A Research on Urban Logistics Development Level and Spatio-temporal Network Analysis

-Perspective of China Railway Express

도시 물류 발전 수준 및 시공간적 네트워크 분석에 관한 연구

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Contents

Chapter 1. Introduction

1. Introduction

❖ Research Background

✓ What is China Railway Express ?

Which is organized by China Railway Corporation and has fixed trips, route, schedule, and transport time, is a China–Europe block train ferry operated in international railway **container** intermodal transportation mode.

Belt and Road Initiative (BRI)

- **Silk Road Economic Belt (SREB)**
- **Maritime Silk Road (MSR)**

✓ Policy & Plan

1	12th 5-year plan: 2011–2015
2	13th 5-year plan: 2016–2020
3	"Vision and Actions on Jointly Building Silk Road Economic Belt and 21st-Century Maritime Silk Road - 2015"
4	"China Railway Express construction and development plan (2016–2020)"

✓ Development Stage

Exploration(2011-2013)

↓

High-speed growth(2014-2018)

↓

High-quality(2019~NOW)

1. Introduction

❖ Scope & Objective

"China Railway Express construction and development plan (2016–2020)"

Nodes of main inland sources of goods:	Chongqing	Chengdu	Zhengzhou	Wuhan	Xi'an	Lanzhou
	Changsha	Hefei	Shenyang	Dongguan	Suzhou	Yiwu
Main railway hub nodes:	Chongqing	Chengdu	Zhengzhou	Wuhan	Xi'an	Lanzhou
	Changsha	Hefei	Shenyang	Beijing	Harbin	Jinan
	Nanjing	Hangzhou	Tianjin	Urumqi	UlanQab	
Important coastal port nodes:	Dalian	Yingkou	Tianjin	Qingdao	Lianyungang	Ningbo
	Xiamen	Guangzhou	Shenzhen	Qinzhou		
Nodes along the border land ports:	Alataw	Horgos	Erenhot	Manchuria		

Space Range: 19 Inland node Time Range: 2013-2016-2019

High operation costs

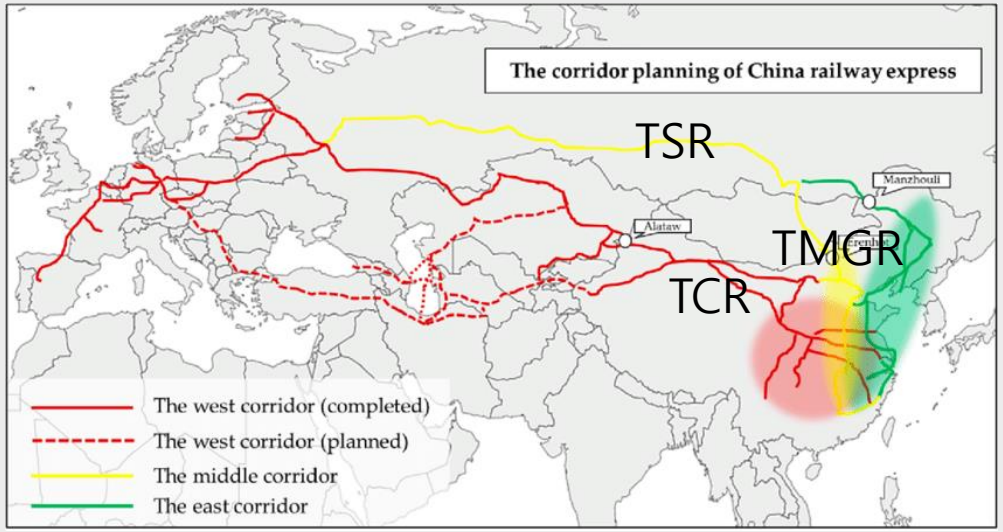
- Relying subsidies
- Low loading rate

Hub City Selection

Chapter 2. Overview of China Railway Express

2. Overview of China Railway Express

❖ The major Transport Corridors

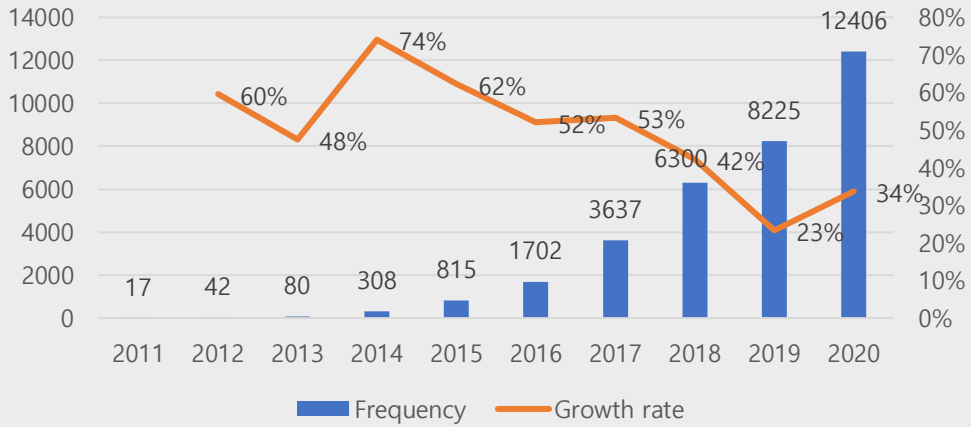


Source : Liu, W., Zhu, X., & Wang, L. (2019)

Routes	Corridors	Main Railway Border	Main Supply Regions
Eastern	Beijing–Harbin–Manchuria–Russia–Belarus–Poland–other European countries	Manchuria	East China, South China and North China
Central	Erenhot–Mongolia–Russia–Belarus–Poland–other European countries	Erenhot	Central China and North China
Western	Alataw (Khorgos)–Kazakhstan–Russia–Belarus–Poland–other European countries	Alataw / Khorgos	Southwest,Northwest

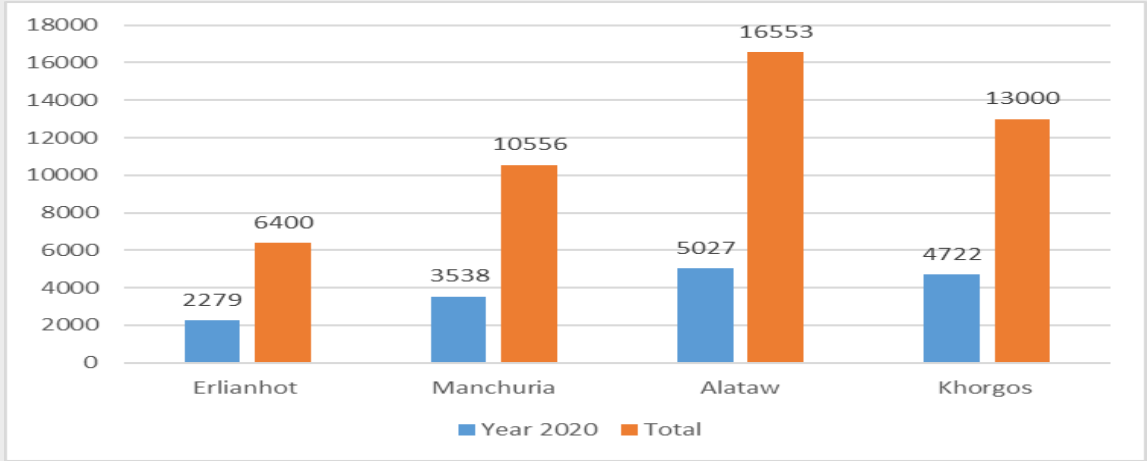
Source: Choi, K. S. (2021)

