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The analysis of logistics network in China cities based on logistics enterprises internal links

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Abstract: In this paper, the network analysis method is applied with branches' space layout network of the logistics enterprise above Class A as sample. The study is about the general characteristics of logistics network among Chinese cities, the level structure of urban logistics nodes, and the regional characteristics of network. The results show that: (1) the characteristic of logistics network among Chinese cities is scale-free, clustering and non-homogeneous. (2) The hierarchical structure of city nodes is obvious, Shanghai and Beijing are the national central cities, and Guangzhou and Shenzhen are the national secondary central cities. (3) The development of network area among Chinese cities is not in balance. The three economic zones, with tight contact between each other, are more developed, and the eastern coastal economic zones have an obvious clustering property. This paper on the one hand reveals the characteristic of different cities in the logistics network; on the other hand it also provides references for regional expansion of the logistics enterprises in their development process.

Keywords: Logistics Network, Logistics Enterprise, Regional Logistics, Network Analysis

1. Introduction

Research on regional logistics is focused on the cities which are the important nodes of social economic system. The development of entire national economy is linked with cities. A complex element circulation network where various elements float, such as capital, labor, information and commodities, etc, is established among cities (Zhang and Meng, 2007). The network is a logistics network among cities if only logistics element is considered. The logistics enterprises, whose management behaviors promote logistics element floating

among cities, are the subject of logistics network and the cities are the nodes of logistics network.

Logistics as a cross-regional activity is difficult to be organized and operated based on a single geographical spatial layout. So the logistics enterprises must construct network with branches distributed in different regions to form a unified operation of the whole logistics activity (Wang, 2008). Transportation convenience, labor availability, agglomeration economy and market scale are main influence factors to logistics enterprise location. As a result of differences in economy, location and policy, it is different in quantity, scale and grade of logistics enterprises among cities. From the macroscopic view of point, the difference will give some cities command and control function to some other cities. This paper studies the spatial structure of urban logistics network using network analysis method based on the space arrangement relationship between headquarters and branch offices of Chinese logistics enterprises.

The method of studying relationships among cities on the basis of contacting among enterprises is earliest applied in the research about world cities. Sassen used financial multinational companies' agencies layout structure to study global city system (Sassen, 2001). Japanese scholars used wholesale and retail relationships among enterprises to study circulation network among cities. In China, scholars used retail chains' distribution network to study circulation network hierarchy among cities (Xia, 2005). Combining logistics enterprise hierarchy network with the urban system to study logistics network among cities has not been seen yet in related studies. And in previous researches, the most commonly used method is basic statistical analysis, while network analysis is rarely used.

2. Model of Urban Spatial Structure of the Logistics Network

2.1 Data

In general, a mature logistics enterprise has a four-level management hierarchy, namely corporate headquarters, regional offices, local branches and transaction service points. When these branches are located in different cities, linkages among cities established through the way that the superior unit conveys orders to the lower unit, and lower unit reacts to the superior. On "Classification and Evaluation index of logistics enterprises in China" issued by National Standards Committee, the logistics enterprises are divided into A~5A five different grades, annually selected by China Federation of logistics and Purchasing. The selected

logistic enterprises operate normative and establish a relatively good organization, which represent modern development level of logistics enterprises in China. This paper chooses all of the "A-5A class logistics enterprises" and "The top 100 logistics enterprises in China," as the sample to study the logistics network in Chinese cities. This study includes 697 samples, of which 399 enterprises without branches have been eliminated, and some samples have been merged into the parent company. Finally we get 249 valid samples.

This study collects the information about the cities where logistics enterprises set up headquarters, regional headquarters and branches. The transaction service points are so widely distributed that we can't study them in this paper. Through data collection, we realize that most logistics enterprises in China are still in the primary stage, and a considerable number of enterprises haven't set up branches. Vast majority of logistics enterprises with branches yet to be established regional branches of the hierarchy, with organization level as the "headquarter-branch-transaction service point" mode, therefore, classified as a branch to deal with regional offices, business organization are combined into "headquarter -- branch" two levels. Headquarters, branch agencies of 249 logistics enterprises cover many Chinese cities, including some county-level cities. In order not to make data dispersed, we limit the scope of cities to prefecture-level city and put the data of county-level city into the corresponding prefecture-level city. 249 valid samples cover 95 cities. Data mainly come from logistics enterprise websites, annual reports of listed companies, state statistics.

