Spatial Pattern Change of Employment Centers in Tokyo Metropolitan Area

Tawhid MONZUR and Yan LI

Abstract: *Whereas numerous researches have been conducted to understand the spatial pattern change of employment centers of the metropolitan areas over the globe, those related to Tokyo Metropolitan Area (TMA) are insufficient. Therefore, this research aims to analyze the spatial pattern change of employment centers of TMA from 1999 to 2009. A gird-cell based approach in combination with String method and Local Moran's I (LMI) is selected. Centers in different hierarchies are delineated for both the years. Through the analysis, we found that the change of number and area of centers varies in prefectures. We identified some specific center change patterns, including decline, extended, joined, separated and the level of center changed. Some new centers were also found.*

Keywords: *Spatial pattern, grid-cell, employment center, LMI*

1. Introduction

Since the end of 19th century, the introduction of "Garden city" concept (Howard, 1898) revolutionized the understanding of the urban area. Later, following Hoyt's (1939) "Sector Model" and Harris and Ullman's (1945) "Multiple nuclei or multi-nucleation", different urban development patterns were proposed where multiple center idea was encouraged for urban spatial structure development (Lynch, 1961). Consequently, the Monocentric Model (Alonso, 1964; Muth, 1969; & Mills, 1972) was questioned for its accuracy in understanding large cities with multiple-centers (Odland, 1978). The concept of multiple-centers was introduced to reduce the excess concentration within CBD and to improve the economic performance as well as social and environment conditions (Doxiadis, 1968, 1969).

However, the multiple-centers pattern did not follow a specific model; ended up in shaping more complex urban system in monocentric, polycentric and dispersed forms. Numerous theoretical and empirical studies have been conducted and discussed over urban studies field from the perspectives of- first, to what extent the spatial patterns are different in case of regional urban studies? And second, which empirical approaches can best address the spatial pattern changes? But a suitable consensus is still to be found.

Regarding Tokyo Metropolitan Area (TMA), various scholars have tried to understand the spatial structure of employment, but ended up analyzing the population distribution and social amenities influences. Very little research has been conducted to understand the employment spatial structure (e.g., see, Hebbert & Nakai, 1988; Fujita & Kashiwadani, 1989; Seibert, 2000; Jacob, 2005; Alpkokin et al, 2007; Kazutoshi, 2008; Kagawa,2012). The 21st century modern cities are no longer polycentric or monocentric but emerging as more complex spatial patterns. Henceforth, it is important to know whether this urban shift has affected the TMA as well. Also, TMA is less researched in case of employment center identification, compared with those conducted for various large cities around the globe. Through a recent research, it is found that the difference exist between the National Capital Regional Plan of 1986 in comparison with the current spatial pattern of TMA. This made to conduct this research to look further into the spatial structure of TMA through the lens of employment centers.

2. Study area and data treatment processes

For this research, we have selected Tokyo Metropolitan Area (TMA), including seven prefectures: Saitama, Kanagawa, Chiba, Gumma, Ibaraki, Tokyo and Tochigi; an area of 32,236 km2 with a population concentration of 40,406,059 in 1999 and 42,276,270 in 2009 and employment was about 19,871,480 (1999) and 21,595,215 (2009), respectively.

The employment data of ten years is used for this analysis, collected from the Ministry of Internal Affairs and Communications (MIC). Census tracts (CTs) are for 1999 is 66,724 and 56,686 in 2009. To understand better the clusters and their differences, the ten years of employment data is combined into one, by using the following Python String method (Shipman, 2013):

$$\boldsymbol{str}\,(!\,t_{1999} + "" + t_{2009}\,!) + "\mathbf{to}" + \boldsymbol{str}\,(!\,t_{1999,2009}\,!)$$

Where, *str ()* is a String conversion Command.

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Also, Because of the CTs size differences, specific grid-cell size is used. A *250X250 m2* or *0.0625km2* grids is selected in this case. Several grid-cell sizes (e.g., *200m2* to *1500m2*) were being observed and found that major features of the spatial structure are almost identical. Also, a small grid size is used to find out local level employment centers which cannot be identified by using larger grid sizes (Redfearn, 2007, p.521). The following formula is constructed to reduce the effect of CTs sizes-

$$Em_g = \sum_i D_i \times A_{gi}$$

Where, A_{gi} is the area of the polygon i and D_i is employment density of i.

3. Employment centers identification

Multiple approaches were introduced in identification of employment centers as well as the overall employment spatial structure in regional and national level. For example, Cutoff approach (Giuliano & Small, 1991); E/R ratio approach (Shearmur & Coffey, 2002); Nonparametric and Two-stage Nonparametric approach (McMillen & McDonald, 1997; McMillen, 2001) and Cubic Spline approach (Craig & Ng, 2001). However, these methods have been criticized because of the differences in center concept as well as data processing criteria (e.g., see, Coffey & Shearmur, 2001; Redfearn, 2007; Cladera et al, 2009; Veneri, 2013). Moreover, spatial econometric approach (Baumont et al, 2004) were used to get rid of the issues related to local knowledge and arbitrary employment thresholds that can affect the spatial pattern analysis.