✓ The growth of China Railway Express (2011-2020)



Source: CRCT

✓ Operation of freight trains at four major border stations (2020)



Source: CRCT

Chapter 3. Literature Review

3. Literature Review

❖ China Railway Express

Researcher	Title	Method
(Jiang et al., 2018)	Hinterland patterns of China Railway (CR) express in China under the Belt and Road Initiative: A preliminary analysis	Binary logit model
(Zhao et al., 2018)	Evaluation of consolidation center **cargo capacity** and locations for China railway express	TOPSIS
(Liu et al., 2019)	Distribution organization optimization for Inbound China Railway Express at **Alataw Pass Railway Station**	Model
(Sun et al., 2020)	Selection of consolidation centres for China Railway Express	TOPSIS
(Zhang et al., 2020)	**Importance rankings of nodes** in the China Railway Express network under the Belt and Road Initiative	MADM
(Ma et al., 2020)	Hierarchical multimodal hub Location with **Time Restriction** for China Railway (CR) Express Network	mix integer programming
(Zhao et al., 2020)	European hub location problem for China Railway Express in the context of the Belt and Road Initiative	TOPSIS
(Cheng et al., 2021)	Selection of consolidation center locations for China Railway Express to **reduce greenhouse gas emission**	Augmented ε-constraint method

Differentiation

1. Geographic information system (GIS) is applied to represent the evolution of node cities in different periods to visualize the formation process of hub cities.

2. The dynamic analysis using temporal and spatial perspectives is the differentiator of this paper.

Chapter 4. Methodology

4. Methodology

❖ Entropy Weight Method

1) Normalize the collected data matrix X_{ij}, $X_{ij}' = X_{ij} / X_{ij}\max$* and thus the normalized matrix of data $Y_{ij}=(Y_{ij})m*n$

$$Y_{ij} = X_{ij} / \sum_{i=1}^{m} X_{ij} \quad \text{(eq.1)}$$

2) Calculate the entropy value of the jth indicator ej. Where k=1/ln n, y_{ij} is the normalization matrix

$$ej = -k \sum_{i=1}^{m} y_{ij} \ln y_{ij} \text{ (eq.2)}$$

Calculate the deviation of the jth index d_j, where e_{ij} is the entropy value

$$d_j = 1 - e_{ij} \quad \text{(eq.3)}$$

Calculate the weight w_j of the jth indicator. where d_j is the deviation degree

$$wj = \frac{d_j}{\sum_{i=1}^{n} d_{ij}} \quad \text{(eq.4)}$$

3) Composite score U is calculated

$$U = \sum_{i=1}^{n} y_{ij} w_j \quad \text{(eq.5)}$$

❖ Modified Gravity Model

$$G_{ij} = k \frac{M_i M_j}{D_{ij}^d}$$

where: G_{ij} is the spatial gravity between cities i and j;

M_i, M_j denote the "mass" of cities i and j;

$$D_{ij} = \sqrt[3]{d_{ij} t_{ij} c_{ij}}$$

d_{ij}denotes the spatial distance between city i and j. The value is the geometric mean of the road and rail distances between city i, j.

t_{ij} denotes the time distance between city i and j. The value is the geometric mean of the road and rail transportation time between city i, j.

C_{ij} denotes the unit transportation rate between city i and j. The rate is the geometric mean of the road transportation rate and the rail transportation rate between city i and j. Based on the results of existing studies (Dong 2016), the road transportation rate is 1.5, and the rail transportation rate is 1.

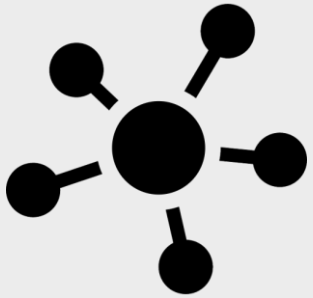
The modified gravity model is calculated as:

$$G_{ij} = \frac{M_i M_j}{\left(\sqrt[3]{d_{ij} t_{ij} c_{ij}}\right)^2}$$

4. Methodology

❖ Social Network Analysis

✓ Degree centrality



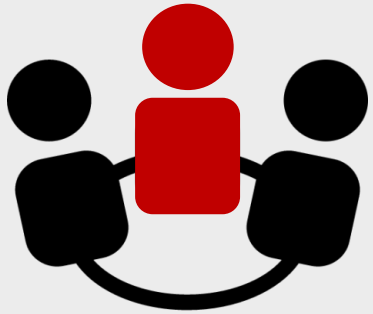
$$C_D(N_i) = \frac{\sum_{j=1}^{g} x_{ij}}{g-1}$$

$C_D(N_i)$: The degree centrality of node i.

$\sum_{j=1}^{g} x_{ij}$: The number of connections node i has with $(g-1)$ other nodes. $x_{ij} = 0 \; or \; 1$,

g: The number node.

✓ Betweenness centrality



$$C_B(N_i) = \frac{\left[\sum_{j<k} \frac{g_{jk}(N_i)}{g_{jk}}\right] * 2}{(g-1)(g-2)}$$

$C_B(N_i)$: The betweenness centrality of node i

g_{jk}: The number of shortest paths from j to k.

$g_{jk}(N_i)$: The number of paths including I among the shortest paths between j and k.

✓ Closeness centrality

$$C_C(N_i) = (g-1)\left[\sum_{j=1}^{g} d(N_i, N_j)\right]^{-1}$$

$C_C(N_i)$: The closeness centrality of node i

$\sum_{j=1}^{g} d(N_i, N_j)$: The sum of the shortest path distances between node i and node j.

g: The number node.

