

GIS SUPPORTED ANALYSIS ON CITY GATHERING IN CHINA

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ABSTRACT:

Urbanization is one of the most important development in this century. The feature of city gathering to groups in special geographical locations is a sign of high level urbanization. The measurement of spatial characteristics in the key problem to analyze city groups. Supported by GIS, the author detected the DENSITY and DNC — DISTANCE TO THE NEAREST CITY of cities in China and with which extracted the existing six largest city groups. processed the data of sixty-two years (1926 - 1988), the author discovered an important relationship between CITY NUMBER and DNC. The author discussed about the impact of political and economical events on city gathering and analyzed the development of city gathering in China. The results are significant either for making regional development policy and for urbanization research.

KEY WORDS: GIS, Analytical, Urbanization, human Settlement, Economic.

1. INTRODUCTION

City group is a gathering of cities in special geographical locations. Organized by metropolis, the cities in the same group are connected by advanced transportation network and have a great communication in information, population and economics.

City group is formed with two trends (Yang, 1989):

- (1) the extension of the population and economics from metropolis;
- (2) centralized development of cities in most optimal locations.

City gathering is one of the most important trend of urbanization in this world, and it has a great impact on economics and life quality of mankind.

Big metropolis has caused many urban disease, such as heavy traffic, limited living room, terrible environment, etc.. It is a big headache in either developed and developing countries. Up to 1988, China already has eight metropolis of more than 200 million population. The government has to stop the population increase in this cities. To support the development of metropolis, the best way is to construct city group around it. City group is effective to improve the connection among cities, adjust the industrial construction, get the group benefit, extend the functions of metropolis, prevent the extension of metropolis and improve environment, etc..

During China's 6th Five Year Development Plan (1980 - 1985), the city number increased rapidly. The following number shows the increasing times for different

grades of cities:

metropolis	1.44
big cities	2.00
meddle cities	3.06
small cities	0.52
totally	1.06

In advanced areas, the city's density is increased greatly. Around the big metropolises as Beijing, Shenyang, shanghai etc., the city groups appeared (Guo, 1989). Systematic research is urgently needed to guide the government to make suitable developing policies for this city groups.

Being different with City Series, which may be formed by economical linkage among cities in any region, the city group can only formed in the locations of high density of cities. City group is a spatial geographical phenomenon, without the spatial characteristics it is impossible to detect exactly the existence of it. Among the spatial characteristics the most important and effective two are City's Density showing the concentration and Distance between cities showing the accessibility.

Geographic Information System (GIS) is the most powerful tool to do the detection of spatial characteristics and numerical analysis. It should be useful and effective in applying to city gathering and city group research. Supported by our development of Micro-GIS tool (Wang Zheng and Ren Fuhu and Xie Kunqing, 1989), the author set up a China urban information system which includes the city information of China from 1926 to 1988 and researched the city gathering process and the situation of the development of city groups in China. This is the first systematic

research of city gathering and city group about whole China. The research has got new results significant either for the government making decision and for city group theory. This paper is to report part of the research results.

The material used in this paper was collected from the Manual of China's Cities (Zhu, 1987), Almanac of China's Cities (Zhang, 1988), the city location and transportation network are digitized with the administration map of 1:600 million scale of China (1989). The research area does not include Taiwan and the islands in South China Sea.

2. CITY NUMBER, CITY'S DENSITY AND DISTANCE TO NEAREST CITY

Urbanization takes place in the following four aspects:

- (1) increase of urban population
- (2) increase of city number
- (3) expansion of urbanized area
- (4) increase of city's density

To detect and analysis the city gathering and city groups with GIS, the following definition of index is necessary, among them the DNC — the Distance to the Nearest City, is first defined by the author.

2.1 City Number

City is the center of politics, culture and economics in a region. Usually a city is given the title by government with a judgment on the population, industrial output and importance. In this paper, the city was selected according to the year it was first given the title as a city by the government in that time. Fig. 1 shows the increasing trend of city number from 1926 to 1988.

