Analyzing Urban Population Change Patterns in Shenyang, China 1982-90: Density Function and Spatial Association Approaches

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Abstract:

Based on the subdistrict (*jie-dao*) data from 1982 and 1990 national population censuses, this research employs two approaches to investigate the urban population change patterns in Shenyang, China. The density function approach examines what function best characterizes its density distribution, how the density pattern has changed over time, how many centers can be identified in the city, and how influential each center has been on the citywide population distribution. Unlike the socialist cities in Russia, Shenyang has a negative density gradient, bearing more resemblance to western cities. A polycentric model explains the spatial variation of densities in Shenyang much better than a monocentric model. The spatial association approach analyzes the core-peripheral relationship between a city center and its neighboring areas. Both approaches show that people moved from the central city to suburbs, indicating a trend of population decentralization. This trend is attributable to the land use reform, central city renovation projects and improvements of suburban infrastructure and services.

I. INTRODUCTION

The empirical research on the change of urban structure is rich on developed countries but much less so on developing countries. Part of the reason is that data are less plentiful and less reliable in developing countries (Mills and Tan, 1980, pp.133). The scarcity of public accessible research data on China is evident because of the country's longtime concern of national security and reluctance of releasing data to the public. After an 18-year absence of any census, the third national population census of China was resumed in 1982, followed by the fourth national population census in 1990. The 1982 and 1990 censuses open opportunities to investigate many urban issues in China, including urban development and urban structure change. However, population censuses in China are not accompanied by a spatial database such as the TIGER files in the U.S. This creates the largest barrier to the study of urban spatial structure in China. Few applications of modern spatial analysis techniques can be found in the literature on Chinese cities since they usually require a digital spatial database or a Geographic Information System (GIS).

Data for this research were collected when the second author worked on a regional planning project for the City of Shenyang. Population data came from the 1982 and 1990 censuses, and the spatial boundaries of subdistricts (jie-dao) were compiled from various sources of local governments and numerous field trips. A GIS database is set up to obtain density and distance measures, visualize spatial patterns, and conduct advanced spatial statistical analyses. We use two approaches, complimentary to each other, to investigate the population change patterns in Shenyang. The density function approach examines how population densities vary with distance from the city center, what function best characterizes the density pattern, and in the case of a polycentric model, how influential each center has been on the citywide population distribution. The spatial association approach analyzes the core-peripheral relationship between a city center and its neighboring areas.

This research makes contributions to the literature in four aspects:

(1) Density function studies on western cities suggest that urban population density decline with distance from the city center. This observation is supported by theoretical urban economic models (Muth, 1969; Mills, 1972), which are based on a free market economy. In socialist cities such as in Russia in the absence of land markets, Bertaud and Renaud (1997) found a perversely positive population density gradient, indicating the land misallocation and inefficiency. Researchers wonder whether Chinese cities, also under the socialist regime, exhibit a similar pattern. Some recent work on Chinese cities has been related to, though not focused on, urban density. For example, Yeh *et al* (1995, pp. 600) use population density as one of

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the components for defining urban social areas in Guangzhou, and Ning and Yan (1995, pp. 590-591) illustrate the spatial variation of population change in Shanghai. However, none of them revealed a density pattern or fitted a density function. The question remains unanswered.

(2)Wang and Zhou (1999) use a monocentric model to analyze various density function forms in Beijing. However, the study does not incorporate the concept of polycentricity. The changing urban structure from monocentric to polycentric is a major theme in recent urban studies on western cities. For brief surveys, see Ladd and Wheaton (1991) and Berry and Kim (1993). Good examples of empirical work on urban density distributions in a polycentric framework can be found in Griffith (1981), Gordon *et al.* (1986) and Small and Song (1994). Do Chinese cities exhibit a polycentric structure like western cities? Wu (1998) finds that the land use change in Guangzhou can be characterized by a polycentric form, but his study does not discuss the change pattern of population density. How well does a polycentric model fit Shenyang=s urban densities? How has the role of each center changed in the new era of economy reforms?

(3) With modern GIS technologies in place, some advanced spatial statistical analysis methods, which were difficult to implement previously, have now been widely applied to urban and regional studies. One of populous methods is the usage of spatial association indexes, such as the G statistic (Getis and Ord, 1992), Moran I index, and Local Indicator of Spatial Association or LISA (Anselin, 1995). Shen (1994) uses the global Moran I index to test different hypotheses on the impact of growth control policies on the regional population change in the San Francisco Bay Area. Barkley et al. (1995) use both the G and LISA indexes to analyze the intra-*regional* spatial association in eight functional economic areas in the southeast U.S., and identify various regional growth patterns. This research makes the first attempt to apply the spatial association approach to analyzing the *urban* population change pattern.

