development mode of small and medium-sized cities in the new era is necessary.

Cities in China have long been integrated into the global network and are gradually made progress in the high-level competition. It can be said that China's urban network is really a crucial part of the world's urban network [18]–[22]. However, there shows a specific network form in some regions influenced by China's local context [23]. Chinese researchers also paid more attention to the developed regions such as Yangtze River Delta and Pearl River Delta [24], and the mid-west in recent years [2], [25], [26], but with little attention to the west. These less developed areas in western edges are almost locked by poverty. So, in the network era under the global-local interaction, what kind of topological

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structure do these regions generate and what challenges do they face? Are there any opportunities to break through? A series of problems need to be explored by studying more cases.

Taking the south-central part of Yunnan, a less developed province in China, as an example, this paper uses the method of Social Network Analysis (SNA) to analyze the networking degree in the edge from the aspects of the overall characters, node centralities and core-periphery structure. The development dilemma and the possible strategies to break through this low-level lock are finally discussed.

II. Data and Methods

A. Study Area

There are great development gaps between different provinces in the vast territory of China. Yunnan province, one of the provinces with relatively lagging development in China, is located on the southwest border of China with 8 cities and 8 autonomous prefectures of ethnic minorities. With a total territory of 3,941,000 km^2, Yunnan achieved a GDP of 16531.34 billion yuan, and a total population of 48,050,000 in 2017. The study selected 8 municipal administrative regions in south-central Yunnan as research objects, including Kunming, Yuxi, Qujing, Pu'er, Yi Autonomous Prefecture of Chuxiong, Dai Autonomous Prefecture of Xishuangbanna, Hani-Yi Autonomous Prefecture of Honghe, Zhuang-Miao Autonomous Prefecture of Wenshan (Fig. 1). In order to more carefully reflect the spatial topology within the region, each administrative region was further subdivided, and 76 county-level units were generated as the basic study units.

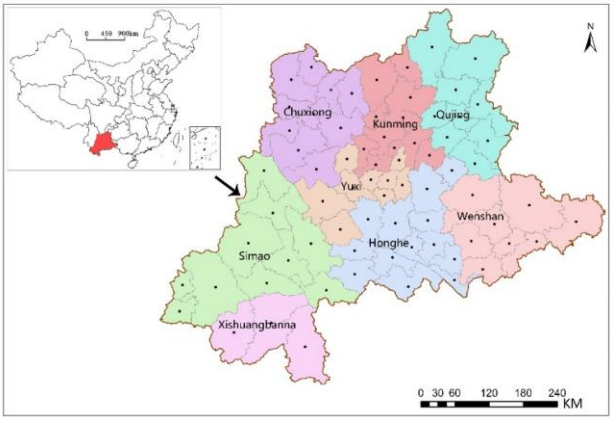


Fig. 1. The location of the study area.

In 2017, there was a permanent population of 29.98 million in the study area, taking up 62.46% of Yunnan. Additionally, GDP of 124.57 billion-yuan, accounting for 75.36% and the value added of 502.75 billion yuan, making up 78.71%. The economic statistics of each administrative region is given in Table I. This region is generally regarded as the core area of Yunnan, which the government hopes to promote into an urban agglomeration. However, they are also typical cases of less developed areas in China owing to poverty, multi-ethnicity and economic recession. Therefore, it is more appropriate to choose south-central Yunnan to study the effect of factor flows on less developed regions.

TABLE I: Statistics of the Study Area in 2017

Cities	Population (10000 people)	GDP (billion yuan)	Industrial added value (billion yuan)
Chuxiong	274.4	937.37	366.11
Kunming	678.3	4857.64	1865.97
Qujing	604.7	1941.12	756.87
Yuxi	238.1	1415.1	729.4
Pu'er	262.7	624.59	222.89
Honghe	458.73	1478.57	687.94
Xishuangbanna	118	393.84	106.63
Wenshan	363.6	809.11	291.67
Yunnan	4800.5	16531.34	6387.53

B. Data Resources

This study analyzed the correlation between cities and towns in south-central Yunnan by population flow, cargo transportation and capital flow. Considering the availability of data, population flow was replaced by the transportation shifts, cargo transportation by express delivery outlets, and capital flow by bank outlets. Among them, the highway shifts are collected from the web http://www.checi.org/, the data of express delivery outlets are collected from the web http://www.ickd.cn/, and the data of bank outlets are collected from the web http://www.yhwdt.com/. After extracting relevant data from the target website and removing invalid data through the network technology, the basic data needed for the research were prepared.