Chapter 5. Experimental Analysis

5. Experimental Analysis

❖ Process of experimental analysis

Node

City i

Line

i j

Network

Entropy Weight Method

Ranking

LDL Score(M)

Modified Gravity Model

$$G_{ij} = \frac{M_i M_j}{\left(\sqrt[3]{d_{ij} t_{ij} c_{ij}}\right)^2}$$

Weighted

Social Network Analysis

- Degree centrality
- Betweenness centrality
- Closeness centrality

Regional economic level	GRDP
	Total Retail Sales of Consumer Goods
	Total import and export value
Logistics infrastructure level	Mileage of highway, railway
	Freight volume of highway, railway
	Freight Turnover of highway, railway
	Employment in transportation, storage and post
	Investment in transportation, storage and post
Informatization level	Internet penetration

Visualization : GIS + Gephi

Data source:

- Statistical yearbooks of the provinces and cities
- Region statistical bureau
- China State Railway Group Co., Ltd.
- China Railway Container Transport Corp., Ltd

新华丝路 silkroad.news.cn

中国铁路12306 12306 CHINA RAILWAY

CRCT 中铁集装箱

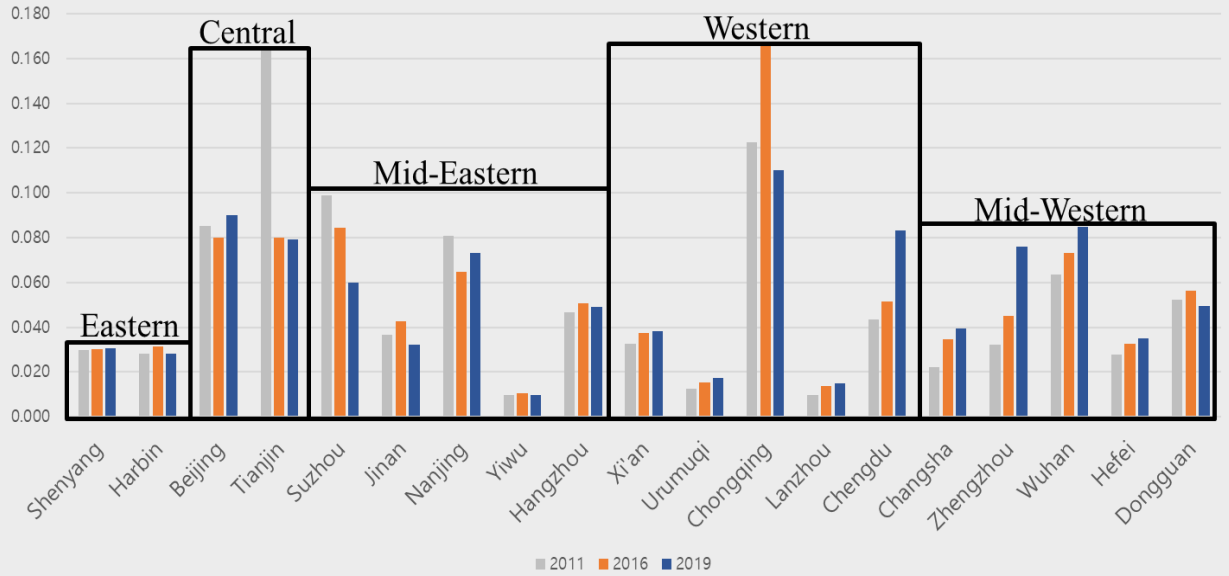
5. Experimental Analysis

❖ Analysis of LDL in CRE node cities

✓ The logistics development level Score

Region	City	2013	Rank	2016	Rank	2019	Rank	2013-2019
Eastern	Shenyang	0.030	13	0.030	16	0.031	15	↓3
	Harbin	0.028	14	0.031	15	0.028	16	↓2
Central	Beijing	0.085	4	0.080	3	0.090	2	↑2
	Tianjin	0.166	1	0.080	4	0.079	5	↓4
Mid-Eastern	Suzhou	0.099	3	0.084	2	0.060	8	↓5
	Jinan	0.037	10	0.043	11	0.032	14	↓4
	Nanjing	0.081	5	0.065	6	0.073	7	↓2
	Yiwu	0.010	18	0.011	19	0.010	19	↓1
	Hangzhou	0.047	8	0.051	9	0.049	10	↓2
Western	Xi'an	0.033	11	0.037	12	0.038	12	↓1
	Urumuqi	0.012	17	0.015	17	0.017	17	→0
	Chongqing	0.123	2	0.166	1	0.110	1	↑1
	Lanzhou	0.010	19	0.014	18	0.015	18	↑1
	Chengdu	0.044	9	0.051	8	0.083	4	↑5
Mid-western	Changsha	0.022	16	0.035	13	0.040	11	↑5
	Zhengzhou	0.032	12	0.045	10	0.076	6	↑6
	Wuhan	0.063	6	0.073	5	0.085	3	↑3
	Hefei	0.028	15	0.033	14	0.035	13	↑2
	Dongguan	0.052	7	0.056	7	0.049	9	↓2
Geometric Mean		0.039		0.043		0.044		

✓ Logistics development level in major corridor

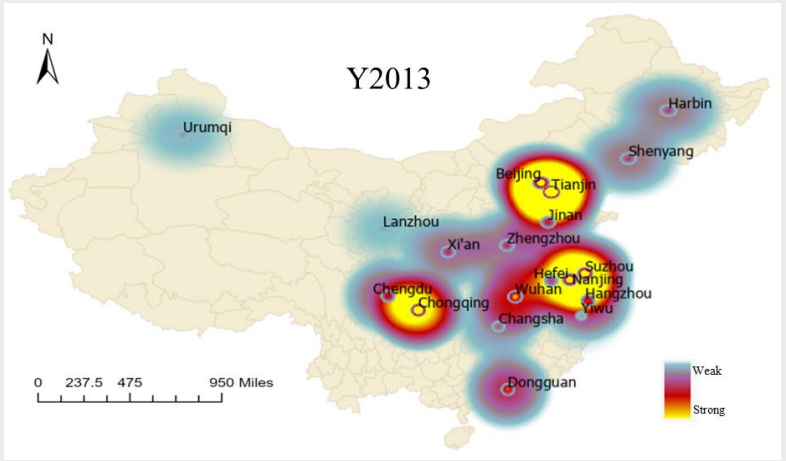


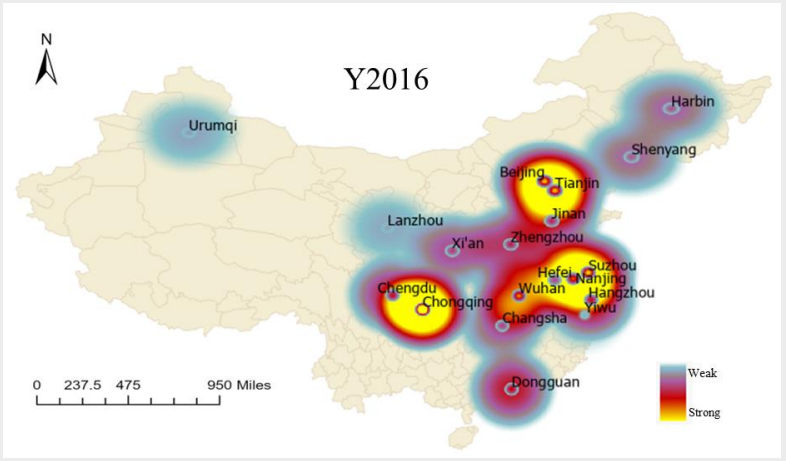
Decrease : Central & Mid-Eastern Corridor