(4) One of major conclusions we can draw from the analysis is that the central city in Shenyang has lost population to suburban areas, similar to the trend of suburbanization in western cities. This trend of population decentralization has its unique Chinese characteristics. The discussion on decentralization in Shenyang offers insights to the impact of economic reforms on urban structure.

The remaining of this paper is organized as follows. Section II is an overview of the study area. Section III uses the density function approach to analyze the change of spatial structure in both monocentric and polycentric frameworks, and section IV experiments with the spatial association approach using both global and local Moran indexes. The analyses are followed by section V of discussion on the negative density gradient in a socialist city and on the population decentralization. Finally, the paper is concluded with a brief summary.

II. THE STUDY AREA OVERVIEW

Shenyang is the capital city of Liaoning Province, one of China=s oldest industrial bases. It is also the largest city in the Three Northeast Provinces (Liaoning, Jilin and Heilongjiang). Shenyang is about 620 kilometers northeast of Beijing. The legislative boundary of Shenyang includes a large territory of rural areas in addition to a mostly urbanized municipality, i.e., 59 villages (*xiang-zhen*) in addition to 109 subdistricts (*jie-dao*). A subdistrict is an administrative level below district, and is designated whenever the majority of population in the area is engaged in nonagricultural activities. Therefore, the region of subdistricts is a good approximation for Shenyang=s urbanized area. Our research excludes eight remote subdistricts and focuses on the continuous built-up area, which is made of 101 subdistricts adjacent to each other. In Shenyang, the 101 subdistricts belong to seven districts (*qu*): Heping, Shenhe, Dadong, Huanggu, Tiexi, Dongling and Yuhong (refer to Figure 6). Since Figure 6 shows only the urbanized portions of districts, some districts are made of several polygons that are not contiguous to each other.

The total urban population in the study area is 2,765,553 in 1982 and 3,317,237 in 1990, with an annual growth rate of 2.30%. (See Table 1.) Subdistricts have an average area of 1.98 km^2, ranging from 0.40 to 7.89 km^2. Densities vary among subdistricts from the lowest density of 1,064 persons per km^2 (later ab-

Table1. Basic statistics for the subdistricts in Shenyang

	Area (km^2)	1982 Population	1990 Population	1982 Density (p/km^2)	1990 Density (p/km^2)
Minimum	0.40	2,996	11,578	1,064	3,817
Maximum	7.89	50,595	76,491	60,692	57,740
Mean	1.98	27,656	32,844	24,001	25,284
Standard Deviation	1.78	10,153	12,622	14,563	13,057
Sample Size	101	100 [1]	101	100 [1]	101

[1]One subdistrict (Linggong) was a small airport, and not yet designated in 1982.

breviated as p/km²) to the highest density of 60,692 p/km² in 1982, and from 3,817 to 57,740 p/km² in 1990. The gap between the highest and lowest densities has been narrowed over time. While the average population size of subdistricts increases 18.8% from 27,656 in 1982 to 32,844 in 1990, the average density increases 5.3% from 24,001 to 25,284 p/km².

III. THE DENSITY FUNCTION APPROACH: FROM MONOCENTRIC TO POLYCENTRIC

The Monocentric Model

A monocentric model assumes that a city has only one center. If we assume one center in Shenyang, where is this center? Without any information on its employment distribution, we adopt Alperovich=s (1982) method to identify the city center as a point producing the highest R^2 of density functions. A density function characterizes how population density changes with increasing distance from the city center, such as

$$D_r = f(r), \quad (1)$$

where r is distance from the city center, D_r is the population density there, and f is a function of r. Distance is measured in aerial distance between the city center and a subdistrict=s centroid. Following Alperovich (1982), we will test four functions:

(1) linear, $D_r=a+br$;
(2) exponential, $D_r=ae^{br}$ (or the log-transformation $\ln D_r=b_0+br$);
(3) reverse-exponential, $D_r=a+b\ln r$; and
(4) power, $D_r=ar^b$ (or the log-transformation $\ln D_r=b_0+b\ln r$).

We first limit the search to a few subdistricts, within which the city center is likely to locate. Overall, the centroid of Beizhan Subdistrict yields the highest R^2 for the four functions in both 1982 and 1990. By trying various places within this subdistrict, we then find the exact location of the city center (see Figure 6). Interestingly, it is very close to Shenyang=s City Hall Square, generally recognized by the public as the center of the city.