2.2 Definition of Model

Construct logistics network between cities with nodes and edges in which the nodes are the cities that are covered by logistics branches and the edges are the relations among the logistics branches. That is,

$$G=(V,E,W) \tag{1}$$

Where $V=\{v_1,v_2,...,v_N\}$ is the set of city nodes, and N is the number of city nodes; $E=\{e_{ij}=(v_i,v_j)|\theta(v_i,v_j)=1\}$, $i,j\in(1,2,...,N)$ is the set of edges, and $\theta(v_i,v_j)=1$ means v_j is related with v_i ; $W=\{w_{ij},i,j\in(1,2,...,N)\}$ is edge-weight matrix.

Define a set of logistics companies to be $T=\{t_1,t_2,...,t_m\}$, if logistics company t_k has established the headquarter in city v_i , and has established branch office(s) in v_j , we define $t_{kij}=1$, otherwise $t_{kij}=0$. Then:

$$w_{ij} = \sum_{k}^{m} t_{kij} \tag{2}$$

Thus, a directed weighted network of the relations among cities has been constructed whose edges are hierarchical relations of headquarters and branch offices in logistics companies. As the centre of companies, the headquarter executives the functions of command, management and control, and the branch offices mainly complete the specific functions of the logistics business operations, thus, this network reflects the hierarchical relations of logistics command and operation among cities.

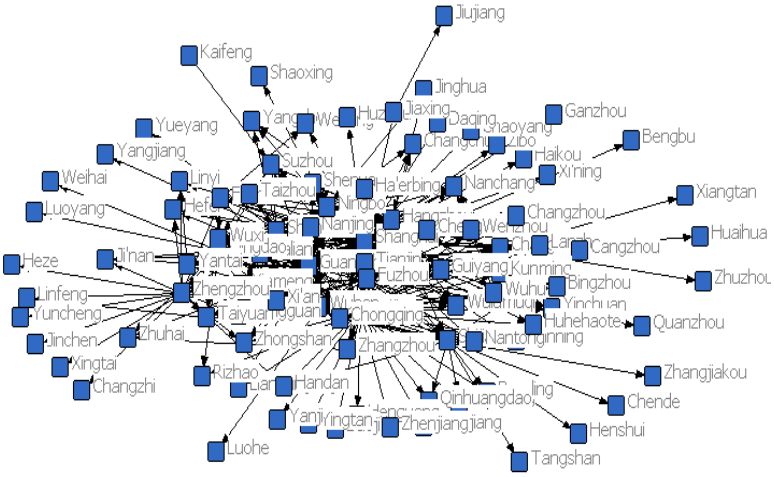

Figure 1: Logistics network among Chinese cities.

3. Network Overall Structure Analysis

3.1 Indicator of Overall Network

(1) Degree distribution

The degree of a city node is the number of city nodes which are connected to this city node. The degree distribution reflects the basic structure characteristic of the network .the degree of node i is defined as:

$$k_i = k_i^{out} + k_i^{in} = \sum_{j=1}^{N} a_{ij} + \sum_{i=1}^{N} a_{ji} \tag{3}$$

Where a_{ij} and a_{ji} denotes the value corresponding to the topological adjacency matrix.

(2) Clustering coefficient

Clustering coefficient reflects the cluster characteristics of the network. Clustering coefficient of city node in Network topology is defined as:

$$C_i = \frac{1}{k_i(k_i-1)} \sum_{j \neq k} a_{ij} a_{ik} a_{jk} \tag{4}$$

The average clustering coefficient of the network node which degree is K is:

$$C(K) = \frac{1}{NP(K)} \sum_{k_i = K} C_i \tag{5}$$

The weighted clustering coefficient of network nodes is defined as:

$$C_i^W = \frac{1}{s_i(k_i-1)} \sum_{j,k} \frac{w_{ij}+w_{ik}}{2} a_{ij} + a_{jk} + a_{ki} \tag{6}$$

Where s_i is the strength of node i, $s_i(k_i-1)$ is the normalization coefficient, and make sure that $0 \le C_i^W \le 1$. Then the weighted average coefficient of the node is $C^W(K) = \frac{1}{NP(K)} \sum_{k_i = K} C_i^W$, where $P(K)$ denotes the probability of that the node degree is K in the network.