C. Research Methods

SNA method is adopted to depict the connection characters among various study units in south-central Yunnan on UCINET and ArcGIS. The former software was utilized to analyze the overall features and structure of the network [27], while the latter was adopted for spatial analysis and visualization. It is necessary to construct a connect network and use the above-mentioned data for SNA. Among them, taking the number of shifts as the contact degree between units in the transit network. Contact weight between different cities were respectively counted, and a matrix of 41×41 was constructed after normalization. The express network first constructed a matrix of 41 × 21 contained study units and express companies, and then takes the score of express outlets in a certain unit as the important degree in the network. The degree between two study units of an express network weighted by the product of its score value, and the correlation strength of the two study units was the sum of the weight of different express network outlets. Consequently, the express network was developed after normalization. The construction of banking network was similar to express network. Relevant construction methods can be found in reference [1]. After the networks' construction, it was analyzed from the connection hierarchy, node centrality and core-periphery structure.

III. Features of Network Spatial Structure

A. Hierarchies of Networks

Using the regional networks in south-central Yunnan provided above, we could learn the hierarchies in them. Jenks' Natural Fracture Point method was used to divide the connection weight between nodes into 5 classes. It was identified the topological relationship and the dominant current direction of different networks in the region, which

shows that the "single-center" structure in south-central Yunnan is strongly inclined. Kunming, as the provincial capital city, locates at the highest hierarchy and controls the factor channel. In banking network, primary links spread around the units surrounding Kunming, among which the first hierarchy concentrates between the central districts of inner Kunming. The second hierarchy includes peripheral nodes such as Chuxiong, Qilin District, Jinghong. The third and fourth hierarchies radiate to the southwest. The whole network is of a single-center radial form, and the core cluster is tightly shrunk in the urban Kunming (Fig. 2a). In network of express, the structure is expanded compared to bank network, among which Chuxiong, Honghe, Wenshan join the top hierarchy, presenting a shape of "star". The second hierarchy gradually expands to Jinghong, Qilin District, Mengzi, Kaiyuan and others, showing a trend of north-south oblique distribution (Fig. 2b). Unlike polarization of above two networks, the transit network appears to be more fragmented. Although Kunming still holds the most advanced links, its influence weakens obviously. While the nodes such as Jinghong, Mengzi, Wenshan and Qilin District begin to rise (Fig. 2c). Additionally, because of more loose structure, there is no obvious oriented corridors inner network. The network is still dominated by the administrative hierarchy, may be caused by the complicated geography, and the lagging construction of transport facilities.

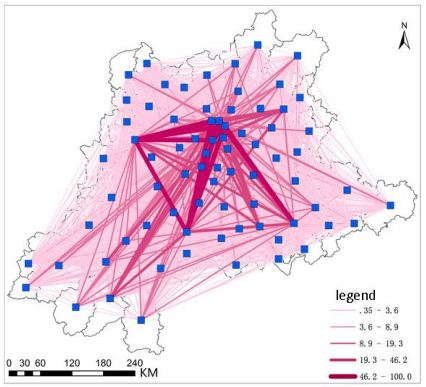
The above analysis shows that the spatial structure in south-central Yunnan is mainly characterized by central agglomeration. However, the differentiated organization mode in peripheral areas is fostered by the formation of discrete network flows. Uneven circulation channels of factors have limited nodes in the study area to form a closely contacted network, but in an atomized spatial structure.

B. *Centralities of Nodes*

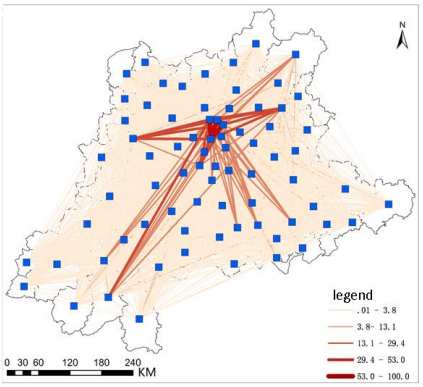
Centralities of node is indicators to measure the degree of node centrality in the entire network, reflecting the "power" of one particular node. It includes two dimensions: influence and domination. Degree Centrality (DC) represents how close a node is to the central position, with a range of 0 to 100. The Betweenness Centrality (BC) refers to the extent of node control over resources, ranging from 0 to 100.