Linear and reverse-exponential functions (1 and 3 in Table 2) are estimated by linear least square regressions, and exponential and power functions (2 and 4 in Table 2) are estimated by nonlinear least square regressions. From Table 2, the exponential function fits both the 1982 and 1990 density patterns best, though its advantage over other functions is marginal. The fitting power of functions based on the monocentric model has dropped over time. The exponential function explains about 25% of the density variation in 1982 and only 14% in 1990. Unlike the city of Moscow (Bertaud and Renaud, 1997), the socialist city Shenyang exhibits a negative density gradient in both 1982 and 1990, bearing more resemblance to western cities. Section V will discuss the issue in depth. Consistent with the findings on western cities (McDonald, 1989), the gradient b (absolute value) in all the four functions has declined, and the city center intercept a has also dropped. This change can be explained by the variation of population growth rates at different distances from the city center (see Figure 1). During 1982-1990, most subdistricts at 0-2 km from the city center experienced loss of population, while subdistricts further than 6 km gained population. Opposite growth rates at the two ends flattened the density curve and lowered the city center intercept.

Two statistical issues deserve some discussion. One argument involves the choice of either estimating the exponential function and the power function directly by non-linear least square regressions (as presented in Table 2) or estimating their log-transformation functions by linear least square regressions. Generally they yield different results since the two regressions have different dependent variables and imply different assumptions of error terms (Greene and Barnbrock, 1978). We use the exponential function and its log-transformation to illustrate the problem. The first

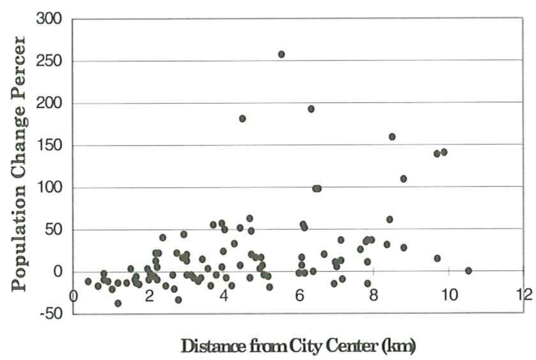

Figure 1. Population change rates (1982-90) vs. distances from city center

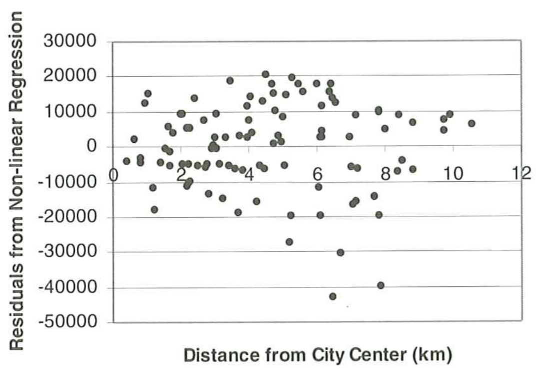

Figure 2. Residuals from the non-linear regression for 1982 population densities (exponential)

Table 2. Monocentric density functions in Shenyang

	1982			1990		
	a	*b*	R^2	*a*	*b*	R^2
$D_r = a + br$	37432	-2929.4	.246	34334	-1966.2	.137
$D_r = ae^{br}$	42222	-0.1349	.258	36136	-0.0819	.14
$D_r = a + b\ln r$	38720	-10989	.256	34904	-7154.9	.134
$D_r = ar^b$	38205	-0.3682	.236	34670	-0.2443	.126

approach assumes additive errors and weights all equal absolute errors equally, such as:
$D_r = ae^{br} + e$.
The second approach assumes multiplicative errors and weights equal percentage errors equally, such as $D_r = ae^{br+e}$.
The first approach is implemented by a non-linear least square regression, and the second is implemented by a linear least square regression using its log-transformation. We believe that the first approach is a better choice for two reasons. First, using the log-transformation function yields a different dependent variable, $\ln D_r$ rather than D_r, and therefore the resultant R^2 is no longer comparable with other functions (linear and reverse-exponential). Second, a plot of the residuals from the non-linear regression of the 1982 population densities (Figure 2) shows no indication of heteroscedasticity, which would be the justification for using the second approach. Four underestimated outliers near the bottom of Figure 2 are those high-density subdistricts on the west of the city, which form a new city center. A monocentric model underestimates densities around suburban centers. This will be captured in a polycentric model.

Another issue in estimating urban density functions concerns the randomness of sample (Frankena, 1978). A common problem for U.S. census tract data is that too many high-density observations near a city center and much fewer low-density ones in remote areas. In other words, high-density tracts or tracts at short distances from the city center could be over-represented while low-density tracts or tracts far from the city center could be under-represented. This is referred to as non-randomness of sample, which causes biased estimators. Researchers usually use weighted regressions to address this issue. However, this problem is less evident for our subdistrict data in Shenyang. Figure 3 displays the numbers of subdistricts at various distance ranges from the city center. There is no steady trend of declining frequencies with increasing distances. The same conclusion is reached by plotting observation frequencies against density ranges in 1982 or 1990. There is no need of weighted regressions.