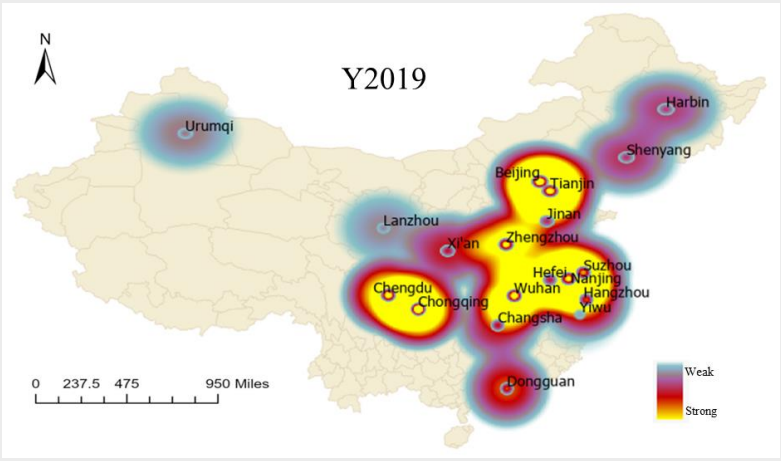
Increase : Western & Mid-western

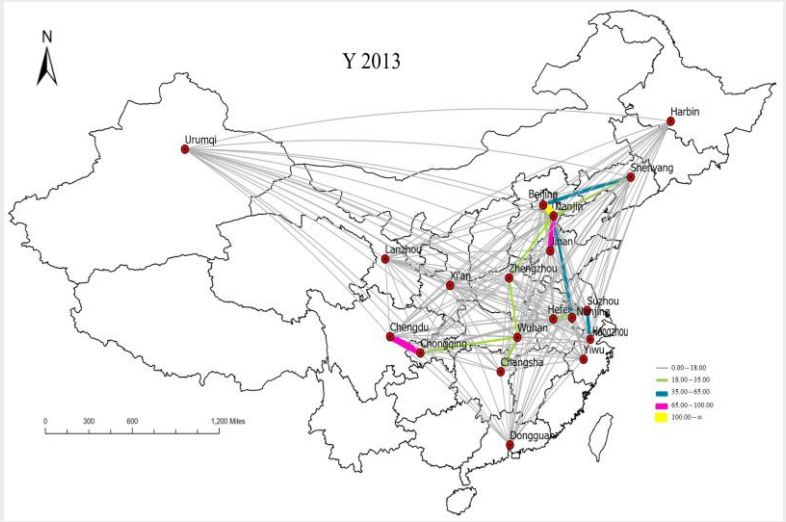
5. Experimental Analysis

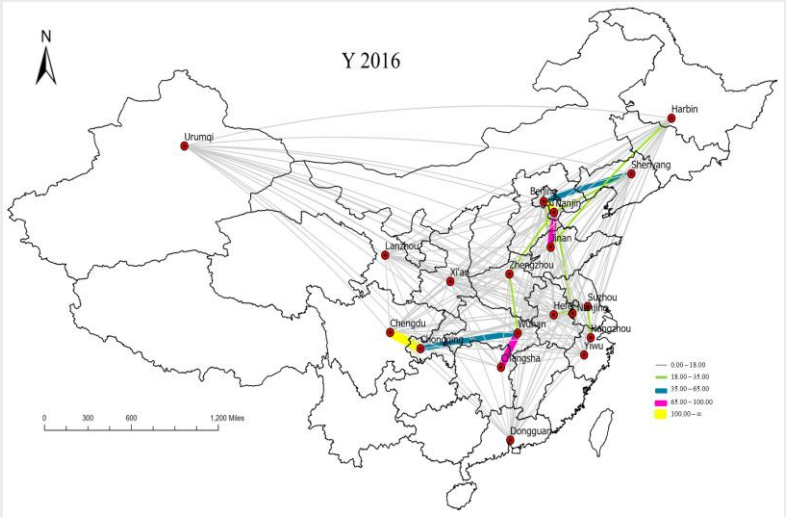
❖ **Analysis of LDL & Gravity**

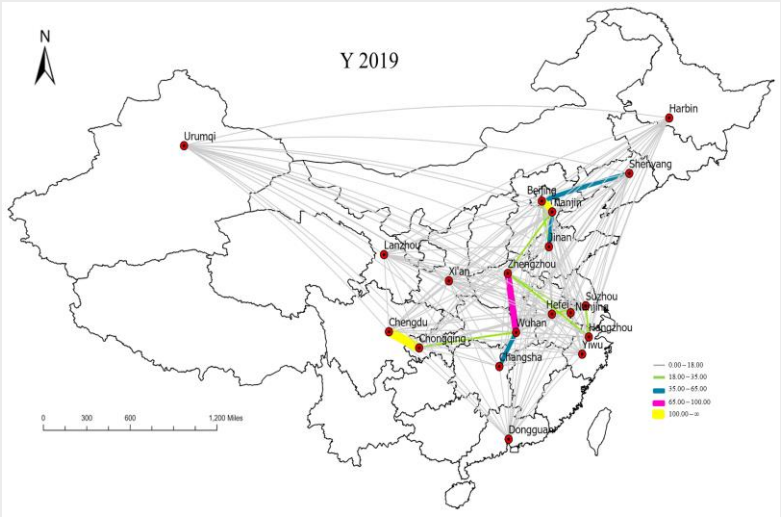












5. Experimental Analysis

❖ Social Network Analysis

City	Rank	D.C-2013	Rank	D.C-2016	Rank	D.C-2019
Zhengzhou	5	21	4	22	1	30
Wuhan	1	28	1	28	2	28
Nanjing	3	22	6	21	3	26
Tianjin	2	27	3	24	4	22
Chongqing	3	22	2	25	5	22
Suzhou	5	21	4	22	6	21
Beijing	8	17	7	18	7	19
Hangzhou	7	18	7	18	8	18
Changsha	12	10	11	13	9	17
Jinan	8	17	9	17	10	16
Hefei	10	15	10	16	10	16
Xi'an	11	14	11	13	10	16
Chengdu	16	5	15	5	13	13
Shenyang	14	6	15	5	14	8
Dongguan	13	9	13	9	14	8
Harbin	16	5	15	5	16	7
Yiwu	14	6	14	7	16	7
Lanzhou	18	1	18	2	18	4
Urumqi	19	0	19	0	19	0