The unique attributes of different flows resulted in an enormous disparity in the differentiation of nodes' DC between the three networks. In banking network, the maximum value of DC is 92 and the minimum value is 5.33, showing a 17-fold gap. The maximum value in express network is 100 while the minimum is 20, with a 5-fold gap. However, in the transit network, the maximum value is 97.06 and the minimum value is 2.94, with a 33-fold gap. This means that the goods flow is wider across space, and the rise of Chinese e-commerce has influenced even in remote areas. In banking network, the flow tends to move to more developed cities, which widens the contrast between the developed and the undeveloped. The obstacles of Yunnan's geography hindered the transportation, limiting long-distance and cross-city travel of passenger transport routes. Therefore, human flow in general areas is concentrated in the seat of the municipal government. Kunming has received the largest inflow of population, amplifying the gap between itself and other small towns.

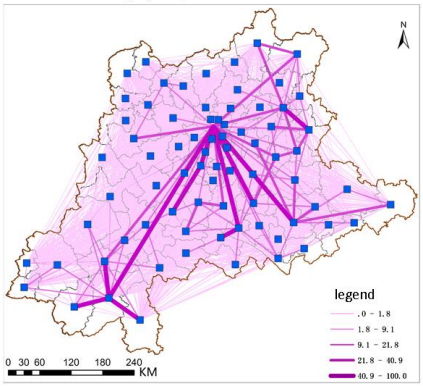
When come to spatial distribution, Kunming is stable in the high-valued area, namely, a dominant position in the network (Fig. 3). In addition, Chuxiong, Qilin District, Jinghong, Mengzi, Gejiu and other critical nodes are also in high-valued area. Differently in the express network, some of those nodes are of equal importance as Kunming. Apart from the cluster surrounding Kunming, Gejiu and Mengzi, Jinghong and Simao also form stable clusters. We can claim that the spatial structure in south-central Yunnan is multi-centered rather than simple single-centered, under the power of networking.



(a) bank network



(b) express network



(c) transit network

Fig. 2. Three networks in south-central Yunnan.

While in BC, the unique attributes of different flows also result in an enormous disparity in the differentiation of nodes' BC between the three networks. Among them, maximum value of BC in bank network is 8.52, the minimum non-zero value is 0.004, and 50 zero valued nodes. The maximum value in express network is 2.12, the minimum non-zero value is 0.003, and 39 zero valued nodes. In transit network, the maximum value is 61.02, the minimum non-zero value is 0.004, and 16 zero valued nodes. However,

the fact that many nodes have no intermediary function means that the great weighted links in the two networks are concentrated between crucial city-nodes. On the contrary, the small towns with extremely weak intermediary ability can only serve as terminals. The number of nodes without intermediary capacity in transit network is the smallest among all networks. At the same time, Kunming's intermediary power is far beyond others, which demonstrated that the concentration of links is even greater than that of the other two networks. Although small towns are able to connect other nodes through passenger transport routes, most of the linkages converge to Kunming, which highlights Kunming's dominant position as a transport hub in Yunnan.

