Recent Changes in the Spatial Structure of Employment: A Case Study of the Tokyo Metropolitan Area

By

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ABSTRACT

Intra-metropolitan spatial structure and its changes have become an important research theme in understanding the city since the end of World War II and the acceleration in the process of suburbanization that considerably affected the distribution of employment. Whereas numerous studies have been conducted from the theoretical and empirical point of view to understand and analyze the spatial structure of employment in contemporary metropolitan areas across the globe, those related to Tokyo Metropolitan Area (TMA) are insufficient. To fill the gap, this study explored the spatial structure of employment in the TMA through identification of the locations and rank hierarchies of its employment centers. The spatial pattern changes of employment centers including their growth, decline, and so on were also investigated.

The main purpose of this research was to a) identify the employment centers in different ranks; and b) to explore changes in the spatial pattern of employment centers in recent years. For this analysis, economic census datasets from the year 1999 and 2009 were chosen. The Local Indicator of Spatial Association (LISA) technique, specifically, the Local Moran's I was selected and employed for the center identification. For the visual representation and statistical analysis of the obtained results, GeoDa 1.6.7 and 1.8.12 and ArcGIS 10.1 were used.

Through the research, a grid-approach (GA) is proposed for the detection of the comprehensive spatial structure of employment. Grid–cell maps were created based on spatial scale sizes: *250m by 250m or* $0.0625km^2$; *500m by 500m*

or 0.25km^2; *1000m by 1000m or 1km^2*; *2000m by 2000m or 4km^2*; and *3000m by 3000m or 9km^2*, respectively. It is revealed that the GA better captured the comprehensive spatial structure of employment by reducing the spatial irregularity in the data. The research also proved that employment centers can be identified effectively by comparing them with the immediate surrounding areas.

To analyze the locations and changes of the employment centers in different ranks, the fine scale size (*250m by 250m*) was chosen. The research revealed a total of 279 employment centers which are equal or greater than 1 km^2 (*hereafter abbreviated as ECs*) in different rank orders across the TMA in 2009. Further investigation on the location and rank of the ECs in 20*km*, 30*km* and 50*km* distance bands disclosed that the majority of the upper rank ECs (EC1, EC2 & EC3) are located close to the city center (20*km*), whereas most of the lower rank ECs (EC4) are located in the peripheries (30*km*, 50*km* & above). The research further revealed that out of 32 planned business centers in the 4th National Capital Region Development Plan (NCRDP), only 11 were confirmed as EC1. Besides, several EC1, EC2, and EC3 that were disclosed near the main center as well as in the peripheries went unnoticed by the 4thNCRDP.

The spatial pattern change analysis in the ECs between 1999 and 2009 was conducted firstly at the prefecture level and covered total employment and average density. The findings revealed that whereas employment has been more concentrated in the main center of the Tokyo-to; concentration of employment was detected prefecture-wide in the case of Kanagawa and Chiba between 1999 and 2009. The *average density* in Tokyo-to, Saitama, Kanagawa, and Chiba ECs became higher, indicating the strength of the ECs in these prefectures. Addtionally, despite that most of the suburban areas were revealed showing a decreainsg trend in employment density some of the ECs located in the suburban areas of Gunma in fact has become denser which indicates that not only the core areas but also some of the suburban areas have increased in denisty in the ten-year period.

The spatial pattern change analysis between 1999 and 2009 found nine types of spatial pattern changes in the ECs among which No change (31%), Shrinking (31%) and extended (25%) stands out in the ten-year period in TMA. Moreover, the highest number of shrinking ECs was detected in Saitama, whereas Kanagawa holds the highest number of extended and no change patterns of the ECs between 1999 and 2009. Also, a great number of ECs of the No change and extended were located between 30km to 50km distance bands from Tokyo CBD in the ten-year period. Further analysis of the nine change pattern types by prefectures revealed the locations of the specific change patterns of the ECs.

To conclude, the research presents GA assisted scale size analysis that can provide new outlooks on the metropolitan areas of the world in respect of spatial structure studies. Besides, an inclusive analysis of the spatial structure of employment in TMA was conducted, which revealed the accurate location, rank, size, total employment, average density, and changes of the employment centers throughout the Tokyo Metropolitan Region that can assist in further development strategies.

Keywords: Spatial Structure; Tokyo Metropolitan Area; Employment Center; ESDA; LISA; Local Moran’s I; CBD; NCRDP; EC.

雇用の空間構造における最近の推移：
東京大都市圏のケーススタディ

<u>要約:</u>

都市の空間構造とその推移は、第二次世界大戦後の都市と雇用の分布に重大な影響を与える郊外化を理解するうえで重要な研究課題となっている。世界中において現在の都市における雇用の空間構造を理解し分析するため、理論的および実証的観点から多数の研究がなされているが、東京大都市圏(TMA）に関するものは十分ではなかった。そのギャップを埋めるため、本研究は、雇用センターの位置とランク階層を特定することで、大都市圏における雇用の空間構造を調べた。その成長と衰退などを含む雇用センターの空間パターンの推移も調査した。

本研究の主目的は、a）様々なランクの雇用センターの特定、およびb)最近の雇用センターの空間パターンの推移の調査であった。この分析には、１９９９年と２００９年の経済国勢調査データを用いた。ローカルな空間的相関指標（Local Indicators of Spatial Association (LISA)）法、具体的には Local Moran's I を採用し、センターの特定を行った。得られた結果の視覚的表示と統計的分析においては、GeoDa 1.6.7 および 1.8.12、そして ArcGIS 10.1 を用いた。

本研究により、格子を用いたアプローチ（GA）が雇用の包括的な空間構造の検出について提案された。いくつかの空間スケールサイズ（２５０ｍ ｘ ２５０ｍ （０．０６２５ｋｍ^2）、５００ｍ ｘ ５００ｍ（０．２５ｋｍ^2）、１０００ｍ ｘ １０００ｍ（１ｋｍ^2）、２０００ｍ ｘ ２０００ｍ（４ｋｍ^2）、３０００ｍ ｘ ３０００ｍ（９ｋｍ^2））にそれぞれ基

づいた格子マップを作製した。

GA は、データの空間的不規則性を抑制し、雇用の包括的空間構造をより良く捉えることができることが分かった。また、本研究は、雇用センターは、直近の周囲エリアと比較すれば、効率的に特定できることを証明した。

異なるランクの雇用センターの位置と推移を分析するため、微細スケールサイズ（２５０ｍ ｘ２５０ｍ）を採用した。本研究により、２００９年に東京大都市圏では１ｋｍ^2 以上の異なるランクの雇用センター（以下ＥＣと略す）が全部で２７９か所、存在していることが分かった。東京中心部からのＥＣの位置とランクを調査したところ､上位のＥＣ（ＥＣ１、ＥＣ２およびＥＣ３）の多くは、都市の中心（２０ｋｍ）に位置するが、下位のＥＣ（ＥＣ４）の多くは、周辺部（３０ｋｍ、５０ｋｍ、およびそれ以上）に位置していることが分かった。また、本研究により、第４次首都圏整備計画（ＮＣＲＤＰ）における計画中の３２か所のビジネスセンターの内、ＥＣ１とランクされたのは１１か所に留まった。一方、メインセンターの近隣や周辺部において発見されたＥＣ１、ＥＣ２、およびＥＣ３の中には第４次ＮＣＲＤＰでは見過ごされているものもいくつか存在した。

1999 年と 2009 年の間のＥＣの空間パターン推移の分析を、まず都道府県レベルで行い、全雇用と平均密度をカバーした。結果、東京都のメインンセンターにおける雇用の集中度がより高いものであったものの、１９９９年と２００９年の間で神奈川県と千葉県では県単位で雇用が集中していることが検出された。東京都、埼玉県、神奈川県、および千葉県のＥＣの平均密度はより高くなっており、これらの都道府県でのＥＣの強さ

を示した。また、郊外エリアの多くでは、雇用密度が減少している傾向がみられたが、群馬の郊外エリアに位置するＥＣの中にはより密度が高くなったものもあり、この１０年間でコアエリアだけでなく、郊外アリアの中にも密度が高くなったものがあることを示した。

１９９９年と２００９年の間の空間パターンの推移の分析により、ＥＣには９つのタイプの空間パターンの推移があることが分かった。その内、変化なし（３１％）、縮小（３１％）および拡大（２５％）がこの１０年間での首都圏では顕著であった。また、１９９９年と２００９年の間で、縮小しているＥＣが最も多いのが埼玉県であり、拡張パターンのＥＣと変化なしのパターンが一番多いのが神奈川県であった。また、この１０年間において、変化なしまたは拡大したＥＣの多数は東京の中心業務地域（ＣＢＤ）から３０ｋｍから５０ｋｍ圏内に位置していた。９つのパターンタイプの推移を都道府県毎に分析したところ、ＥＣの特有の変位パターンの位置が分かった。

結論として、本研究は空間構造の研究に関し、世界の都市エリアに関する新しい視点を提供できるＧＡに基づくスケールサイズ解析を提供した。また、大都市圏の雇用の空間的構造の包括的分析を行い、東京大都市圏の雇用センターの実際の位置、ランク、サイズ、全雇用、平均密度、および変遷を明らかになった。将来の開発戦略の一助となるであろう。

Keywords: *Spatial Structure; Tokyo Metropolitan Area; Employment Center; ESDA; LISA; Local Moran's I; CBD; NCRDP; EC*

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NOMENCLATURES

CBD - Central Business District

CTs- Census Tracts

DID - Density Inhabited District

ECs - Employment centers $\geq 1km^2$

ESDA - Exploratory Spatial Data Analysis

GA - Grid Approach

LISA - Local Indicator of Spatial Association

LMI - Local Moran's I

NCRDP - National Capital Region Development Plan

TMA - Tokyo Metropolitan Area

CHAPTER 1
INTRODUCTION

1.1 Statement of the problem

Since World War II, the spatial structure of the metropolitan areas significantly has altered because of the acceleration in the processes of decentralization and suburbanization of economic activities. The spatial structure is the framework of a city's socio-economic land uses which results from the economy, environment, and society of an urban area. Thus, it is important to learn about the spatial structure because it can help understand the distribution and the development of urban functions, and thus it is helpful for policy making.

The spatial structure of the contemporary metropolitan area has been investigated by a number of research scholars analyzing employment distributions (e.g., McDonald, 1987; Giuliano & Small, 1991; Coffey & Shearmur, 2001; Hajrasouliha & Hamidi, 2016). Through these studies, new employment has been found to concentrate in employment centers located in the suburbs of the metropolitan areas. Also, some new employment centers have been found located close to the city center. Therefore, the identification and selection of employment centers has become an attractive method to detect the overall spatial structure of employment in metropolitan areas.

However, while the distribution of employment has been shown to concentrate in the employment centers, the center identification and selection procedures were greatly varied. The spatial structure analysis results are found to be greatly affected by the variation in the identification and selection of employment centers. For example, through the research of Arribus-Bel and Sanz-Gracia (2014), majority of the American metropolitan areas were revealed as monocentric, whereas a generalized dispersion pattern was confirmed by Hajrasouliha and Hamidi (2016). Such differences in spatial structure were related to another issue that was discussed in the paper of Agarwal, Giuliano, and Redfearn (2012), in which the authors have mentioned that the number of employment centers identified for the same location (i.e., Los Angeles metropolitan area) considerably varied because of the differences in the data used and the methodologies chosen. Moreover, Krehl (2016) has pointed out that the identification of employment centers is affected by the researchers' own interpretation, understanding, and operationalization of employment centers. As a result, it has been hard to reach a consensus about accurate numbers, total employment, density, and the area of employment centers. Thus, the ongoing debate on intra-metropolitan spatial structure still seeks for new ways to identify and select employment centers. Accordingly, the present study investigates the identification and selection procedure of employment centers to reveal the spatial structure of employment in the case of the Tokyo Metropolitan Area (TMA), the largest megaregion in the world.

The TMA has been well discussed from the side of global city formation, planning policies related to urban growth, and functions of cities (e.g., Fujita & Kashiwadani, 1989; Pernice, 2006, 2007; Okata & Murayama, 2011; Matsubara, 2014). However, employment center level studies have been less focused. For example, Alpkokin, Komiyama, Takeshita, and Kato (2007) have tried to identify the business centers based on the existing national capital region development plans (NCRDPs). However, they only looked at the municipal level, which was too large for identifying employment centers. Besides, despite the TMA being considered as one of the powerhouses of the world from the side of technology, environment, and economy, a comprehensive study regarding the spatial structure of employment has not been done. Data unavailability, fragmented administrative divisions, and technical difficulties in data collection have made it difficult to explore the TMA fully in this respect. Conversely, another group of scholars has focused on studying specific parts of the TMA (e.g., Zheng, 1991; Ichikawa, 2003; Kikuchi, & Obara, 2004; Yoshida, 2014).

This study selected from the TMA seven prefectures (Tokyo-to, Kanagawa, Saitama, Chiba, Ibaraki, Tochigi, and Gunma) for analysis to fill in the gap in spatial structure studies related to TMA, and to reveal the exact location, size, rank, area, density, total employment, and spatial pattern changes of TMA employment centers.

1.2 Research questions and purpose of the study

A comprehensive analysis of the spatial structure of employment was conducted through this study to determine the employment centers and their ranks. Furthermore, the study also investigated the spatial pattern changes in employment centers. The main research questions were – *What is the spatial structure of employment in TMA? What are the recent changes?* Specifically, the research is focused on- *to identify the employment centers in different ranks*; and to *explore the spatial pattern change of the employment centers between 1999 and 2009*.

Previous theoretical and empirical studies as mentioned in the literature review section (Chapter 2) have contributed specifically to the definition, identification and delineation of the employment centers used to detect the overall spatial structure of employment in metropolitan areas. However, there have been fewer studies focused on using size selection in identification of the employment centers. Hence, different scale sizes were chosen as the minimum center sizes and they were compared with 1^{st} order contiguity (8 neighboring grid cells adjacent to the observed cell), and 2^{nd} order contiguity (24 neighboring grid cells adjacent to the observed cell).

The scope of this research is related to the spatial structure of the metropolitan area. Following Giuliano, Redfearn, Agarwal, Li, and Zhuang (2007), Fernandez-Maldonado, Romein, Verkoren, and Parente Paula Pessoa (2014) and Hajrasouliha and Hamidi (2016), the analysis has also explored the identification and selection of employment centers that can be used to identify the entire spatial structure at the metropolitan level. The TMA was selected because it has not been studied fully compared to other global cities in terms of the analysis of its spatial structure. Despite that, a large number of research studies have been conducted to understand the comprehensive spatial structure of the TMA. Abe (2008), and Kagawa, Koga, and Neda (2012) have pointed out that the most of these studies were focused on the individual functions of the city rather than its internal structure. Thus, this research has explored the identification and selection of employment centers to detect the overall spatial structure of employment in the TMA.

The spatial pattern change analysis of the Employment centers $\geq 1km^2$ (*hereafter abbreviated as EC*) was conducted on data collected in 1999 and 2009. The employment census datasets of the year 1999 and 2009 were selected for the analysis. They covered the entire TMA area and contains very detailed and necessary information for the investigation of the spatial structure of employment at the smallest census tracts (CTs) level and can further provide comprehensive results on the change pattern analysis that was conducted by this research. Here, the identified spatial structure was investigated at the EC level and included the distribution of employment, density and area. The research was performed to show that in the ten-year period the spatial pattern of the ECs changed as well as their total employment, density and area.

1.3 **Significance of the study**

Through this research, an identification and selection procedure was established that was found to effectively capture the employment centers. The spatial pattern of employment centers was explored, and the results provided valuable insights for further analysis related to the de-concentration of economic activities. The empirical procedure used fits in the corpus of urban policy based research on the urban spatial structure of the 21st century urban agglomeration that has become crucial to ensuring a sustainable and inclusive urbanism (United Nations, 2014; World Bank, 2015; UN-Habitat, 2015, 2016).

Another implication of the research relates to the selected case study area for the analysis of the spatial structure of employment. The TMA, the largest region of the world, is less researched in the case of spatial structure based studies (e.g., Bertaud & Malpezzi, 2003). Therefore, a clearer view of the full spatial structure in the case of the TMA is hard to detect. Through the present research, the spatial structure of the TMA has been revealed at the regional level. Also, the research has identified 286 ECs in 1999 and 279 in 2009 in different ranks in the TMA, and their accurate location. Such findings can help in TMA regional planning; for example, in areas where earthquake frequency has become an issue. Because of the earthquake hazard it has been suggested that the central functions managed by Tokyo City should move to a safer location inside the TMA (Todokoro, 2014). Therefore, the findings of this research can help in the selection of better locations to minimize the effects of post-decentralization of the central functions. Moreover, the shrinking cities phenomena, ageing population, and depopulation issues are major concerns of Japan’s future progress from the side of economy, environment, and society (e.g., Kikuchi, Inazaki, Kumaki, Kureha, Sano, Sugai, & Marui, 2014; Hino & Tsutsumi, 2015). The findings of this study can provide useful insights into urban policies related to consolidation of the shrinking opportunities to ensure sustainable urbanism from the side of socio-economic and socio-cultural perspectives (Hino & Tsutsumi, 2015).

To conclude, the research suggests that GA assisted scale size analysis can provide a new outlook for the metropolitan areas of the world in the case of spatial structure studies. The 21st century TMA is facing new challenges in city planning, which has to deal with the depopulation and ageing issues that triggered the shrinking cities phenomena, and still considerably affect its economic development. The complexity of the shrinking cities cannot be well addressed until the regional spatial structure of employment is researched in detail. Through this research, a complete analysis of the spatial structure of employment in TMA was conducted which revealed the accurate location, rank, size, total employment, average density, and changes in the employment centers throughout the region. The research highly recommended that further development strategies should also be complemented by employment center based studies. Also, the Asian and Pacific regions are going through an urban transformation that needs proper and careful attention at both local and regional levels. Thus, the results of this research can shed some light on planned urbanization of the emerging cities.

1.4 Organization of the research

This section briefly describes the arrangements of the dissertation in consecutive order. At the end of the section a flowchart of the organization of the research is presented (Figure 1.2).

Chapter 2: The Literature review outlines the limitations in the previous literature on spatial structure studies and the spatial pattern analysis of employment centers through time from theoretical and empirical point of view.

Chapter 3: Following the limitations which were addressed after reviewing the literature, this chapter of the dissertation describes the selection of the study area and the datasets for the research. Moreover, the employment center identification methodology adopted for this research is discussed in this chapter.

Chapter 4: This chapter introduces a Grid-Approach (GA) for the identification and selection of employment centers for the study of the comprehensive employment structure of the TMA. This is based on two center criteria: 1) minimum center size; and 2) the range of surrounding areas that the observed location will be compared with. Later, the advantage of using grid approach (GA) is compared with the municipal boundary (polygons) in identification of the local employment peaks by using the Local Moran's I (LMI) in data treatment for the spatial structure analysis of employment. Moreover, different scale sizes *250m by 250m or* $0.0625km^2$*; 500m by 500m or* $0.25km^2$*;1000m by 1000m or* $1km^2$*; 2000m by 2000m or* $4km^2$; and *3000m by 3000m or* $9km^2$ as mentioned above were selected as the minimum center sizes and they were compared with one-order contiguity (8 neighboring grid cells adjacent to the observed grid cell) and two-order contiguity (24 neighboring grid cells adjacent to the observed grid cell) by using LMI in identification and selection of the employment centers.

Chapter 5: The chapter addresses the first objective of the research: *identify the spatial structure of employment between 1999 and 2009* by using the fine scale *(250m by 250m grid*) case that was proved in chapter 4 to best capture the overall spatial structure of the TMA. This chapter gives the location of the ECs in different ranks at the 20*km*, 30*km*, and 50*km* distance bands from the city center. Also, the 4th National Capital Region Development Plan (NCRDP) is compared with the identified ECs in different ranks to reveal its weakness in planning for suburbanization in TMA

Chapter 6: The Chapter addresses the second objective of the research: to *explore the spatial pattern change of employment in a given period*. Following the identified ECs, this chapter further explores the spatial pattern change of the ECs. Firstly, the distribution of employment, density and area of the ECs is identified; and secondly, spatial pattern change analysis is conducted in at the ECs level in the chosen ten-year period. For the spatial pattern change analysis at the ECs level, ArcMap and ArcEditor 10.1 were used to provide unique numbers to each ECs of the both 1999 and 2009. Later, 2D spatial maps of both years were then overlaid to identify the changes. And *Chapter 7*: the last chapter of the dissertation synthesizes the research findings from the chapters 4, 5, and 6. Also, research achievements were mentioned in this chapter. Future directions of research drawn from the limitations are also provided.

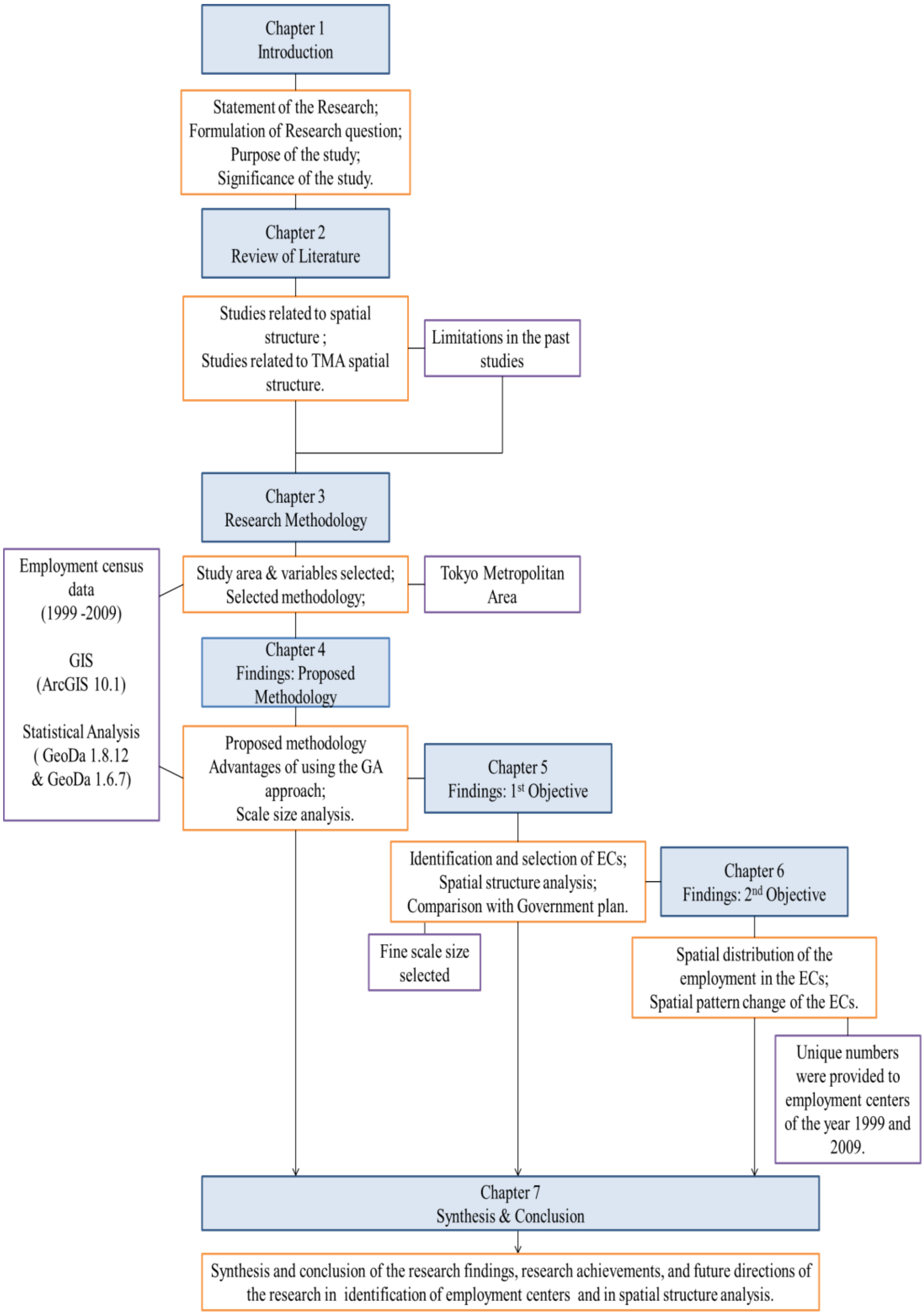

Figure 1.2: Organization of the research.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This chapter is divided into two parts. The 1st part of the chapter provides a general review of the limitations existing within the scholarly literature related to spatial structure of employment at the metropolitan level over the globe; and the 2nd part of the chapter reviews the spatial structure studies related to the TMA. The main ideas related to understanding the structure of employment activities, the ongoing debates over the spatial structure of employment and center concept, and the previous empirical studies about Tokyo are presented and discussed. The chapter starts with the discussion of the theoretical background of the studies related to employment structure. Later, the economic forces that greatly affected the spatial pattern of employment are discussed. Following the discussion on the economic forces, the ongoing debate on the detection of spatial pattern changes in the employment in the metropolitan area over the globe is presented. Also, the debated center concept and the empirical approaches are discussed. Following the above discussions, the limitations of the previous literature on the TMA, and the aims of this study are presented at the end of the chapter.

2.2 Studies related to Spatial Structure of employment

2.2.1 Classical Urban form theories

The spatial structure of cities was first observed and modeled by looking at differences in the economic landscape influenced by the proximity to the market (Center). This pattern was named as "Concentric" or "Monocentric" and pioneered by Von Thunen (1826). Later, during the 1960-70s, Alonso (1964), Muth (1969) and Mills (1972) developed and introduced a more constructive model called the "Monocentric Model[1],[2]" to analyze the urban pattern a gain a better understanding of the distribution of the economic and social activities in the city. Since the introduction of the "Monocentric Model," it is widely accepted as to analyze the spatial structure of cities. Also, Sir Ebenezer Howard (1898) pioneered a different type of concentric urban pattern called the "Garden City[3]" that revolutionized the understanding of the urban areas. Later, following Hoyt's (1939) "Sector Model" and Harris and Ullman's (1945) "Multiple nuclei or Multinucleation" model, a succession of different urban development models were proposed. Through these models, the multiple center idea was encouraged in urban spatial structure analysis (Lynch, 1961), in the decentralization of population and employment activities outside the central business district (CBD).

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[1] The Monocentric city model concept was inspired by the works of Von Thunen (1826); Burgess (1925) and Hoyt (1939).

[2] The main characteristics of a monocentric city model as stated by Berry and Kim (1993, p.1) were: "The concentrated core-oriented metropolis that emerged to solve the problem of slow and expensive transportation by agglomerating industry and employment in a single center and packing the population and around that center and along radiating transport network".

[3] The "Garden city" urban concept is based on several satellite cities clustered nearby the main urban core; keeping the characteristics of classical concentric pattern of (Von Thunen,1826).

Consequently, the monocentric model was questioned for its appropriateness in the understanding the large cities with multiple centers (Odland, 1978). The concept of multiple centers was then introduced to reduce the excess concentration within the CBD, and to improve economic performance as well as social and environment conditions (Doxiadis, 1968, 1969).