The entire city nodes' average clustering coefficient is defines as $<C>$. When $<C>=O(N^{-1})$, it means any two city nodes are randomly connected. And when $O(N^{-1})<<C><1$, it represents that these city nodes have some cluster characteristics

(3) Degree correlation

Degree correlation reflects the urban connection rule in the urban logistics spatial network. It's called similar mixing when the high degree node tends to connect with other high degree node. When the high degree node tends to connect with other low degree node, it's called heterogeneous mixing.

The degree correlation in Topology network is defined as:

$$K_{nn}(K) = \frac{1}{NP(K)} \sum_{k_i = k} k_{nn}(i) \tag{7}$$

Where $k_{nn}(i)$ is the average degrees of node i's nearest neighbors. It's defined as $k_{nn}(i) = \frac{1}{k_i} \sum_{j \in N_i} k_j$, where N_i represents sets of node i's neighbor nodes. In the weighted network, it's strength degree correlation corresponding to the degree correlation. It's defined as:

$$K_{nn}^{W}(K)=\frac{1}{NP(K)}\sum_{k_i=k}k_{nn}^{W}(i) \tag{8}$$

$$\text{Where } k_{nn}^{W}(i)=\frac{1}{s_i}\sum_{j\in N_i}a_{ij}w_{ij}k_j$$

3.2 General Characteristics of the Network

Fig.2 shows the accumulative total degree's distribution of urban logistics network in bi-logarithm coordinates of graphics. As can be seen from the Figure, the node degree follows power-law distribution. Power exponent is 0.97, which illustrates that the urban logistics network is a scale-free network. A lot of logistics enterprises set up agencies in a few major cities, so there are direct internal contact of logistics enterprises between such a few cities and many other cities, while most cities establish direct contact to a few cities because they have only limited logistics enterprise branches. The major cities occupy very important position in the network. If such several cities were destroyed, the network will be paralyzed. Other cities have little impact on the network (Lu, 2006).

The urban logistics enterprise network has clustering because $<C>=0.425$ far outweigh $1/N$. Fig.3 shows the situation of $C(K)$ and $C^{W}(K)$ change with node degree in urban logistics network. As can be seen from the graph, accumulation modulus drop with the increase of degree K, which demonstrates the urban logistics enterprise network, has local cluster structure. The city nodes which connect with other cities less tend gather more easily (Liu, 2007). Considering the influence of weight, stronger city node's cluster coefficients have also been increased. It illustrates that the logistics enterprises which set up in a central city tend to build branches in other central cities. Actually such logistics enterprises have strategies or strength to establish a national logistics network.

Fig.4 shows that both of $K_{nn}(K)$ and $K_{nn}^{w}(K)$ decreased with increasing K, which demonstrates the logistics network of urban space is heterogeneous network. Low degree city tends to contact with centre city of the area because of the small geographical distance. Then centre city of the area will attract more logistics enterprises that it forms a regional spatial structure with centre city as the core. Considering the influence of weights, $K_{nn}(K)$ is always above $K_{nn}^{w}(K)$ and the shape of the curve is relatively gentle, which shows the

city gathering more logistics enterprises tends to establish mutual contact with another low degree city.

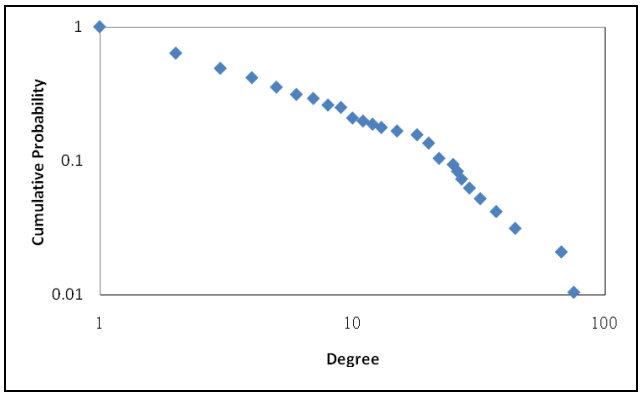

Figure 2: Accumulative total degree's distribution in bi-logarithm coordinates of graphics.