City	Rank	C.C-2013	Rank	C.C-2016	Rank	C.C-2019
Zhengzhou	5	0.727	7	0.708	1	0.895
Wuhan	1	0.889	1	0.850	2	0.850
Nanjing	3	0.762	3	0.773	3	0.810
Tianjin	1	0.889	1	0.850	4	0.773
Beijing	3	0.762	3	0.773	5	0.773
Suzhou	5	0.727	5	0.739	6	0.708
Chongqing	7	0.696	5	0.739	7	0.680
Hangzhou	7	0.696	9	0.654	7	0.680
Hefei	10	0.640	9	0.654	9	0.654
Changsha	12	0.593	12	0.531	9	0.654
Jinan	7	0.696	8	0.680	11	0.630
Xi'an	11	0.615	11	0.586	11	0.630
Chengdu	14	0.516	14	0.515	11	0.630
Yiwu	14	0.516	14	0.515	14	0.548
Dongguan	12	0.593	12	0.531	15	0.531
Shenyang	14	0.516	16	0.486	15	0.531
Harbin	17	0.500	16	0.486	17	0.515
Lanzhou	18	0.425	18	0.436	18	0.436
Urumqi	19	0.000	19	0.000	19	0.000

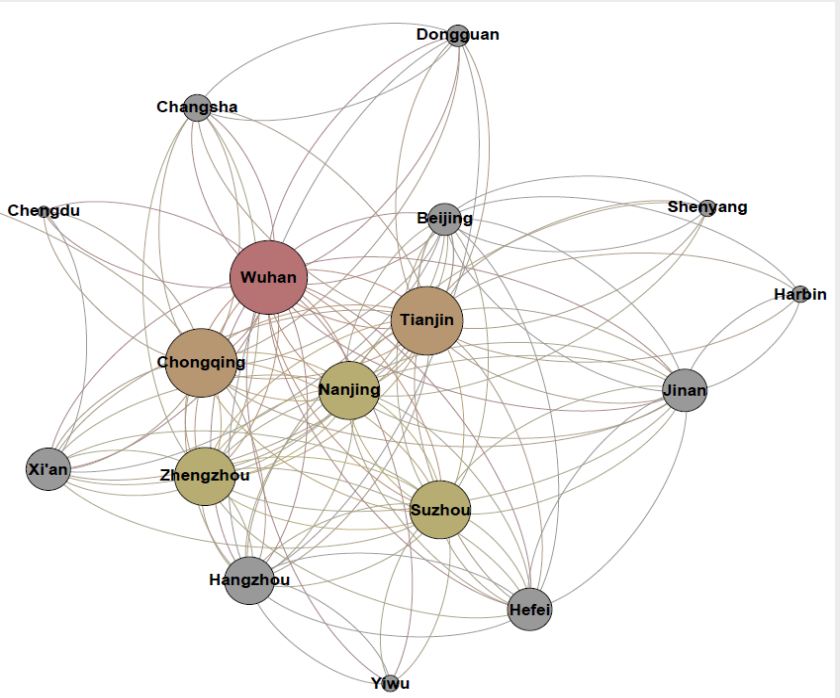
City	Rank	B.C-2013	Rank	B.C-2016	Rank	B.C-2019
Zhengzhou	9	0.020	6	0.032	1	0.136
Wuhan	2	0.136	2	0.140	2	0.094
Chongqing	3	0.095	1	0.165	3	0.079
Nanjing	4	0.041	7	0.032	4	0.055
Tianjin	1	0.142	3	0.119	5	0.047
Suzhou	5	0.038	4	0.040	6	0.034
Hangzhou	6	0.030	9	0.025	7	0.028
Xi'an	10	0.006	10	0.005	8	0.027
Beijing	8	0.023	5	0.036	9	0.017
Changsha	11	0.003	11	0.004	10	0.017
Chengdu	14	0.000	14	0.000	11	0.014
Jinan	7	0.025	8	0.030	12	0.012
Hefei	12	0.002	12	0.003	13	0.004
Dongguan	13	0.001	13	0.001	14	0.000
Shenyang	15	0.000	15	0.000	15	0.000
Harbin	16	0.000	16	0.000	16	0.000
Yiwu	17	0.000	17	0.000	17	0.000
Lanzhou	18	0.000	18	0.000	18	0.000
Urumqi	19	0.000	19	0.000	19	0.000