However, the multiple center form did not follow a specific growth direction, and ended up in shaping more complex urban system in polycentric and dispersed forms after the World War II because of acceleration in the process in suburbanization or decentralization. The differences in spatial forms started to affect the economic, political, social, cultural, and environment conditions of the urban area. To understand the influence of differences in spatial forms, numerous theoretical and empirical studies have been conducted and discussed from the perspectives of - first, to what extent the spatial forms are different in the case of metropolitan regions? And second, which practical approaches can best address these spatial structure changes? However, a consensus has still not been established to detect the complexity of the decentralized urban form.

2.2.2 Theoretical explanation of decentralization and role of agglomeration economies

During the post-war suburbanization period, different urban forms emerged in North American cities[4] that have been described as “dispersed” (Burton, 1963) and “core dominant” (Bruckner, 1979). Highway construction, private cars, household subdivision and bedroom towns have played a crucial role in the

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[4] Erickson, (1985) found that the American metropolitan areas were more randomly suburbanized in the 25 years since World War II.

creation of such differences in the spatial form followed by firms (Mills, 1972; Ellickson, 1971; Erickson & Gentry, 1985), and office stock which rose about 57% outside the CBD (Fulton, 1986; Pivo, 1990). This has been true for most of the American metropolitan areas. Through the research of Pivo (1990), economic activities were found to be located in employment clusters or centers[5] distributed in spatial forms dispersed and along the single and multiple freeway corridors. Besides, McMillen (2004) found that firms and employment in most of the American metropolitan areas was suburbanized in a dispersed and concentrated manner along the transportation nodes. Additionally, Lee (2007) found three different spatial forms[6] in American metropolitan areas was greatly influenced by the agglomeration economies.

The differences in the spatial structure (i.e. Monocentric, Polycentric and Dispersed) are explained as an outcome of the relative strength of centripetal and centrifugal forces (Fujita & Ogawa, 1982; Wieand, 1987; Yinger, 1992; Helsley & Sullivan, 1991; Krugman, 1993). The centrifugal forces lead urban functions to locate outside the CBD, whereas the centripetal forces attract other city functions to its core area. As described by Colby (1933), the centrifugal forces are controlled by six specific stimuli: 1) *the spatial forces*: congestion lead outward migration; 2) *The site forces*: less used and transformed natural landscapes become attractive than the overused and modified natural landscapes in the city

[5] Subcenters or centers are non-market areas of the industries that arise not only because of “the good transportation, face to face information flow and telecommunication flows” as mentioned in the paper of Greene, (1980; p. 30-31), but also greatly depends on the locations which are close to the export nodes and directly controls the value of the houses.

[6] First, employment was found dispersed in Portland and Philadelphia metropolitan areas; second, employment was found agglomerated in the CBD of the New York and Boston metropolitan areas; and third, polycentricity was confirmed in the Los Angeles and San Francisco metropolitan areas where employment was found agglomerated more in the suburban centers.

center; 3) *the situational forces*: Unsatisfactory organizational management and spacing in the city center (i.e., business and architectural designs and plans) leads to migration; 4) *The force of social evaluation:* high taxes, austerity policies and high land prices in the city center lead migration; 5) *The status of organization and occupance:* Traffic issues, lack of well managed transportation systems lead to migration; and 6) *The human equation:* religious issues, personal choices and so on lead to migration. Also, the author has identified five main centripetal forces that work as a gravitational field in the central area: 1) *site attraction*: important landscapes in the city center (e.g., Sumida river area); 2) *Functional convenience*: well managed transport network inside the core areas of the city and to its connected locations in the region (e.g., inter regional transportation network in TMA); 3) *Functional magnetism*: cluster and colocation of industries in the city center (e.g., Ginza business district); 4) *Functional prestige*: co-location of important industries (e.g., Akihabara electric town), and professional groups in specific locations in the city center; and 5) *The human equation*: Personal preferences to live in the city center. The centripetal and centrifugal forces regulated by agglomeration/disagglomeration economies in the case of distribution, concentration, and resource allocation in a city (Agarwal, Giuliano, & Redfearn, 2012; Shearmur & Coffey, 2002a).

Related to the spatial structure change of employment, White (1973) predicted the suburbanization of jobs and household in dispersed or concentrated forms. This prediction of White's later was proved to be true through the research of Odland, 1976, Greene, 1980, Erickson and Gentry, 1985, Pivo, 1990, and

Kloosterman and Musterd, 2001. Subsequently, new urban forms are observed and explained in theoretical and empirical studies; Garreau's (1991) "Edge City"; Gordon and Richardson's (1996) "Generalized Dispersion"; Fujii and Hartshorn's (1995) "Scatteration"; and Lang's (2003) "Edgeless Cities." These types of urban forms have their own discrete spatial characteristics. For example, edge cities are path specific (Henderson & Mitra, 1996), whereas dispersed cities are spread out from the city center (Cutsinger & Galster, 2006). Besides, scattered cities tend to locate in under-developed areas (Real Estate Research Corporation, 1974) contrary to Edgeless Cities which locate far from the city sub centers (Lang & LeFurgy, 2003).

Nonetheless, most of these differences in the spatial pattern were conceptualized based on the density of economic activities; regulated by factors such as "land cost, freeway access, market growth, transportation cost and the effects of agglomeration and competition" (Erickson, 1986, p. 331). From that time on, a debate over detection of the spatial structure changes of employment has emerged. Through the anlaysis of Arribus-Bel and Sanz-Gracia (2014), monocentricity was confirmed for majority of American Metropolitan areas in year 1990, 2000 and 2010. Conversely, generalized dispersion was identified by Hajrasoliha and Hamidi (2016) for the metropolitan regions of the United States. Despite their differences both studies have revealed that monocentricity better reflected small metropolitan areas.

Despite a systematic and controlled decentralization of employment for a better economic growth, Crevero & Wu (1997, 1998) pointed out an imbalance that has been overlooked between employment centers and journey-to-work ratio. They observed that the employment centers located in the bay area of San Francisco have increased the journey-to-work time of the workers resulting in high payment of private and social cost. Besides, high housing price near and around the suburban centers were found have displaced many low payment workers. Also, Jun and Ha (2002) have found that the commuting time to the identified suburban centers in Seoul metropolitan area become longer than the CBD because of their location as well as improved transportation network. As a result, both employment share and total employment have decreased in the CBD of Seoul. To avoid such imbalance, explanatory variables such like job-housing-population ratio is necessary to analyze (Modarres, 2011). Moreover, National and Local Government's planned decentralization as well as improvement of infrastructures and neighborhood level research can further address the imbalance exists in decentralization process (Bollinger & Ihlanfeldt, 2003; Yue, Liu & Fan, 2010). Moreover, in global and regional level, urban system varies when it is observed from the side of path- dependent trajectories (Kloosterman & Lambregts, 2007) because of the differences in city growth history and characteristics.

2.2.3 Debate over urban pattern changes

Giuliano, Redfearn, Agarwal, Li, and Zhuang (2007) have revealed a mixed urban pattern for Los Angeles. These authors also revealed the degree of stabilty in the system of centers meanwhile the emergence and growth of employment centers and growth dispersion of employment in outer suburbs had occurred simultaniously. Also, Shearmur and Coffey, (2002b), Shearmur, Coffey, Dube, and Barbonne (2007) and Sweet, Bullivant, and Kanaroglou (2016) have shown different patterns for Canadian metropoltan areas. These authors seem to have agreed upon the observation that the characteristics of most of the spatial patterns are visible in Canadian metropolitan regions; including a strong CBD, small metropolitan areas being mostly concentric, and large cities having the tendancy to develop subcenters.

The debate over spatial pattern change of employment also invloved the ccontemporary metropoltian areas across the globe. Ingram (1998) observed that in market-based industrial countries, urban efficiency and structure is greatly influenced by the land market. This has been also true for Ile-de-France, (France), Frankfurt, (Germany) where employment is decentralized (Keil & Ronneberger, 1994; Guillain, Le Gallo, & Boiteux-Orain 2006). In contrast, Krehl (2016) has revealed that most German city regions are fairly monocentric, where most of the identified subcenters are of local relevence. The same type of spatial patterns have also been identified by Bontje and Burdack (2005) for Paris, (France) and Randstad, (Netherlands); Riguelle, Thomas and Verhetsel,s (2007) for Brussels, Antwerp, Ghent, and Liege, (Belgium); Rodriguez-Gamez, and Dallerba (2012) for Hermosillo (Mexico) and Escamilla, Cos, and Cardenas (2015) for Mexico City. These authors have shown that, despite decentralization of employment activities, traditional center have hardly lose its economic supremacy as well as employment density. Moreover, Fernandez-Maldonado, Romein, Verkoren, and Parente Paula Pessoa (2014) found that Latin American metropolitan regions such as Mexico City in Mexico, Lima in Peru, and Fortaleza in Brazil were developing polycentric structures, however their subcenters were located near to the city center. In contrary, Garcia-López, and Muñiz (2010) studied the Barcelona metropoltian area in Spain between 1986 to 2001 to detect the status of its employment structure. The authors reveal that employment in Barcelona became more decentralized and deconcentrated between 1986 and 2001. Finally, Pfister, Freestone, and Murphy (2000) have identified the existence of generalized dispersion in the Greater Sydney area, despite an increase in employment in the center between 1981 and 1996.

The debate over spatial pattern changes has no longer stayed within the polycentricity, monocentricity and dispersed model but has indentifed new urban spatial patterns. For example, Shearmur, William, Christian, & Barbonne, (2007) and Hackworth's (2005) pointed out the existence of a "chaotic" urban pattern; Ahlfeldt & Wendland (2012) reviewed "micro-level polycentric structures," and Krehl (2016) identified "core dominant spatial pattern." This debate over the differences in urban pattern analysis have been looked at by Agarwal, Giuliano & Redfearn (2012), who showed that the differences in center sizes and selection processes have significantly influenced urban spatial patterns. It seems that it is a never-ending process to understand the spatial pattern that seemingly goes back and forth.

Regarding the spatial structure of employment studies, Hall (1997)[7] and Phelps (2004)[8] have both emphasized the use of the new and modified urban

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[7] According to the author, the traditional urban models and theories of the past is not sufficient to address the complex urban forms and dynamics of the global city regions (London, New York, Los

theories and models to analyze the differences in the cluster of employment activities or employment centers in the new urbanized world. Following Böventer's (1976) center formation criterion and McDonald's (1987) center concept, numerous theoretical and empirical research studies have looked at center formulation (e.g., see, Wieand, 1987; Fujita & Ogawa, 1982; Helsey & Sullivan, 1991; Yinger, 1992), and the construction of new center concepts (e.g., see Giuliano & Small, 1991; McMillan, 2001; Baumont, Ertur, & Le Gallo, 2004). However, recent studies have also found a major problem in urban center conceptualization. Martin and Sunley (2003) characterized clusters as "chaotic"- because of their ever-growing typologies and multi-focused characteristics. Also, Coffey and Shearmur (2001) have stated that the center concept is "inconsistent" rather than homogenous. Moreover, several other studies also have pointed out the issues regarding the center concept; based on the size and number of centers and the specific research focus of individual studies (Veneri, 2013; Agarwal, Giuliano & Redfearn, 2012). Also, Zhang and Sasaki (1997), Agarwal, Giuliano and Redfearn (2012), and Craig, Kohlhase, and Perdue (2016) have found that center characteristics are greatly influenced by the larger cities of the same location. This confusion in center the concept led Martin and Sunley (2003; p.13) to state that: "despite the vast and still expanding the literature on the cluster, however, there has been little detailed work on the deconstruction of the cluster concept."

Angeles, & Tokyo) of the post- industrialized world.

[8] The author has pointed out that rather considering the external economics which has been a key component to understand the cluster of economic activities "locked into an idiographic realm of self-contained places defined at whatsoever scale" (p.984). As a result, a banal situation has been created in the urban forms (e.g., suburbs, edge cities, and edgeless cities) without proper and logical explanations.

2.2.4 Empirical studies on decentralization

Following theoretical explanations of (Boventer, 1976; Fujita & Ogawa, 1982; Helsely & Sullivan, 1991; Fujita, Thisse & Zenou, 1997) on suburban center development led empirical researchers to study more on the distribution and location of the suburban centers. From an empirical perspective, decentralization is studied based on identification of suburban centers, the number of suburban centers and their influence over distribution of industries, employment and population in metropolitan area (e.g., see, McDonald, 1987; Giuliano & Small, 1991; Cervero & Wu, 1998; McMillen & Smith, 2003; Giuliano, Redfearn, Agarwal, Li, & Zhuang, 2007). Therefore, To understand spatial structure several empirical approaches have been applied which were mostly constructed based on large American metropolitan areas (Richardson, 1971).

For example, center identification methods, regression models, and point pattern analysis are among some of the best research approaches that are still in use to understand urban spatial patterns (e.g, McMillan & McDonald, 1997; Baumont, Ertur, & Le Gallo, 2004; Giuliano, Redfearn, Agarwal, Li, & Zhuang, 2007; Garcia-López, & Muñiz, 2010, Lee, 2007). Despite debates over methodological advantages and disadvantages, the matter that still must be solved is to what extent can the different spatial patterns be analyzed. Some of the new approaches, such as spatial concertation methods (Arabia, 2001); degree of polycentricity (Yang, French, Holt, & Zhang, 2012; Hajrasouliha & Hamidi, 2016); degree of centrality (Pereira, Nadalin, & Albuquerque, 2013); De Dominicis, Arbia, and De Groot, (2013) and Guillain and Le Gallo's (2010) agglomeration study; “bottom up” appraoch of Cladera, Duarte, & Moix (2009); functional polycentricity (Veneri, 2013); and Ban, Arnott, and Macdonald’s (2017) exponentially declining cutoffs were introduced to find and study specific employment centers.

2.3 Limitations in the previous literature

From the above discussion, the first thing to observe is that a vast literature from both theoretical and empirical perspectives has analyzed the spatial structure of employment. Also, the debate over spatial pattern changes has shown that a consensus on the decentralization of employment is still unreached. Different empirical approaches have been introduced for data treatment, and for the identification and selection of employment centers, however several scholars have found limitations in the whole center identification and selection approach. For example, as mentioned by Anas, Arnott, and Small (1998), “the urban landscape is highly irregular when viewed at a fine scale, and how one averages these local irregularities determines the look of the resulting pattern.” Also, Fujita & Ogawa (1982) have pointed out that that decentralization does not change the characteristics of the CBD, but is one of the parameter values that influences change. Moreover, Coffey and Shearmur (2001), who looked at the different methods used to identify the employment centers concluded that none of the center selection approaches were appropriate enough to define employment centers at the metropolitan level. Affix to that, according to Martin and Sunley (2003, p:19) “there is no agreed method for identifying and mapping clusters, either in terms of the key variables that should be measured or the procedures by which the geographical boundaries of clusters should be determined". Additionally, Krehl (2016) has pointed out that it is not the differences in the methodologies, but the researchers own interpretation, understanding, and operationalization of their specific approach to understanding employment centers that affects characterization of urban spatial structures.

2.4 The growth history of the TMA spatial structure

Edo city (Tokyo) first appeared as a castle in the late 16th century, and later went through city reconstruction plans developed by the Tokugawa shoguns (1600-1868), and became a major urban area. By the 1868s Imperial restoration and the fall of Tokugawa shogunate or bakufu (feudal Japanese military government), Tokyo had a population of nearly one million within an expanded spatial land use pattern (Ichikawa, 1994; Waley, 2002). Following the restoration, urban reformers implemented western style urban techniques in Japan's urban planning for economic development (Ichikawa, 1994; Okata & Murayama, 2011). By that time, high density, congestion, and improved transportation networks allowed urban growth in peripheral areas of TMA. As a consequence, the city planning law of 1919 failed to stop suburbanization, and the city later expanded as a result of the great Kanto earthquake in 1923 and World War II (Hein, 2010; Pernice, 2006, 2007; Watanabe Takeuchi, Nakabayashi, & Kobayashi, 1980).

The post-war reconstruction period had a direct impact on the spatial structure of TMA. First, urban Tokyo was reinforced by a transition in economic activities and priorities in industrial development, and mass migration towards developed regions (Tokyo, Osaka, and Nagoya) from rural areas. Second, the development of sub-centers and satellite cities and the development of expressways further intensified the city–suburbs commute that decentralized residential and commercial firms into urban fringe areas (Hebbert & Nakai, 1988; Machimura, 1992; Waley, 2007; Sorensen, 2001a, 2001b). Third, the five National Capital Region Development Plan (NCRDPs) have had a direct impact in shaping the spatial structure of the TMA as well as the suburbanization process (Itsuki, 2006; An, 2008). To reduce the influence of negative urban externalities (i.e., congestion, overpopulation and land price hikes) in Tokyo's central areas, the 1st NCRDP (1958), had the profound aim to control decentralization with a green belt as a margin. Unfortunately, it exacerbated the problems in land use planning because of the above population and economic growth pressure as well as the antiquated landowner system (e.g., uncompleted infrustructure within the build-up areas, subdivisions of the small lands and conflicts asociated with builing infrustructure) (Hebbert & Nakai, 1988; Itsuki, 2006; Takeuchi & Ishikawa, 2009; Morita, Nakagawa, Morimoto, Maruyama, & Hosokawa, 2012, Sorensen, 2001a). Consequently, a multi-nucleated urban structure was introduced through the 2nd to 5th NCRDPs (1968-1998), which divided areas from the city center to 20*km* as city core areas, from 30*km* to up to 60*km* as "suburban development areas" for the improvement of economic and social activities, and locations outside 60*km* as urban fringe areas of the TMA (Itsuki, 2006). Later, the Tokyo metropolitan government enacted several projects and development plans at the prefectural level in making a well-managed polycentric structure in the TMA (TMG, 2011, 2013).

2.5 The Spatial structure studied in the TMA

The growth of Tokyo from an Edo period castle to the capital of the nation occurred through different political domains, and was concurrent with a considerable change in spatial structure and scale. Policy and environmental upheavals and its geographical location have determined the shape of urban Tokyo. Past urban policies have been initiated to control urban expansion, but failed to do so and rather extended the growth towards suburban areas.

Studies related to the spatial structure of the TMA are available in large quantities. The spatial structure has been analyzed based on a historical review, the categorization of relevant events, location and amenity preferences, and employment distribution and inter-urban population distribution/migration (for example see: Watanabe, 1972, Watanabe, Takeuchi, Nakabayashi, Itsuki, & Kobayashi, 1980; Ichikawa, 1994; Tonuma, 1998; Sorensen, 2001a, 2001b; Kikuchi & Obara, 2004; Pernice, 2007; Okata & Murayama, 2011; Hein, 2010). Besides this, personal income, transportation costs, land price fluctuations, and land use changes also found to have influenced the growth of spatial structure (Fujita & Kashiwadani, 1989; Zheng, 1991; Kikuchi & Obara, 2004). However, only a few studies have been conducted to understand its spatial structure growth, and are limited to the individual functions of urban areas (Abe, 1996, 2008; Kagawa, Koga, & Neda, 2012).

Despite the abundance of literature on the TMA, few have focused on the spatial structure of the TMA at its full scale. Alpkokin et al. (2007), based on the EASTS (ICRA) awarded project called Asia Polycentric The Employment Collaborative-Transport (APEC-TR) study, plotted the employment density ranks and gross employment density of each municipality in a two-dimensional map. Later, it was divided into four to create a cluster hierarchy of employment density in the TMA. However, the Japanese administrative boundaries are usually composed of urban and rural areas, and even mountainous regions, and therefore, municipality as a basic unit cannot provide accurate information about employment centers. Sorensen (2001b) studied the population and employment structure of the TMA, concluding that a polycentric structure for jobs existed in the TMA. Again, this study focused on 23 wards in Tokyo-to and 342 suburban municipalities, and failed to delineate the location of the core area or sub-centers.

Moreover, several studies have only studied selected areas or prefectures of the TMA. For example, Siebert (2000) analyzed the urbanization transition zones of Tokyo-to and Kanagawa prefecture; and Zheng (1991) used a cubic spline method and a varying parameter model for spatial structure analysis in three directions to analyze the land use profiles along the railroad lines that radiate from Tokyo-to to its west, and the nearby two prefectures i.e., Saitama & Ibaraki.

2.6 Limitations in the previous literature

To summarize, the large amount of research that has been conducted to try to understand the spatial structure of the TMA was mainly policy oriented and related to urban activities (e.g., Hattori 1965, 1966; Tsubomoto 1996; Hamada 2003). Consequently, a comprehensive spatial structure of employment in the TMA has hardly been researched, but could provide important insights to the current depopulation, aging population and shrinking cities problems. Also, despite the fact that several scholars have studied the post-war spatial structure growth that resulted in suburbanization within the TMA, these studies have been limited to growth patterns as well as formation of the city structure (i.e., Yamaga, 1967; Tomita, 1975). Therefore, this literature review has shown that the studies related to spatial structure are limited in their explanatory power to understand the full spatial structure of employment in the TMA. Therefore, this research is aimed at unveiling the full spatial structure of employment in the TMA.

2.7 The Research focus of the study

To conclude, the limitations in the literature can be filled if the center identification and selection procedure is looked at from the scale point of view to detect the comprehensive spatial structure of employment in metropolitan areas. Besides, by investigating the scholarly literature, it was found that the minimum areal size of a center is less focused in the event of center characterization but more on the spatial structure of employment, and it was also found that less has been done in the case of the TMA. Therefore, this research aims to detect the whole employment structure in the TMA to identify the employment centers. Also, for the analysis, better center identification and selection procedures will be explored. Here, the research has considered the minimum scale size of the center before spatial structure analysis is performed to reveal the accurate size of a center. In addition, a thorough investigation of the detected employment centers will also be conducted, to reveal the accurate location, rank, size, density, and pattern of employment changes. The center identification methodologies are discussed in Chapter 3.

CHAPTER 3
METHODOLOGY

3.1 Introduction

This chapter deals with the research methodology used in this study as well as the methods used to answer the research questions and objectives. Research design, study area, selected data and variables, and selected employment center identification techniques are included in this chapter and broadly discussed. At the end of the paper the framework of the research is presented.

3.2 Study area

The research used quantitative data for the analysis. The main goal of this investigation is to analyze and unveil the spatial structure of employment in the Tokyo Metropolitan Area. Foremost, it is necessary to identify the employment centers and the employment distribution over a given period. For that purpose, this research used a local version of the Exploratory Spatial Data Analysis Approach (ESDA) in combination with a proposed center identification approach. The collected data were tabulated and calculated using *Excel 2010*. Furthermore, GIS and Geoda spatial analysis software were used for the projection and graphical representation of the datasets.

The research selected the entire Kanto are (Figure 3.1), to avoid the confusion about the delimitation of the metropolitan region previously discussed in several studies and the political plans. Figure 3.1 shows the boundary of the

Kanto region; it consists of seven prefectures: Tokyo-to, Saitama, Kanagawa, Chiba, Gunma, Ibaraki, and Tochigi. Also, some distinctive characteristics can be observed such as the fact that the distribution of Density Inhabited District (DIDs) is mostly concentrated to up to 70*km* range from the urban core, and most of the DIDs are connected by the railways and highways to the 23 wards of Tokyo city proper.

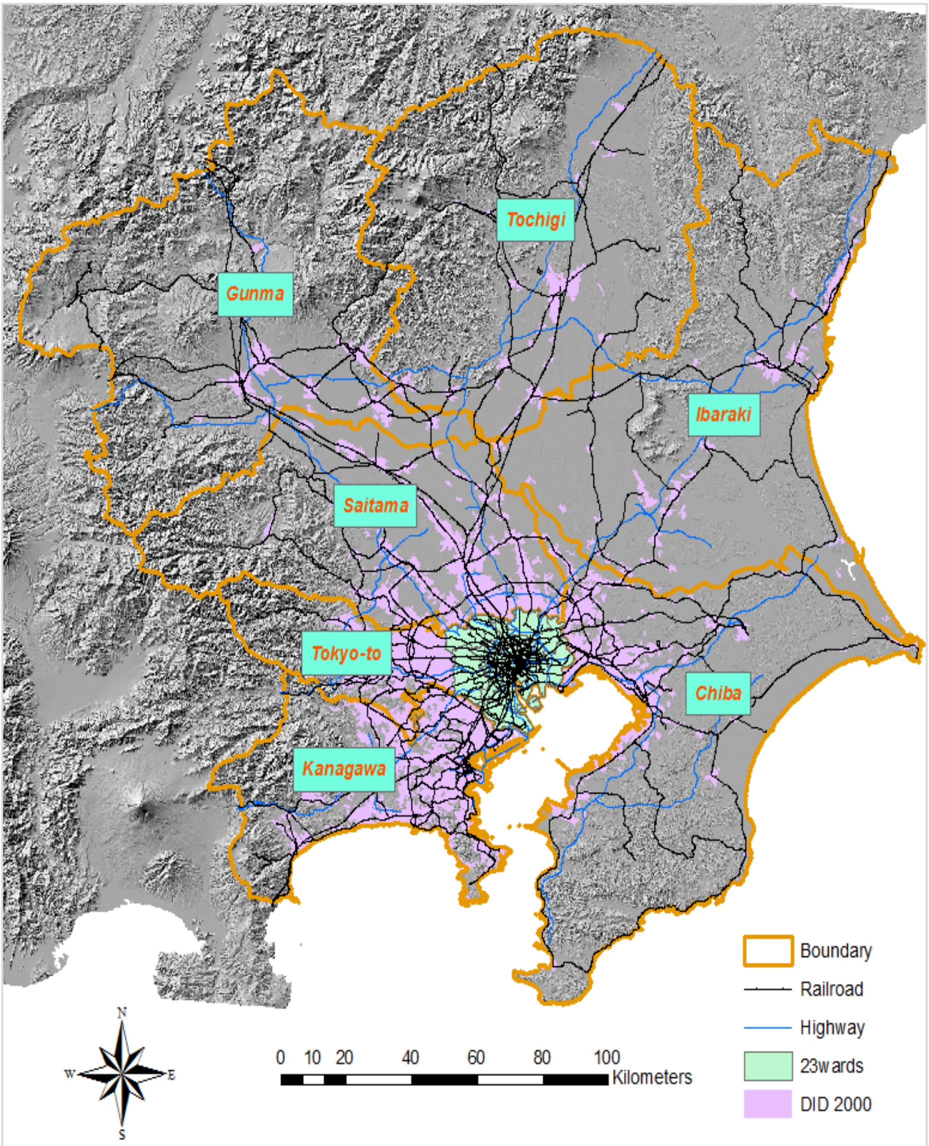

Figure 3.1: The Geographical features of Tokyo Metropolitan area.

The Tokyo Metropolitan Area is the largest mega-region in the world, and had a population concentration during the study period of 40,406,059 million in the year 1999 and 42,276,270 million in the year 2009 (World Bank, 2015). It has an area of 32,028km^2, and there are 360 municipalities within the seven prefectures. It is the economic, research, technology, commerce and financial hub of Japan and one of the major world cities (Reed, 1980; Sassen, 1991; Beaverstock, Smith, & Taylor 1999; Waley, 2007; METI, 2009).