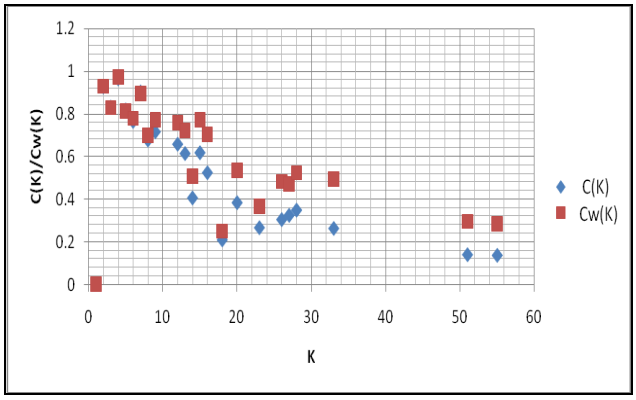

Figure 3: Relationship between degree and weighted and topological clustering.

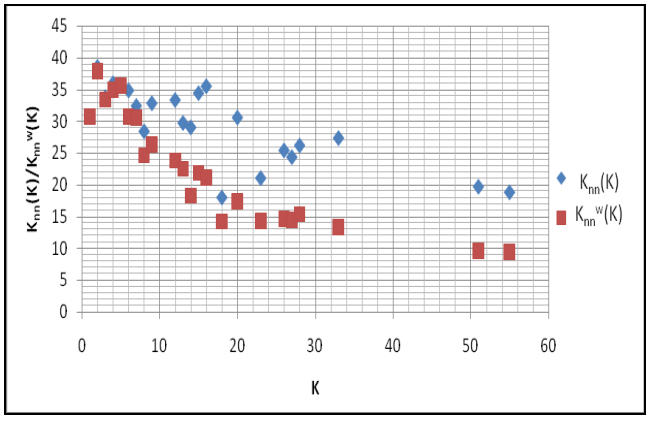

Figure 4: Relationship between weight and topological average degree of nearest neighbor and degree.

4. City Logistics Nodes Structures Analysis

The general characteristics of logistics network among cities have shown that the network is an uneven network; City nodes form level, low level nodes tend to link with top level nodes; Cities contact closely in some areas, and top level node is the key to link different areas. Therefore, we have a further research on city nodes level. There are two factors on dividing city nodes into different levels: (1) the city's central values, (2) city affected area. National center cities perform with the biggest central value and the widest influence scope. Regional central cities perform with high central values and relatively small geographical area. Peripheral cities have small central value and small influence scope. The rest of the massive urban area constitutes the edge cities.

4.1 Centrality Analysis of City Nodes

Centrality is a main indicator to depict city node's place in the network. The centrality includes out-degree centrality, in-degree centrality and between's centrality. Out-degree centrality indicates the total number of connections from the city node to others, while in-degree centrality indicates the total number of connections from others to the city. Such two indicators reflect city node's position in the network. The bigger the value is, the higher the status is. Betweenness centrality reflects the city node's ability as media to connect other cities (Luo, 2010). The definition of out-degree centrality equates to k_i^{out} and the definition of in-degree equates to k_i^{in}. Betweenness centrality is defined as:

$$C_{Bi}=\sum_{j}^{n}\sum_{k}^{n}\frac{g_{jk}(i)}{g_{jk}}(j\neq k\neq i, j<k) \tag{9}$$

g_{jk} shows the number of shortest path between node j and node k, of which $g_{jk}(i)$ shows the number through node i.

Based on the indicator of centrality, the centralization reflects the level of center structure (Scott John, 2000). The out-degree centralization of the city logistics space network is 41.860%, and the in-degree centralization is 19.843%. It illustrates that the out-degree concentration of the city logistics space network is far greater than the in-degree concentration. The site of logistics corporate headquarters is obvious in the some cities center, and the branches of logistics enterprises are relatively spread around the cities.