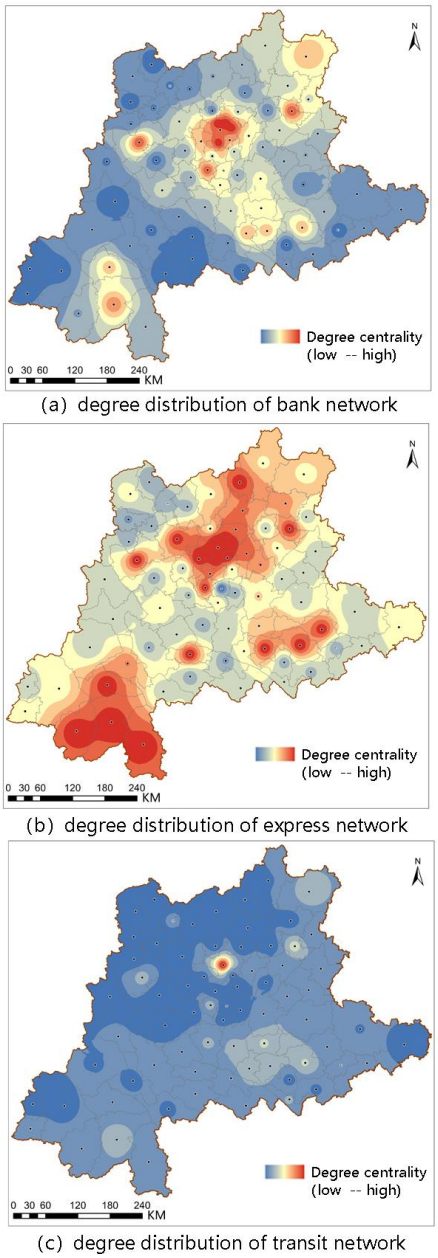


Fig. 3. DC distribution of the three networks in south-central Yunnan.

The unbalance in spatial distribution of BC is greater compared to DC (Fig. 3,4). Kunming has always been a high betweenness value zone as a key bridge connecting various nodes. Chuxiong, Qilin District and Jinghong are the remaining high-value nodes in bank network. High-value zones in express network are widespread. While there are no other high-value zones in the transit network, which shows the south-central Yunnan adopts the localized development mode. The drawback of this mode is with insufficient capital flow and human flow and lacking enough interaction. It is to be noted that, as a necessary condition for industrial development and daily life, freight flow can stimulate the interaction between cities and counties.

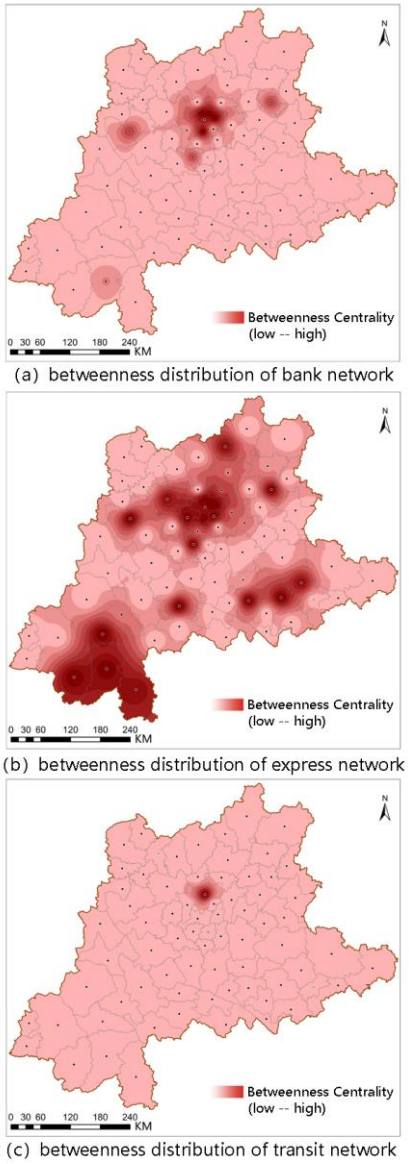
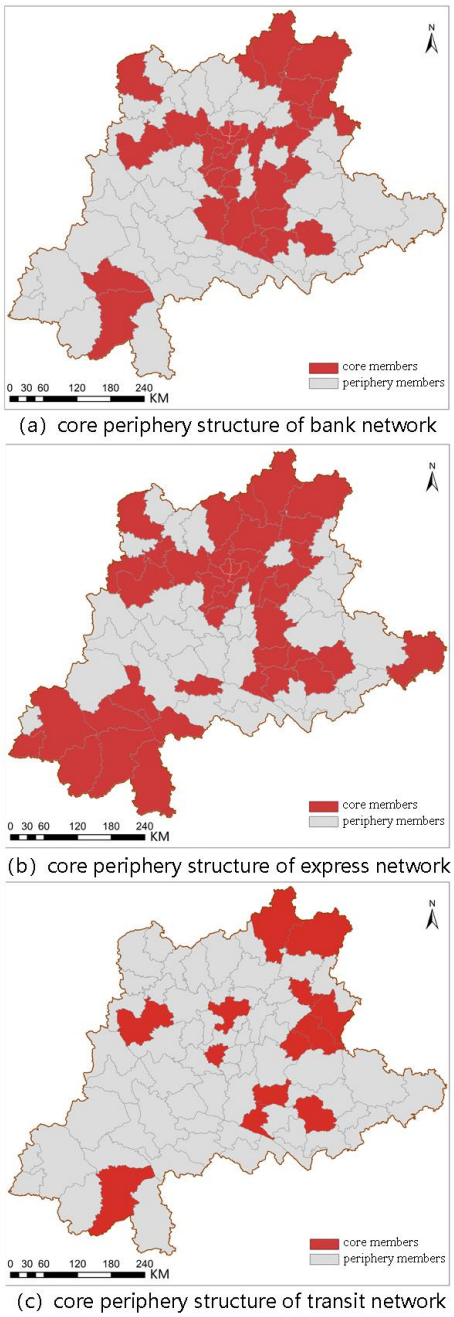