3.3 Data description and the variable selected

Two Economic census datasets were used for this research: 1) Establishment and Enterprise census of the year 1999, and 2) Employment census data of the year 2009 which were provided by the Center for Spatial Information Science (CSIS) of University of Tokyo and Statistical Information Institute for Consulting and Analysis (Sinfonica). There were 66,724 Census tracts (CTs) for the year 1999, and 56,686 for the year 2009 (see Figure 3.2). Employment in TMA in the year 1999 was 19,871,861, and in the year 2009, it was 21,595,215. Table 3.1 gives detailed information about the physical, social, economic characteristics of Tokyo metropolitan area, in the years 1999 and 2009.

Both the censuses were carried out by the Ministry of Economy, Trade, and Industry (METI), and the Economic Census is the successor of the Establishments and Enterprise Census. They varied in industry classification and survey method, however the coverages of the survey objects, i.e. the economic entities were the same[9]. For the current research, the number of employees was selected as the variable and since both the censuses covered all the persons who were involved in the business during the time of survey, the influences of methodological differences were considered minor.

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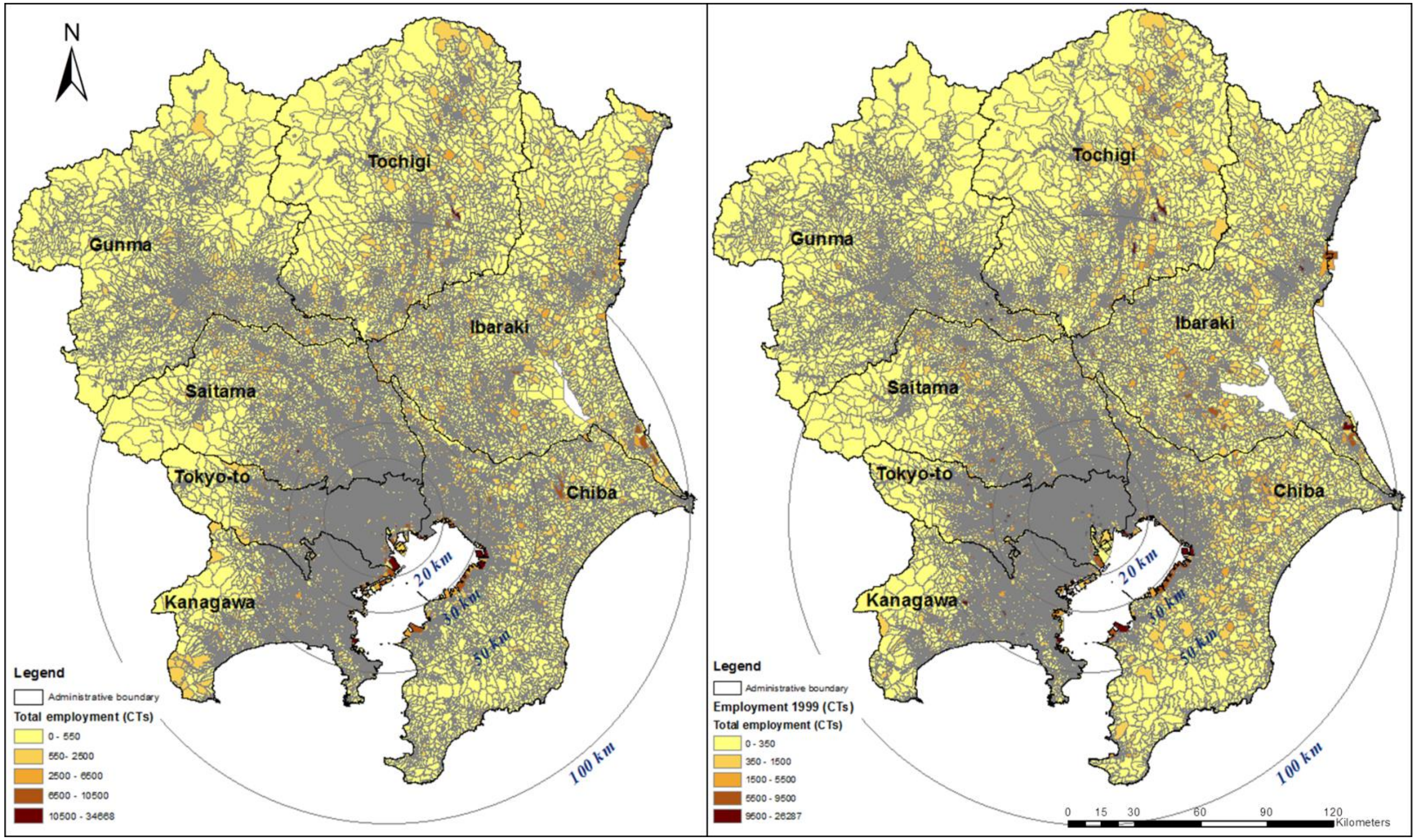
[9] http://www.stat.go.jp/data/e-census/2009/kakuho/riyou

Table 3.1: Physical, Social, Economic characteristics of Tokyo Metropolitan area, a) year 1999 & b) 2009.

a) Year 1999	Tokyo-to	Kanagawa	Saitama	Chiba	Ibaraki	Tochigi	Gunma	Total
Surface Characteristics								
Municipalities	54	56	79	61	44	30	36	360
Area(km^2)	1795	2418	3793	5156	6096	6407	6363	32028
Demographic Characteristics								
Population	12,040,875	8,490,236	6,938,159	5,921,994	2,982,323	2,007,773	2,024,699	40,406,059
Households	5,413,504	3,341,301	2,482,408	2,171,144	9,84,814	6,68,352	6,95,058	15,756,581
Economic Characteristics								
Establishments	7,21,504	3,08,849	2,60,469	2,06,631	1,35,484	1,03,734	1,09,613	18,526,02
Per km^2	402	128	68	40	22	16	17	58
Employment	8,590,687	3,365,623	2,506,825	2,125,480	1,304,855	9,42,709	9,84,531	19,871,480
Per km^2	4786	1392	661	412	214	147	154	620

Table 3.1: Continued.

b) Year 2009	Tokyo-to	Kanagawa	Saitama	Chiba	Ibaraki	Tochigi	Gunma	Total
Surface Characteristics								
Municipalities	54	56	79	61	44	30	36	360
Area(km^2)	1795	2418	3793	5156	6096	6407	6363	32028
Demographic Characteristics								
Population	13,131,573	9,048,331	7,194,556	6,216,289	2,669,770	2,007,683	2,008,068	42,276,270
Households	6,380,096	3,844,525	2,841,595	2,515,904	1,088,411	7,45,604	7,55,756	18,171,891
Economic Characteristics								
Establishments	6,91,078	3,14,552	2,67,629	2,08,089	1,31,129	98,483	1,04,555	1,815,515
Per km^2	385	130	71	40	22	15	16	57
Employment	9,497,139	3,689,368	2,777,221	2,295,672	1,372,518	9,73,407	9,89,890	21,595,215
Per km^2	5291	1526	732	445	225	152	156	674



a. Year 2009 b. Year 1999

Figure 3.2: Employment census tracts of the a) year 2009 and b) year 1999 and the distribution of employment within the ten-year period of the seven prefectures in TMA.

3.4 Employment Center Identification

Before explaining the alternative approach used in this empirical research, it is necessary to understand the different employment center identification approaches that have been in use to analyze the urban spatial structure.

3.4.1 Employment Center Identification Methods

Multiple empirical approaches have been introduced in identifying employment centers, as well as to understand the overall employment structure at the regional level. For example, in the early 80s - 90s, empirical models such as the "Two-center Model" or "Multi-centric Model" (Wieand, 1987; Yinger, 1992), and the "Non-Monocentric Model" (Fujita & Ogawa, 1982; Ogawa & Fujita, 1980) were introduced to address the polycentric form of urban structure. Both models have studied and analyzed the growth process of employment centers, and invigorated the different types of empirical center identification approaches to understanding the structure of urban areas to a broader extent. Among empirical center identification approaches, the most influential ones were: 1. Clustering Approach (Giuliano & Small, 1991); 2. Regression-Based Approach (McMillen, 2001; McMillen & McDonald, 1997); 3. Spline Approach (Craig & Ng, 2001); and 4. Spatial Statistical Approach (Baumont, Ertur, & Le Gallo, 2004)[10]. Figure 3.3 shows the variation in the center identification and selection methodologies that have been used to understand the spatial structure of metropolitan

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[10] Spatial statistical approach is for the first time used in urban studies in case of employment distribution studies and employment centers identification.

areas[11].Table 3.2 shows the four experimental methodologies and their center selection criteria and limitations in the determination of employment centers. Among the four mentioned approaches, this study used the Local Indicator of Spatial Association (LISA), a local version of the ESDA technique, for multiple reasons: Firstly, the algorithm of spatial autocorrelation addresses observed values in consideration of its surrounding values. This matches with the concept of an employment center defined for this research (see, the center definition on page:42). Secondly, the ESDA techniques have been used in various fields, and found to be useful in case of the urban spatial structure of metropolitan areas across the globe (e.g., Han, 2005; Riguelle, Thomas & Verhetsel, 2007; Hakim & Parolin, 2009; Arribus-bel & Sanz-Gracia, 2014; Krehl, 2015). Thirdly, the selected technique (LISA) needs no further local knowledge of the research area and, unlike other methods, arbitrary cutoffs of the employment density based on assumptions to identify high employment peaks are also not necessary. Fourthly, the intensity of the spatial associations can be assessed based on statistical significance levels, which makes the classification of center levels possible. Finally, LISA techniques can easily be computed by using GIS software.

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11 http://www.ecap.uab.es/RePEc/doc/wpdea0506.pdf#search=%27Decentralization+of+employment%3A+Polycentric%2C+compaction+or+dispersion%3F+The+case+of+Barcelona%2C+19861996%27

Figure 3.3: Employment center identification methodologies and their criteria in the selection of the centers.

Source: (Garcia-López, & Muñiz, 2005, p.11)

Table 3.2: The four used and modified practical approaches, their center definitions, center selection criteria and the constraints in the identification of the employment centers in spatial structure studies.

	(Giuliano & Small, 1991)	(McMillen, 2001)	(Craig & Ng, 2001)	(Baumont, Ertur, & Le Gallo, 2004)
Model Type	Cluster Model	Regression Model	Regression Model	Econometric Model
Method	Ō/Ē Ratio	Locally weighted regression (LWR) & Semi-parametric regression	Quantile Smoothing Spline (QSS)	Local Moran's I (LMI)
Center definition	"A contiguous set of zones each with density above some cutoff Ō, that together have at least Ē total employment and for which all the immediate adjacent zones outside the sub center have density below Ō." (P.166-167)	"A sub center in an area with an employment density that is significantly higher than would be expected based only on its distance from the CBD" (P.450)	"Changes in the gradients of upper employment density quantile splines of about 5% of the probability distribution for each distance from the CBD" (P. 102)	"An area having significantly higher employment and employment density than neighboring sites." (P.151)

Table 3.2: Continued

	(Giuliano & Small, 1991)	(McMillen, 2001)	(Craig & Ng, 2001)	(Baumont, Ertur, & Le Gallo, 2004)
Center Criteria	Threshold of 10 jobs per acre and 10000 employment for the contiguous zones	LWR is use to estimate the smoothed values of employment density in *y* site.	One area influences surrounding areas to certain degree	Falls within the high quadrant in Moran's scatterplot
	The highest density zone of the center is referred as the peak	Density peaks those with high residuals at 5% significant level are considered as potential centers	Employment density falls within 95th percentile employment density function	Employment density at least falls within 5% significance level
Limitations	Priori cut-offs and depends on the local knowledge of the area. *(Baumont, Ertur, & Le Gallo, 2004)*	Complexity of the employment distribution cannot be addressed. *(Redfearn, 2007)*	Requires local knowledge of the area & detects rings of density peaks rather than sub centers. *(McMillen, 2001)*	Only considers locations from broader spatial associations. *(Krehl, 2016)*

3.4.2 Local Indicator of Spatial Association (LISA)

Local Moran's I (LMI); one of the LISA techniques has been used for this empirical analysis to identify the statistically significant high clustering locations and outliers. The Local Moran's I is written as follows (Anselin, 1995):

$$I_i = p_i \sum_j \hat{w}ij \, p_j \qquad (1)$$

Where p_i and p_j are the deviations from the mean and $\hat{w}ij$ is the connectivity of the values of i with j.

Where:

$$p_i = \frac{b_i - \bar{b}}{\sigma^2} \qquad (2)$$

$$[\sigma^2 = \frac{\sum_j wij}{S - 1} - \bar{b}^2] \qquad (3)$$

Here b_i represents the employment number of i-th location and S is the total observed values.

Statistical significance is calculated as follows:

$$Z(I_i) = \frac{I_i - G(I_i)}{\sqrt{Var(I_i)}} \qquad (4)$$

Where the expected values take the form of:

$$G(I_i) = -\frac{\sum_i wij}{S - 1} \qquad (5)$$

The variance is calculated as:

$$\sqrt{\mathrm{Var}(\mathrm{I_i})} = \sqrt{\frac{(\mathrm{S}-\mathrm{C}_{2_i})\sum_j \mathrm{wij}^2}{\mathrm{S}-1} - \frac{(2\mathrm{C}_{2_i}-\mathrm{S})\sum_a \sum_b \mathrm{w_{ia}w_{ib}}}{(\mathrm{S}-1)(\mathrm{S}-2)}} \quad (6)$$

Where:

$$c_{2_i} = \frac{\mathrm{S}\sum_i(\mathrm{b_i}-\bar{\mathrm{b}})^4}{\left(\sum_i(\mathrm{b_i}-\bar{\mathrm{b}})^2\right)^2} \quad (7)$$

$$\sum_a \sum_b \mathrm{w_{ia}w_{ib}} = 2\mathrm{w}_{\mathrm{i}_{(ab)}} \quad (8)$$

Further, the method separates all the observed locations into five groups based on the LMI values and the significance levels. This is explained by a Moran's scatterplot where observed value (I_i) was plotted on the *X*-axis and neighboring values $(\sum_j \hat{w}ij\ p_j)$ on the *Y*-axis (Anselin, 1996). The output of the data then can be illustrated by a choropleth map (Figure 3.4). According to the location on the scatterplot, the observed values are then divided into five types:

- ***High-High group*** (i.e. high values are clustering with other neighboring high values and are above the mean);
- ***Low-Low group*** (i.e. low values are clustering with other low values and below the mean);
- ***High-Low group*** (i.e. high values clustering with low values and are below the mean);
- ***Low-High group*** (i.e. low values are clustering with high values and are below the average);
- ***Insignificant*** (i.e. no significant clustering exists).

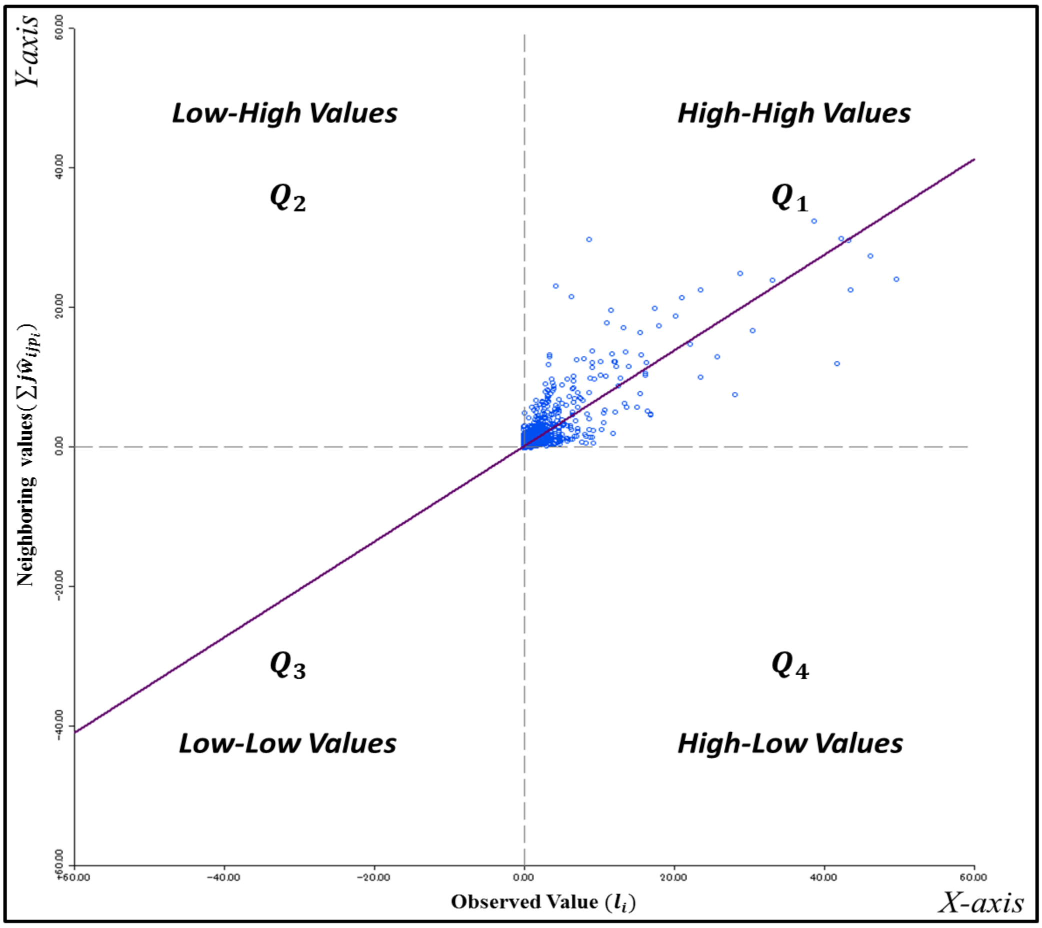

Figure 3.4: The four quadrants of the Scatter plot.

LMI analysis has divided the locations into five separate groups which can give a clear understanding of where the similar and dissimilar values are located. The 1st group (High-High) signifies a positive spatial autocorrelation, or in other words, the High values are clustering with High values, and 2nd group (Low-Low) signifies the Low values are clustering with Low values (Anselin, 1995; Baumont, Ertur, & Le Gallo, 2004; Griffith, 1992). The 3rd and fourth groups (High-Low and Low-High) signify a negative Spatial Autocorrelation or different values. The High-High and High-Low groups are considered the potential centers.

3.4.3 The Centers Defined

Baumont, Ertur, & Le Gallo (2004) and Guillain, Le Gallo, and Boiteux-Orain (2006) defined a center as the location of high employment density at a certain significance level than the surrounding areas. In their definition, high employment density peaks are located either within the 95.0% (0.05) confidence level or even at the 99.0% (0.01) confidence level. Later, Arribas-Bel and Sanz-Gracia, (2014) provided a similar center definition but selected the high employment density locations (HH and HL) that fall within the 90.0% (0.10) confidence level. For this research, the employment center is considered based on two criteria: a) HH values that fall within the 1st quadrant of the Moran scatterplot; and b) the concentration of HH values at certain significance levels based on the strength of their spatial associations. Consequently, for this research, the employment center is defined as (Li & Monzur, 2017):

The contiguous set of areas in which each of them shows a statistically significant higher employment density at the confidence level of 99.99% for Rank 1, 99.9% for rank 2, 99.0% for Rank 3 and 95.0% for Rank 4.

The divisions created in total employment were based on the significance levels (Ranks); which was decided after a sensitivity analysis by "changing the number of permutations, rerunning the permutation several times and by changing the significance cutoff values" (Anselin, Syabri, & Kho, 2006). Here, permutations are used as a numeric approach "to observe the Moran I value of an actual distribution under conditions of spatial randomness"[12]. For example, x and y are two locations of length A_i& B_i .To reveal the mean (M) of the two locations$(M_x$ & $M_y)$ randomization analysis is conducted. For the analysis, the original locations (x & y) are provided with vector numbers (x_a & y_b) of the same length (A_i& B_i). The output generated by the assigned vector numbers are different every time (M_a & M_b) they are computed based on the selected permutations (I.e., 99; 999; 9999 & 99999). Later, the generated random Moran I values (M_a & M_b) are compared with the observed Moran's I values (M_x & M_y) to determine the Pseudo – P values by using the following formula (Arribas-Bel, & Sanz-Gracia, 2014):

$$P_{pseudo} = \frac{1 + \sum_{i=1}^{(99;\,999;\,9999;\,\&\,99999)} L_i}{1 + P(99; 999; 9999; \& \, 99999)} \tag{9}$$

Where: L_i= the function which determines the Moran's I value (positive or negative) by the differences between the randomly generated Moran's I values and observed Moran's I values in the i-th permutation; P = the number of repetitions; and here, for the permutation test, the replication of 99999 or minimum p-value of $1/100000 = 0.00001$ was chosen.

[12] GeoDa glossary: https://geodacenter.github.io/glossary.html

3.4.4 Weight Matrix Selection

Conceptual representation is necessary to identify the spatial associations in the features of the selected study area by creating a weight matrix file. A spatial weight matrix is constructed based on the notion that each observed value linked to a set of adjacent neighboring values; the elements of the weight matrix (w_{ii}) have 0 diagonals whereas the elements $(w_{ij} = 1)$ represent the spatial influence of location i to location j (Baumont, Ertur, & Le Gallo, 2004; Guillain, Le Gallo, & Boiteux-Orain, 2006). Previously, research conducted by Le Gallo and Ertur, (2003) have investigated the difference in the selection of weight metrics focuing on the geographical characteristics (e.g., size) of the spatial area. Similarly, several research have followed the same criterion to select weight metrics. For example, Baumont, Ertur, and Le Gallo, (2004), Guillain, Le Gallo, and Boiteux-Orain, (2006), Guillain and Le Gallo, (2010), and Rodriguez-Gamez and Dallerba, (2012) have used diferent average number of neighbours or k-nearest neighbours (distance between the central points of polygons)[13] over distace based metrics because of size heterogenity or irrigular shapes of the polygons (Baumont, Ertur, & Le Gallo, 2004). Besides, Riguelle, Thomas and Verhetsel, (2007) and Arribus-bel and Sanz-Gracia, (2014) have used contiguity which considers the neighboring values that shares a boundary with the observed neighboring value. Such differences in the selection of neighbors have significant influence over the research outputs when irregular shaped polygons (e.g., Census tracts) are used than the regular shaped polygons (grid-cells) (Krehl, 2015).

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[13] https://geodacenter.github.io/glossary.html#k

Similar to Krehl (2015), the research has used regular shaped spatial data (grid-cells) and selected Queens contiguity weight matrix (Q-CWM) at 1^{st} order contiguity (8 neighboring grid-cells adjacent to the observed grid-cell) and 2^{nd} order contiguity (24 neighboring grid-cells adjacent to the observed grid-cell).

Table 3.3 presents the framework of the research (methodological approach, variables, Software used and research steps) was used to address the research question and objectives.

Table 3.3: The framework of the research.

<table>
<tr><th>Research questions</th><th>Chapters</th><th>Research objectives</th><th>Methodological approach</th><th>Variables</th><th>Software Used</th><th>Research Steps</th></tr>
<tr><td>What is the spatial structure of employment in TMA?</td><td>Chapter 5</td><td>To identify the employment centers in different ranks</td><td rowspan="2">Grid-Cells
&
Local Moran's I</td><td rowspan="2">Number of Employees</td><td rowspan="2">ArcGIS (Version 10.1)

GeoDa (Version 1.8.12)

GeoDa (Version 1.6.7)</td><td rowspan="2">1. Merging of two years employment data;
2. Concatenated the two years datasets;
3. Integration of polygons & grid-cells (250m*250m or 0.0625km2);
4. Spatial heterogeneity analysis;
5. Selection of high level clusters;
6. Significance level to categorize level of clusters;
7. Employment center selection ($1km^2$ & above);
8. Employment, density and area changes analysis in centers;
9. Spatial pattern change analysis of centers.</td></tr>
<tr><td>What are the recent changes?</td><td>Chapter 6</td><td>Explore the Spatial Pattern Change of Employment over a specific time period</td></tr>
</table>

CHAPTER 4
THE GRID-APPROACH AND THE COMPREHENSIVE SPATIAL STRUCTURE OF EMPLOYMENT IN TOKYO METROPOLITAN AREA

4.1 Introduction

This chapter deals with the proposed center identification method called the "Grid-approach," and the detected comprehensive spatial structure of employment in the TMA. The main ideas to identify and select a center and their advantages in spatial structure of employment analysis are also presented and discussed. A flowchart of the data processing is provided to show the preparation of the datasets for the empirical analysis by the proposed grid approach. At the end of the chapter, a framework is provided to show the steps of the research to answer the research objectives in Chapters 5 and 6.

4.2 Center size

Despite the number of studies, the accurate size of a center has not yet been studied sufficiently. From both theoretical and empirical points of view, a high-density peak in a density gradient curve was considered as a center, which depends on the zone size of a location. That is, zone size was used to determine the center size of a region (Fortstall & Greene, 1997; Coffey & Shearmur, 2001). Fortunately, Giuliano, Redfearn, Agarwal, Li, and Zhuang (2007) have looked at the issue firsthand, focusing on the Los Angeles metropolitan area during the period 1980 to 2000. Through this research, the authors have found that when density cutoffs were raised, the sizes of the employment centers as well as the number were greatly affected. However, although center size was well discussed, minimum center size was not recognized in this research.

In most previous research articles, zone size was less emphasized and rather neglected in investigating the influence of spatial patterns over center identification results, even though the great areal size variations were visible in the plotted two-dimensional maps used. For example, Baumont, Ertur, & Le Gallo (2004) studied a small urban area (Dijon, France) of 172.4km^2. The area was divided into 114 communes, and the average zone size was 1.5km^2. Guillain, Le Gallo, & Boiteux-Orain (2006), studied the region of Ile-de-France, an area of 12,000km^2, which is composed of 1280 communes and the 20 districts of Paris city. Their average zone size is 9.2km^2. Riguelle, Thomas, and Verhetsel (2007), studied the four largest Belgian cities (Brussels, Antwerp, Ghent, and Liege), with a mean area of 1.297km^2 in 9925 wards; and Rodriguez-Gamez and Dallerba (2012) studied a small Mexican city, Hermosillo, with an area of 154.8km^2 and an average of 2.4km^2 in zone sizes.

As has long been pointed out by Anas, Arnott, and Small (1998), any geo-referenced data should carefully be handled because of the conversion of the 3-dimensional world to 2-dimensional data, which has the tendency to create a jagged situation at the time of center selection. The authors have also pointed out that because of such conversions in the detailed geo-referenced data, it is difficult to determine a local employment peak from the studied location that could be defined as a subcenter. Thus, a location with higher employment density compared to its neighboring areas should be considered to define a center. In that sense, a center should be defined based on two criteria: 1) The minimum size of a center; and 2) The surrounding areas that the potential center is compared with. After selection of the possible centers, cutoffs of the total employment and minimum density can be later performed.