There are 32 cities whose out-degree centrality value is not zero, which shows those 249 sample enterprises only established headquarters in 32 cities.

Table1 rank top 10 cities on out-degree centrality, in-degree centrality and betweenness centrality. The city which is high on out-degree centrality has strong ability to command and control. While logistics demand is strong, logistics investment environment is better on the city which is high on in-degree centrality. Those cities which are high on betweenness degree can not only have the strong command and control ability, also can attract the logistics enterprises to establish branch, as a communication bridge between cities (Liu Jun, 2004).

There are basically three influence factors in choosing logistics enterprise headquarters locations as follows: the first is the city's economic development level and influence. Beijing and Shanghai, as China's political and economic centre, accommodate most logistics enterprise headquarters, the amount of which is far more than other cities. The second is the urban transportation development level. Ningbo city gathering many logistics:

Table 1: Centrality of city node top 10.

Number	City	Out-degree centrality	City	In-degree centrality	City	Betweenness centrality
1	Beijing	51	Shanghai	26	Shanghai	3462.615
2	Shanghai	50	Guangzhou	17	Beijing	2922.210
3	Ningbo	29	Beijing	16	Ningbo	1757.344
4	Guangzhou	27	Wuhan	15	Zhengzhou	1436.266
5	Shenzhen	25	Shenzhen	14	Shenzhen	1101.479
6	Zhengzhou	23	Tianjin	12	Shijiazhuang	995.429
7	Fuzhou	19	Nanjing	12	Guangzhou	714.737
8	Hangzhou	17	Hangzhou	12	Qingdao	653.112
9	Qingdao	17	Chengdu	10	Changsha	634.426
10	Dalian	15	Ningbo	10	Hangzhou	564.244

Table 2: Comparison on three kinds of centralities.

Item	Out-degree centrality	In-degree centrality	Betweenness centrality
Mean	3.632(3.459)	3.632(3.459)	152.764(1.399)
Variance	79.836(72.414)	18.157(16.469)	260133.594(21.815)

Enterprises headquarters is neither economic center, nor capital city, but it gathers many logistics headquarters relying on Ningbo city port. According to the National Bureau of Statistics (NBS), 2010 cargo throughput of Ningbo port ranked the first. Zhengzhou as the largest railway hub has irreplaceable advantages and is more attractive than other capital cities. Guangzhou and Shenzhen are not only the economic development front of our country, but also have important port and superior geographical conditions, near Hong Kong. The third factor is about the influence area and logistics enterprises development phase. Enterprises, the service scope of which was limited in the local area, tend

to set up headquarters in the area center city. Then, it tends to move the headquarters to the higher level city as spanning service network to another economic area. Taking Hoau as an example, the headquarters of the company was in Jiamusi when it was just a local company. With company expansion and setting up branches in other areas, it moved headquarters to Guangzhou. With the construction of the national network, the headquarters of Hoau was migrated to Shanghai and form "Jiamusi -Guangzhou - Shanghai" evolution locus finally (Wang Chengjin, 2008).

Table 2 lists mean and variance of the three kinds of centralities. The variance of out-degree centrality and betweenness centrality is large, which illustrates the big difference among cities on these two indicators. Although there are 32 cities which have logistics enterprise headquarters, Beijing and Shanghai apparently gather more enterprise headquarters. There is only 1 logistics enterprise headquarter in cities such as Changchun, Kaifeng and Cangzhou. So hierarchy is obvious among these cities. When out-degree centrality is higher, the cities' ability of attracting top level logistics enterprise is stronger, and the core position is more outstanding. So is intermediary of central. Shanghai and Beijing are the most important intermediary point of network. When removing Shanghai off network, the eight cities Huzhou, Jiaxing, Daqing, Haikou, Chaoyang, Xining, Zibo and Jiujiang at the top of figure 5 altogether become isolated nodes. When removing Beijing off network, the six cities Zhenjiang, Zhanjiang, YanJi, Hengyang, Yingtan, Baoji in lower-left of figure 6 become isolated nodes, and other cities were needed to contact each other through longer channels. In network diagram the more peripheral the city node lies, the less influential to other nodes the city gets.