2.2 City's Density

City's density in each location is defined as the city number within a unit area around the location, which can express the general state of city concentration. It is an important spatial index to detect city groups. For the convenient of calculation with GIS, the author defined the unit area as a circle with radius of 100 KM, that is about 31400 square KM. City's density in location i can be defined as :

$$D_i = \sum_{j=1}^n I_{ij} \quad (1)$$

$$I_{ij} = \begin{cases} 0 & \text{when } D_{ij} > D_0 \\ 1 & \text{when } D_{ij} \leq D_0 \end{cases}$$

where n is the total number of cities, D_{ij} is the distance between city j and location i , D_0 is the radius of unit circle.

2.3 Distance to the Nearest City — DNC

It is easy to calculate the average distance between cities with the formula

$$D = \frac{2}{n(n-1)} \sum_{i=1}^n \sum_{j=i+1}^n D_{ij} \quad (2)$$

where n is the total number of cities and D_{ij} is the distance between city i and city j .

But this distance includes the distance between cities belonging to different city groups, so it is not efficient to detect the situation of city gathering in groups. To avoid this problem, the author defined the DNC index, which is an average distance of each city to its nearest neighbor city.

$$DNC(t) = \frac{1}{n(t)} \sum_{\substack{j=1 \\ j \neq i}}^{n(t)} [D_{ij}(t)] \quad (3)$$

where t is the year, $DNC(t)$ is the average DNC in the year t , D_{ij} is the distance between city i and city j in the year t , the $n(t)$ is the total number of cities in the year t .

Because a city and its nearest neighbor city should be in the same city group, obviously DNC can exclude the distance among cities belonging to different groups. So it is suitable to be used to show the state of city gathering.

Fig. 2 shows the DNC decrease in China from 1926 to 1988 while the city number was increasing.

3. THE EXTRACTION OF SIX LARGEST CITY GROUPS IN CHINA

With the calculated city's density map of 1987, the author revealed out the six largest city groups existed in China. They are:

- (1) Liaoning Group in the northeast of China.
- (2) Huabei Group around Beijing and Tianjin.
- (3) Yangzhi River Delta Group around Shanghai.
- (4) Wuhan Group in the middle part of China.
- (5) Shichun Group in Shichun Basin.
- (6) Pearl River Delta Group around Guangzhou.

Table 1 shows the basic indexes of those groups. The detail geographical characteristics of those city groups will be discussed in another paper.

4. CITY GATHERING PROCESS IN CHINA — THE RELATIONSHIP BETWEEN CITY NUMBER AND DNC

With the increase of city number, the city's density increase and DNC decrease. Table 2 lists the city number and calculated DNC with formula (3) based on urban database of 1926 to 1988

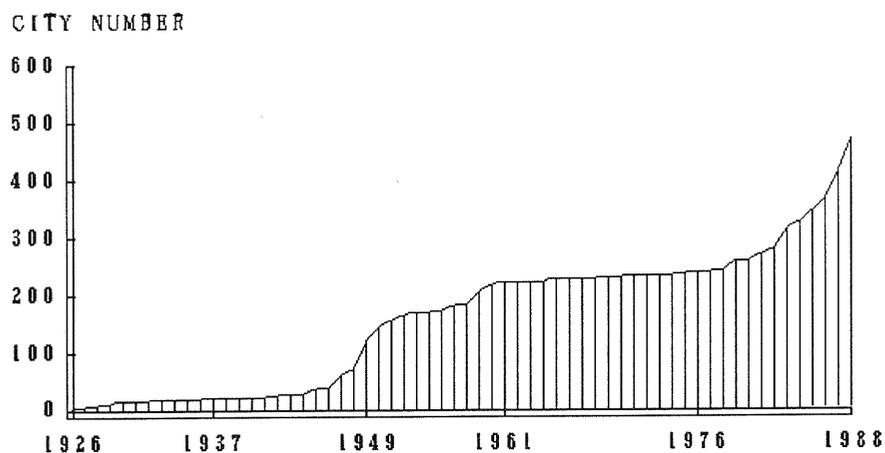


Fig.1 Increasing Curve of City Number in China (1926 - 1988)