4.3 Center size selection

For the identification of the minimum center size in this study, different spatial scale of grid-cells were chosen: *250m by 250m; 500m by 500m; 1000m by 1000m; 2000m by 2000m*; and *3000m by 3000m*, respectively. The rationale behind choosing specific scale sizes were to analyze which scale size (small or large) better defines the minimum size of a center. Such issue was observed by Kane, Hipp, and Kim (2016) to identify the employment concertation in Los Angeles metropolitan area. The authors have selected spatial scale of 1000m by 1000m ($1km^2$) grid-cells for their analysis and later compared with the 500m by 500m ($0.25km^2$) grid–cells, and 2000m by 2000m ($4km^2$) grid-cells to show its accuracy. Through their investigation spatial scale of 500m by 500m grid-cells was identified as having a tendency to detect much denser areas than its larger counterparts. Despite the findings of the authors, it is still not clear what makes the spatial scale of 500m by 500m grid-cells to select denser locations over the space than the larger grid-cells. Moreover, Huang, Liu and Zhao, (2015) have selected multiple spatial scales (1000m by 1000m ; 1225m by 1225m and 1415m by 1415m grid-cells, respectively) to identify the spatial structure of employment in Beijing, out of which 1225m by 1225m (1.5km^2) scale-size was considered for the analysis and identified five employment sub-centers with a large employment center located at the center of Beijing. Conversely, Maoh and Kanaroglou (2007) have preferred 707m by 707m (0.5km^2) scale size to identify the geographic clustering of firms and urban forms of a city (Hamilton in Ontario, Canada). According to the authors 707m by 707m grid-cells has better spatial resolution than the 317m by 317m (0.01 km^2) and 448m by 448m (0.2 km^2) spatial resolutions to "measure the intensity or the firms per area (grid-cell) without introducing spurious spatial autocorrelation in the data" (page. 37). The author have also showed that 1000m by 1000m spatial resolution will create a aggregation bias that in result can arise an issue "capturing spatial effect of the geographic clustering of firms" (Page 37). Besides, Krehl (2015, 2016) have selected 1000m by 1000m grid-cells to identify the urban spatial structure of four German city regions: Cologne, Frankfurt, Munich and Stuttgart. According to the author, because of the censoring issue under the German privacy law involved in the collected data in grid-cells (1km^2), employees have actually erased despite having a small share of the datasets, even before identification of the high employment concertation areas.

Based on the differences in the selection of grid-cells and their findings, the current research has selected five specific spatial scales of grid-cells to investigate the issue related to minimum center size selection and in identification of spatial structure of employment. Afterwards, the selected scale sizes were compared with 1st order contiguity (8 neighboring grid-cells adjacent to the observed grid-cell) and 2nd order contiguity (24 neighboring grid-cells adjacent to the observed grid-cell).

4.4 The Grid-Approach (GA)

The identification of employment centers in this research was conducted by using the Grid-Approach (GA) instead of municipal boundaries. The reasons behind selection of GA over municipal boundary for the research are presented below.

4.4.1 Use of the Grid-approach over Census tracts

Whereas the scholarly literature has conducted on the identification of employment centers in the detection of overall spatial structure of employment, only a few studies have been focused on whether the GA has any influence over the results of spatial structure. For instance, Kane, Hipp and Kim (2016) have selected different special scale of 500m by 500m, 1000m by 1000m and 4000m by 4000m grid-cells not only to identify the employment centers but also to investigate if the employment concentration is sensitive to different scale-sizes. The authors have stated in their paper that “the component of employment centres (i.e., employment concentration varied by using different grid-cell sizes) that could not be realized in previous tract-level studies (page 23)”.

Another issue that was observed during data processing is that the fact that employment is distributed in fragmented shape over the space was less analyzed or rather neglected by previous literature (e.g., Riguelle, Thomas, & Verhetsel, 2007). Furthermore, Huang, Liu, and Zhao (2015) have used 1225m by 1225m grids to reveal the comprehensive spatial structure of employment in Beijing, China, however, further information related to the selection of spatial scale of specific grid-cells for the spatial structure of employment analysis was not mentioned. Hence, to understand further, the GA was investigated in the following section to show the advantages of using the GA over municipal boundaries.

4.4.2 Data treatment for the cluster analysis in GA case

The employment census data of the TMA has census tracts (CT) from less than 0.00001km^2 to 304km^2 in area sizes. To reduce the influence of the CT sizes first, the density for each CT was calculated. Next, a grid–cell map was created based on the selected study area where all the CTs distributed within the specific grid-cells. Later, the census boundary and grid-cell map were intersected. After this intersection, new polygons were identified that belong to each grid-cell (Figures 4.1 and 4.2) were aggregated and an employment distribution map used for the spatial autocorrelation analysis (Figure 4.3).

The total jobs in grid-cell g, EM_g, was recalculated using the following equation (Li & Monzur, 2017):

$$\mathrm{EM_g} = \sum_{\mathrm{i}} \mathrm{D_i} \times \mathrm{A_{gi}} \tag{10}$$

Where: A_{gi} is the area of the polygon i that composes grid g, and D_i is the employment density of i.

By using this method, the grid-cells can be utilized for analysis of minimum center sizes. Also, the grids used in the identification of the employment centers were based on the contiguous grids that contain statistically higher employment than the surrounding grids.

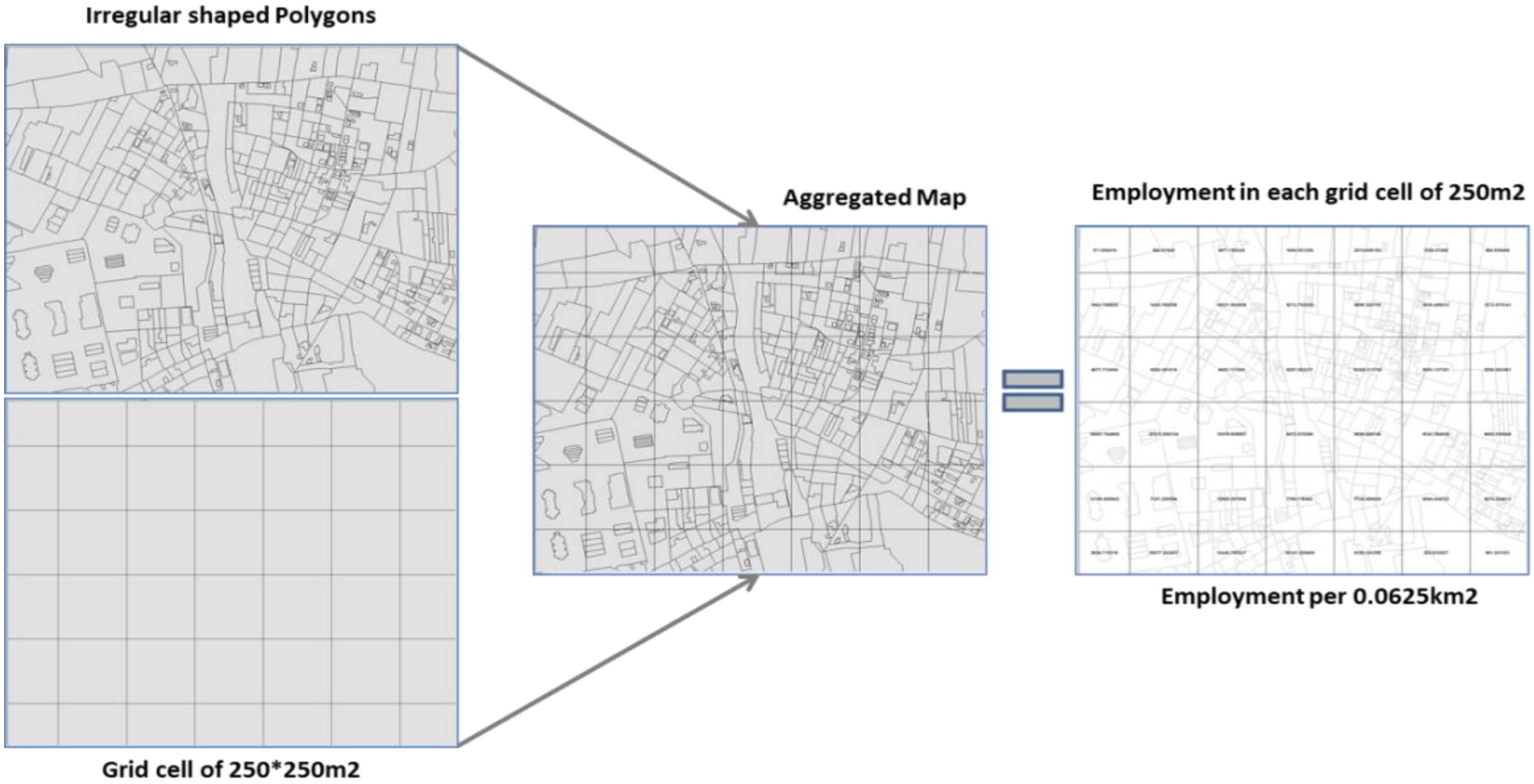

Figure 4.1: The data refinement technique by using the specific grid-cell size (*250m grids*).

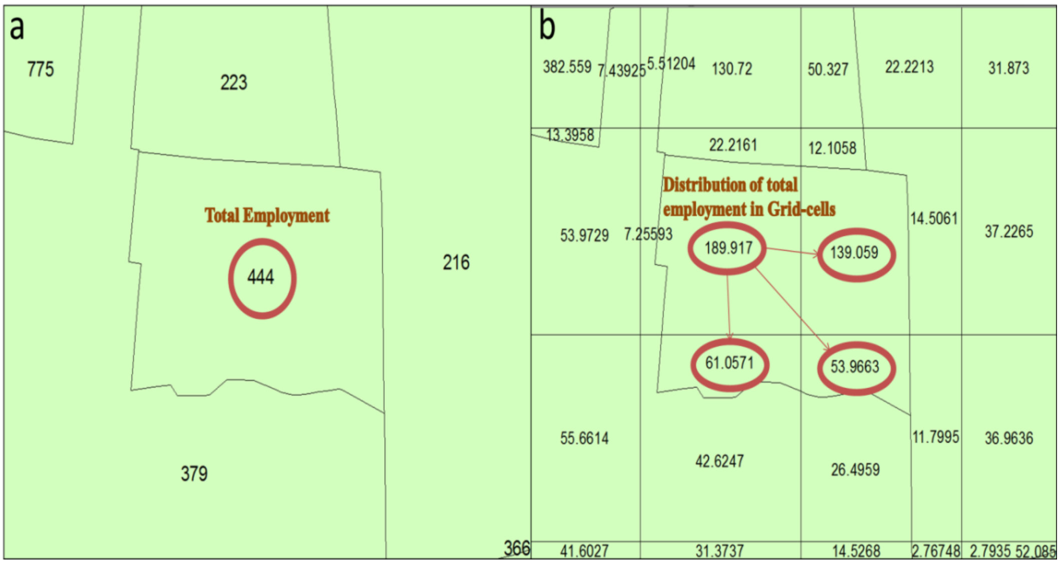

Figure 4.2: Distribution of employment before and after the intersection with the grid-cell map (in this case 250m by 250m grid-cells) and distribution of total employment within each grid-cell. Figure (a) shows the total employment of a selected census tract (444). Figure (b) demonstrates the distribution of total employment of the same census tract in four grid-cells according the share of the area: (1st grid-cell (189.917) + 2nd grid-cell (139.059) + 3rd grid-cell (61.0571) + 4th grid-cell (53.9663) = 443.999).

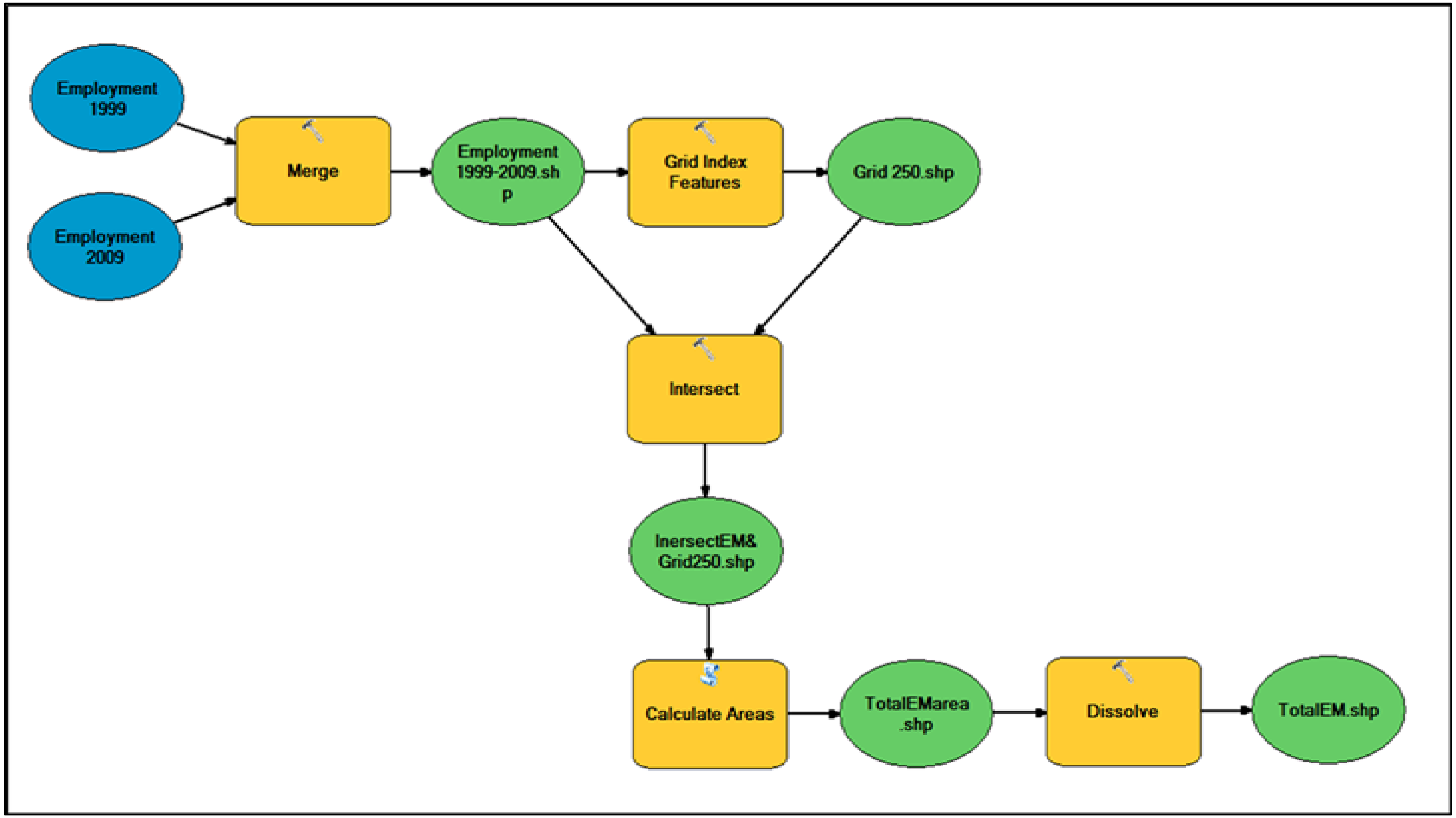

Figure 4.3: Data processing flowchart of the empirical analysis.

4.4.3 The Advantages in using GA in cluster analysis

To show the advantage of GA in spatial structure studies, the GA and CTs (polygons) were further analyzed by using LMI, to observe their identification and selection of local employment peaks in case of the TMA. For this analysis, a specific threshold distance of $800m$ was selected for the CTs ($Total\ area\ of\ CTs\ /number\ of\ CTs$) , the same as in the $250m$ by $250m$ grid case ($Total\ area\ of\ grid - cells\ /number\ of\ grid - cells$).

Figure 4.4 shows the identified local employment peaks before and after using the GA. Note that the identified employment density peaks were very small in number, and mostly located at the core area of the TMA when the CTs was considered (the figures on the left). In contrast to this, the results of the Grid-Approach (the figures on the right) showed clear clustering of the spatial structure at all scales including the core area, the 30-km distance range, and the whole region. From a regional view, employment density can be seen expanded in all direction from the city core. Both city center and suburban areas are highly concentrated. Moreover, a concentric pattern is visible in employment up to 20km distance. The high-density areas were found located close to each other in the clusters. At the 30km distance from the core area, several large and small local density peaks were identified surrounding the main core area.

Table 4.1 demonstrates the employment dense locations in different ranks before and after the use of GA. Before using the GA, it is noticeable that the rank3 and rank4 clusters have large employment with an average density lower than the rank2 clusters. Also, rank1 was found less concentrated than the rest of the ranked clusters. Despite their differences in the average density and total employment, the employment share% was very low in all four clusters. For example, the overall employment share of the selected four clusters is about 16.28% in the regional employment. As long pointed out by McMillen (2001) that a cluster or subcenter should have a substantial influence over the regional employment. Therefore, the results that were provided using CTs are less accurate in identification of local employment peaks through the cluster analysis.

In contrary, after using the GA, rank1 has the highest concentration of employment as well as average density and employment share. Also, the employment share in four clusters is about 73.60% in the regional employment. Moreover, as McMillen (2001) has pointed out that employment density decreases based on the distance from the CBD however, increases near the sub-centers. Similar to that notion, several employment clusters of rank1, rank2 and rank3 were located at the 20km, 30km and 50km distance from the main core of TMA with high employment density when GA is used. From the findings, it can be said that the GA has better illustrated the clustered locations as well as local employment peaks in the studied region.

Table 4.1: Before and after using GA in clusters analysis.

Year 2009 Census Tracts (polygons) case				
	Rank1 (99.99%)	Rank2 (99.9%)	Rank3 (99%)	Rank4 (95%)
Employment	4,678	2,76,407	1,272,328	1,961,553
Area/km^2	0.04	1.43	8.13	17.29
Average Density	601	2,516	1,413	824
Land Share(%)	0.00%	0.00%	0.03%	0.05%
Employment Share(%)	0.02%	1.28%	5.89%	9.08%
Year 2009 Grid-approach case				
	Rank 1 (99.99%)	Rank2 (99.9%)	Rank3 (99%)	Rank4 (95%)
Employment	5,779,081	1,338,786	3,126,097	5,637,075
Area/km^2	97.69	77.56	371.25	1805.56
Average Density	59,159	17,261	8,420	3,122
Land Share(%)	0.3%	0.2%	1.1%	5.5%
Employment Share(%)	26.8%	6.2%	14.5%	26.1%

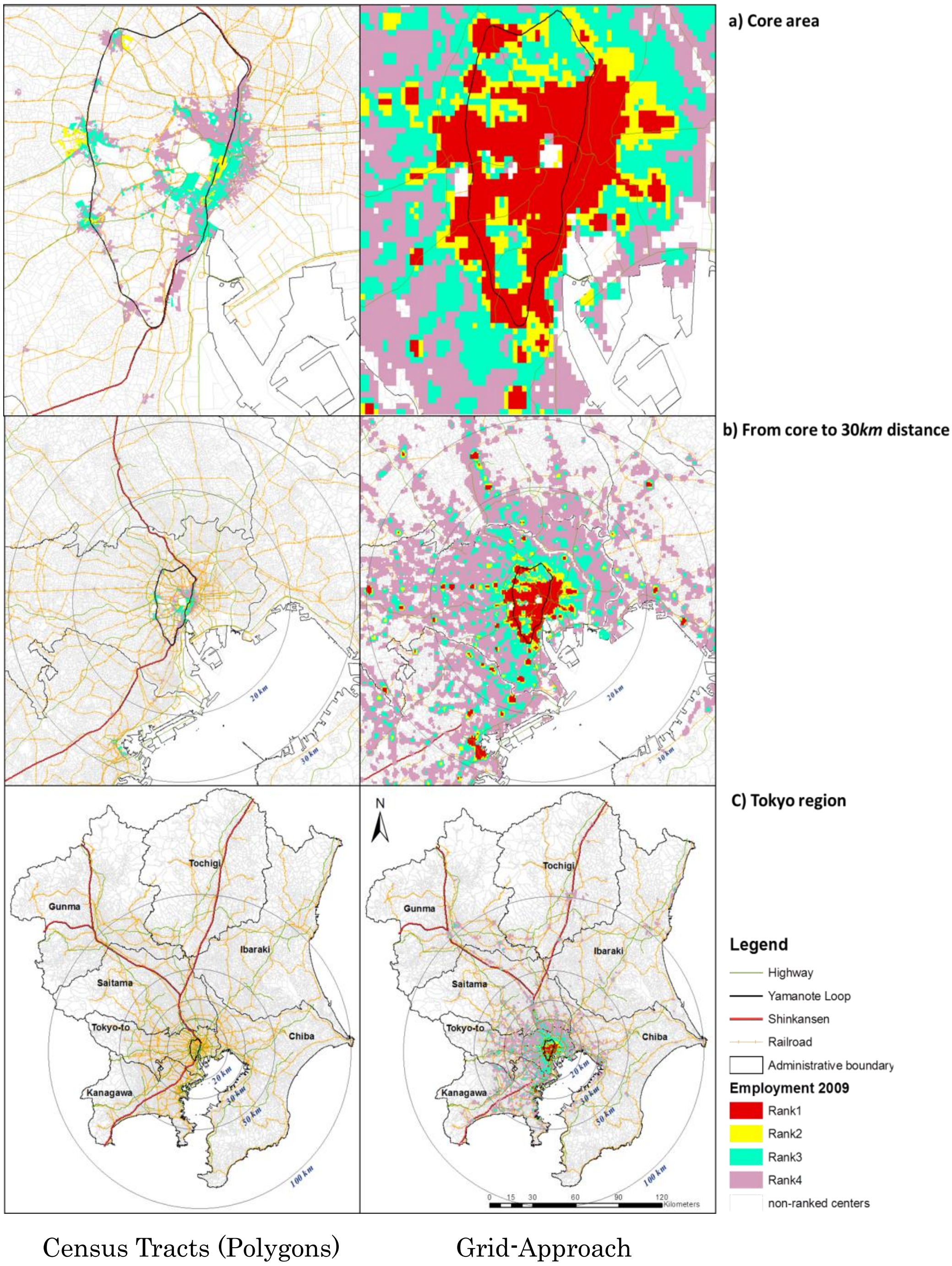

Figure 4.4: Cluster analysis before and after using GA: a) the core area of TMA; b) 30*km* distance from the TMA core; and c) the regional view of the TMA.

4.5 Scale size and the overall spatial structure of employment in the TMA

The advantage of the GA in the identification of the local employment density peaks was presented in the previous section, however, the minimum center size was still untouched. Therefore, this section of the chapter has further used both the different spatial scale sizes (i.e., *250m by 250m; 500m by 500m; 1000m by 1000m; 2000m by 2000m*; and *3000m by 3000m)* and GA to identify the influence of minimum size for the employment centers. These results are compared with 1st order contiguity and 2nd order contiguity in the detection of the accurate spatial structure of employment in TMA using LMI. The research was intended to prove that such centers can be identified efficiently by comparing them with surroundings areas at different minimum center sizes.[14] For the analysis, both year 1999 and 2009 were analyzed however in case of 1999, the identified locations of the ranks are almost identical to year 2009 as portrayed in figure 4.5 & 4.6. Therefore, the year 2009 is further explored and discussed in the latter sections.

The output of the analysis was presented in the total employment, employment density, employment share, land share, and the employment share/land share ratio.

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14 Here the term minimum center size is used instead of saying minimum grid-cell size because it is unclear till now which spatial scale of grid-cells will better define the centers over space.

4.5.1 Minimum center size analysis: 1st order contiguity

By using the 1st order contiguity, Figure 4.5 illustrates the employment centers at different scale sizes identified in the year 1999 and 2009 within the *20km*, *30km*, and *100km* distance bands in the TMA. Despite that the center criteria and the use of GA have revealed all minimum center sizes, a concentric shape is observed in TMA. The figure further shows that the number of centers has reduced when the minimum center size increased. For example, 24 rank1 centers in (250,1st order), four rank1 centers in (500,1st order), one rank1 center in (1000,1st order) and (3000,1st order) cases were identified. In case of (250,1st order) there are many locations identified in different ranks. When (500,1st order) and (1000,1st order) were considered, a star shaped structure can be visible expanding to its neighboring prefectures. Selection of (3000,1st order) shows a monocentric spatial structure with 23 wards in the center of TMA.

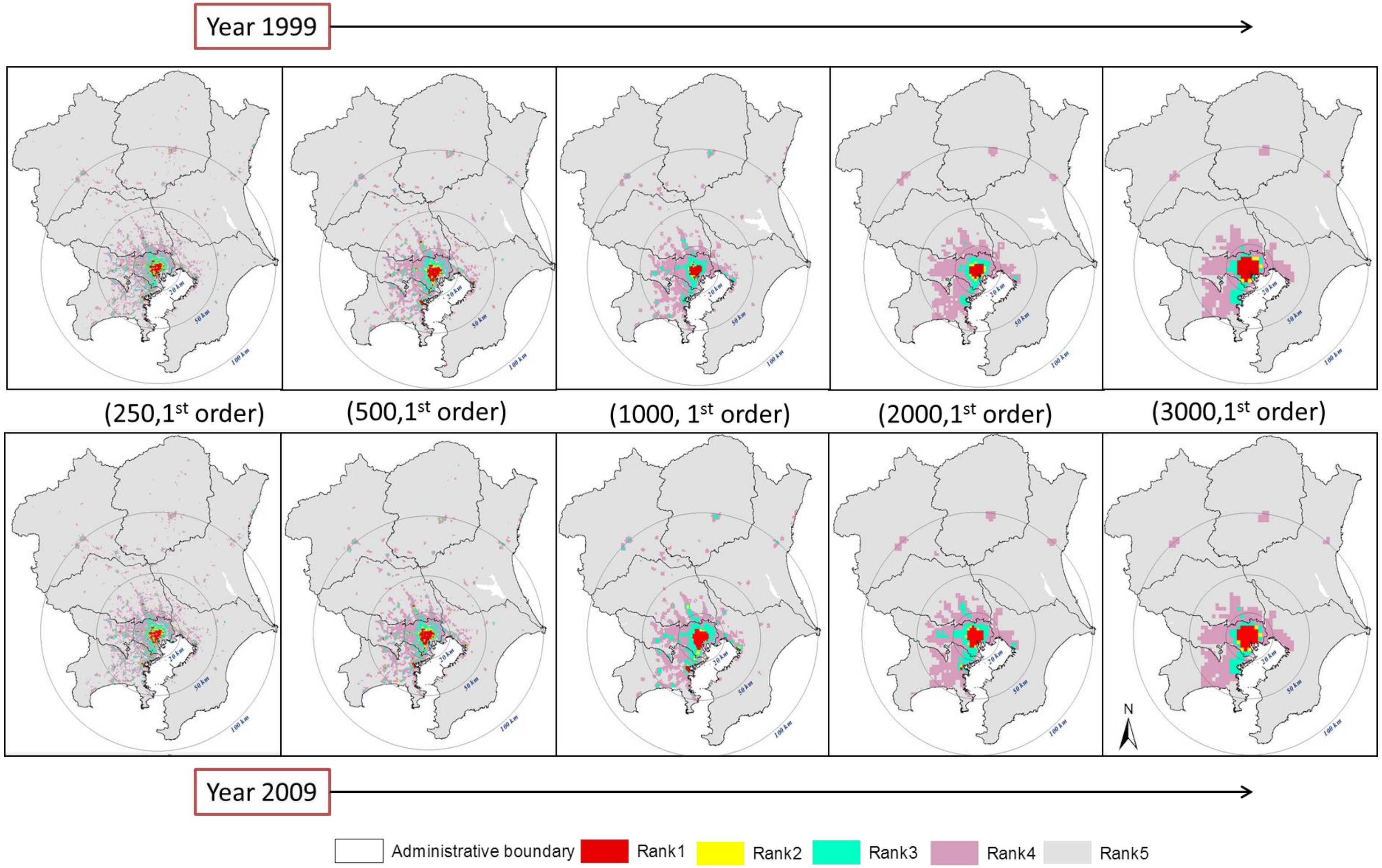

Figure 4.5: Illustration of center sizes in different scales in 1st order contiguity cases.