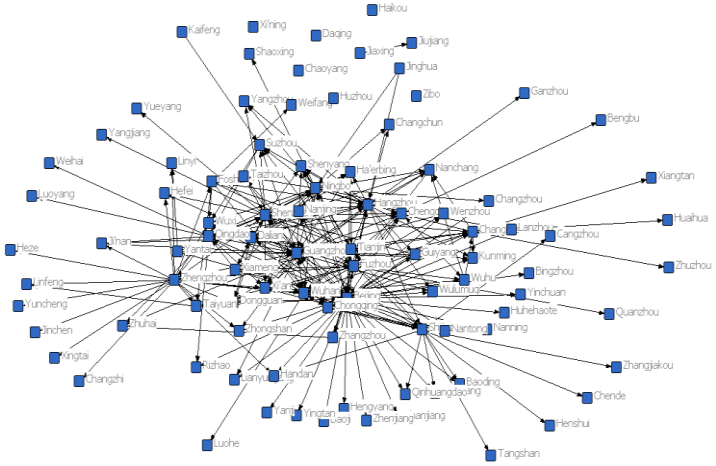

Figure 5: Network without Shanghai.

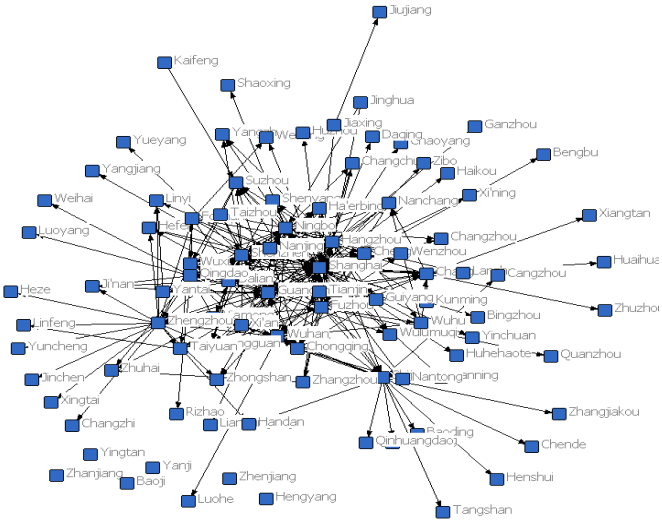

Figure 6: Network without Beijing.

In comparison, scattering degree of introverted centrality is much smaller, which accords with network layout regularity that logistics enterprise's command and control function is centralism, and business operation function is in the scattered space. Branch is closer to the layout of logistics market, and also has a rank tendency. Most provincial capital cities have high centricity values, which indicate that logistics enterprises tend to locate new branches in regional central cities to guarantee cargo supply.

Thus, judging by the characteristics of city nodes' three centrality distribution, logistics network among Chinese cities presents a "core-periphery" structural feature around different grades of central cities.

4.2 The Influence Area of City Nodes

By observing the relationship between the distance and the contact strength weight between cities, this paper draw the cumulative rate curve of contact strength between logistics enterprises to identify the influence area of city nodes. In this paper, we choose six cities whose out-degree centralities are above 20 to draw the cumulative rate curve.

The slope of the curve of cumulative distance reflects the accumulation speed. The higher is the slope, the smaller is the influence area of the city node. Accumulated strength has reached a high accumulated speed to 60 percents of the total strength of Ningbo within 250km in distance. It shows the area where Ningbo influences mainly is the Yangtze River delta region. Accumulated strength of Zhengzhou has reached 60 percents within 800km. Away from Ningbo 250 kilometers, and Zhengzhou 800km, it displays the rule of ladder

shaped growth. Mutant growth points outside the region are the cities such as Beijing, Shanghai, Guangzhou, while the contact with other cities is quite rare. Therefore, although the centrality value of Ningbo and Zhengzhou is high, they can only be considered as regional central city.

Change trend of cumulative rate curve of Shanghai, Beijing, Guangzhou and Shenzhen are gentle. It shows the influence of the four cities is nationwide. At the same time, the mutual contact strength among Shanghai, Beijing, Guangzhou and Shenzhen is also very strength. Figure 8 shows the allocation rate cure among four cities. The space distances among four cities show high contact intensity. It demonstrates that Shanghai, Beijing, Guangzhou and Shenzhen are cores of regional logistics contact. Further consideration, Beijing and Shanghai are the center cities of country while Guangzhou and Shenzhen are national secondary centre city because the centrality of Guangzhou and Shenzhen, although which influence large area, is much lower than Beijing and Shanghai.