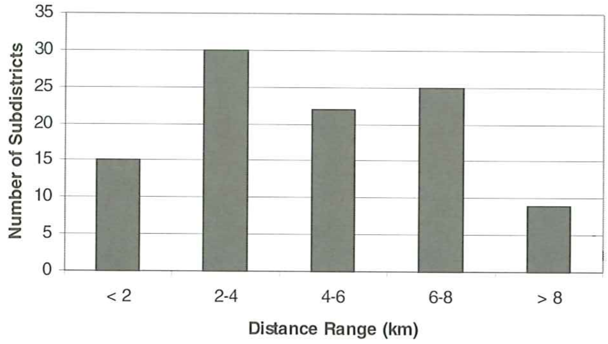

Figure 3. Numbers of subdistricts at various distance ranges

The Polycentric Model

From the monocentric model, even the best among four functions only explains 25% of the variation of densities in 1982 and 14% in 1990. This indicates that the population distribution pattern in Shenyang is far more complicated than concentric. Recent urban density studies use a polycentric model to better capture the urban structure. Based on a polycentric model, urban residents and firms value access to all centers, so that population densities are functions of distances to all these centers (Small and Song, 1994, pp. 294). Centers other than the city center may be called subcenters.

Following Heikkila et al. (1989), a polycentric density function could be established under several alternative assumptions:

(A) If the influences from different centers are perfectly substitutable, so that only the nearest center matters, then the polycentric function is degraded to several monocentric functions. A city is segmented into several subregions, each of which is composed of subdistricts around their closest subcenter. A monocentric function is then estimated within each subregion.

(B) If those influences are complementary, so that some access to all centers is necessary, then the polycentric density is the product of such functions as specified by McDonald and Prather (1994). A log-transformation of the polycentric exponential function can be estimated by a simple multivariate linear regression (density in logarithm as the dependent variable and distances from individual centers as the independent variables).

(C) Most researchers believe (Griffith, 1981; Small and Song, 1994) that the relationship among centers= influences is between these two extremes, and the polycentric density is the sum of center-specific functions. Using the exponential functional form, a polycentric model is expressed as:

$$D = \sum_{i=1}^{n} a_i e^{b_i r_i} \qquad (2)$$

where D is the density of a subdistrict; n is the number of centers; r_i is the distance between the subdistrict and center i; a_i and b_i are parameters to be estimated for each center i.

GIS surface modeling techniques help us visualize the geographic pattern of density distributions and identify potential centers. Figures 4 and 5 are the 1982 and 1990 urban density contour maps respectively, generated by Arc/Info. In the figures, density contours have an interval of 5,000 p/km^2, with contour lines of 10,000, 30,000 and 50,000 p/km^2 highlighted in bold. The contour maps show that multiple centers are evident in both 1982 and 1990. However, a density peak shown in the maps may not qualify as a city center if it only exerts some local effect, as explained in assumption (A). A non-linear regression model based on eq. (2) helps verify if a center=s influence is local or citywide. By experimenting with various scenarios, we identify five centers in Shenyang: center A in Tuanjielu (very close to the city center in the monocentric model), center B in Xingshun on the city=s west side (an old industrial area), center C in Xiaodong in the east, center D in Changjiang (northwest of center A), and center E in Shandongmiao (south of center A). See Figure 4 and 5 for their locations. No additional centers are statistically significant in either 1982 or 1990. Two points deserve attention in identifying centers. First, we omit the smaller one (e.g., the one west of center B) of two centers adjacent to each other to reduce collinearity among the variables r_i for different centers i. Second, for examining possible changes over time, we include not only centers visible in both maps such as centers B and C, but also centers only noticeable in one map such as A in the 1982 map and D in the 1990 map. Center E is more noticeable in 1990 than 1980.

The regression results are presented in Table 3. The polycentric model explains 72.1% of Shenyang=s spatial variation of densities in 1982 and 67.8% in 1990. This is a significant improvement over the monocentric model. Coefficients a_i and b_i in eq.(2) are the estimated intercept and gradient for center i. A higher intercept indicates a stronger center (higher density at the center), and a steeper gradient implies a faster decline of density with distance from the center. For old centers A and B, both the intercept a and gradient b have become less significant statistically, and their magnitudes have also dropped. This indicates loss of population in the old city centers. Center C has also lost population over time. On the other side, young centers D and E in the suburbs grew stronger (higher intercepts a). The changing role of centers in the central city and suburbia reflects the population migration trend as more population moves from the central city to suburbia. This is characterized as "suburbanization" in Zhou and Meng (1997).