In Table 4.2 the characteristics of employment centers in the various scale sizes were summarized as total employment, average employment density, land share, employment share, and their ratios. The first thing to notice is that the employment characteristics of the centers greatly varied when different scale sizes were selected. For instance, rank1 of (250,1st order) cases have a density of 59,159 per km^2 with a share of 26.8% in employment at 0.3% of the land, and with an E/L ratio of 89.23. In the (500,1st order) case, the employment share is 26.30%, however, they shared 0.40% of the land with an E/L of 69.29. This demonstrates that the larger the scale size the lower the E/L ratio becomes, which is because of the aggregation of the differences of the neighbouring areas surrounding the observed area.

Table 4.2: Total Employment and average employment density distribution in each employment center in different scale sizes, 2009, (1^{st} order contiguity cases).

Cases (1^{st} order)	Total Employment							Average Employment Density (Jobs/km^2)				
	Rank1	Rank2	Rank3	Rank4	Total	Non Ranked	Total Employment	Rank1	Rank2	Rank3	Rank4	Non Ranked
Case (250m,1)	5,779,081	1,338,786	3,126,097	5,637,075	15,881,039	5,714,176	21,595,215	59,159	17,261	8,420	3,122	189
Case (500m,1)	5,676,960	1,104,800	2,819,159	6,091,514	15,692,432	5,902,783	21,595,215	45,235	13,682	7,619	3,096	193
Case (1000m,1)	5,675,965	492,666	3,516,539	5,573,578	15,258,748	6,336,467	21,595,215	35,475	12,965	6,280	2,861	202
Case (2000m,1)	5,537,628	347,500	2,809,887	6,232,543	14,927,558	6,667,657	21,595,215	30,765	12,411	5,665	2,748	203
Case (3000m,1)	6,255,808	234,768	1,912,865	6,205,619	14,609,060	6,986,155	21,595,215	22,422	5,217	5,593	2,471	203

Table 4.2: Continued.

Cases (1st order)	Land Share (%)				Employment Share (%)					E/L			
	Rank1	Rank2	Rank3	Rank4	Rank1	Rank2	Rank3	Rank4	Total	Rank1	Rank2	Rank3	Rank4
Case (250m,1)	0.30%	0.24%	1.14%	5.54%	26.76%	6.20%	14.48%	26.10%	73.54%	89.23	26.03	12.70	4.71
Case (500m,1)	0.38%	0.24%	1.12%	5.95%	26.29%	5.12%	13.05%	28.21%	72.67%	69.29	20.96	11.67	4.74
Case (1000m,1)	0.47%	0.11%	1.65%	5.73%	26.28%	2.28%	16.28%	25.81%	70.66%	55.88	20.42	9.89	4.51
Case (2000m,1)	0.50%	0.08%	1.38%	6.33%	25.64%	1.61%	13.01%	28.86%	69.12%	51.04	20.59	9.40	4.56
Case (3000m,1)	0.74%	0.12%	0.91%	6.68%	28.97%	1.09%	8.86%	28.74%	67.65%	39.01	9.08	9.73	4.30

4.5.2 Minimum center size analysis: 2nd order contiguity

By using the 2nd order contiguity, Figure 4.6 illustrates the employment centers in different scale sizes in the year 2009 within the 20km, 30km and 100km distance bands in the TMA. Similar to the listing of the 1st order contiguity cases, an increase in scale size decreases the number of employment centers. For example, 15 rank1 centers and 16 rank1 centers identified in the year 1999 and 2009, two rank1 centers in (500, 2nd order), one rank1 in (1000, 2nd order), (2000, 2nd order) and (3000, 2nd order) for both years, respectively. Also, 2nd order contiguity found small differences in the spatial structure than that was identified by the 1st order contiguity in TMA.

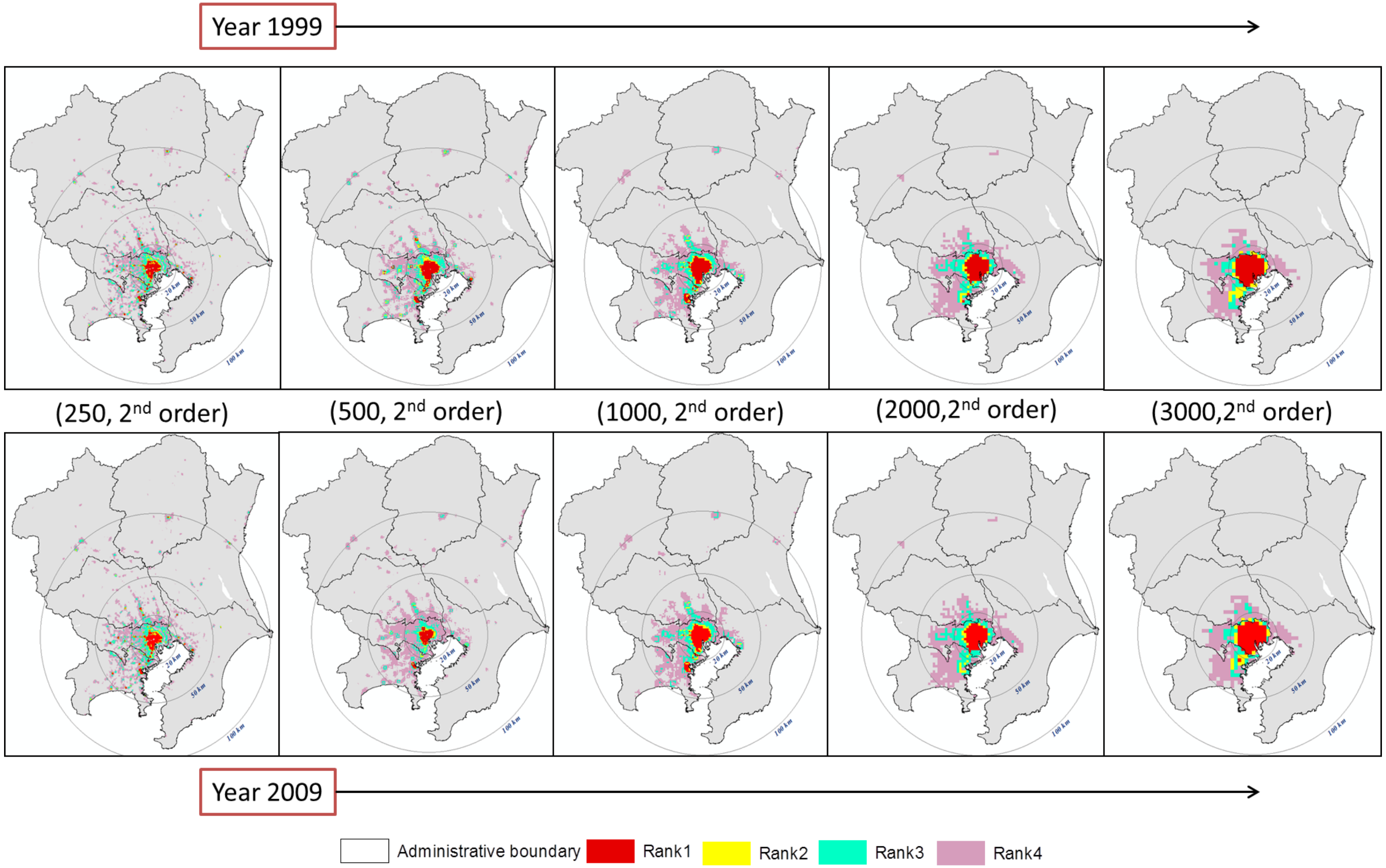

Figure 4.6: Illustration of center sizes in different scales in 2nd order contiguity cases.

Table 4.3 shows the characteristics of employment centers in various scale sizes. In a similar way to the listing of the 1st order contiguity cases, the table summarizes the employment, average density, land share, employment share and E/L ratio. Compared to 1st order cases, the 2nd order contiguity cases identified large areas for centers. For example, in rank1 of (250,1st order) case, the E/L ratio was 89.23 which is based on high employment share within less land area. In contrary, the (250, 2nd order) case has employment share of 29.30% at the 0.60% of the land with 52.9 in E/L ratio for rank1 at a density of 35,076 per km^2. Although (250, 2nd order) case have shown similarities however, have less density per km^2 than the (250,1st order) case. This proves that (250,1st order) is the best selection for the center size as well as in identification of employment centers compared to other minimum center sizes.

Table 4.3: Total Employment and Average employment density distribution in each employment centers in different scale sizes, 2009 (2nd order contiguity cases).

Cases (2nd order)	Total employment							Average employment density (jobs/km^2)				
	Rank1	Rank2	Rank3	Rank4	Total	Non Ranked	Total Employment	Rank1	Rank2	Rank3	Rank4	Non Ranked
Case (250m,2)	6,331,289	1,142,987	2,856,049	5,080,984	15,411,309	6,183,906	21,595,215	35,076	10,115	6,038	3,076	205
Case (500m,2)	6,234,202	836,982	2,410,331	5,398,584	14,880,100	6,715,115	21,595,215	27,373	6,846	5,069	3,178	220
Case (1000m,2)	6,408,621	604,226	2,152,862	5,164,764	14,330,473	7,264,742	21,595,215	23,824	5,755	4,213	2,935	232
Case (2000m,2)	6,523,401	435,687	2,393,374	4,449,168	13,801,630	7,793,585	21,595,215	19,649	4,538	4,127	2,429	236
Case (3000m,2)	7,472,641	875,589	1,242,238	3,834,038	13,424,507	8,170,708	21,595,215	13,838	4,422	2,817	2,367	235

Table 4.3: Continued.

Cases (2nd order)	Land share (%)				Employment share (%)					E/L			
	Rank1	Rank2	Rank3	Rank4	Rank1	Rank2	Rank3	Rank4	Total	Rank1	Rank2	Rank3	Rank4
Case (250m,2)	0.55%	0.35%	1.45%	5.07%	29.32%	5.29%	13.23%	23.53%	71.36%	52.90	15.26	9.11	4.64
Case (500m,2)	0.69%	0.37%	1.44%	5.14%	28.87%	3.88%	11.16%	25.00%	68.90%	41.93	10.49	7.77	4.87
Case (1000m,2)	0.79%	0.31%	1.50%	5.17%	29.68%	2.80%	9.97%	23.92%	66.36%	37.53	9.06	6.64	4.62
Case (2000m,2)	0.93%	0.27%	1.62%	5.11%	30.21%	2.02%	11.08%	20.60%	63.91%	32.60	7.53	6.85	4.03
Case (3000m,2)	1.44%	0.53%	1.17%	4.31%	34.60%	4.05%	5.75%	17.75%	62.16%	24.08	7.69	4.90	4.12

4.6 Summary of the Chapter

In summary, this chapter has proposed a new employment center identification and selection approach for the detection of the comprehensive spatial structure of employment. The core idea to identify and select a center is that one should consider the minimum scale size and the range of surrounding areas that the observed location will be compared with. The advantage of using the grid approach (GA) compared with municipal boundary (polygons) in identification of the local employment peaks was demonstrated by using the LMI. Later, both scale size and GA were used in the identification of employment centers with 1st order and 2nd order contiguity to detect the overall employment spatial structure in the case of the TMA. The analysis has provided two interesting outputs:

1) *Finer spatial resolution is better than using Coarse spatial resolution in the identification of local employment density peaks.*

When census tracts (polygons) were used in the identification of local employment density peaks through LMI, a fragmented shape was revealed in the density distribution. The five largest clusters were identified surrounded by small and large rank2, rank3 and rank4 clusters. Additionally, no rank1 clusters were identified at the center of the TMA. Furthermore, the identified high density clusters were found to share only 16.28% of regional employment, and the employment density of the identified clustered locations was found to be very low.

Also, no significant high density peaks were found in the suburban areas of the TMA.

In contrast, the GA identified all potential high employment density peaks over the region (figure 4.4). By using GA, a concentric form was revealed in employment density where the largest cluster was found multi-cored and located at the middle of the region. Besides, the employment density peaks were not only identified in the central areas but also outside the peripheries. In addition, the clusters were found to share about 73.60% of the regional employment.

2) Scale size and grid-approach at different spatial resolution can reveal better the overall employment spatial structure in the TMA.

Furthermore, different scale sizes (*250m by 250m; 500m by 500m; 1000m by 1000m; 2000m by 2000m; and 3000 by 3000m*) were selected as minimum center size and compared with 1st order and 2nd order Queens contiguity to prove that the centers can be identified efficiently by comparing them with the surroundings areas. The analysis showed that the center sizes have significantly influenced the center identification results. That is, from a regional view, a typical monocentricity in the spatial structure is identified in the TMA. Conversely, in a fine-scale view, polycentricity is revealed in the spatial structure of TMA in both the CBD and peripheries. Thus, the analysis has proved that a fine scale (250,1st order) can efficiently detect the detailed employment centers compared to its larger counterparts.

CHAPTER 5
A DETAILED ANALYSIS OF THE IDENTIFIDED EMPLOYMENT CENTERS AND THEIR DISTRIBUTION

5.1 Introduction

In the previous chapter, different scale sizes (*250m by 250m; 500m by 500m; 1000m by 1000m; 2000m by 2000m*; and *3000m by 3000m* grid-cells) and GA were used to identify the employment centers in the detection of the full spatial structure of employment in the TMA. The research has proved that the fine scale (250,1st order) as a minimum center size efficiently detects the potential employment centers compared to other minimum sizes. However, it is still unknown that whether such small sized locations can be selected as employment centers.

Therefore, this chapter has selected the fine scale (250, 1st order) result to address the first objective of the research, to *identify the employment centers in different ranks*. To identify the potential employment centers in different ranks, the high clustering grid cells of (250,1st order) case were first integrated and then grouped into two types: 1) employment centers those are less than 1km^2; and 2) employment centers of 1km^2 and above. Afterwards, the TMA spatial structure was explored in *20km*, *30km 50km* distance bands from the city core to disclose the distribution of the identified ECs in their different ranks. Later, the detected ECs in different ranks were compared with the 4th National Capital Region Development Plan (NCRDP) implemented in 1986, to show its shortcomings in suburbanization planning for employment in the TMA.

5.2 Identification and selection of the potential employment centers in different ranks

The fine scale *(250, 1^{st} order*) case for the year 2009 contains 520,248 grid-cells in total, out of which 37,363 were detected as located in the high-high group of the Moran's scatterplot (1^{st} quadrant). Table 5.1 shows the distribution of the high clustering grid-cells in different ranks.

Table 5.1: Distribution of the grid cells in different ranks, 2009.

Number of Grid-cells	Rank1	Rank2	Rank3	Rank4
Year 2009	1,563	1,241	5,940	28,889

To identify and select the employment centers from the detected high clustering grid cells, a center was determined based on the criteria where the observed grid-cell shares a contiguous boundary, or is within *250m* of a grid-cell of the same rank category. The reason for this choice was that the 250*m* distance between two detected centers often means shrines or a public park or a construction site in the location, rather than the boundary of the centers. Same was addressed by Kane, Hipp and Kim (2016) who mentioned in their paper that 0.25 km^2 resolutions is very small to capture employment concentration areas of large suburban corporate campus whose employees might have counted as single point. In addition to that, the authors have also mentioned that "single office building with high employment and somewhat smaller office building across a wide atrial road might not be a contiguous cell in such small resolution that could open up the possibility of missing key auxiliary portions of employment centres" (page 23) . Affix to that, the centers were further divided into two groups: 1) the employment centers < 1km^2; and 2) the employment centers ≥ 1km^2. A small number of employment centers <1km^2 were detected and they shared only 1.68% of the employment, with a density of 2,832 on 5.44% of the land in 2009. Therefore, only those ≥ 1km^2 are considered as ECs for further analysis.

5.3 Spatial structure of TMA and the Identified ECs in different ranks, 2009

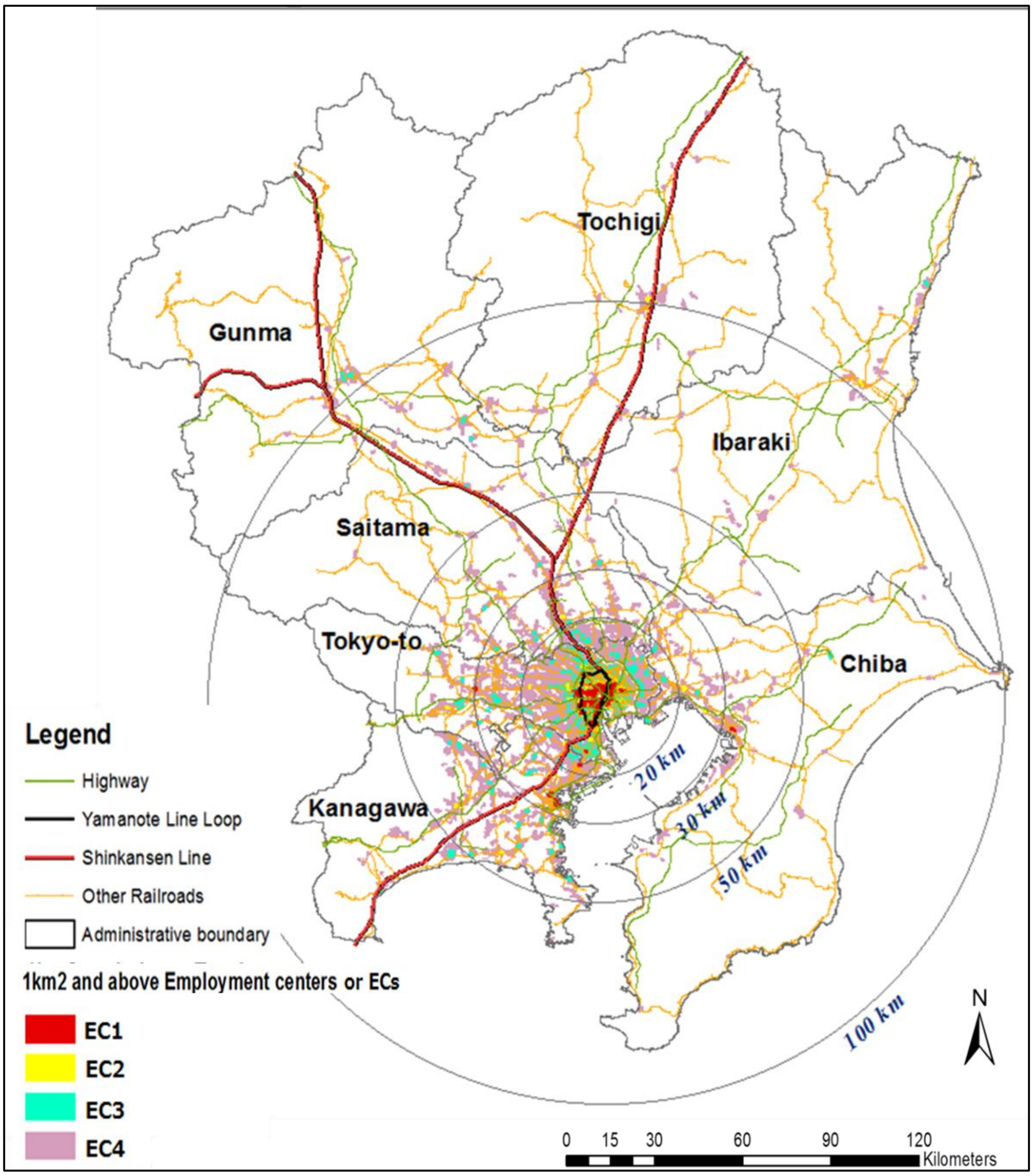

Figure 5.1: Spatial structure of the TMA and the identified ECs in different ranks, 2009.

Figure 5.1 demonstrates the detected spatial structure of the TMA as well as the potential ECs in different ranks in 2009. A total of 279 ECs in rank order, including 10 rank1 ECs or EC1, 17 rank2 ECs or EC2, 67 rank3 ECs or EC3, and 185 rank4 ECs or EC4, were found to be distributed all over the TMA. From regional view, a concentric pattern is visible up to the 20km distance band and at the 50km distance band development corridors were identified in multiple directions along the railway corridors. Also, the three development spines from the main center to Saitama prefecture along the main railroads are clearly visible.

In the case of the ECs, the largest EC1 was identified to situate at the center of the TMA. Here, the largest EC was considered as the main center of the region (Table 5.2). The largest EC1 contains the centres of Marunouchi, Shinjuku, Shibuya, Osaki; and Ueno, Asakusa has expanded in three directions towards its nearby independent EC1s': Takadanobaba (to the west); Oota (to the south) and towards the waterfront sub-metropolitan area (to the east) (Figure 5.2).

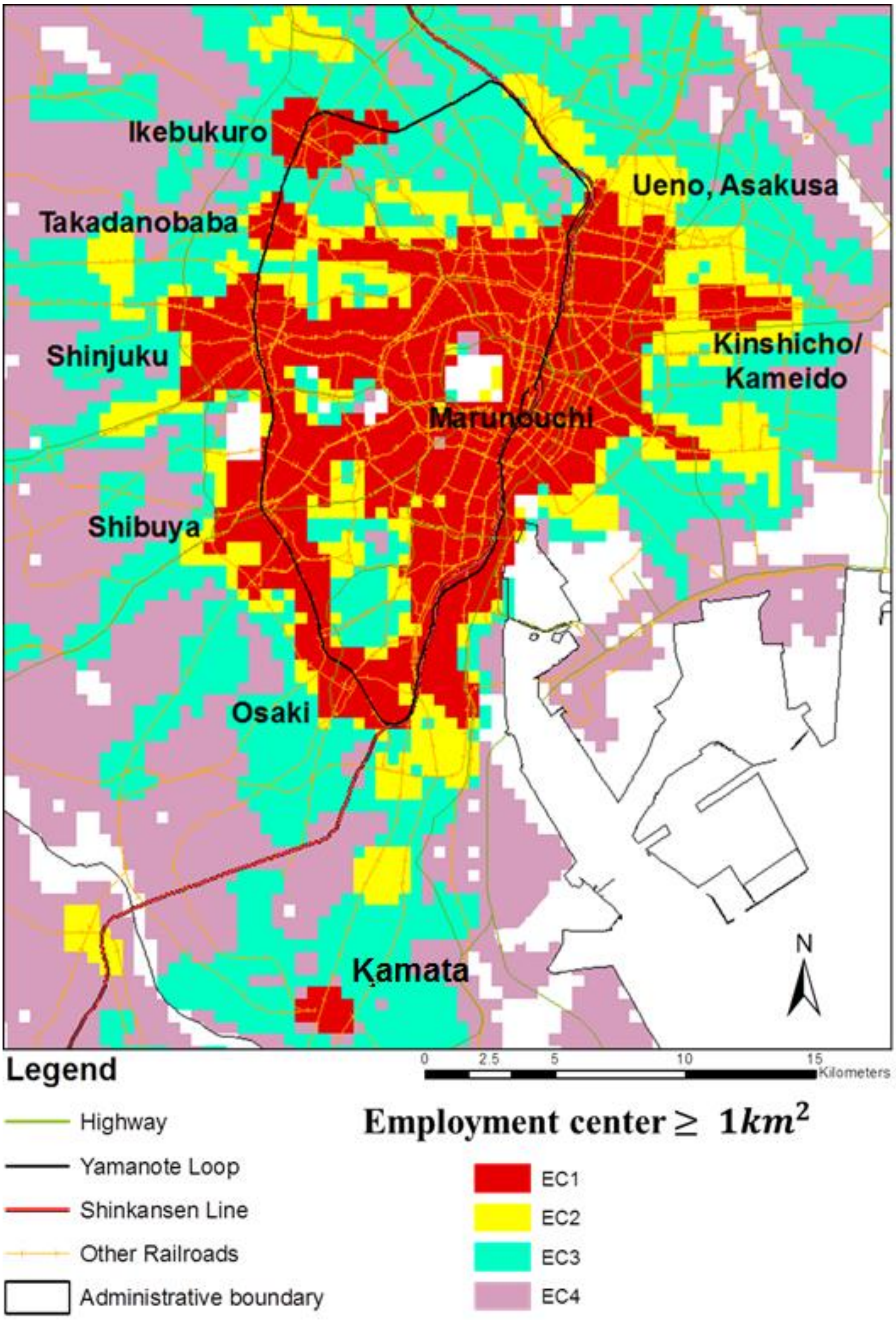

Figure 5.2: The Main center of the TMA in different ranks, 2009.

Table 5.2: Employment characteristics of the multi-cored main center in different ranks, 2009.

Main center of each rank				
Year 2009	Rank1	Rank2	Rank3	Rank4
Total Employment	4,151,427	462,212	1,007,753	5,573,429
Average Density	68,548	15,973	8,415	5,841
Area(km^2)	60.56	28.94	119.75	954.25
Employment share (%)	27.22%	3.03%	6.61%	36.54%
Land share (%)	2.57%	1.23%	5.09%	40.57%
E/L ratio	1057.09	246.32	129.78	90.07

Further, a visual investigation of figure 5.2 shows some specific spatial characteristics in the 20km, 30km and 50km distance bands from the CBD in explaining the spatial structure of TMA. The results were presented in the following parts of the section.

5.3.1 Distribution of identified ECs in different ranks (20*km* & 30*km* distance bands)

Figure 5.3 shows the distribution of the ECs in different ranks at the *20km* and *30km* distance bands where most of the ECs were found near to the multi-cored main center. Also, Table 5.3 has listed the number of ECs identified in the 20-30km distance bands in the year 2009 (including the main center).