5. Experimental Analysis

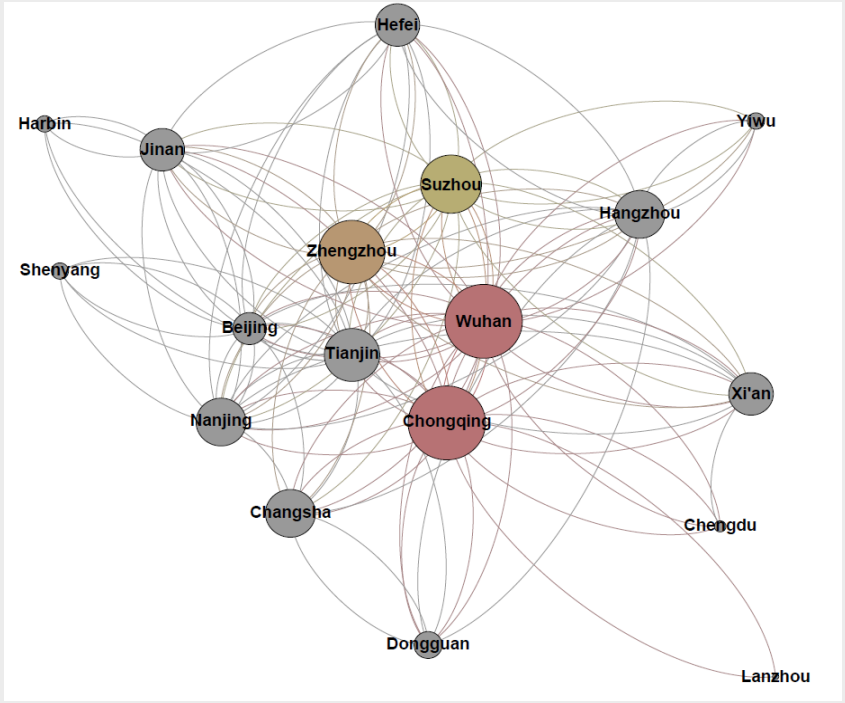
❖ **Social Network Analysis**

In-Degree Centrality

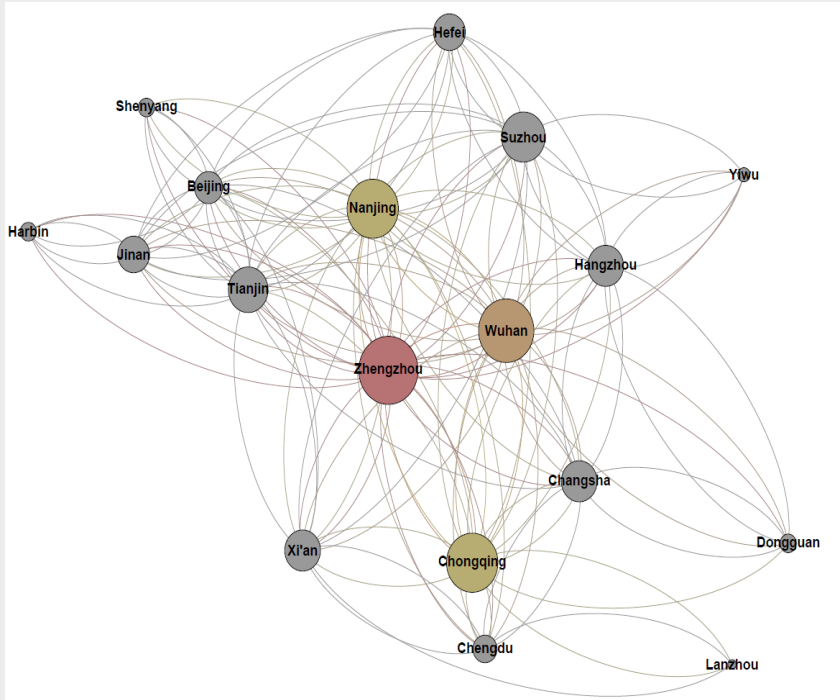
Year 2013



Year 2016



Year 2019



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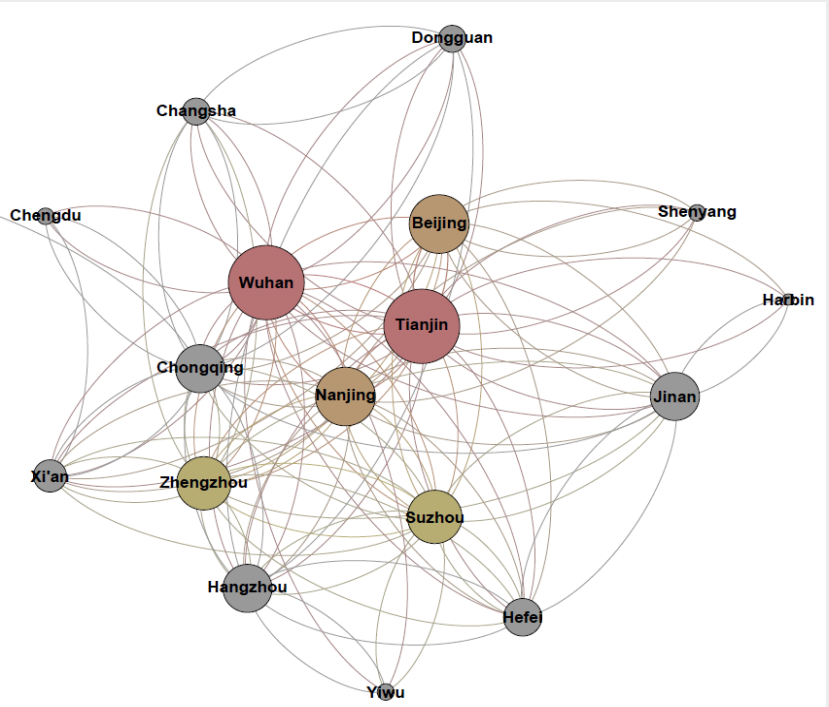
5. Experimental Analysis