IV. THE SPATIAL ASSOCIATION APPROACH: CENTER-PERIPHERIAL LINKAGE

The density function approach tells us how the density changes with distance from the city center, how the gradient changed over time, and how the role of multiple centers shifted. However, it does not reveal much of the spatial linkage between a center and its surrounding area. Specifically, in order to understand how the change of population in a center is related to the change in its peripheral area, it calls for the spatial association analysis.

As demonstrated in Barkley et al. (1995), the G sta-

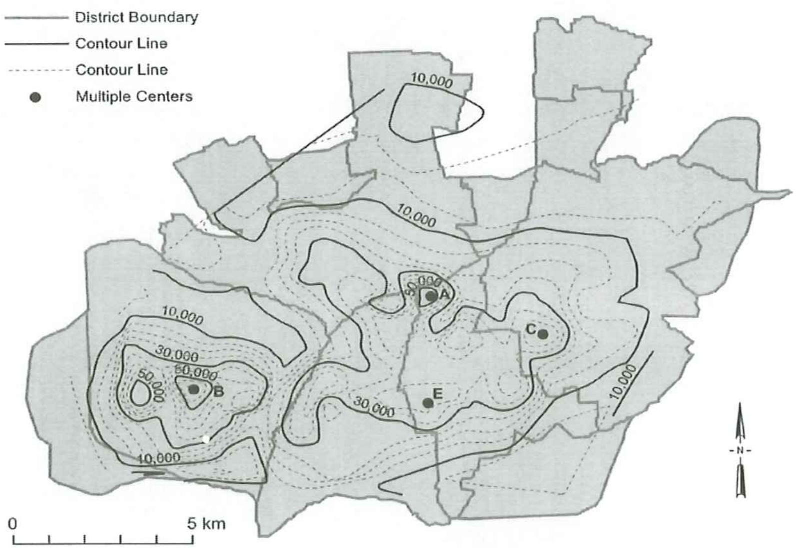

Figure 4. Population density contour map in 1982

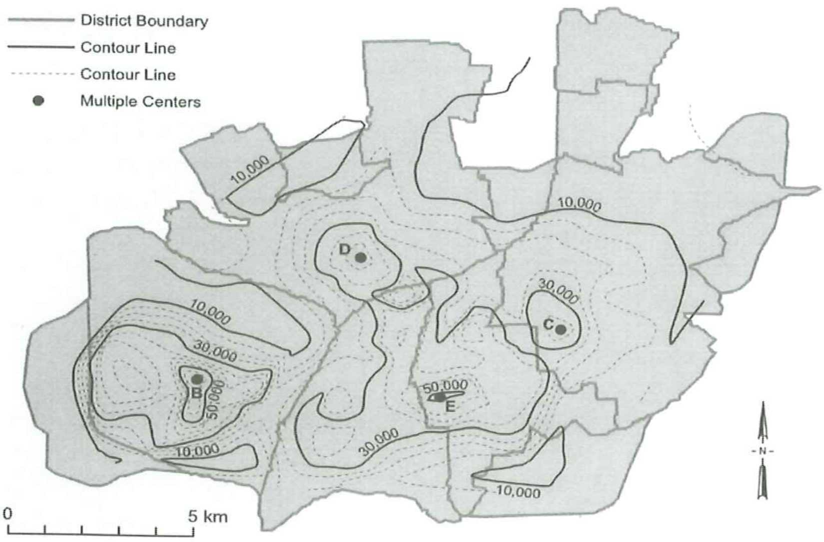

Figure 5. Population density contour map in 1990

Table 3. Regression Result of Polycentric Density Function in Shenyang

Center	1982 a	1982 b	1990 a	1990 b
A	27232***	-0.8749*	13553	-0.1287
	-3.54	(-1.96)	-1.68	(-1.75)
B	54894***	-0.4236***	51421***	-0.4069***
	-10.11	(-5.54)	-9.66	(-4.85)
C	35944***	-0.7593***	23374***	-0.5774
	-4.54	(-2.92)	-3.47	(-1.70)
D	25412**	-0.7156*	30245**	-1.1622*
	-3.11	(-1.97)	-3.31	(-2.15)
E	42758***	-0.4225***	44006***	-0.6082***
	-6.95	(-3.74)	-6	(-3.64)
	R^2=0.721		R^2=0.678	

* significant at the 0.05 level; ** significant at the 0.01 level;
*** significant at the 0.001 level.

tistic and Moran I can be used to identify the overall degree of spatial autocorrelation of population growth (using their global indexes) and the core-hinterland interdependence of regional growth pattern (using their local indexes). By the conditional permutation approach, the G statistic and Moran I have very similar interpretation. The calculation of their pseudo-statistical-significance is also similar (Anselin, 1995; Bao and Henry, 1996). Therefore, only Moran I index is discussed in this section.