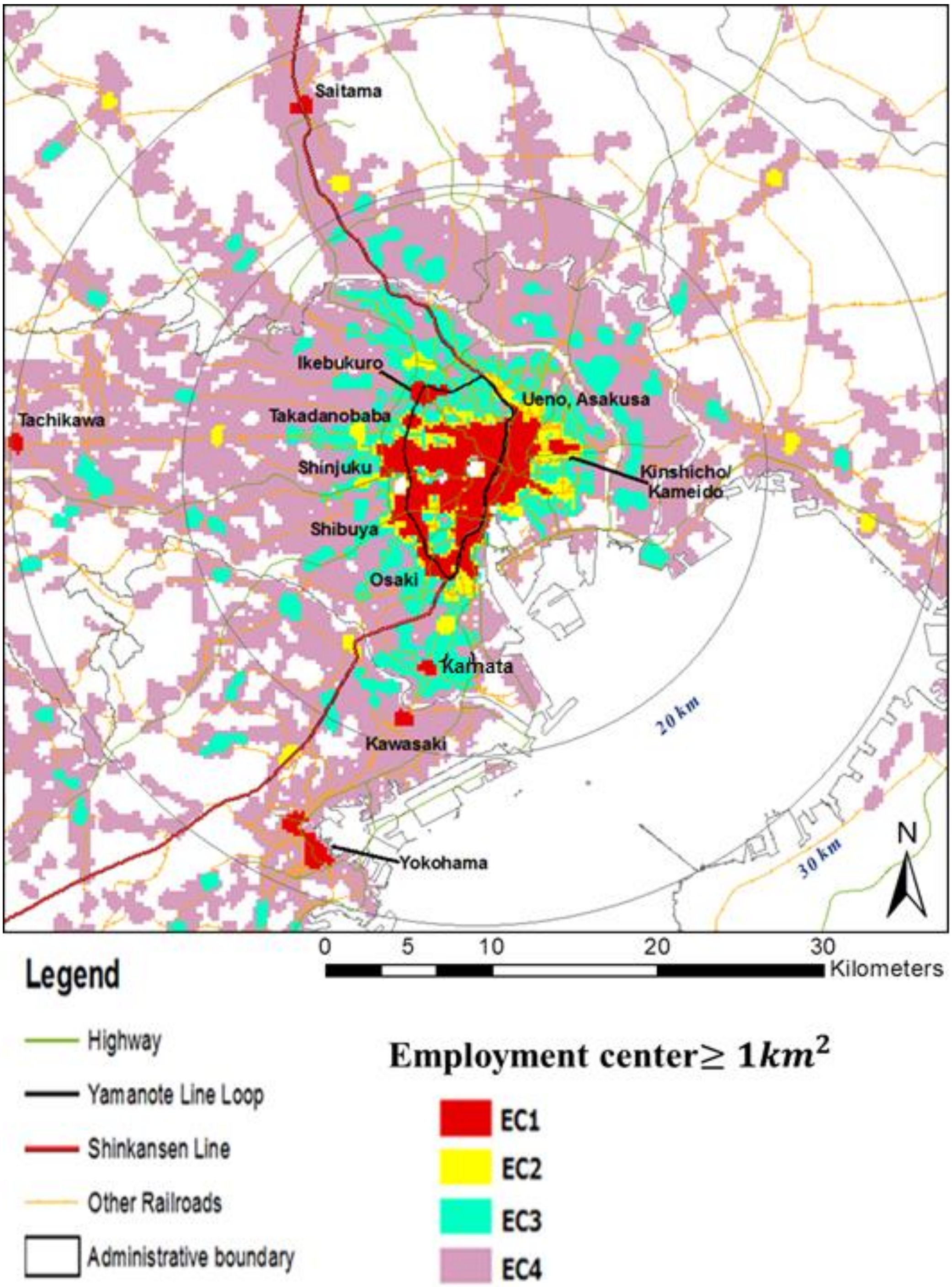

Figure 5.3: ECs at the *20km* and *30km* distance bands and their distribution in different ranks, 2009.

In the 20km distance band, six EC1 (including main centers), five EC2, 28 EC3 and two EC4 were detected. The detected ECs are well connected by the railway and highway networks located in Tokyo-to, Saitama, Kanagawa and Chiba prefectures. Within the 20km distance band, rank2 main center has the smallest radius and has expanded towards the Tokyo bay area to the east side, Kanagawa to the South side and Saitama to the North side along the major railroads. Also, the rank3 main centers have expanded in three directions: Saitama (to the north sides), Tachikawa (to the west) of Tokyo-to, and Kanagawa (to the South). The multidirectional expansion of Rank3 main centers is also visible towards the south-west side of the Kanagawa prefecture along the railway corridors and at junctions. However, the Rank4 main centers have the largest radius (20km) among the main centers of different ranks. It consists of Tokyo-to, Saitama, Kanagawa and Chiba prefectures and expanded further up to the 50km distance bands along the railroad corridors. Most of the ECs in different ranks (within 20km) were found in close proximity, and surrounded the multi-layered city center.

A closer inspection of the figure shows that the EC1s such as Yokohama (to the South), Tachikawa (to the West), and Saitama (to the North) located at the edge of the development corridors at the distance of 30km from the city center. Notice that several small and large EC1s, 2s and 3s appeared within the core area to the EC1s (i.e., Tachikawa, Yokohama, and Saitama) in both 20km and 30km distance bands. The figure also shows that the multi-cored city center is connected by highways and the busiest railway lines, the Yamanote line, Shinkansen (Bullet train) line, and the other main rail networks.

As summarized in Table 5.3, in the case of the 30km distance band, the number of ECs greatly differed compared to 20km distance band. For example, a large number of EC3s were found within the 20km distance band, whereas the 30km distance band holds a significant number of EC4s (35). Also, the total number of ECs differed; 52 ECs were located within the 30km distance band compared to 41 ECs in the 20km distance band in 2009. However, a large number of ECs were identified in the 30km distance band, while most of the upper ranked ECs were located within the 20km distance bands, and near to the multi-layered city center. This signifies that distance from the main center influences the distribution of the ECs in different ranks.

Table 5.3: Distribution of ECs by rank hierarchies within the 20km and 30km distance bands.

Distance bands	EC 1	EC 2	EC 3	EC 4	Total
20km	6	5	28	2	41
30km	3	5	9	35	52

5.3.2 Distribution of ECs in different ranks (50*km* distance band)

In the 50km distance from the historic downtown area[15], the number of EC1, and EC2 centers has considerably decreased, however, the number of EC3s increased

[15] Historic downtown or CBD in other word is the location "which is the focus of commercial, social and cultural life where land value are highest. Also, the heart of the city is downtown shopping areas with large department stores and the most exclusive shops as well

more than in the 30km distance band. Table 5.4 shows the distribution of ECs in different ranks that fall within the 50km distance band, where 69 potential EC4s were identified in 2009. Unlike the 20km and 30km distance bands, the EC1 and EC2 were few in number. Note that most of the upper ranked ECs (EC1, EC2 & EC3) at the 50km distance band were surrounded by lower ranked ECs (EC4) (Figure 5.4).

Table 5.4: Distribution of the ECs in different ranks (50*km* distance band), 2009.

Year	Distance bands	EC 1	EC 2	EC 3	EC 4
Year 2009	*50km*	1	4	21	69

as holds the main financial institutions, headquarters of civic and political organizations, the main theatres and cinemas and the more expensive hotels." (Burgess, 1925; mentioned in Pacione, 2006, p 141).

To sum up, the investigation on the distribution of ECs in different ranks by using the fine scale (250, 1) revealed a more complex picture of the region. The investigation revealed that in the case of the TMA, both CBD and the suburban areas were polycentric in 2009. Not only potential ECs in different ranks were identified (279 in total) in the TMA in this analysis, but also the distribution of the ECs and their ranks were disclosed at the 20km, 30km, and 50km distance bands. The analysis showed that the distance from the city center has considerably influenced the location of the ECs in different ranks in 2009.

The identified ECs were compared with the 4th National Capital Region Development Plan enacted in 1986 for the suburbanization of the TMA and this is presented in the following section.

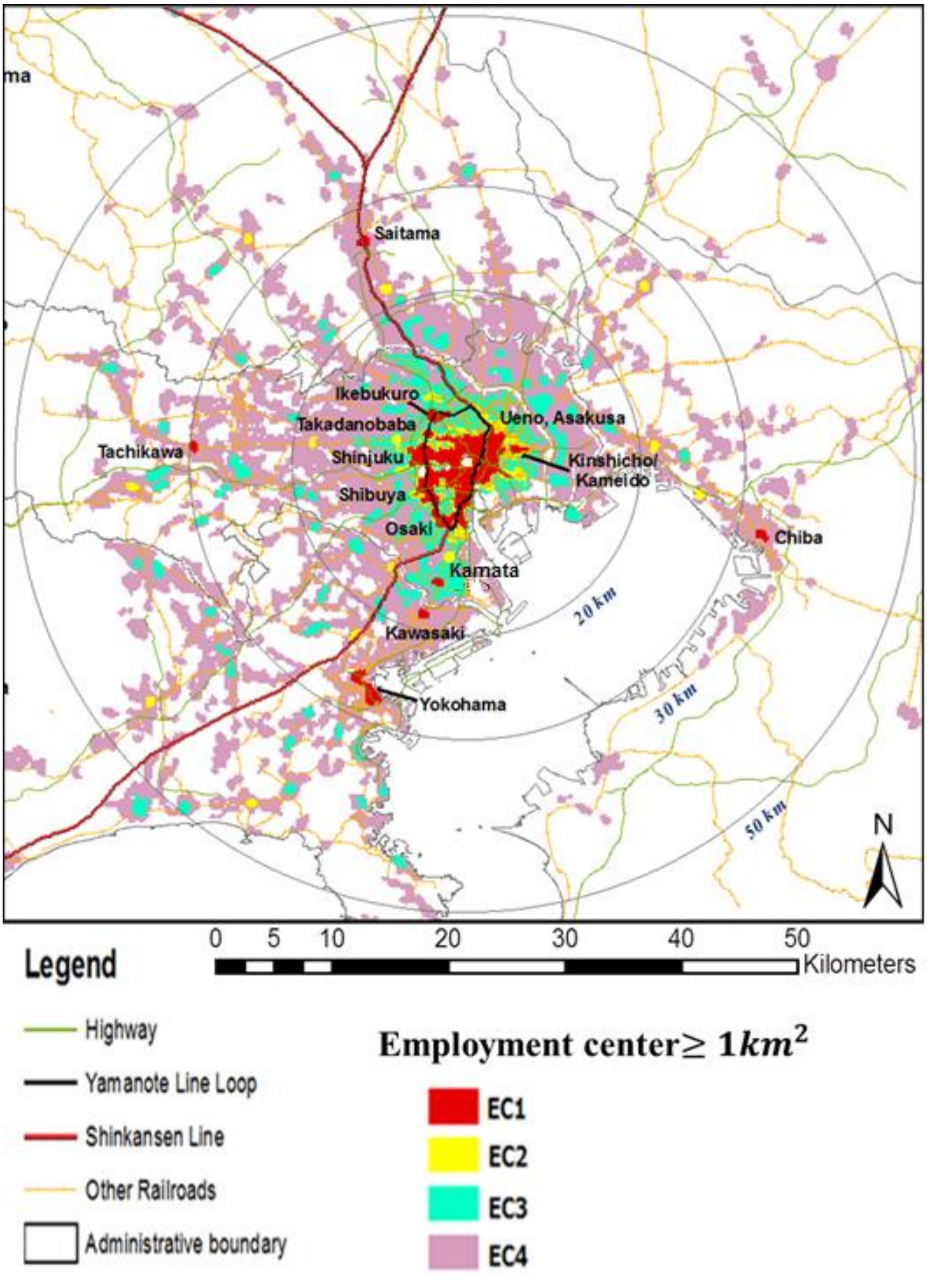

Figure 5.4: ECs at the *50km* distance band and their distribution in different ranks, 2009.

5.4 The 4th National Capital Region Development Plan (NCRDP), 1986 compared with the identified ECs

The main goal of the 4th NCRDP was to create an organized polycentric structure that could control the unbalanced spatial growth in case of employment in the TMA. Many employment nodes and core cities were proposed for the TMA (Itsuki, 2006). Later, according to the 3rd long-term plan of the 1990s, subcenters were delineated in five categories namely: 1) City sub-centers; 2) Tama core; 3) Business sub-centers; 4) New towns; and 5) Principal cities (TMA, 1994). Out of the 32 sub-centers: 1) seven centers were designated as City sub-centers (Ikebukuro, Shinjuku, Shibuya, Osaki, Ueno, Kinshicho/Kameido and Waterfront); 2) five centers (Ome, Hachioji, Tachikawa, Tama new town and Machida) as "Tama core"; 3) 11 centers (Kumagaya, Omiya, Urawa, Tsukuba Science City, Tuchiura, Narita, Togane, Chiba, Kisarazu, Yokohama and Kawasaki) as "business sub-centers"; 4) Four centers (Tama new town, Chiba new town, Kohoku new town and Ryugasaki new town) as "New town centers"; and 5) Five centers (Tokorozawa, Kashiwa, Funabashi, Odawara, and Yokosuka) as principle cities as designated under the 4thNCRDP (TMG,1994) (Figure 5.5a). Later, Kasukabe/Koshigaya as a business core city was added with the 4th NCRDP (MILT, 2006).

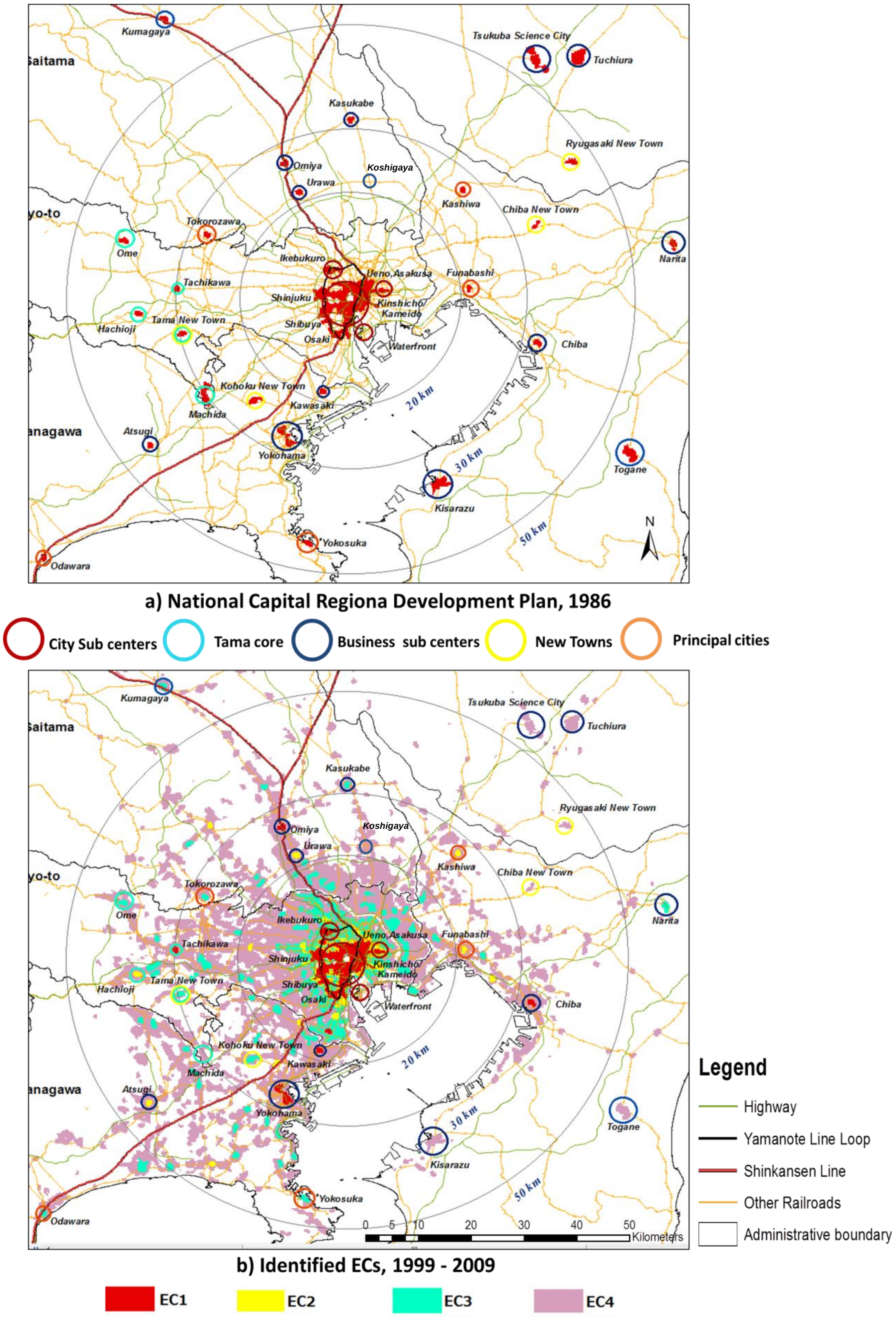

Figure 5.5: Comparison between the identified ECs and the 4thNCRDP: a) 4thNCRDP selected business sub centers (TMG, 1994); and b) Identified potential

ECs in different ranks.

Figure 5.5b shows the identified ECs through the analysis in different ranks. Note that among the 32 business sub-centers[16] (4th NCRDP), only 11 (sub-centers) were identified though the research as EC1, five as EC2, ten as EC3 and seven as EC4 (Table 5.5). ECs such as- Tsukuba Science City, Ryugasaki new town, and Tuchiura in Ibaraki prefecture; Kisarazu, Togane, and Chiba new town in Chiba prefecture; and Machida in Tokyo-to have been Identified as EC4, the lowest in the rank hierarchies. In addition, Chiba new town was only identified as EC4 and Koshigaya, in fact, was not even identified as ECs. Table 5.6 presents the employment centers of 4th NCRDP in ECs and the identified ECs where a substantial number of ECs (250 in total) were identified in TMA. Also, most of the ECs were found in EC1, EC2 and EC3. At the prefecture level, highest number of ECs was identified in Kanagawa and Saitama followed by Chiba and Tokyo-to. In case of Ibaraki, Gunma and Tochigi a total of 61 ECs in different ranks were revealed that went unnoticed by the 4th NCRDP. These indicate that not only the core areas have decentralized but also in the suburban areas.

Moreover, Figure 5.5b shows the distribution of the identified ECs in four prefectures where several potential EC1s, EC2s, and EC3s are located (Tokyo-to, Saitama, Ibaraki, and Kanagawa), along with the ECs of the 4th NCRDP. For example, Kamata, Takadanobaba (Tokyo-to), and the Yokohama Station area (Kanagawa prefecture) were identified as EC1 but rarely addressed as potential business sub-centers for the 4th NCRDP. Additionally, as omitted by the

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[16] The Waterfront sub-metropolitan area was not identified as ECs ≥1km^2 in 2009.

4th NCRDP, the analysis has also identified potential ECs in the Gunma and Tochigi prefectures that are located near the main railway networks and corridors.

Table 5.5: Distribution of employment centers (4th NCRDP) in ECs and different ranks by Prefecture.

Prefectures	EC1	EC2	EC3	EC4
Tokyo-to	Ikebukuro, Shinjuku, Shibuya, Osaki, Ueno, Asakusa, Kinshicho/Kameido, Tachikawa	Hachioji	Ome, Tama new Town,	Machida
Saitama	Omiya	Urawa	Kumagaya, Tokorozawa, Kasukabe (2006)	-
Kanagawa	Yokohama, Kawasaki	Atsugi	Yokosuka, Kohoku new town, Odawara	-
Chiba	Chiba	Funabashi, Kashiwa	Narita	Kisarazu, Togane, Chiba new town
Ibaraki	-	-	-	Ryugasaki New Town, Tsukuba Science City, Tuchiura
Tochigi	-	-	-	-
Gunma	-	-	-	-

Table 5.6: Employment centers of 4th NCRDP in ECs and the identified ECs in different ranks by prefectures, 2009.

	Employment Centers (4th NCRDP)				
Prefectures	EC1	EC2	EC3	EC4	Total
Tokyo-to	4	1	2	1	8
Saitama	1	1	3	-	5
Kanagawa	2	1	3	-	7
Chiba	1	2	1	3	7
Ibaraki	-	-	-	3	3
Tochigi	-	-	-	-	0
Gunma	-	-	-	-	0
	Identified ECs				
Prefectures	EC1	EC2	EC3	EC4	Total
Tokyo-to	2	4	22	8	36
Saitama	-	1	9	45	55
Kanagawa	-	2	20	33	55
Chiba	-	1	4	38	43
Ibaraki	-	1	1	22	24
Tochigi	-	1	1	16	18
Gunma	-	1	4	14	19

5.5 Summary of the Chapter

In summary, this chapter reports on the detailed analysis conducted at fine scale (250, 1) to identify and select the potential employment centers and their distribution in different ranks. Furthermore, the identified ECs were compared with the 4th NCRDP to determine the weakness in the planned suburbanization of employment in the TMA. The analysis has provided some distinctive results.

First, using the fine scale *(*250, 1*)* in the identification and selection of employment centers has captured the potential employment centers in different ranks in the TMA. Also, the fine scale has further revealed that a concentric pattern is visible up to the 20km distance band, and at the 50km distance band the analysis could identify development corridors in multiple directions.

Second, the distribution of the ECs in different ranks has shown that most of the EC1s, EC2s, and EC3s are found within the 20km and 30km distance bands. Also, most of the EC4s were found at the 50km distance band and beyond, which indicates that the distance from the CBD has substantially influenced the distribution of ECs in different ranks. Additionally, most of the EC1s, EC2s and EC3s that were identified in the periphery of the TMA are surrounded by EC4s, and located along the railway tracks and junctions.

Lastly, through this analysis, the identified ECs were compared with the 4th NCRDP, and it was found that only 11 of the employment sub-centers out of the 32 that were selected for the 4th NCRDP qualified as EC1s. Also, several EC1s, EC2s, and EC3s disclosed near the main center as well as in the peripheries went unnoticed by the 4th NCRDP. Also, the Tokyo Waterfront sub-metropolitan area and Koshigaya were not identified as ECs in 2009.

CHAPTER 6
A DESCRIPTIVE ANALYSIS OF THE SPATIAL PATTERN CHANGE OF THE IDENTIFIED ECs 1999-2009

6.1 Introduction

In Chapter 5, the identification and selection of potential ECs as well as their distribution in different ranks in 2009 were revealed by using the fine scale (250,1st order) case at the regional level. This chapter further investigates the recent changes in the identified ECs those are $\geq$ 1km^2, summarized at the prefectural level which were found more concentrated and denser than the rest of the identified ECs (hereafter abbreviated as RECs) (table 6.12). Additionally, the second objective raised by the research: *the spatial pattern change of employment over a given period,* is explored in this chapter. For the analysis, the identified ECs were first investigated in terms of total employment and average density for the years 1999 and 2009 at the prefecture level; and secondly, at the EC level for the spatial pattern change analysis. For these purposes, a unique number was provided to each EC from the years 1999 and 2009 using ArcMap and ArcEditor 10.1, and the resulting datasets were overlaid to spatially locate the changes. 286 ECs were identified in 1999 and 279 in 2009, and these were used for the spatial pattern change analysis (figure 6.1).

6.2 Employment center changes by prefectures

The overall employment in the ECs presented in Table 6.1. A general observation of the overall employment characteristics of the ECs is that, in 2009 the ECs shared a total area of 731.78 km^2, and a total employment of 8,570,452; with a density of 11,712 employees perkm^2. Also, total employment increased by 671,877 in the ten-year period. In addition to that, between 1999 and 2009 the area of ECs decreased by 5.31 km^2 but employment density increased by about 996 perkm^2. This signifies that between 1999 and 2009 the ECs became concentrated and denser in the TMA, and the area of ECs has slightly decreased. Summary statistics of the total employment, average density, and area of the ECs in different ranks by prefectures are presented in Appendix A. The changes in the total employment and average density are however further explored at the prefectural level presented in the following sections.

Table 6.1: Total employment, average density, and area of the ECs and their changes, 1999-2009.

ECs	Total Employment	Area(km^2)	Average density (employees/perkm^2)
Year 1999	7,898,575	737.09	10,716
Year 2009	8,570,452	731.78	11,712
Change from 1999 to 2009	+671,877	**-5.31**	+996

a) Identified ECs arranged by total employment, 1999

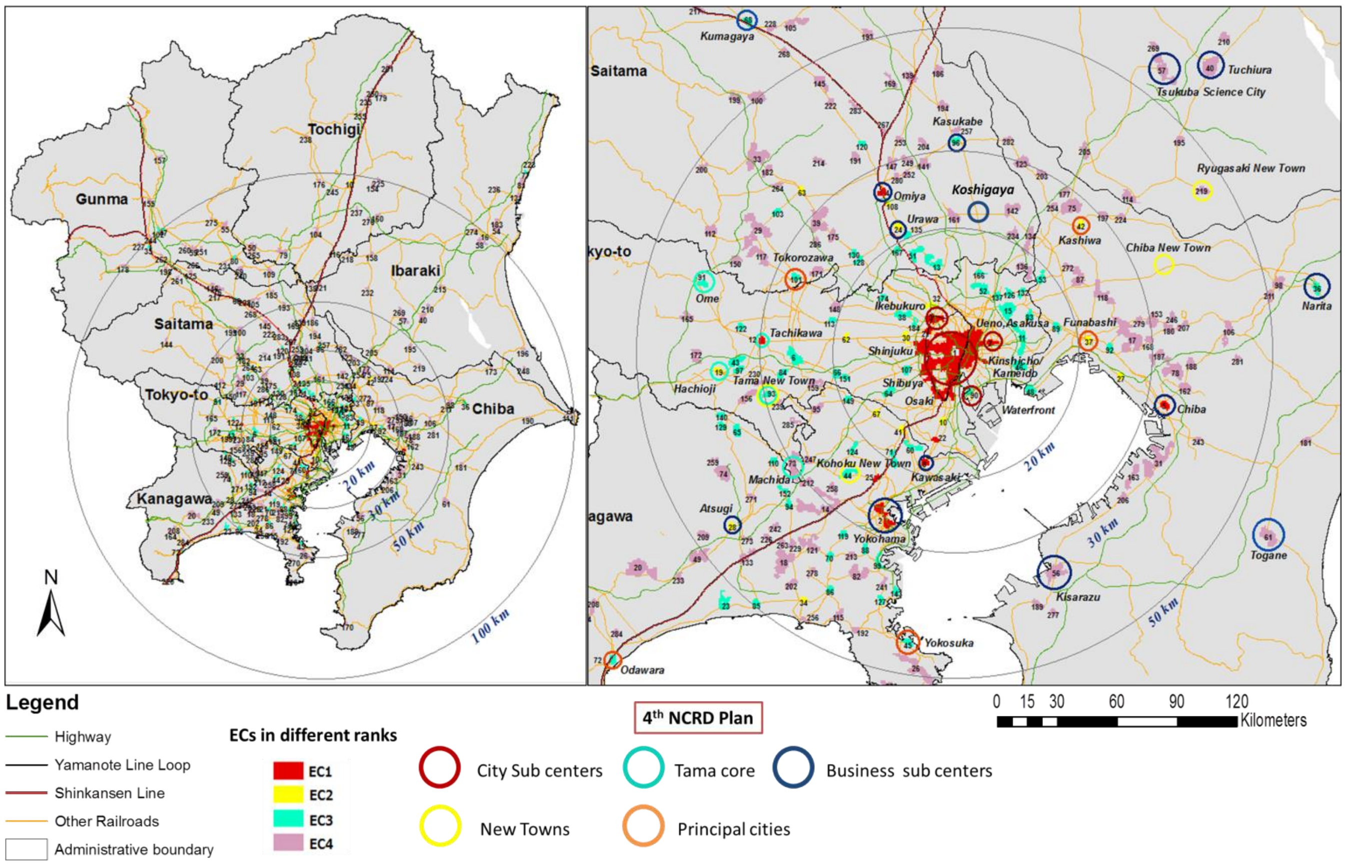

Figure 6.1: location of ECs in different ranks by prefectures: a) 1999 & b) 2009.[17]

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17 The total employment arranged in numerical order where the largest EC considered as the 1st and so on.