Another issue regarding employment center analysis that lacked in the previous studies was to what extent the spatial patterns are different? This directly linked to the influence of center delimitation procedure (Cladera, et al, 2009).

However, through this research, a difference is observed. The variation in center selection in case of area in study, using grid-cell approach can provide better understanding of the differences in spatial pattern as well as center identification.

3.1 Cluster analysis using ESDA

To identify clusters in local level, a spatial econometric model is preferred because of its advantage in identification of cluster in consideration of spatial lags (i.e., influence of the neighboring locations on their observed location). A Local version of *Exploratory Spatial Data Analysis* (ESDA), is used which can be written as (Anselin, 1995)-

$$I_i = b_i \sum_j \hat{w}ij \, b_j$$

Where, b_i is the variance

The *LMI* divides all the observed values into five types of clusters; HH (*High-High*); LL (*Low-Low*); LH (*Low-High*); HL (*High-Low*); and IS (*Insignificant*). The HH and HL are considered as positive spatial autocorrelation; whereas the LL and LH are considered as the Negative spatial autocorrelation and IS considered as non-significant spatial relationship (Anselin, 1995; Baumont et al, 2004; Griffith, 1992). Since our objective is to find out the employment clusters with high density values (HH); the other density groups are omitted.

3.2 Center definition and the spatial weight matrix selection

Following (Baumont et al, 2004) and (Guillain et al, 2006), we have defined employment center as CTs within a specific significance band with high employment density. For the spatial weight a contiguity weight matrix (1st order) is considered; performed well in delineation of the clustering groups. The cluster analysis distinguished five distinctive employment centers named as- Rank1(0.0001), Rank2(0.001), Rank3(0.01), Rank4(0.05) and Rank5(P>0.05). Each has different spatial patterns despite the same central influence.

4.Empirical Results

4.1 Employment center distribution in ten years transition

Figure 1 shows the three pairs of employment distribution. Without using any grid cell method (pair a) provided a confusing spatial pattern where in most cases low density locations are predominant than high density locations. In contrary, the second pair (pair b), by using 250x250m2 grid-cells provided satisfactory results in identifying employment centers. Later, to find out the potential employment centers, we selected only the locations with an area of no less than 1km2 (pair c). Table1 shows the distribution of the employment in each Ranks and centers (pair c); density falls exponentially in both the Ranks and the possible centers identified.

Though, the number of centres in both years stayed almost the same (Table2); differences in center patterns appeared in forms of – decline (centers shrink or disappeared); extended (centers enlarged to nearby non-center areas); joined (two neighbouring centers joined together); separated (one center divided into two centers); and new centres (non-center locations become place of new employment concentration) and Level of center changed (lower level centers evolved as upper level centers) (Table 3).