The global Moran I is a popular measure of spatial autocorrelation, which detects whether nearby areas have (dis)similar attributes overall. It is calculated as follows:

$$I = [\Sigma_i \Sigma_j (w_{ij} c_{ij})] / [s^2 \Sigma_i \Sigma_j w_{ij}], \quad (3)$$

where c_{ij} measures the attribute similarity defined as $(x_i\text{-}x_{mean})(x_j\text{-}x_{mean})$, s^2 denotes the sample variance, weight w_{ij} measures locational proximity between i and j, and x_i is the attribute value for area i. In our case, we define w_{ij} = 1 if area j is adjacent to i, and 0 otherwise. As we are interested in the population change pattern, the attribute is defined as the percentage change of population in each subdistrict from 1982 to 1990 (see Figure 6). It is positive when nearby areas have similar attributes, negative when attributes are dissimilar, and approximately 0 when the attribute values are arranged randomly in space. A test of the significance of Moran I can be made under one or both of the two assumptions: the "normalization" hypothesis (the sample is obtained independently from an infinitely large population) and the "randomization" hypothesis (the sample represents one random arrangement of attribute values from all possible arrangements that could occur).

Based on Shen (1994) and others, we developed an Arc/Info AML program to obtain the matrix of w_{ij}, and input it to a FORTRAN program to calibrate the global Moran I index. Defining w_{ij} = 1 if area j is adjacent to i, and 0 otherwise, we obtain that the global Moran I in the whole study area is 0.2321 with a t statistic (the sample size n=101) of 4.5234 under the normalization hypothesis and 5.5383 under the randomization hypothesis. It is highly significant with a pseudo-P value < 0.001. Thus, similar population change rates tend to cluster in Shenyang, i.e., areas with population gain (loss) are located proximate to each other, and are not randomly arranged.

A local Moran index or Local Indicator of Spatial Association (LISA) is proposed by Anselin (1995) to examine local pockets of nonstationarity. A local Moran for a zone i is defined as

$$I_i = z_i [\Sigma_j (w_{ij} z_j)], \quad (4)$$

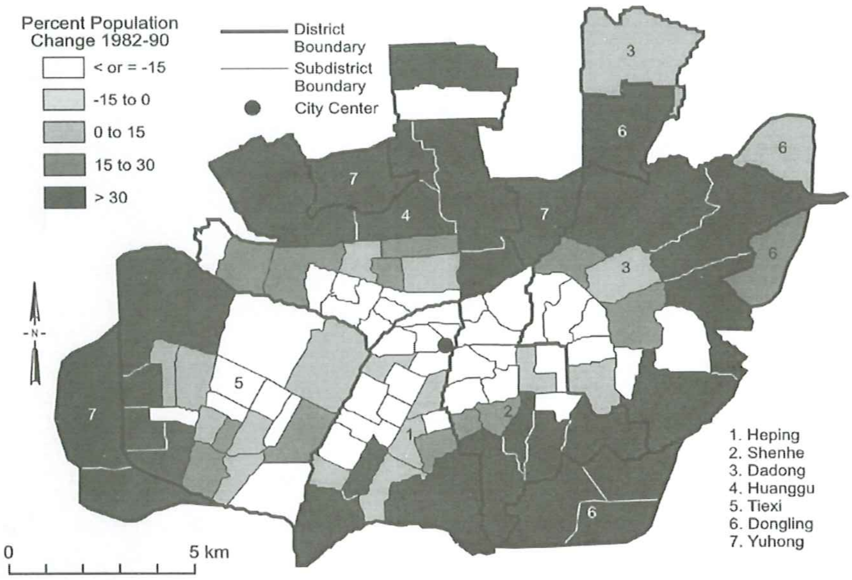

Figure 6. Population chang rate form 1982 to 1990

where z_i and z_j are the standardized attribute values with mean = 0 and standard deviation =1, and the spatial proximity measure w_{ij} is in row-standardized form, i.e., w_{ij} = 1/m (m is the number of nonzero elements in row i of the matrix w_{ij}) if area j is adjacent to or with a distance d from i, and w_{ij} = 0 for all areas not adjacent to or beyond a distance d from i. Pseudo-significance levels for each i can be obtained by means of a conditional permutation approach. Since the normalization and randomization hypotheses provide similar results, the following analysis is based on the randomization hypothesis (see Anselin, 1995, for details).