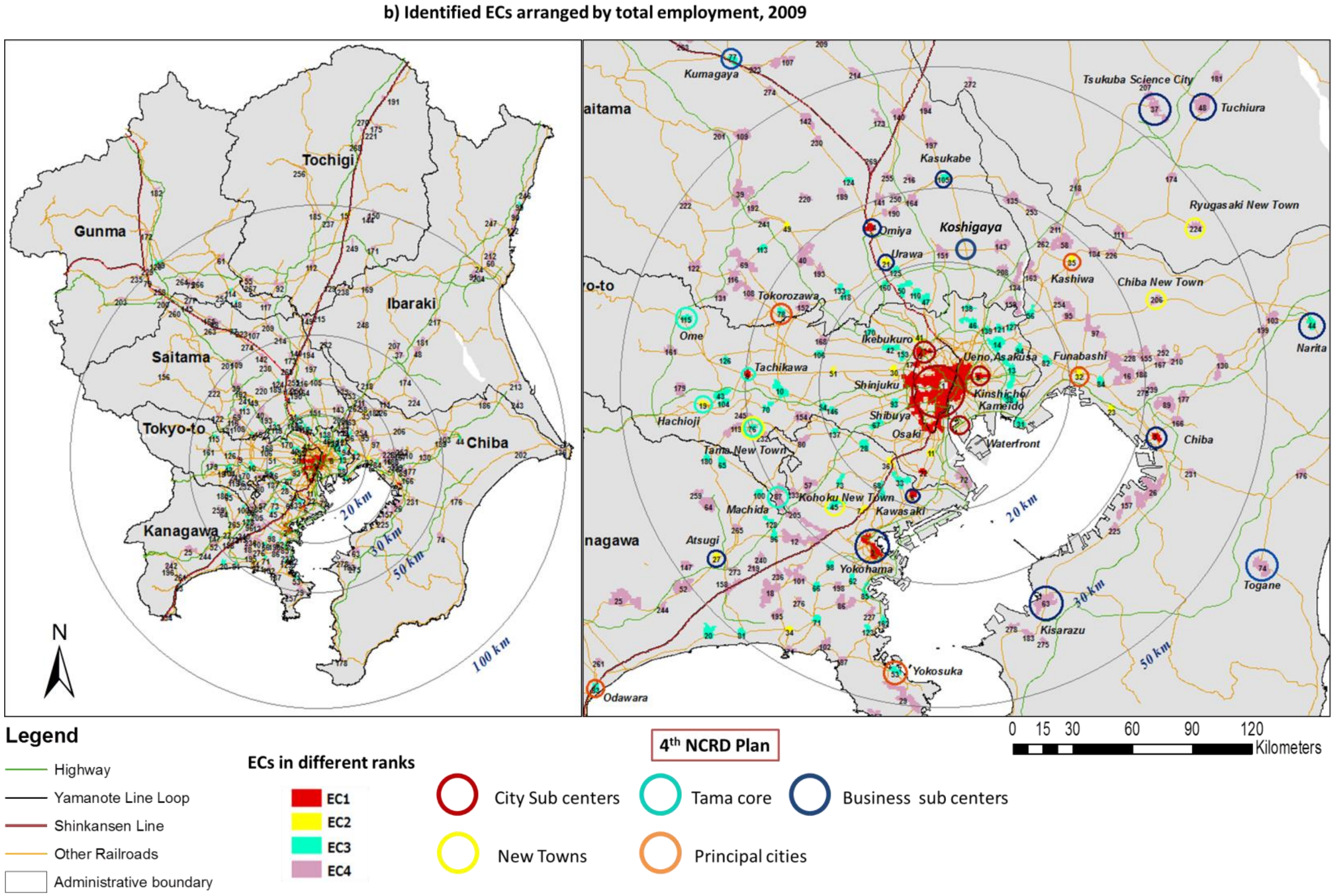

Figure 6.1: Continued.

6.2.1 Total employment change

Figure 6.2 shows the total employment change between 1999 and 2009 for ECs by prefectures. Table 6.2 shows the distribution of the total employment and employment change in the ECs of different ranks by prefectures between 1999 and 2009.

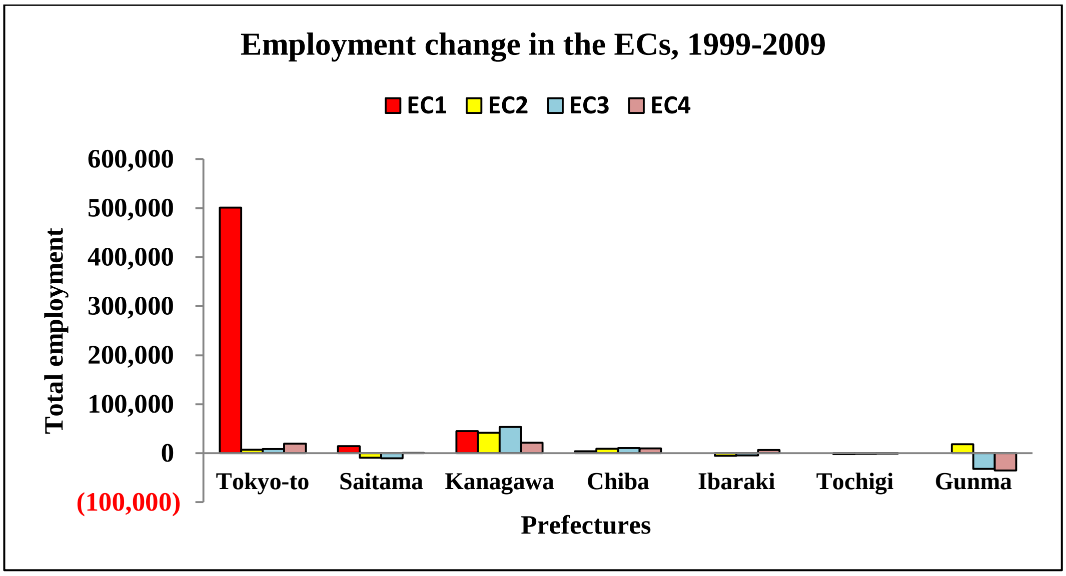

Figure 6.2: Total employment change in the ECs, 1999-2009.

In this ten-year period, an absolute change in the employment of the ECs was clearly visible at the prefecture level. Growth in employment occurred in all ranks of the ECs in Tokyo-to , Kanagawa, and Chiba, however, the EC1 of Tokyo-to stands out (+501,123), followed by Kanagawa (+45,025), and Chiba (+4,159). Despite a substantial increase in total employment in the EC1 of Tokyo-to, the increase in the total employment was considerably lower than in the other ranked ECs. On the other hand, Kanagawa and Chiba showed an increase in employment in the EC2 and EC3 compared to Tokyo-to. Additionally, the EC4 of Chiba was less concentrated than those in Tokyo-to. Nonetheless, whereas employment has become more concentrated in the main center of the Tokyo-to, concentration of employment was detected prefecture-wide in the case of Kanagawa and Chiba, between 1999 and 2009.

Table 6.2: Total employment and employment change of the ECs in prefecture level, 1999-2009.

Total employment					
Year 1999	EC1	EC2	EC3	EC4	Total
Tokyo-to	4,021,232	163,206	470,033	69,887	4,724,359
Saitama	58,736	71,021	179,437	404,685	713,879
Kanagawa	315,258	108,779	364,068	359,744	1,147,850
Chiba	58,681	88,460	108,136	377,564	632,841
Ibaraki	0	39,086	18,234	219,948	277,268
Tochigi	0	43,484	12,257	123,481	179,221
Gunma	0	0	86,419	136,742	223,161
Year 2009	EC1	EC2	EC3	EC4	Total
Tokyo-to	4,522,355	170,138	478,907	89,714	5,261,114
Saitama	72,885	61,822	169,227	405,050	708,984
Kanagawa	360,282	150,689	417,606	381,128	1,309,705
Chiba	62,840	97,458	118,704	387,448	666,450
Ibaraki	0	33,789	14,072	226,653	274,514
Tochigi	0	41,411	11,062	122,632	175,105
Gunma	0	18,430	54,746	101,412	174,588
Total employment change					
Year 1999-2009	EC1	EC2	EC3	EC4	Total
Tokyo-to	501,123	6,932	8,874	19,826	536,753
Saitama	14,149	**-9,199**	**-10,210**	365	**-4,895**
Kanagawa	45,025	41,911	53,537	21,384	161,857
Chiba	4,159	8,998	10,568	9,884	33,609
Ibaraki	0	**-5,297**	**-4,162**	6,705	**-2,754**
Tochigi	0	**-2,073**	**-1,195**	**-848**	**-4,116**
Gunma	0	18,430	**-31,673**	**-35,330**	**-48,573**

In contrast to Tokyo-to, Kanagawa, and Chiba, total employment in the ECs of Saitama, Ibaraki, and Gunma prefectures has simultaneously increased and decreased in the ten-year period (Figure 6.2). In the case of Saitama, EC1 and EC4 showed an increase in total employment, whereas EC2 and EC3 decreased in total employment. Also, the EC4 of Ibaraki and the EC2 of Gunma increased in total employment. Note that in the mentioned three prefectures (Saitama, Ibaraki, and Gunma), the ECs that lost employment were substantially large in number between 1999 and 2009 (Table 6.2). On the other hand, in Tochigi, total employment decreased in most of the ECs. Additionally, no change in the total employment was revealed in the EC1 of Ibaraki, Tochigi, and Gunma between 1999 and 2009. These results signify that the Saitama, Ibaraki, Tochigi, and Gunma prefectures lost employment in the ten-year period.

6.2.2 Average density change

Figure 6.3 illustrates the average density change of the employment in ECs between 1999 and 2009. As before, absolute numbers were used to show the increase and decrease in average density.

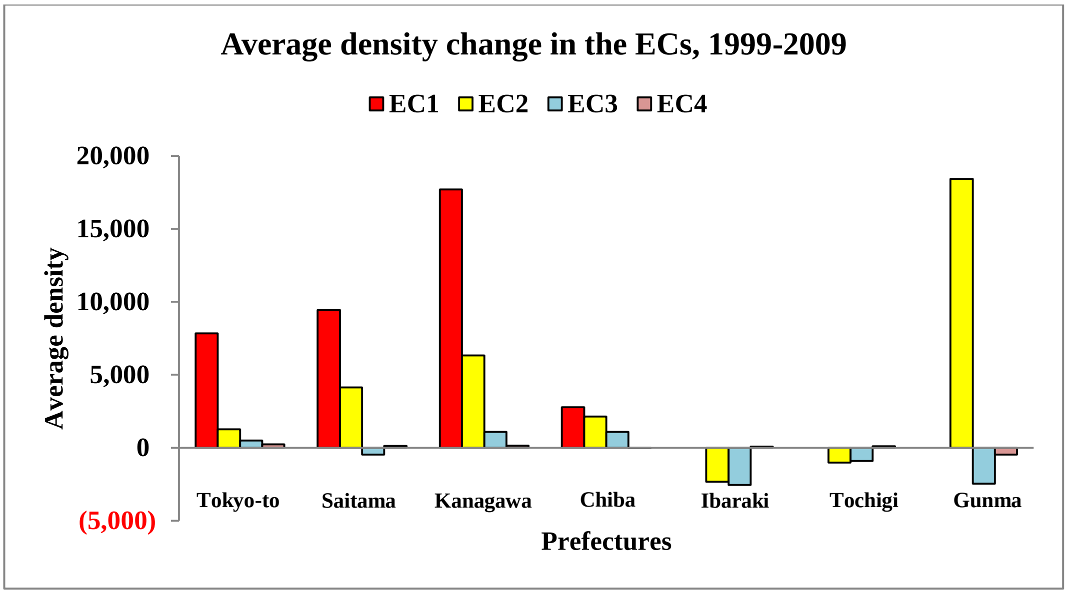

Figure 6.3: Average density change in the ECs, 1999-2009.

During the years 1999-2009, Tokyo-to, Saitama, Kanagawa and Chiba increased in average density, whereas density decreased in Ibaraki and Tochigi prefectures. An exceptional case was Gunma where a significant increase in density was revealed in the EC2.

Table 6.3: Average density change of the ECs, 1999-2009.

Average density				
Year 1999	EC1	EC2	EC3	EC4
Tokyo-to	58,542	23,722	9,593	3,251
Saitama	39,157	21,853	9,763	3,157
Kanagawa	38,777	24,173	10,238	3,680
Chiba	39,121	25,715	12,274	3,283
Ibaraki	0	22,335	11,187	3,355
Tochigi	0	21,109	9,356	2,830
Gunma	0	0	10,884	3,325
Year 2009	EC1	EC2	EC3	EC4
Tokyo-to	66,388	24,984	10,091	3,479
Saitama	48,590	25,976	9,303	3,275
Kanagawa	56,471	30,504	11,323	3,825
Chiba	41,893	27,845	13,368	3,268
Ibaraki	0	19,993	8,633	3,444
Tochigi	0	20,102	8,444	2,924
Gunma	0	18,430	8,422	2,846
Average density change				
Year 1999-2009	EC1	EC2	EC3	EC4
Tokyo-to	7,846	1,262	498	228
Saitama	9,433	4,123	**(459)**	118
Kanagawa	17,693	6,331	1,085	145
Chiba	2,773	2,130	1,093	**(15)**
Ibaraki	0	**(2,341)**	**(2,553)**	89
Tochigi	0	**(1,006)**	**(912)**	94
Gunma	0	18,430	**(2,462)**	**(478)**

Table 6.3 further shows that in case of the ECs in different ranks, average density has increased in all ECs of Tokyo-to and Kanagawa in the ten-year period. Also, the upper ranked ECs of Chiba were found to have become denser. As did the EC1, EC2, and EC4 of Saitama. Unlike total employment, the increase of density at EC1 of Tokyo-to was found to be smaller than the Kanagawa and Saitama prefectures. Also, the density increases recorded by other upper ranked ECs (EC2 & EC3) of Kanagawa and Chiba, and EC2 of Saitama were found to be larger than the EC2 and EC3 of Tokyo-to. However, the density of EC4 of Tokyo-to has increased to a greater degree than that of Kanagawa and Chiba. These indicate that whereas Tokyo-to has shown an increase in average density, the neighboring prefectures (Kanagawa, Saitama and Chiba) also comparatively became denser in the ten-year period.

Moreover, despite the fact that the EC4s in Ibaraki and Tochigi have slightly increased in average density, a significant decrease in average density was revealed in the upper ranked ECs (EC2 & EC3) during this ten-year period. In contrast, whereas the average density of the EC3 and EC4 of Gunma decreased, a significant density increase was found in the EC2 area (18,430). Note that the increase in the average density in the EC2 of Gunma was revealed as being even higher than the upper ranked ECs of Tokyo-to, Kanagawa, Saitama, and Chiba. This indicates that not only did the employment locations near to the core areas of TMA increase in average density, but that the average density across the suburban areas of the TMA also increased between 1999 and 2009.

6.3 Center IDs and the location

For the analysis, carried out by using ArcMap, and ArcEditor 10.1, each EC identified in 1999 and 2009 by using a spatial scale of 250m by 250m grid-cells were first provided with unique numbers and created as a pair. That is, the center ID of 1999 ≡ the center ID of 2009. Consequently, 296 paired ECs were identified in 1999 and 2009; 46 in Tokyo-to, 65 in Saitama, 65 in Kanagawa, 52 in Chiba, 28 in Ibaraki, 21 in Gunma, and 19 in Tochigi prefectures. Figure 6.4-6.10 and table 6.4-6.10 shows the ECs in different ranks with provided center IDs and their distribution in city level by prefectures, 1999-2009.

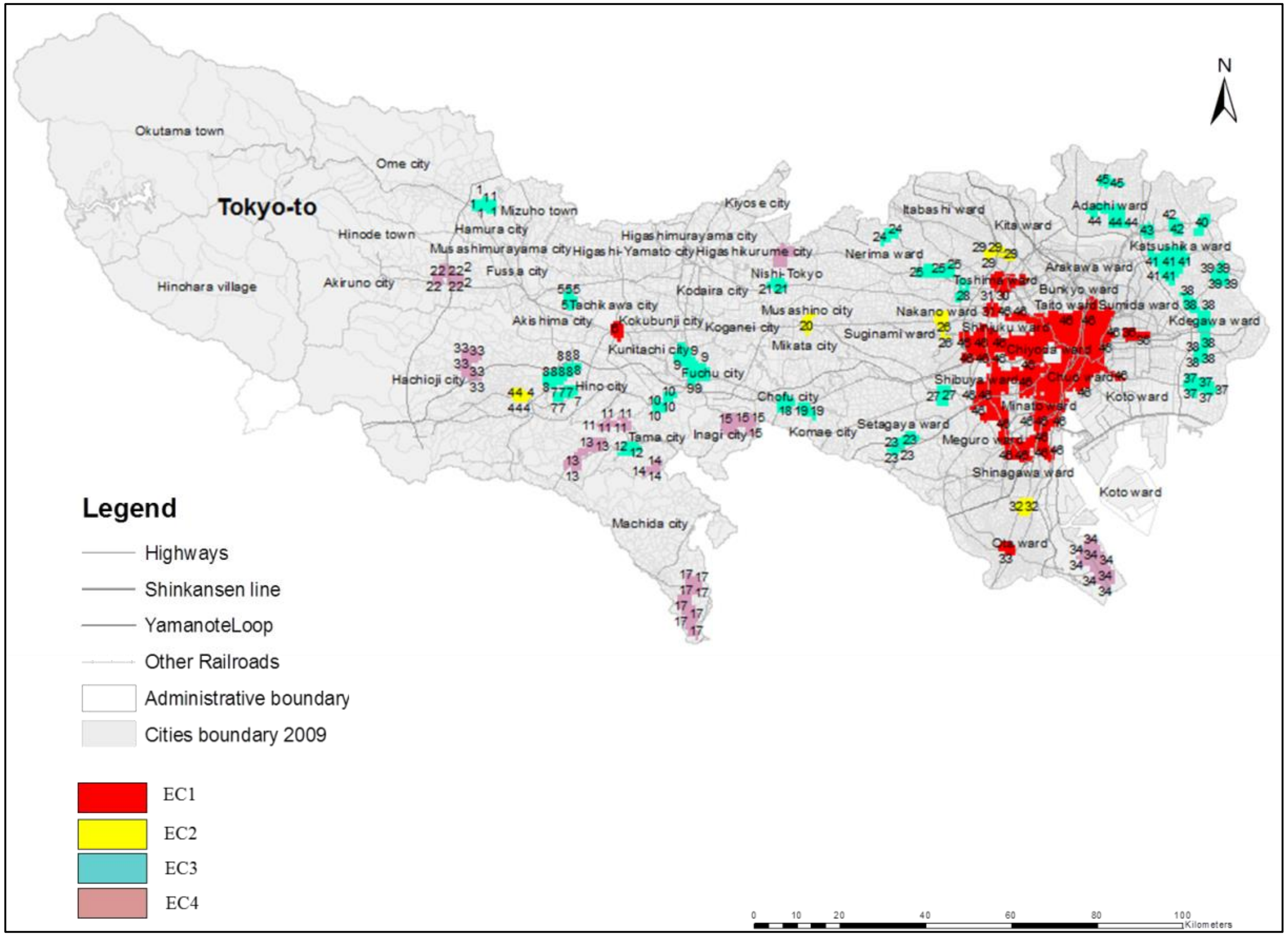

Figure 6.4: Center IDs of the ECs in different ranks and their distribution by cities (Tokyo-to).

Table 6.4: Center IDs and their distribution by cities (Tokyo-to).

Tokyo Metropolis					
City Name	**Center ID**				
Adachi ward	42	43	44	45	-
Akiruno city	2	-	-	-	-
Akishima city	5	-	-	-	-
Arakawa ward	-	-	-	-	-
Bunkyo ward	46	-	-	-	-
Chiyoda ward	46	-	-	-	-
Chofu city	18	19	-	-	-
Chuo ward	46	-	-	-	-
Fuchu city	9	10	-	-	-
Fussa city	-	-	-	-	-
Hachioji city	3	4	8	11	13
Hamura city	1	-	-	-	-
Higashikurume city	22	-	-	-	-
Higashimurayama city	-	-	-	-	-
Higashi-Yamato city	-	-	-	-	-
Hino city	7	8	-	-	-
Hinode town	2	-	-	-	-
Hinohara village	-	-	-	-	-
Inagi city	15	-	-	-	-
Itabashi ward	29	-	-	-	-
Katsushika ward	38	40	41	42	43
Kdegawa ward	37	38	39	-	-
Kita ward	29	-	-	-	-
Kiyose city	-	-	-	-	-
Kodaira city	-	-	-	-	-
Koganei city	-	-	-	-	-
Kokubunji city	-	-	-	-	-
Komae city	19	-	-	-	-
Koto ward	36	46	-	-	-

Koto ward	-	-	-	-	-
Kunitachi city	-	-	-	-	-
Machida city	14	17	-	-	-
Meguro ward	46	-	-	-	-
Mikata city	20	-	-	-	-
Minato ward	46	-	-	-	-
Mizuho town	-	-	-	-	-
Musashimurayama city	-	-	-	-	-
Musashino city	20	-	-	-	-
Nakano ward	25	26	46	-	-
Nerima ward	24	25	-	-	-
Nishi-Tokyo	21	22	-	-	-
Okutama town	-	-	-	-	-
Ome city	1	-	-	-	-
Ota ward	32	33	34	-	-
Setagaya ward	23	27	-	-	-
Shibuya ward	46	-	-	-	-
Shinagawa ward	32	46	-	-	-
Shinjuku ward	28	31	46	-	-
Suginami ward	-	-	-	-	-
Sumida ward	36	46	-	-	-
Tachikawa city	6	-	-	-	-
Taito ward	46	-	-	-	-
Tama city	10	11	12	14	-
Toshima ward	28	29	30	-	-

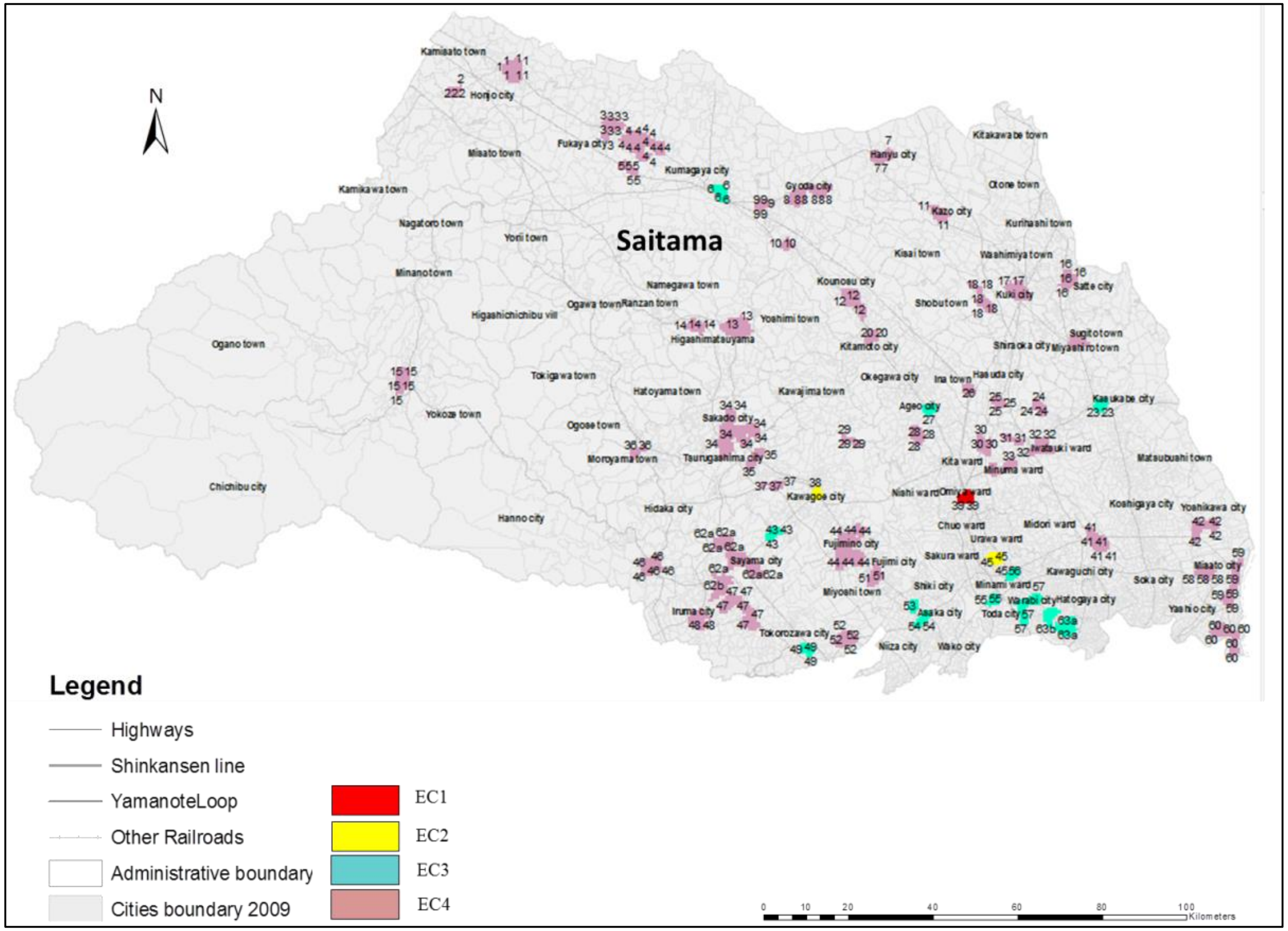

Figure 6.5: Center IDs of the ECs in different ranks and their distribution by cities (Saitama prefecture).

Table 6.5: Center IDs and their distribution by cities (Saitama prefecture).