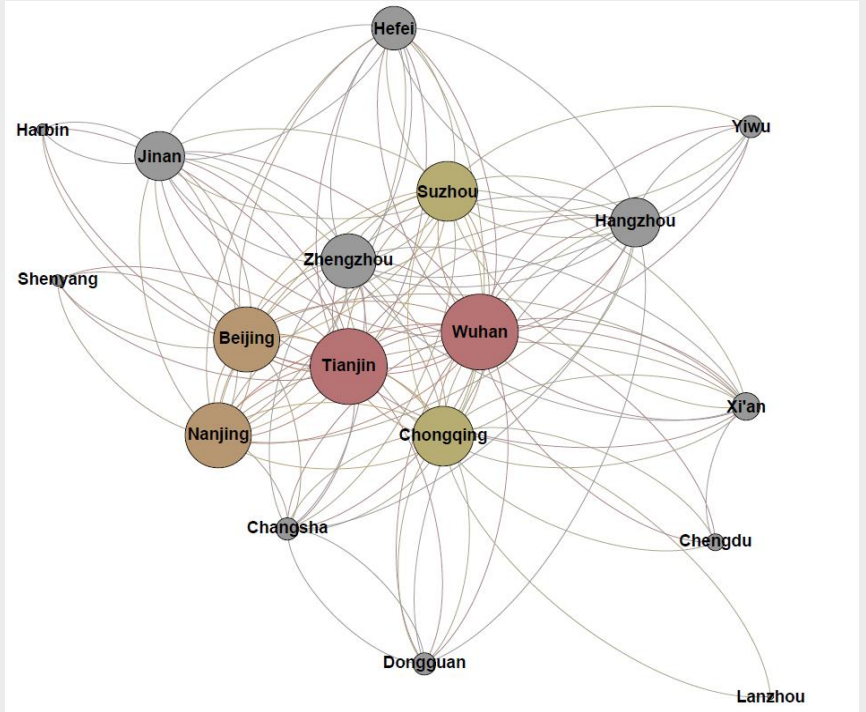
❖ **Social Network Analysis**

Out-Degree Centrality

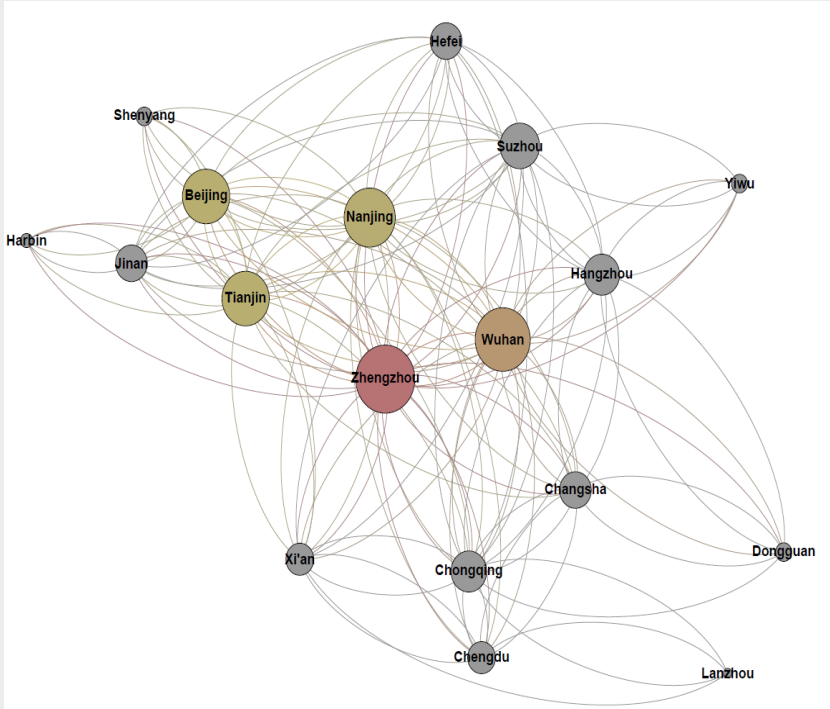
Year 2013



Year 2016



Year 2019



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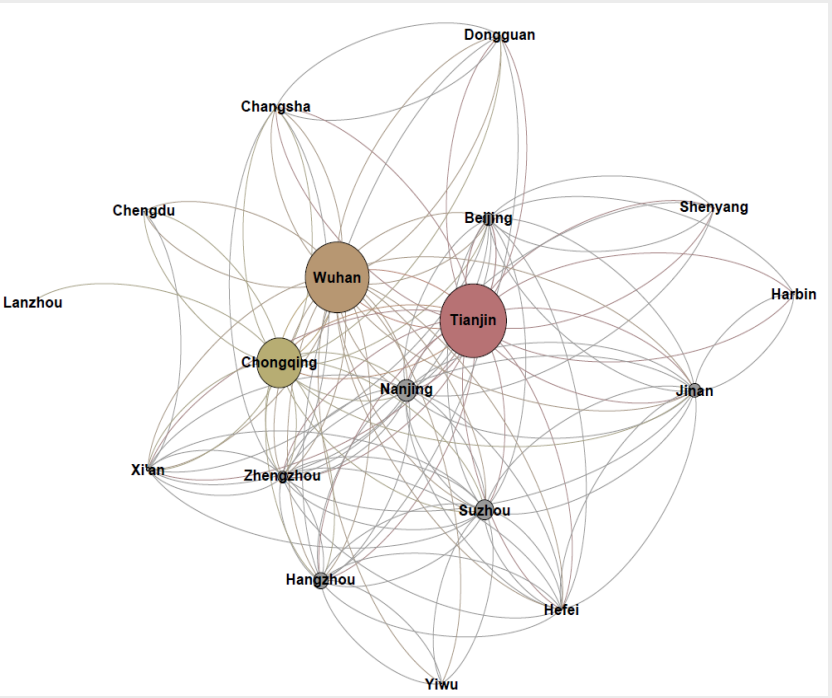
5. Experimental Analysis