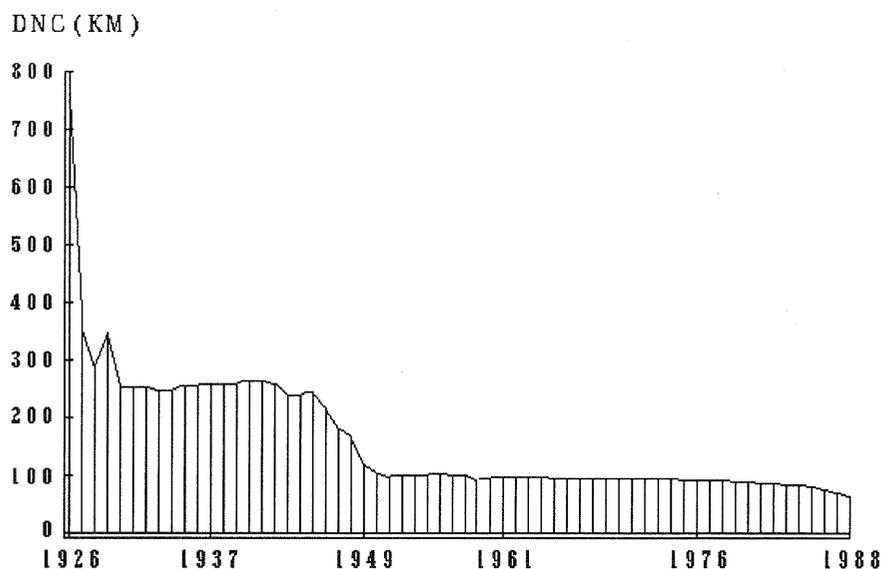


Fig.2 Decreasing Curve of DNC in China (1926 - 1988)

Table 1 Basic Index of City Groups in China

NAME OF GROUP	POPULATION (MILLION)	CITY NUMBER	AREA (1/10000KM ²)
Liaoning	11.1338	20	1.66
Huabei	19.8539	36	1.52
Yangzhi River Delta	16.9467	32	2.14
Wuhan	8.1848	25	1.93
Shichun	5.0111	8	1.05
Pearl River Delta	4.2829	8	2.51

Table 2 Comparison of City Number and DNC

YEAR	DNC(KM) D_r	CITY NUMBER	DNC(KM) D_f	$D_f - D_r$
1926	832.0	2	403.1	-428.9
1927	379.4	5	363.3	-16.1
1928	303.6	7	342.5	38.9
1929	368.7	9	325.0	-43.7
1930	268.4	13	296.6	28.2
1931	268.4	13	296.6	28.2
1932	268.4	13	296.6	28.2
1933	260.4	16	279.7	19.3
1934	260.4	16	279.7	19.3
1935	269.1	18	269.9	0.8
1936	269.1	18	269.9	0.8
1937	273.7	19	265.3	-8.4
1938	273.7	19	265.3	-8.4
1939	273.7	19	265.3	-8.4
1940	279.1	20	261.0	-18.1
1941	279.1	20	261.0	-18.1
1942	274.4	22	253.0	-21.4
1943	252.0	24	245.6	-6.4
1944	252.0	24	245.6	-6.4
1945	257.3	31	224.2	-33.1
1946	228.0	36	212.0	-16.0
1947	191.3	56	177.5	-13.8
1948	177.2	62	170.1	-7.1
1949	123.8	110	132.1	8.3
1950	109.1	134	120.7	11.6
1951	103.1	144	116.7	13.6
1952	106.3	151	114.2	7.9
1953	106.4	155	112.8	6.4
1954	105.2	157	112.1	6.9
1955	107.8	158	111.8	4.0
1956	105.2	166	109.2	4.0
1957	104.1	170	108.0	3.9
1958	97.1	188	103.0	5.9
1959	96.7	189	102.8	6.1
1960	99.6	200	100.0	0.4
1961	100.6	206	98.6	-2.0
1962	100.6	206	98.6	-2.0
1963	100.6	206	98.6	-2.0
1964	100.6	206	98.6	-2.0
1965	98.7	210	97.7	-1.0
1966	99.7	211	97.5	-2.2
1967	99.7	211	97.5	-2.2
1968	99.7	211	97.5	-2.2
1969	99.9	212	97.3	-2.6
1970	99.3	213	97.1	-2.2
1971	98.4	215	96.7	-1.7
1972	98.4	215	96.7	-1.7
1973	98.4	215	96.7	-1.7
1974	98.4	215	96.7	-1.7
1975	97.3	219	95.8	-1.5
1976	96.1	222	95.2	-0.9
1977	96.1	222	95.2	-0.9
1978	96.0	224	94.8	-1.2
1979	92.6	239	91.9	-0.7
1980	93.1	240	91.7	-1.4
1981	90.9	249	90.1	-0.8
1982	89.1	257	88.8	-0.3
1983	86.0	291	83.6	-2.4
1984	86.3	302	82.1	-4.2
1985	84.0	320	79.9	-4.1
1986	78.1	340	77.6	-0.5
1987	72.2	381	73.4	1.2
1988	67.9	434	68.9	1.0