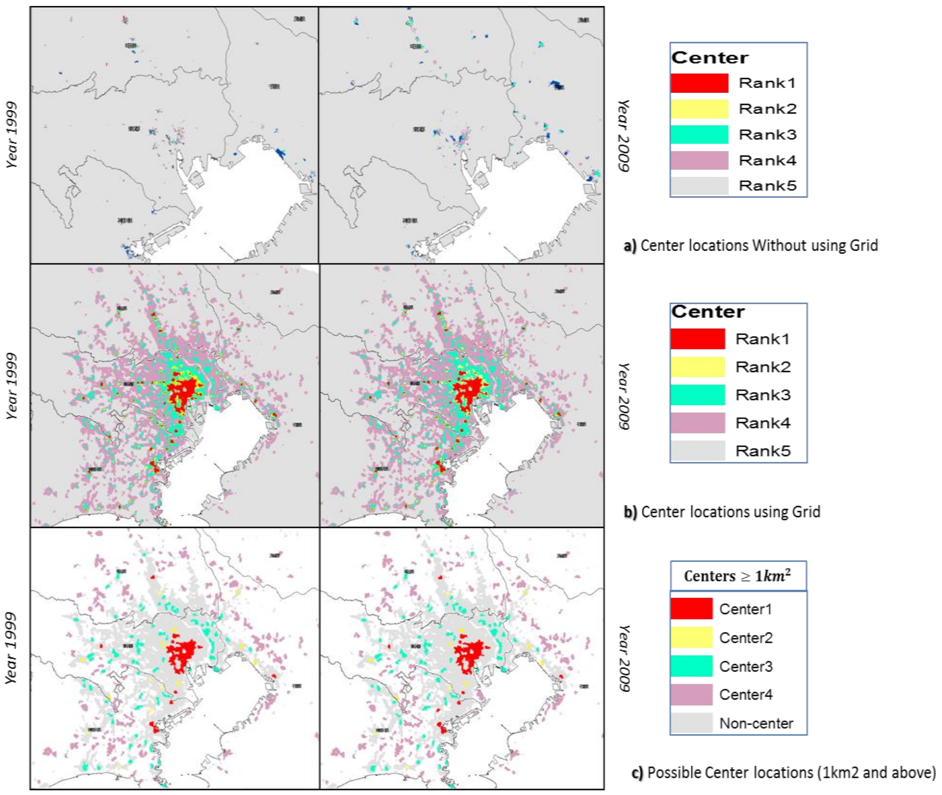

Figure 1: **a)** *Locations of the centers without using any grid-cell;* **b)** *Locations of the centers after using (250x250m2) grid-cell; and* **c)** *The possible employment centers ≥ 1km2.*

Table 1: Employment Distribution in each Ranks and Centers (1km2 and above) in year 1999 and 2009.

		Total Employment in Ranks					Total employment in Centers $\geq 1km^2$			
Year 2009	Prefectures	Rank 1	Rank 2	Rank3	Rank4	Prefectures	Center 1	Center 2	Center 3	Center 4
	Tokyo	4,910,196	805,812	1,726,159	1,615,364	Tokyo	4,534,423	178,966	588,553	97,278
	Kanagawa	124,034	106,913	312,296	1,124,804	Kanagawa	418,601	93,187	418,365	394,014
	Saitama	149,330	95,774	233,659	725,402	Saitama	72,885	36,211	216,206	392,800
	Chiba	544,215	263,554	708,767	1,376,379	Chiba	61,303	97,356	124,167	392,044
	Ibaraki	8,718	26,659	62,609	272,694	Ibaraki	0	33,789	14,269	230,694
	Tochigi	13,556	27,856	26,523	269,319	Tochigi	0	41,411	11,062	122,614
	Gunma	1,939	26,171	66,121	255,602	Gunma	0	0	87,743	100,937
Year 1999	Prefectures	Rank 1	Rank 2	Rank3	Rank4	Prefectures	Center 1	Center 2	Center 3	Center 4
	Tokyo	4,341,458	748,453	1,671,244	1,476,616	Tokyo	3,998,714	174,708	559,041	67,626
	Kanagawa	112,266	85,299	292,902	1,065,613	Kanagawa	300,691	147,983	368,135	368,825
	Saitama	138,979	92,609	224,310	694,320	Saitama	58,736	39,450	192,205	413,252
	Chiba	460,269	232,400	648,619	1,312,998	Chiba	57,065	88,931	116,278	395,130
	Ibaraki	8,679	33,636	72,418	286,514	Ibaraki	0	38,907	29,618	212,921
	Tochigi	15,322	28,163	28,359	269,427	Tochigi	0	43,484	12,257	119,988
	Gunma	0	27,829	77,199	271,436	Gunma	0	17,658	56,991	137,052
		Average Employment Density in Ranks					Average Employment Density in Centers $\geq 1km^2$			
Year 2009	Prefectures	Rank 1	Rank 2	Rank3	Rank4	Prefectures	Center 1	Center 2	Center 3	Center 4
	Tokyo	62,650	16,854	8,443	3,311	Tokyo	66,683	27,014	10,653	3,376
	Kanagawa	44,101	19,662	8,356	3,093	Kanagawa	52,325	26,625	11,345	3,761
	Saitama	38,537	18,462	8,364	3,032	Saitama	48,590	27,589	10,515	3,225
	Chiba	47,323	19,343	8,476	3,161	Chiba	42,645	27,816	12,735	3,260
	Ibaraki	27,897	17,773	8,562	2,878	Ibaraki	0	20,023	8,456	3,418
	Tochigi	24,099	18,570	7,716	2,910	Tochigi	0	20,078	8,429	2,924
	Gunma	31,027	17,447	7,837	2,805	Gunma	0	0	9,682	2,843
Year 1999	Prefectures	Rank 1	Rank 2	Rank3	Rank4	Prefectures	Center 1	Center 2	Center 3	Center 4
	Tokyo	55,349	15,552	8,210	3,090	Tokyo	57,952	25,412	10,039	3,100
	Kanagawa	36,658	16,247	7,850	2,953	Kanagawa	42,956	25,459	10,138	3,647
	Saitama	36,454	17,032	8,120	2,922	Saitama	39,158	27,443	10,050	3,188
	Chiba	39,593	16,825	7,874	3,038	Chiba	38,043	25,409	11,850	3,260
	Ibaraki	27,771	20,699	9,052	2,876	Ibaraki	0	23,056	11,021	3,248
	Tochigi	27,239	18,775	7,960	2,905	Tochigi	0	21,083	9,339	2,861
	Gunma	0	19,359	9,429	2,999	Gunma	0	17,658	10,362	3,322