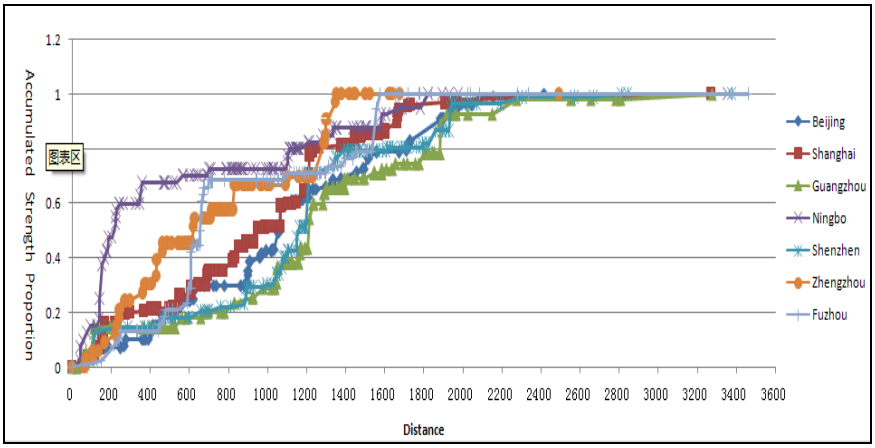

Figure 7: Command and control strength cumulative rate curve.

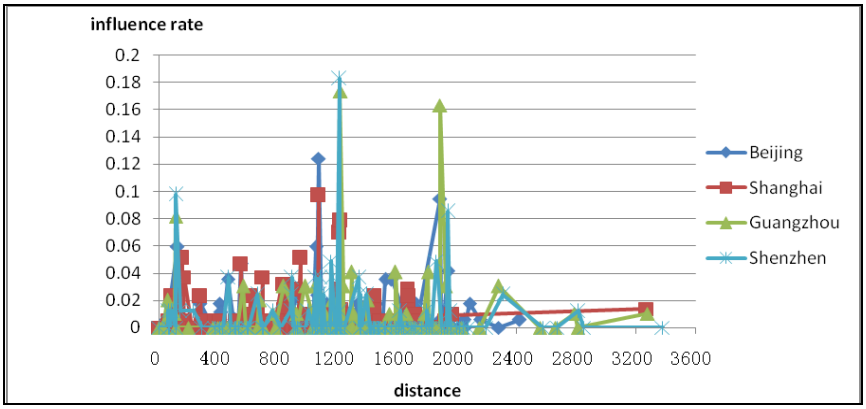

Figure 8: Allocation Rate Curve of Beijing, Shanghai and Shenzhen.

4.3 The Hierarchical Structure of City Logistics Nodes

We can divide our country city nodes into five levels which are national centre city, national second-centre city, regional centre city, peripheral city and edge city by cluster analysis about the centrality and influenced area of city node. Table 3 lists the classification of city nodes.

5. Regional Characteristics of the Network

In China, the regional distribution of urban logistics network is not balanced, 33 percent of logistics enterprise headquarters are in eastern coastal economic zone, 20 percent of the enterprise headquarters are in northern coastal economic zone, and 16 percent of logistics enterprise headquarters are in southern coastal economic zone, but in other economic zone there are fewer logistics enterprise headquarters. And from the east to the west there is a rapid decrease in quantity.

The connection among the three economic zones is relatively tight. 69 percent of enterprises select composite layout in the northern and eastern, southern coastal economic zone, and the layout point selected in every region are usually center cities, such as Beijing, Tianjin, Qingdao and Dalian in north coastal economic zone, Shanghai, Ningbo, Hangzhou in eastern coastal economic zone, Guangzhou, Shenzhen in southern coastal economic zone. Seen from the internal economic zone, the eastern coastal economic zone seem to have the most closely contact of logistics between cities.