and administration map. Table 2 shows some relationship existing between city number and DNC.

According to Location Theory (Yang, 1989), each city will have a certain area of influence. The size of the influence area is determined by the power of the city. With the increasing of cities, eventually each city will occupy a hexagon region. The more the city numbers, the smaller the influence area. So in city groups, the city number should be a function of $1/DNC^2$.

$$N \sim 1/DNC^2 \quad (4)$$

Using the above form to do the statistical regression, we got a very high reliable relationship between city number and DNC:

$$N = 2111612 / DNC^2 - 10.99569 \quad (5)$$

the correlation coefficient reaches 0.99261, t index is 63.877, reliability is 99.9% (Fig. 3).

Formula (5) reveals an very important relationship between city number and DNC. The fact that the city number times square DNC equals a constant strongly suggests that the city trend to appear in some special optimal area, so the city group is an inevitable result of urbanization.

5. THE INFLUENCE OF POLITICS AND ECONOMICS ON CITY GATHERING

Urbanization is greatly affected by the political and economical factors. The influence also appears in the process of city gathering which can be seen by comparing the detected DNC with calculated DNC with formula (5).

Suppose D_f is the regression value of DNC calculated with formula (5) and D_r is the real DNC measured from city distribution map in each year. $D_f - D_r$ listed in Table 2. If $D_f - D_r$ is positive, it means in that year the city gathering in a high speed, vice versa if $D_f - D_r$ is negative, it shows the city gathering is in low speed.

In Table 2, positive and negative values of $D_f - D_r$ appear continuously. It can be proven with Run-Length Examination that this variation of positive and negative value is not random but regular. Compared with the history of China, it is found that the positive values happen in the pacific and high developing years and negative values are identical with the period of war or political event (Table 3).

From Table 3 we can see that the Sino-Japan War and China Civil War are slowed down the speed of city gathering in China. During the first twelve years after setting up the People's Republic of China, the city gathering was speed up greatly. The disaster of Great Cultural Revolution had a very bad

impact on the city gathering, after a long recover period the city gathering return to high speed in 1987.

It is exciting that the DNC in very sensitive to the political and economical environment. This fact proves the formula (5) is a useful result for city gathering research.

6. THE DEVELOPMENT OF CITY GATHERING IN CHINA

The urbanization zone is the next stage after city group with the development of city gathering. When the density of cities grows so high and the distance between cities become so small that travel from one city to another is more convenient compared with the traveling within the city, the boundary between cities has no meaning in fact, the cities area continues from city to city, that is the urbanized zone. Urbanized zone is an important stage of urbanization.

If the city area is considered as a square region, the extension index can be defined as :

$$D_4 = \sqrt{\text{City Area}} \quad (6)$$

In the ideal situation, the shape of city area should be a hexagon (Yang, 1989), the extension index can be proven to be:

$$D_6 = 1.075 \sqrt{\text{City Area}} \quad (7)$$

When cities are tightly neighbor each other with no suburbs among them, the DNC will equal the extension index D_4 or D_6 .

Table 4 shows the increasing trend of city area and extension index D_4 in China from 1078 to 1987. While DNC decreases, D_4 increases. In city groups the DNC is much smaller than other regions. Suppose in the future the D_4 in China will not be smaller than 50 KM as in 1987, we can calculate the city number to make DNC decrease to 50 KM with formula (5). We got the answer that when city number increases to 834, the DNC will decrease to 50 KM. That is to say, when the city number in China reaches about 800, the distance between neighbor cities will approximately equal to the extension size of the cities. That will be the coming time of urbanized zone in China. The urbanized zone will form in the existing city groups.