In this research, we are particularly interested in detecting the spatial relationship between the city center and its nearby areas. For this purpose, we follow Barkley et al. (1995) to calculate various local Morans for "bands" of subdistricts. We start with those subdistricts adjacent to the subdistrict where the city center is located ("the central subdistrict"), and move outward to the next band of subdistricts until all subdistricts in the study area are included in one of the bands. A subdistrict j is considered in proximity to the central subdistrict i if it is within the band, and therefore w_{ij}=1/m; otherwise, w_{ij}=0. From an inside to an outside band, the criterion for defining proximity becomes looser, and more subdistricts are considered proximate to the central subdistrict. We adopt Shen's (1994) approach to define a band, which includes all subdistricts within a certain buffer distance from the central subdistrict. Note that the buffer is based on the polygon not its centroid. Shen (1994, p.170-171) argues that the approach for deriving the spatial weight w_{ij} proposed by Ding and Fotheringham (1992) is based on the proximity of polygon centroids, and is likely to produce a biased result when the spatial objects display large variations in size and shape (which is our case). Figure 7 shows the five bands around the city center corresponding to a buffer distance = 0, 1, 3, 5, and 7 kilometers respectively. When all subdistricts are considered as the neighboring areas (e.g., if a buffer distance of 9 km is used), the local Moran index is not meaningful. We made some minor modifications of the previous AML program to calculate w_{ij}, and developed a FORTRAN program (based on Anselin, 1995) to obtain the local Moran. The result is reported in Table 4.

The city center has experienced a loss of 11.53 percentage of population with its standardized value =-0.4159. From Table 4, given the positive local Moran, its nearby areas also tend to lose population with a similar population change rate like the city center. Though this is not statistically significant in its immediate adjacent subdistricts, it becomes significant within a 1-km and 3-km buffer bands. Some areas immediately adjacent to the city center are still considered as prime location with good accessibility to various services in the central city, and residents are reluctant to relocate to suburbia even under the pressure of central city renovation projects. These areas have lost population only *slowly*, and the local Moran is not significant. The 1-km and 3-km buffer bands are mostly composed of old residential subdistricts. Most of these areas have lost population during 1982-90. As the bands expand farther away, the local Moran is no longer significant.

In the polycentric framework and under assumption

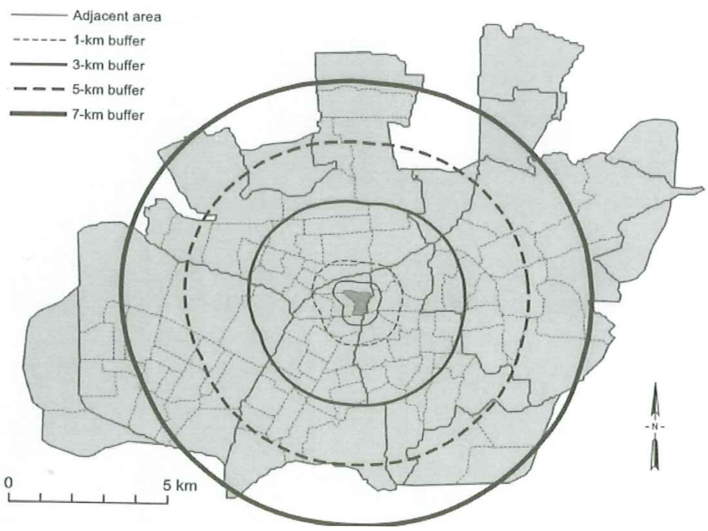

Figure 7. Various bands of buffer distance form the city center

(A) of Heikkila et al. (1989), it would be interesting to divide the city into sub-regions around subcenters, and explore the spatial association between each subcenter and its surrounding subregion. Due to the relative large sizes of subdistricts, there is not a large enough sample size within each subregion to conduct a meaningful spatial analysis. However, center B in the city's west is the traditional center of Tiexi district (see Figure 6 also), separated by a railway from the rest of Shenyang. With 22 subdistricts, it forms a sample size large enough for this experiment. Considering the whole Tiexi district as the new study area, we replicate the previous analysis and obtain a similar result. The subdistrict of center B lost 4.87% population 1982-1990. Within the band of its immediate adjacent subdistricts, local Moran = 0.3461 with t statistic = 1.8918; within the band of 1-km buffer distance, local Moran = 0.3126 with t statistic = 3.1403. Both are significant at 0.05, and indicate that areas proximate to center B also tend to lose population. But the local Moran becomes no longer significant as the band goes beyond.

Table 4. Local morans for bands of subdistricts around the city center (1982-90 population change)

Buffer distance (km)	# subdistricts	Local Moran	t statistic
0 (immediate adjacent)	5	0.1746	0.9686
1	18	0.1547	1.7547*
3	51	0.107	2.6560**
5	75	-0.0038	-0.0859
7	93	0.0092	0.9567

* significant at the 0.05 level; ** significant at the 0.01 level (based on a conditional permutation approach under the randomization hypothesis).