5. Discussion & Conclusion

This research made three major contributions: 1) Grid-cell approach performed well in delineation and identification of the centers which the method of using only the threshold distance failed to identify. In addition, String method has improved the output of the employment datasets, by reducing the problems related to overlap of the datasets. 2) Differences in numbers in the identified Employment centers exist within each prefecture as well as in area/km2. This can further help to analyse the distribution of employment sectors and their influences over differences in number of employment centers. 3) Employment centers follow different spatial patterns. Six distinctive spatial patterns appeared; 16 employment centers have lost their employment concentration; three are extended to nearby non-center locations; 14 new employment centers appeared; one took the form of by joining neighbouring employment centers; three employment centers are separated; and two lower level centers evolved as upper level center. Moreover, most of the changes in spatial patterns are observed in Saitama and Kanagawa prefectures. The research also addressed that, despite a polycentric development of employment is in action, the influence of monocentricity is still strong in case of TMA. Further research will tend to look at the centers by their area/km2 to delineate the employment centers as well as the distribution of employment and their influence over spatial pattern change.

Table 2: Employment centers count, area size (km2) and changes in each prefecture, year 1999 to 2009.

		Center count (16 cells*250m2=1km2) & Change in center number (1999-2009)			
Year 1999	**Prefectures**	**Center 1**	**Center 2**	**Center 3**	**Center 4**
	Tokyo	6	5	26	9
	Kanagawa	2	5	23	37
	Saitama	1	1	11	46
	Chiba	1	3	5	41
	Ibaraki	0	1	2	27
	Tochigi	0	1	1	16
	Gunma	0	1	3	17
Year 2009	**Prefectures**	**Center 1**	**Center 2**	**Center 3**	**Center 4**
	Tokyo	6*(0)*	5*(0)*	26*(0)*	11*(2)*
	Kanagawa	3*(1)*	3*(-2)*	22*(-1)*	36*(-1)*
	Saitama	1*(0)*	1*(0)*	13*(2)*	45*(-1)*
	Chiba	1*(0)*	3*(0)*	5*(0)*	41*(0)*
	Ibaraki	0*(0)*	1*(0)*	1*(-1)*	26*(-1)*
	Tochigi	0*(0)*	1*(0)*	1*(0)*	16*(0)*
	Gunma	0*(0)*	0*(-1)*	5*(2)*	14*(-3)*

		Area size (km2) & Change in Employment centers area/km2 (1999-2009)			
Year 1999	**Prefectures**	**Center 1**	**Center 2**	**Center 3**	**Center 4**
	Tokyo	67.88	6.88	55.69	21.81
	Kanagawa	7.00	5.81	36.31	101.13
	Saitama	1.50	1.44	19.13	129.63
	Chiba	1.50	3.50	9.81	121.19
	Ibaraki	0.00	1.69	2.69	65.56
	Tochigi	0.00	2.06	1.31	41.94
	Gunma	0.00	1.00	5.50	41.25
Year 2009	**Prefectures**	**Center1**	**Center2**	**Center 3**	**Center4**
	Tokyo	68.5*(0.63)*	6.62*(-0.25)*	55.25*(-0.44)*	28.81*(7.00)*
	Kanagawa	8.0*(1.00)*	3.5*(-2.31)*	36.87*(0.56)*	104.75*(3.63)*
	Saitama	1.5*(0.00)*	1.31*(-0.13)*	20.56*(1.44)*	121.81*(-7.81)*
	Chiba	1.43*(-0.06)*	3.5*(0.00)*	9.75*(-0.06)*	120.25*(-0.94)*
	Ibaraki	0.00*(0.00)*	1.68*(0.00)*	1.68*(-1.00)*	67.5*(1.94)*
	Tochigi	0.00*(0.00)*	2.06*(0.00)*	1.31*(0.00)*	41.93*(0.00)*
	Gunma	0.00*(0.00)*	0.00*(-1.00)*	9.06*(3.56)*	35.5*(-5.75)*

Table3: Differences in spatial patterns of employment centers, 2009.

Spatial Pattern Changes							
Year 2009	**Decline**	**Extended**	**New-Center**	**Center-joined**	**Separated**	**Level of center-changed**	**Total**
Tokyo	0	0	2	0	0	0	2
Saitama	5	2	3	0	2	0	12
Chiba	4	0	2	0	0	0	6
Kanagawa	4	1	2	1	0	2	10
Ibaraki	0	0	2	0	1	0	3
Tochigi	1	0	1	0	0	0	2
Gunma	2	0	2	0	0	0	4
Total	**16**	**3**	**14**	**1**	**3**	**2**	**39**

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