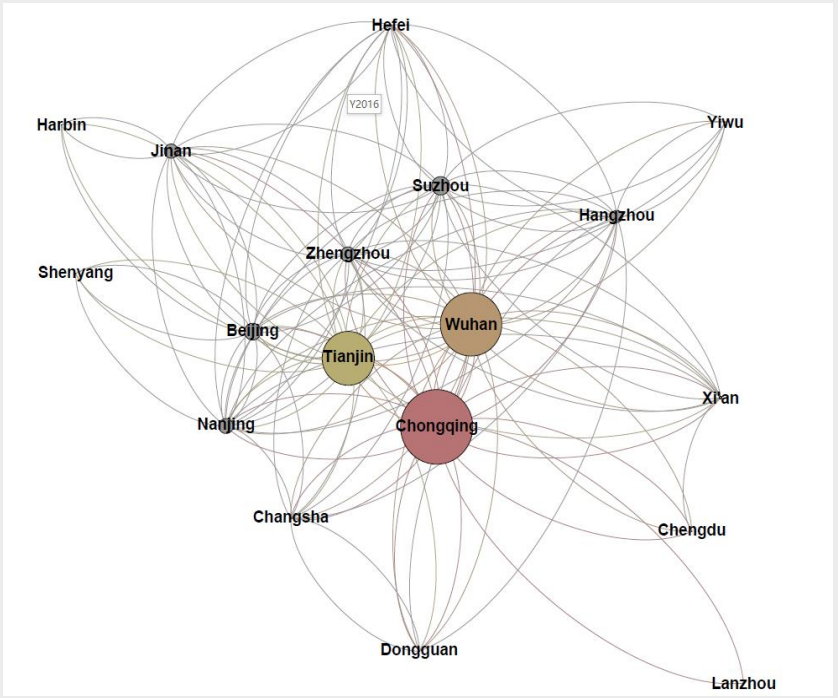
❖ **Social Network Analysis**

Betweenness Centrality

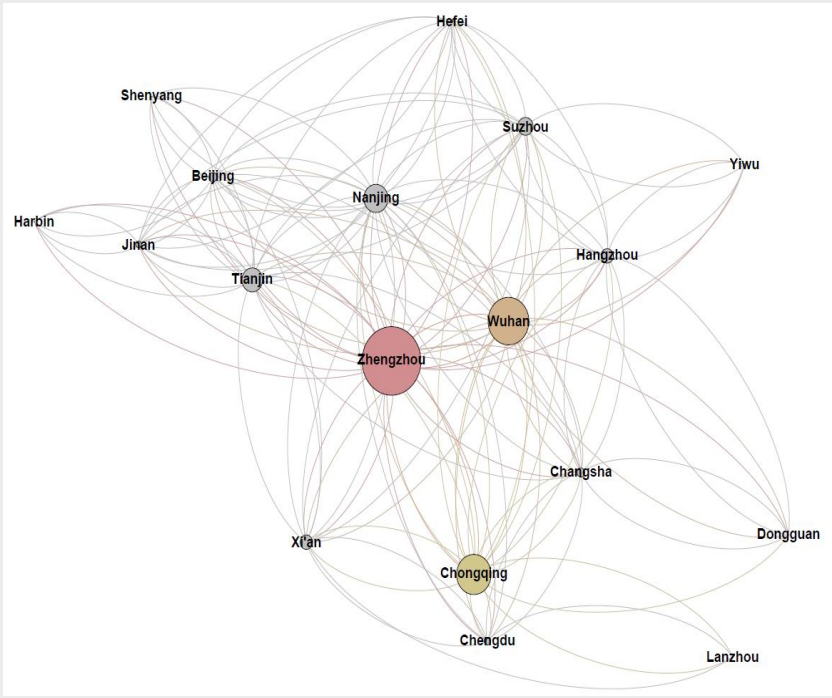
Year 2013



Year 2016



Year 2019



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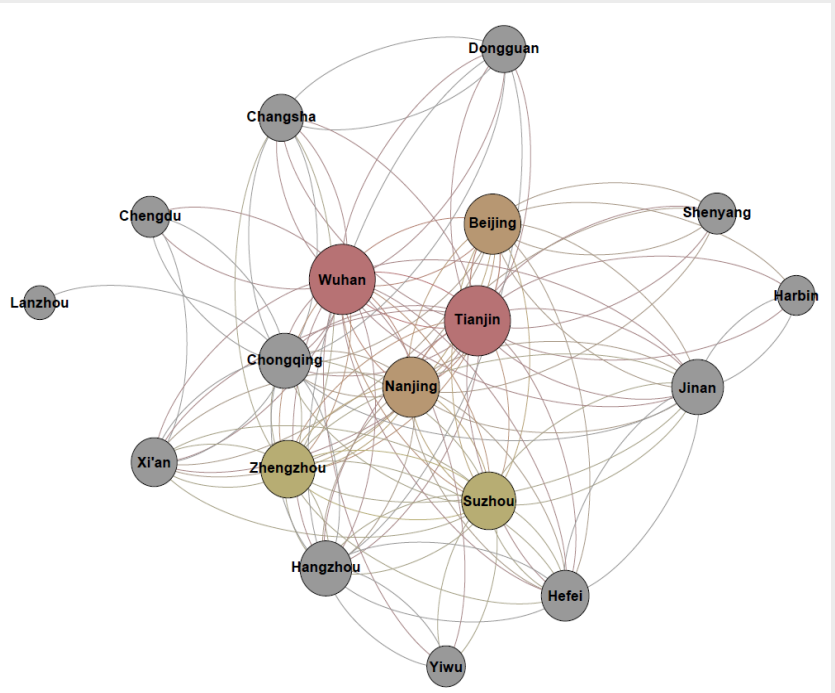
5. Experimental Analysis

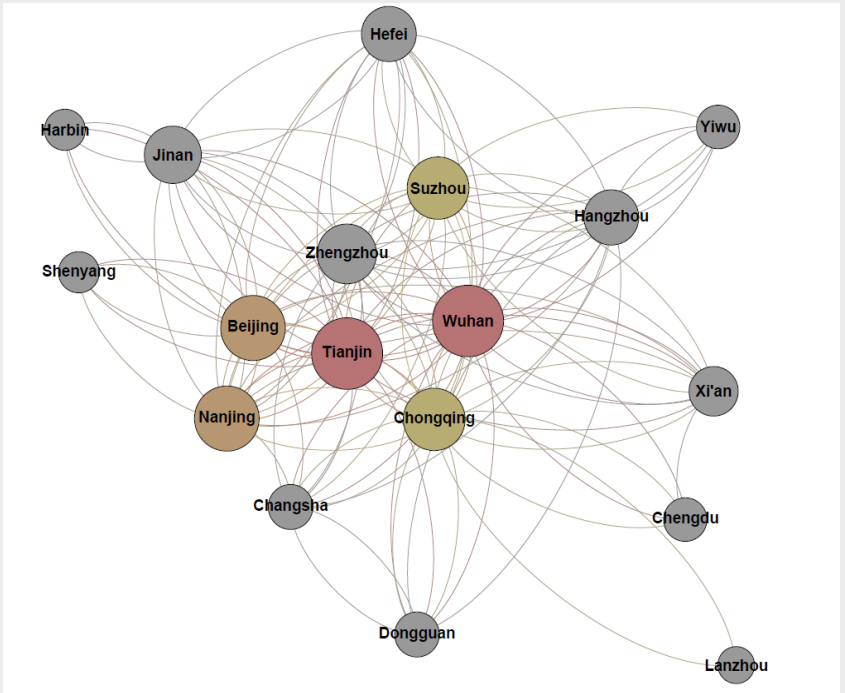
❖ **Social Network Analysis**

Closeness Centrality

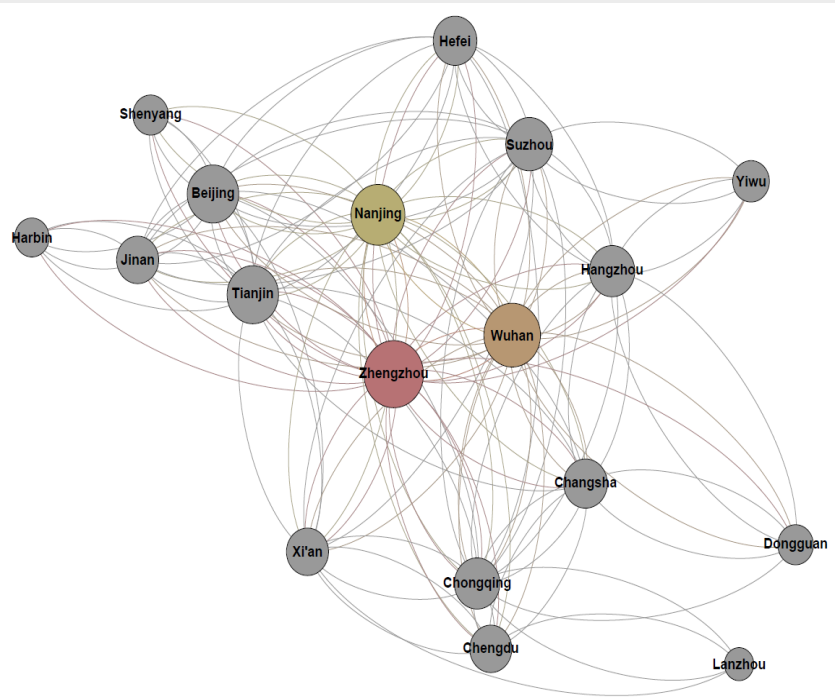
Year 2013



Year 2016



Year 2019



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Chapter 6. Conclusion

6. Conclusion

- The level of logistics development in inland node cities **has increased** from 2013-2019, indicating that the implementation of the "CRE Construction and Development Plan 2016-2020" is **effective.**
- Beijing,Tianjin — Zhengzhou,Wuhan — Chengdu,Chongqing as the main three major **inland core** has been formed.
- The rapid development of the central cities of Zhengzhou and Wuhan can be **connected to the developed areas of the southeast coast.**
- Zhengzhou, Wuhan, Chongqing, Tianjin, Nanjing has an important position in the network and can act as a hub city to provide cargo **consolidation and distribution** for CRE.

❖ **Limitation**:

- The logistics network is generated based on cities already participating in CRE. If the scope of the study is expanded the logistics hub city may not be optimal.

❖ **Future research**:

➢ **Add nodes** outside of China to explore hubs from a global perspective.

Thanks !

Q&A