7. CONCLUSIONS

With the GIS supported analysis on city gathering in China, we can get the following conclusions.

- (1) City gathering and city group is an inevitable trend of urbanization.
- (2) There is a strict relationship

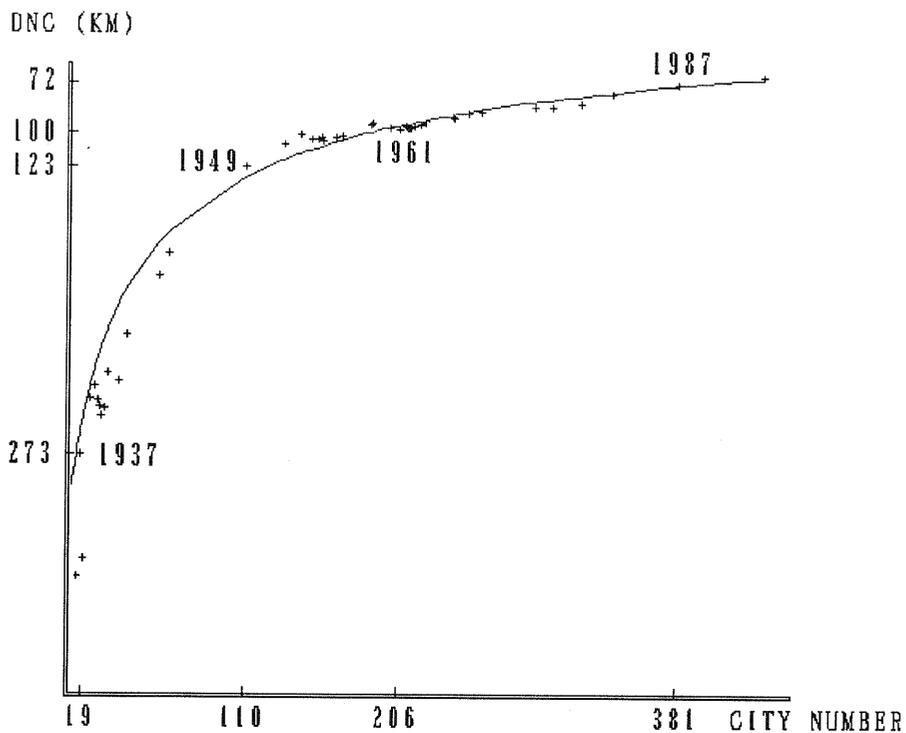


Fig.3 Regressive Curve of City Number and DNC in China (1926 - 1988)

Table 3 Gathering Speed Change with Political Event

YEAR	EVENT	$D_f - D_r$	GATHERING SPEED
1926-1936		+	High
1937-1948	Sino-Japanese War, Civil War	-	Low
1949-1960	Set up PRC	+	High
1961-1976	Great Cultural Revolution	-	Low
1977-1986	Recover and Reform	-	Low
1987-1988	Development	+	High

between city number and DNC.

(3) DNC is a useful index for detecting city gathering and city groups.

(4) The speed of city gathering is strongly affected by political and economical factors.

(5) In China, six important city groups are developing, and when the city number in China increases to about 800, the city groups will develop to urbanized zones.

(6) GIS is a powerful tool to research the city gathering and city groups.

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Table 4 City Area and Extension Index in China
1978 - 1987

YEAR	CITY NUMBER	TOTAL AREA (KM ²)	AVERAGE AREA (KM ²)	D ₄ (KM)	DNC(KM)
1978	224	195029	870.647	29.51	95.97
1979	239	211826	886.301	29.77	92.56
1980	240	228382	951.592	30.85	93.10
1981	249	206684	830.056	28.81	90.88
1982	257	247775	964.105	31.05	89.13
1983	291	530063	1821.522	42.68	85.97
1984	302	726602	2405.967	49.05	86.27
1985	320	823679	2573.997	50.74	84.02
1986	340	869979	2558.762	50.58	78.08
1987	381	967429	2539.184	50.39	72.24

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