Table 3: City node hierarchy of Chinese logistics network.

Levels	City node
National Center City	Shanghai, Beijing
National Secondary City	Guangzhou, Shenzhen
Regional Center City	Ningbo, Zhengzhou, Fuzhou, Hangzhou, Qingdao and Dalian, Shijiazhuang, Changsha, Chongqing, Tianjin, Wuhan, Chengdu
Peripheral City	Foshan, Xiamen, Harbin, Nanchang, Taizhou, Zhangzhou, Jiaxing, Changchun, Kaifeng, Cangzhou, Guiyang, Wuhu, Xian, Nanjing and Wuxi, Suzhou, Shenyang, Dongguan, Hefei, Jinan, Urumqi, Nantong, Kunming, Zhongshan, Wenzhou, Taiyuan

Contact of logistics in internal region is tighter than it with external region, and has the clique characteristics. It has formed the reasonable layout structure of taking Shanghai as the center, and Ningbo, Hangzhou as the center of the region. The northern coastal economic zone including Beijing, Tianjin and Shandong, is China's most powerful technical and manufacturing center. It also

has formed the structure of taking Beijing as the center, Tianjin, Shijiazhuang, Qingdao as the regional center cities. But the contact among cities within the northern coastal economic zone is not as tight as in the eastern coastal economic zone. Southern coastal economic zone includes Fujian, Guangdong and Hainan, but the internal contact is relatively loose. Fuzhou, one of the regional central cities mainly contact with Zhejiang and Jiangsu, instead of Guangdong and Hainan. The logistics enterprises gathering in Shenzhen and Guangzhou also extend their network to Beijing, and Shanghai, respectively as political and economic centre city in the national, rather than to layout only in the southern economic zone.

The internal contact degree of other economic zone weakens gradually with lower level regional economic development. Logistics enterprises with headquarters located in these economic zones will tend to contact with city nodes outside the zones when seeking expansion of branches and they would prefer to establish branches in national core cities or other regional central cities. The number of headquarters and branches of logistics enterprise in Western region cities is so small that in the whole western region no city can undertake the important task of building the bridge between other cities. If removing Beijing and Shanghai off the network at the same time, Hohhot, Yinchuan, Xining all become isolated nodes. It shows that the western cities have highly dependence on the national central city Shanghai and Beijing; the network system in western has not been established yet.

6. Conclusion and Recommendations

Through the above analysis, we can get the following conclusions: (1) the logistics enterprises in China are in process of logistics network construction, logistics network connecting major cities in China has basically taken shape. The network is a scale-free network, which has characteristics of clustering and heterogeneous mixture. (2) Among the cities in China the logistics network is a "core - edge" hierarchy. From comprehensive evaluation of node centrality and influence scope, Shanghai and Beijing are centers of the entire network, Guangzhou and Shenzhen are secondary centers. Ningbo, Hangzhou, Zhengzhou, Fuzhou, Qingdao, Dalian, Shijiazhuang, Changsha, Chongqing and Tianjin are the local centers of network; other cities are the peripheries and edges. (3) The cities with logistics enterprise command and control function are highly centralized, and the cities with logistics business operation function are more decentralized. Beijing, Shanghai, Ningbo, Shenzhen and Shijiazhuang are the bridge among other cities. (4) There exists obvious imbalance about Chinese

cities network in space, 69% of logistics enterprises set up headquarters in eastern coastal economic zone, northern coastal economic zone, and southern coastal economic zone. Among these three economic zones there are strong ties. The eastern coastal economic zone displays obvious clustering characteristic and contact within internal area is tighter than contact with external. The logistics link among China's eight economic zone levels is low, and, is still in isolated position in general.

The above conclusions have the following reference significance to Chinese urban logistics and logistics enterprise's development: the internal network construction of China logistics enterprise is still at the primary stage; the logistics enterprises need to make a scientific and reasonable strategy about branches layout; the logistics enterprises should follow the "from peripheral to the core, again by the core to periphery" network construction mode, using the advantage of different city nodes in the network to the obtain corresponding developments. Following the development of logistics, cities in China should improve their position in urban network structure, to attract modern logistics enterprise branches which have conglomeration effect, and to promote fast development about urban logistics.

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