Fig. 4. BC distribution of the three networks in south-central Yunnan.

C. Core Members of Networks

The core-periphery structure method is utilized to calculate the number of core nodes and periphery nodes, for describing the spatial core-periphery structure of the region. What all networks shared is that the study units where the autonomous prefecture and city administrative organizations are located has traditionally been a core. Due to the left core members differed between the three networks, the geographical proximity of the core clusters in the region reveals significant differences (Fig. 5). Inside, the surrounding area with Kunming in bank network is where the trading usually occurred, in which also the core members mainly located. Jinghong is a single core in the northwest, which is not adjacent to others. In express network, in addition to the "core

member belt" around Kunming, there is a cluster result from the increasing amount of core members in the northwest. However, the distribution of cores in the transport network is very scattered without adequate utilization of geographical proximity, but with a gap between the geographic space and the flow space.



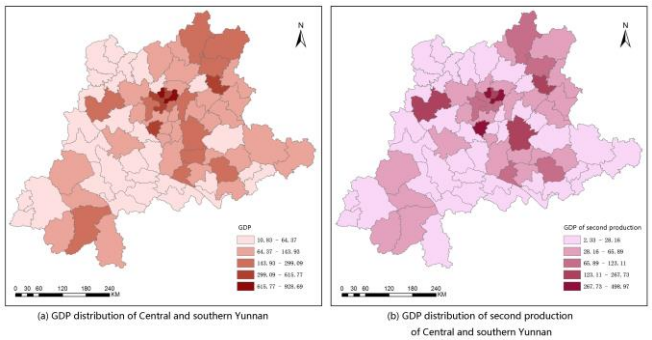
(a) core periphery structure of bank network

(b) core periphery structure of express network

(c) core periphery structure of transit network

Fig. 5. Core-periphery structures of south-central Yunnan.

By comparing the distribution of core members and economic development, we can find the correlation between the influence of the network topology on the spatial structure and actual development level of the region. The distribution of total GDP is similar to GDP only in the second industry in south-central Yunnan, as saw in Fig. 6. The highest value appears surrounding Kunming, while some high-value agglomeration has formed in other parts, which are consistent with the distribution of the core members. It shows that the network development in this region has not got rid of the dependence on the physical space progress so far. This may relate to that the units with well-developed physical space can gain more economic advantages, which mean more opportunity to the core position in the network.



(a) GDP distribution of Central and southern Yunnan

(b) GDP distribution of second production of Central and southern Yunnan

Fig. 6. Economic development in 2016 of south-central Yunnan.

IV. Conclusion

A. Conclusions

Taking the south-central Yunnan as an example, this paper analyzed the shaping effect of the networks on the regional spatial structure in undeveloped areas. With SNA method, the research is carried out on these aspects: connection hierarchies, node centralities, and core-periphery structure. What we found shows:

1) Despite high degree polarization of the networks in south-central Yunnan, they differ with different factors. Therefore, the networking level in undeveloped areas remains low. The result is, the spatial organization of cities and towns can only be carried out in nearby, rather than forming dense urban clusters.
2) The centralities of cities in south-central Yunnan gets a great gap. Only Kunming takes up a central position in the end. Among them, differentiation of centralities in express network is highly flattened, while the passenger transit network is of largest polarization, indicating that the factors have different effects on the optimization of regional organization. Since express network requires a greater goods demand, so port-towns in the edge show stronger advantages. The demand for passenger transport reflects residents' travelling needs, while undeveloped areas have insufficient living demand. This is why the study area still presents a "central place" model.
3) The boundary of the core club in south-central Yunnan remains unclear, with the low degree of node differentiation and greater geographic dependence. The spatial gap between core members is very obvious, especially in the transit network. It reveals that the geographic space in undeveloped areas still plays a great role on the spatial structure, with the weak strength in overcoming the geographical space barrier, leading to the decentralization of core members.