V. DISCUSSION ON THE NEGATIVE DENSITY GRADIENT AND POPULATION DECENTRALIZATION IN SHENYANG

Bertaud and Renaud (1997) find that Russian cities have a perversely positive population density gradient, contradicting to the commonly observed negative density gradient in western cities. They attribute the difference to the 70-year socialist regime in the absence of land markets. Our studies show that Shenyang exhibits a negative gradient in both 1982 and 1990. China has been a socialist country since 1949, and the experiment of land use reform did not begin until the mid-1980s. So why does Shenyang bear more resemblance to western cities than the Russian cities? One reason could be that the central-planned economy in China did not last long enough to generate a positive density gradient. Secondly, we argue that the development of Chinese cities cannot escape the universal influence of economic forces. Many Chinese urban planning guidelines and regional development policies conform to market rules and are no different from those in the West.

From both the density function and spatial association approaches, we notice that many central city subdistricts lost population to suburbia. This indicates a trend of population migration out of the central city, similar to the suburbanization of American cities. However, this massive relocation is accommodated by many high-rise and multi-story apartments in suburbia in China, unlike the single-family houses with big backyards we commonly see in American suburbia. To avoid the misconception, we use the term "decentralization" instead of "suburanization" to characterize this new pattern in Shenyang. Both suburbanization in America and decentralization in Shenyang are attributable to rapid urban growth. However, if Americans move to suburbia for better schooling, property tax incentives, or residential segregation, none of these is an issue in Shenyang. The suburbanization in America has been driven by the popularity of personal automobiles. In China, personal vehicles are still beyond the reach of most families. The population decentralization in Shenyang has its unique Chinese characteristics. We summarize its causes as follows.

(1) Urban land use reform. Before the land use reform in the middle 1980's, urban land values in China were not evaluated, and land users were charged with a low fixed rate. After the reform, land rents were determined by the market values. Many residents in the central city found new homes in suburban areas for cheaper housing and more living space. The residential land use in the central city yielded to higher price bidders such as retailers, banks, hotels and office buildings. This led to the population out-migration.

(2) Central city renovation. Before the housing reform in the 1980's, old residences in the central city got little investment and lacked in basic maintenance. The housing reform in Shenyang started with many projects on the central city renovation. Various incentives were provided for encouraging central city residents to relocate in suburbia. High-rise apartment buildings were built in suburbia for the resettlements. This accelerated the population decentralization.

(3) Improvement of suburban infrastructures and services. After Deng's reform, China has diverted the investment focus from defense-oriented heavy industries to consumers-oriented light industries. Raising people's living standards became a priority. Municipal governments also benefited from fiscal decentralization, and gained more power in controlling local investments. In the new political environment, suburban roadways, sewage, water and utility provisions, and retail services were improved. Suburban areas became more attractive and livable than before. Many residents were willing to resettle in more spacious suburban apartments.

VI. CONCLUSION

Based on the data from the third and fourth national population censuses, this research employs both the density function and spatial association approaches to analyze the spatial pattern of urban population change in Shenyang from 1982 to 1990. The density function approach examines what function best characterizes its density distribution, how the density pattern has changed over time, how many centers can be identified in the city, and how influential each center has been on the citywide population distribution. From 1982 to 1990, the density gradient has become flatter, and the city center intercept has dropped. Both indicate the trend of population decentralization. The polycentric urban structure is evident from the density contour maps generated by GIS surface modeling. A five-center polycentric model explains 72% and 68% of Shenyang=s density variations in 1982 and 1990 respectively, a significant improvement over the monocentric model, which explains 14-25% of the spatial variation of densities. The spatial association approach analyzes the core-peripheral relationship between a city center and its neighboring areas. In Shenyang, similar population change rates tend to be adjacent to each other, i.e., areas with population gain (loss) cluster together, and are not randomly arranged. Subdistricts in the central city experienced loss of population similar to the city center. The population decentralization in Shenyang has its causes unique to Chinese cities. The urban land-use reform since the mid-1980s is one of the major driving forces for decentralization. Before the reform, land rents were very low and almost uniform everywhere in a city. After the reform, banks, large retailers, hotels and high-rise office buildings were able to bid out the residential land use at favorable locations near the city center, and many central city residents relocated in suburbs. The central city renovation accelerated this trend. Finally, the success of economic reforms enabled local governments to improve suburban infrastructure and services, and made suburbs attractive for residents.

ACKNOWLEDGEMENTS

We thank Shuming Bao and an anonymous referee for their constructive comments, and Lenny Walther for his professional cartographic assistance.

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