B. Discussions

The regional spatial structure of undeveloped areas similar to south-central Yunnan is limited by geographical conditions due to the weak economic power. The regional network formed by the circulation of capital, goods and other factors is relatively weak in reshaping the regional structure. Despite great achievements have been made in China's

economy. There are still a large number of undeveloped areas in the peripherals. At present, when the Global Production Network (GPN) is increasingly penetrating into local development, the region can only be promoted to a superior position if it is more efficiently embedded in the network. Which requires the formation of a coordinated and close partnership within the region.

For undeveloped areas, to break through the constraints of geography, there needs more efficient and frequent resource allocation across a wide range. Several strategies are promoted the regional networks. We should pay more attention to:

1) Improving the condition of transportation facilities and increasing the network connection between cities and towns. The lack of transportation is a critical obstacle that hinders the population flow. Therefore, in order to strengthen social interaction and social identity within the region, the human flow should be promoted through the improvement of high-speed and railway passenger transport.
2) Accelerating the agglomeration of key industries to promote the oriented flow of regional resources. Rational allocation of resources at a regional level is an effective way to improve the development efficiency. Specifically, guiding leading industries to gather in important cities like Kunming, Mengzi and others, in order to improve the efficiency of the core regions with the aid of the scale effects brought by the agglomeration. A reasonable industrial layout will further promote the directional inflow of factors. Thus, reorganizing the regional spatial structure from both the flow space and the physical space.
3) Establishing appropriate regional organizations to encourage broadly dialogue between different actors. How to adapt regional collective actions within the network and expand common interests? A probable effective way is regional dialogue platform. There are numerous difficulties in conducting formal regional organizations in China. But it is easier for joint meetings between governments, which are more institutionally flexible, because cities have formed a consensus for development through continuous dialogue. With the help of the meetings, unified policies in economic development, ecological protection, policy formulation are more likely to make to form regional commonwealths on the basis of network.

In summary, China's undeveloped areas, generally located in inland border regions, have to take advantage of cross-border trade to gain more economic benefits in particular. For example, the development of south-central Yunnan is required to open up more to Vietnam. Close trade relations are formed through the construction of industrial bases that serve the external market. This process strengthens the internetwork connection within the region and also contributes to a better regional structure. As a result, an efficient regional spatial system can be brought about with external tendencies.

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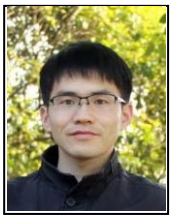
Mr. Nie has won the best paper award of 11th IACP meeting. He is a member of research center of urban and rural planning decision support, Huazhong University of Science and Technology.



He-Lin Liu was born in 1981, at Hubei, China. He is a professor and the doctoral supervisor of school of architecture and urban planning, Huazhong University of Science and Technology. He got his doctor degree in department of the land economy of the university of Cambridge, UK. The main research concerns are urban and regional innovative development (innovation economy), planning decision support based on big data and artificial intelligence, urban and regional spatial structure (network structure of flow space) and climate change and adaptation planning (low-carbon city and regional planning).

He has worked as a postdoctoral fellow in the Cambridge Centre for Climate Change Mitigation Research (4CMR), Department of the land economy of the university of Cambridge, UK. His major books published are: Creative industries and urban spatial structure: agent-based modelling of the dynamics in Nanjing (Heidelberg: Springer International Publishing, 2015), Interpretation and Utilization of Urban Cultural Space. A New Path to Construct Cultural City (Nanjing, China: Southeast University Press, 2010).

Prof. Liu has been selected into 12th National youth thousand talents program. He also won the 2017 Youth May 4th medal of Huazhong University of Science and Technology, and the 2017 "outstanding youth award" of the urban planning alumni association of Nanjing University.