Saitama Prefecture						
City Name	**Center ID**					
Ageo city	27	28	30	-	-	-
Asaka city	54	53	-	-	-	-
Chichibu city	15	-	-	-	-	-
Chuo ward	-	-	-	-	-	-
Fujimi city	51	44	-	-	-	-
Fujimino city	44	-	-	-	-	-
Fukaya city	3	4	5	-	-	-
Gyoda city	8	9	-	-	-	-
Hanno city	46	-	-	-	-	-
Hanyu city	7	-	-	-	-	-
Hasuda city	25	24	-	-	-	-
Hatogaya city	-	-	-	-	-	-
Hatoyama town	-	-	-	-	-	-
Hidaka city	-	-	-	-	-	-
Higashichichibu village	-	-	-	-	-	-
Higashimatsuyama	13	14	-	-	-	-
Honjo city	1	2	-	-	-	-
Ina town	26	-	-	-	-	-
Iruma city	47	48	62b	-	-	-
Iwatsuki ward	24	32	-	-	-	-
Kamikawa town	-	-	-	-	-	-
Kamisato town	2	-	-	-	-	-
Kasukabe city	23	-	-	-	-	-
Kawagoe city	29	35	37	38	43	44
Kawaguchi city	41	63a	63b	-	-	-
Kawajima town	29	-	-	-	-	-
Kazo city	11	-	-	-	-	-
Kisai town	-	-	-	-	-	-
Kita ward	-	-	-	-	-	-
Kitakawabe town	-	-	-	-	-	-

Kitamoto city	20	12	-	-	-	-
Koshigaya city	-	-	-	-	-	-
Kounosu city	12	10	-	-	-	-
Kuki city	17	18	-	-	-	-
Kumagaya city	4	5	6	9	-	-
Kurihashi town	-	-	-	-	-	-
Matsubushi town	-	-	-	-	-	-
Midori ward	-	-	-	-	-	-
Minami ward	56	-	-	-	-	-
Minano town	-	-	-	-	-	-
Minuma ward	30	31	33	-	-	-
Misato city	58	59	60	-	-	-
Misato town	-	-	-	-	-	-
Miyashiro town	21	-	-	-	-	-
Miyoshi town	51	-	-	-	-	-
Moroyama town	36	-	-	-	-	-
Nagatoro town	-	-	-	-	-	-
Namegawa town	14	-	-	-	-	-
Niiza city	53	-	-	-	-	-
Nishi ward	-	-	-	-	-	-
Ogano town	-	-	-	-	-	-
Ogawa town	-	-	-	-	-	-
Ogose town	-	-	-	-	-	-
Okegawa city	-	-	-	-	-	-
Omiya ward	39	-	-	-	-	-
Otone town	-	-	-	-	-	-
Ranzan town	-	-	-	-	-	-
Sakado city	34	-	-	-	-	-
Sakura ward	-	-	-	-	-	-
Satte city	16	-	-	-	-	-
Sayama city	43	62a	-	-	-	-
Shiki city	53	-	-	-	-	-
Shiraoka city	-	-	-	-	-	-
Shobu town	18	-	-	-	-	-

Soka city	-	-	-	-	-	-
Sugito town	-	-	-	-	-	-
Toda city	55	57	-	-	-	-
Tokigawa town	-	-	-	-	-	-
Tokorozawa city	47	49	52	-	-	-
Tsurugashima city	34	35	-	-	-	-
Urawa ward	45	-	-	-	-	-
Wako city	-	-	-	-	-	-
Warabi city	57	63b	-	-	-	-
Washimiya town	-	-	-	-	-	-
Yashio city	-	-	-	-	-	-
Yokoze town	-	-	-	-	-	-
Yorii town	-	-	-	-	-	-
Yoshikawa city	42	-	-	-	-	-
Yoshimi town	-	-	-	-	-	-

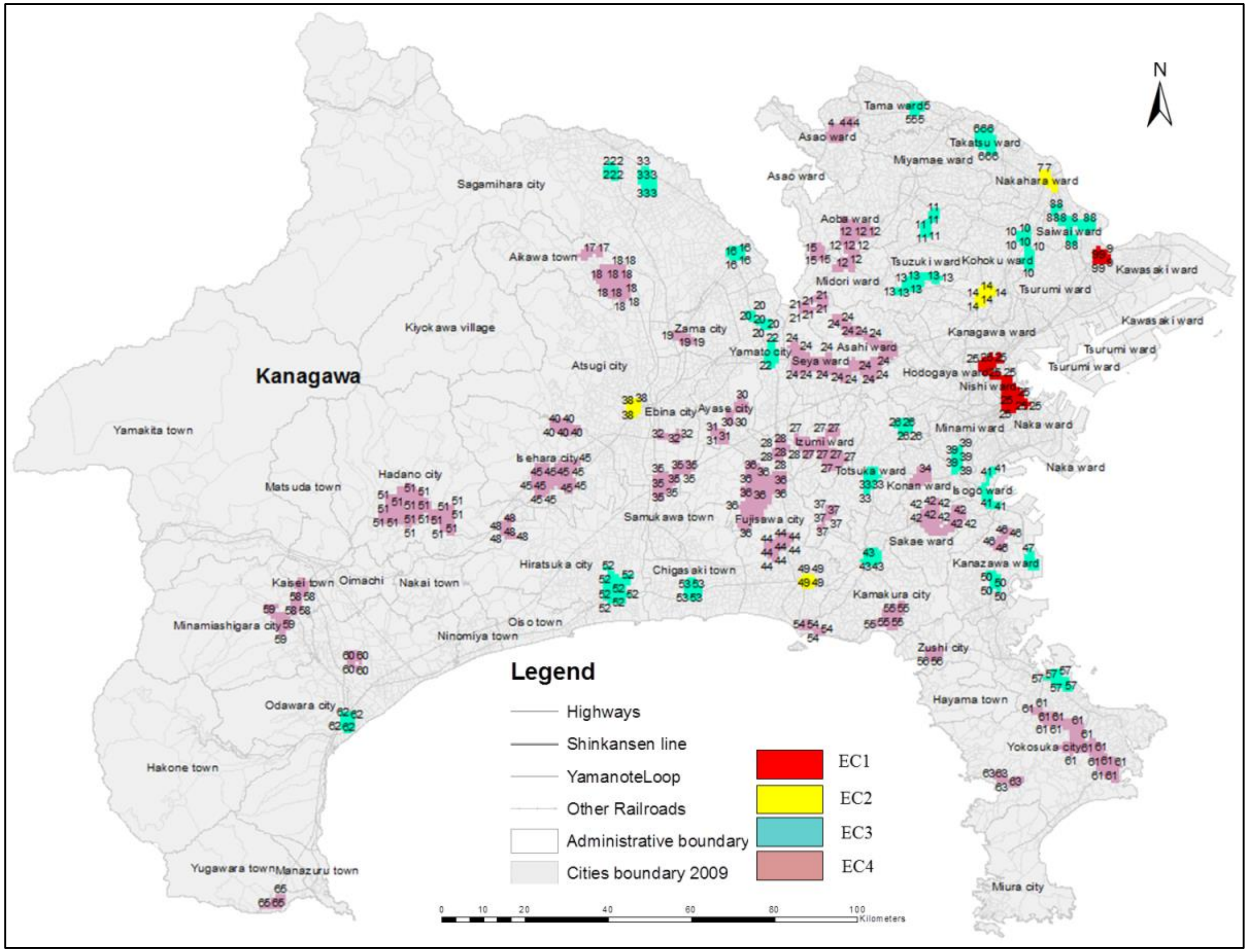

Figure 6.6: Center IDs of the ECs in different ranks and their distribution by cities (Kanagawa prefecture).

Table 6.6: Center IDs and their distribution by cities (Kanagawa prefecture).

Kanagawa Prefecture						
City Name	**Center ID**					
Aikawa town	17	18	-	-	-	-
Aoba ward	-	-	-	-	-	-
Asahi ward	24	21	-	-	-	-
Asao ward	4	-	-	-	-	-
Atsugi city	18	38	40	-	-	-
Ayase city	30	31	-	-	-	-
Chigasaki town	53	-	-	-	-	-
Ebina city	32	35	-	-	-	-
Fujisawa city	28	35	36	44	49	54
Hadano city	51	48	-	-	-	-
Hakone town	-	-	-	-	-	-
Hayama town	-	-	-	-	-	-
Hiratsuka city	48	52	-	-	-	-
Hodogaya ward	-	-	-	-	-	-
Isehara city	40	45	-	-	-	-
Isogo ward	41	42	-	-	-	-
Izumi ward	27	-	-	-	-	-
Kaisei town	58	-	-	-	-	-
Kamakura city	43	54	55	-	-	-
Kanagawa ward	25	-	-	-	-	-
Kanazawa ward	46	47	50	-	-	-
Kawasaki ward	9	-	-	-	-	-
Kiyokawa village	-	-	-	-	-	-
Kohoku ward	-	-	-	-	-	-
Konan ward	34	39	42	-	-	-
Manazuru town	-	-	-	-	-	-
Matsuda town	-	-	-	-	-	-
Midori ward	12	13	15	21	-	-
Minami ward	39	25	-	-	-	-
Minamiashigara city	58	59	-	-	-	-

Miura city	-	-	-	-	-	-
Miyamae ward	-	-	-	-	-	-
Naka ward	25	-	-	-	-	-
Nakahara ward	7	8	-	-	-	-
Nakai town	-	-	-	-	-	-
Ninomiya town	-	-	-	-	-	-
Nishi ward	25	-	-	-	-	-
Odawara city	60	62	-	-	-	-
Oimachi	-	-	-	-	-	-
Oiso town	-	-	-	-	-	-
Sagamihara city	2	3	16	-	-	-
Saiwai ward	8	9	-	-	-	-
Sakae ward	42	43	-	-	-	-
Samukawa town	35	-	-	-	-	-
Seya ward	24	21	-	-	-	-
Takatsu ward	6	-	-	-	-	-
Tama ward	5	-	-	-	-	-
Totsuka ward	26	33	37	-	-	-
Tsurumi ward	8	10	-	-	-	-
Tsuzuki ward	11	13	-	-	-	-
Yamakita town	-	-	-	-	-	-
Yamato city	20	22	-	-	-	-
Yokosuka city	57	61	63	-	-	-
Yugawara town	65	-	-	-	-	-
Zama city	19	-	-	-	-	-
Zushi city	56	-	-	-	-	-

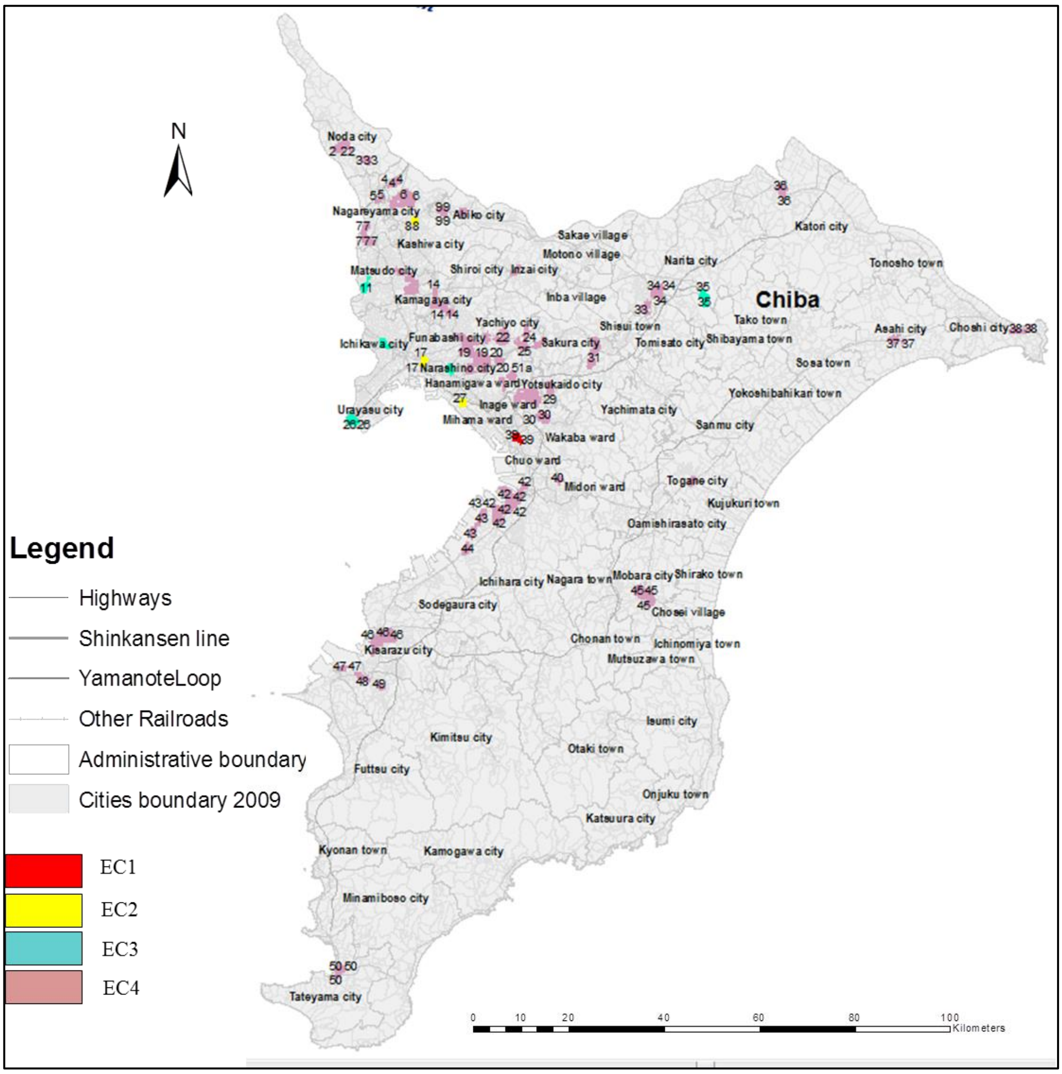

Figure 6.7: Center IDs of the ECs in different ranks and their distribution by cities (Chiba prefecture).

Table 6.7: Center IDs and their distribution by cities (Chiba prefecture).

Chiba Prefecture					
City Name	**Center ID**				
Abiko city	9	10	-	-	-
Asahi city	37	-	-	-	-
Chonan town	-	-	-	-	-
Chosei village	-	-	-	-	-
Choshi city	38	-	-	-	-
Chuo ward	39	42	-	-	-
Funabashi city	17	19	14	-	-
Futtsu city	-	-	-	-	-
Hanamigawa ward	51a	51b	-	-	-
Ichihara city	42	43	44	-	-
Ichikawa city	16	-	-	-	-
Ichinomiya town	-	-	-	-	-
Inage ward	28	-	-	-	-
Inba village	-	-	-	-	-
Inzai city	15	-	-	-	-
Isumi city	-	-	-	-	-
Kamagaya city	14	-	-	-	-
Kamogawa city	-	-	-	-	-
Kashiwa city	4	6	8	-	-
Katori city	36	-	-	-	-
Katsuura city	-	-	-	-	-
Kimitsu city	47	48	49	-	-
Kisarazu city	46	-	-	-	-
Kujukuri town	-	-	-	-	-
Kyonan town	-	-	-	-	-
Matsudo city	11	12	13	-	-
Midori ward	40	-	-	-	-
Mihama ward	27	-	-	-	-
Minamiboso city	-	-	-	-	-
Mobara city	45	-	-	-	-

Motono village	-	-	-	-	-
Mutsuzawa town	-	-	-	-	-
Nagara town	-	-	-	-	-
Nagareyama city	5	7	-	-	-
Narashino city	18	19	-	-	-
Narita city	33	34	35	-	-
Noda city	2	3	-	-	-
Oamishirasato city	-	-	-	-	-
Onjuku town	-	-	-	-	-
Otaki town	-	-	-	-	-
Sakae village	-	-	-	-	-
Sakura city	26	31	-	-	-
Sanmu city	-	-	-	-	-
Shibayama town	-	-	-	-	-
Shirako town	-	-	-	-	-
Shiroi city	-	-	-	-	-
Shisui town	-	-	-	-	-
Sodegaura city	-	-	-	-	-
Sosa town	-	-	-	-	-
Tako town	-	-	-	-	-
Tateyama city	50	-	-	-	-
Togane city	41	-	-	-	-
Tomisato city	-	-	-	-	-
Tonosho town	-	-	-	-	-
Urayasu city	26	-	-	-	-
Wakaba ward	28	30	-	-	-
Yachimata city	-	-	-	-	-
Yachiyo city	21	22	24	25	20
Yokoshibahikari town	-	-	-	-	-
Yotsukaido city	29	-	-	-	-

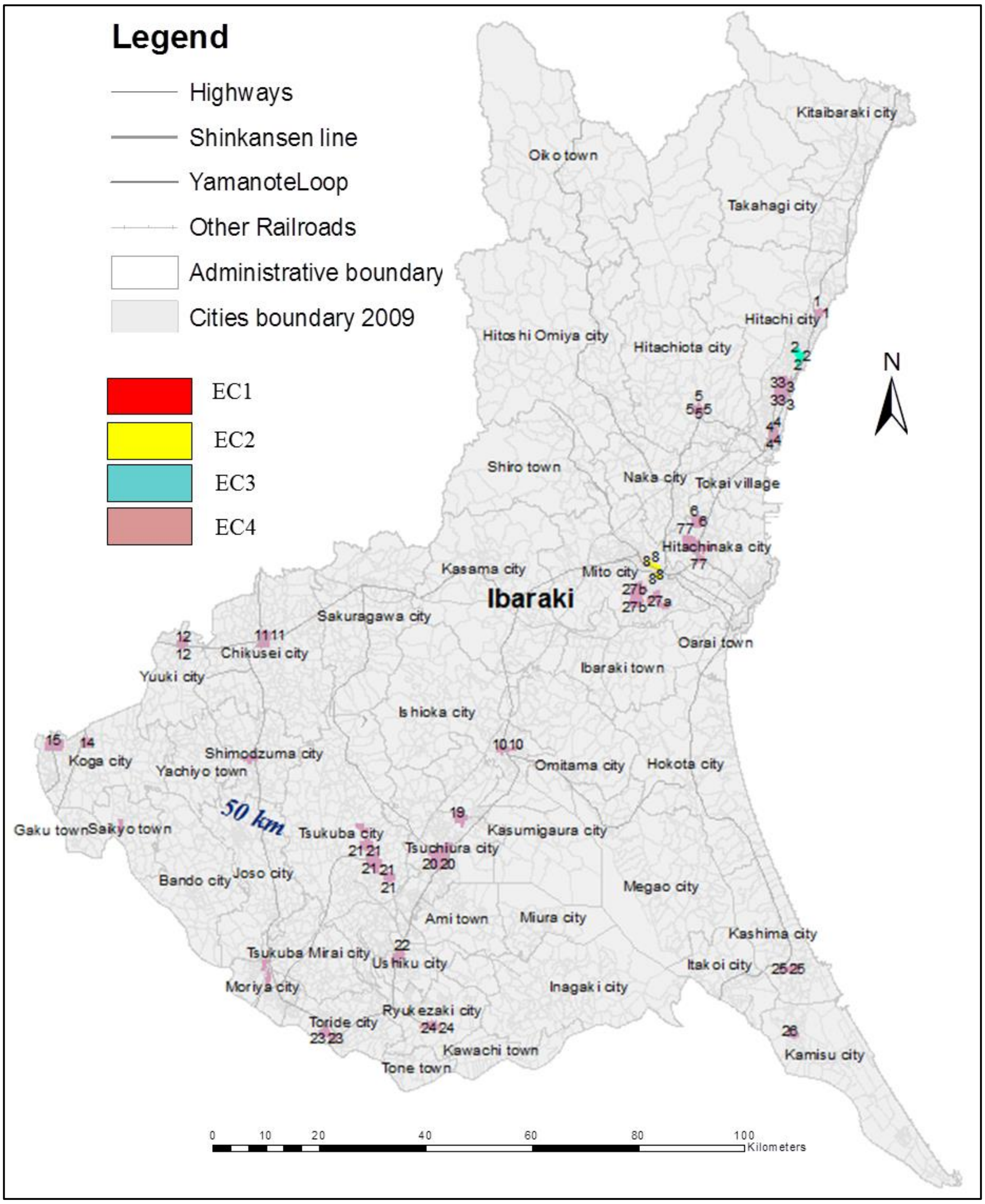

Figure 6.8: Center IDs of the ECs in different ranks and their distribution by cities (Ibaraki prefecture).

Table 6.8: Center IDs and their distribution by cities (Ibaraki prefecture).

Ibaraki Prefecture				
City Name	**Center ID**			
Ami town	-	-	-	-
Bando city	-	-	-	-
Chikusei city	11	-	-	-
Gaku town	-	-	-	-
Hitachi city	1	2	3	4
Hitachinaka city	6	7	-	-
Hitachiota city	5	-	-	-
Hitoshi Omiya city	-	-	-	-
Hokota city	-	-	-	-
Ibaraki town	-	-	-	-
Inagaki city	-	-	-	-
Ishioka city	10	-	-	-
Itakoi city	-	-	-	-
Joso city	-	-	-	-
Kamisu city	26	-	-	-
Kasama city	-	-	-	-
Kashima city	25	-	-	-
Kasumigaura city	19	-	-	-
Kawachi town	-	-	-	-
Kitaibaraki city	-	-	-	-
Koga city	14	15	-	-
Megao city	-	-	-	-
Mito city	8	27a	27b	-
Miura city	-	-	-	-
Moriya city	17	-	-	-
Naka city	-	-	-	-
Oarai town	-	-	-	-
Oiko town	-	-	-	-
Omitama city	-	-	-	-
Ryukezaki city	24	-	-	-

Saikyo town	16	-	-	-
Sakuragawa city	-	-	-	-
Shimodzuma city	13	-	-	-
Shiro town	-	-	-	-
Takahagi city	-	-	-	-
Tokai village	-	-	-	-
Tone town	-	-	-	-
Toride city	-	-	-	-
Tsuchiura city	19	20	-	-
Tsukuba city	18	21	-	-
Tsukuba Mirai city	-	-	-	-
Ushiku city	22	-	-	-
Yachiyo town	-	-	-	-
Yuuki city	12	-	-	-

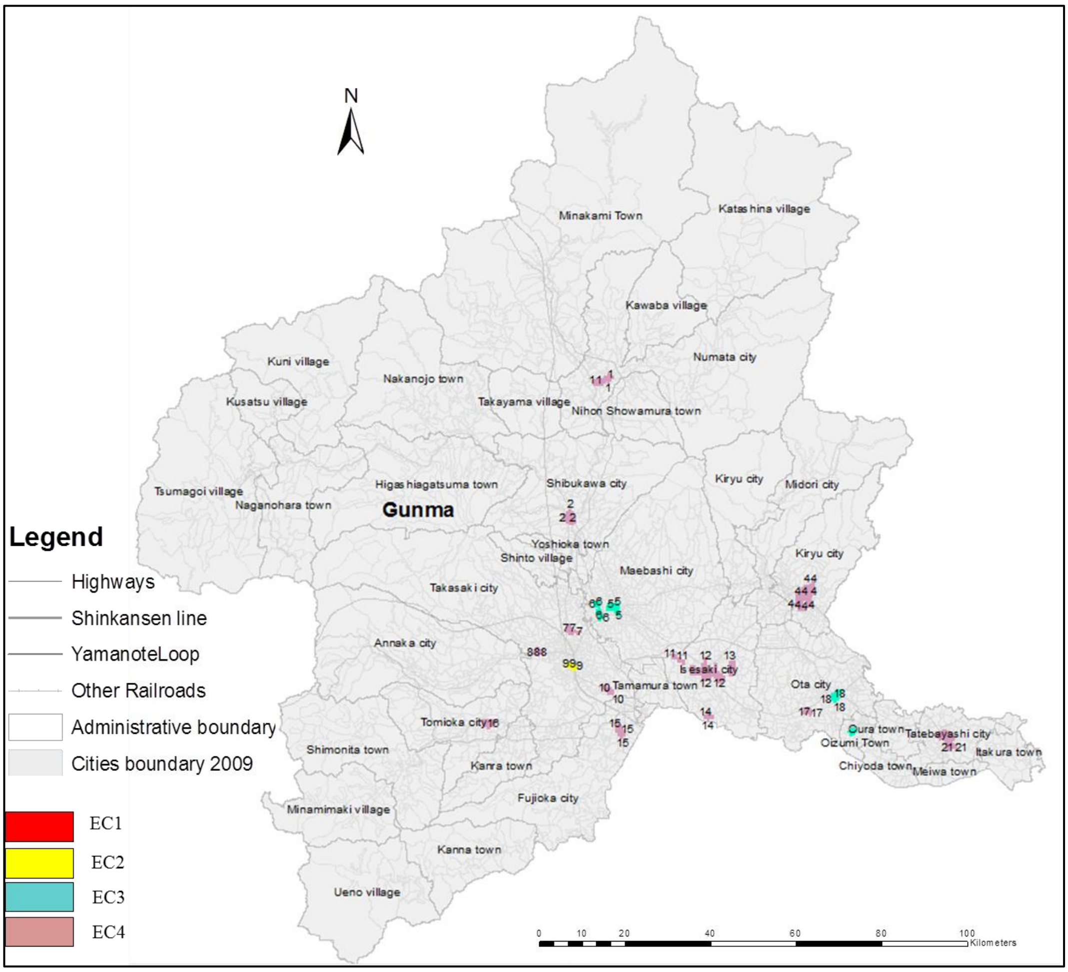

Figure 6.9: Center IDs of the ECs in different ranks and their distribution by cities (Gunma prefecture).

Table 6.9: Center IDs and their distribution by cities (Gunma Prefecture).

Gunma Prefecture				
City Names	**Center ID**			
Annaka city	-	-	-	-
Chiyoda town	-	-	-	-
Fujioka city	15	-	-	-
Higashiagatsuma town	-	-	-	-
Isesaki city	11	12	13	14
Itakura town	-	-	-	-
Kanna town	-	-	-	-
Kanra town	-	-	-	-
Katashina village	-	-	-	-
Kawaba village	-	-	-	-
Kiryu city	4	-	-	-
Kuni village	-	-	-	-
Kusatsu village	-	-	-	-
Maebashi city	5	6	-	-
Meiwa town	-	-	-	-
Midori city	-	-	-	-
Minakami Town	-	-	-	-
Minamimaki village	-	-	-	-
Naganohara town	-	-	-	-
Nakanojo town	-	-	-	-
Nihon Showamura town	-	-	-	-
Numata city	1	-	-	-
Oizumi Town	19	-	-	-
Ota city	17	18	-	-
Oura town	-	-	-	-
Shibukawa city	2	-	-	-
Shimonita town	-	-	-	-
Shinto village	-	-	-	-
Takasaki city	7	8	9	10
Takayama village	-	-	-	-

Tamamura town	-	-	-	-
Tatebayashi city	21	-	-	-
Tomioka city	16	-	-	-
Tsumagoi village	-	-	-	-
Ueno village	-	-	-	-
Yoshioka town	-	-	-	-

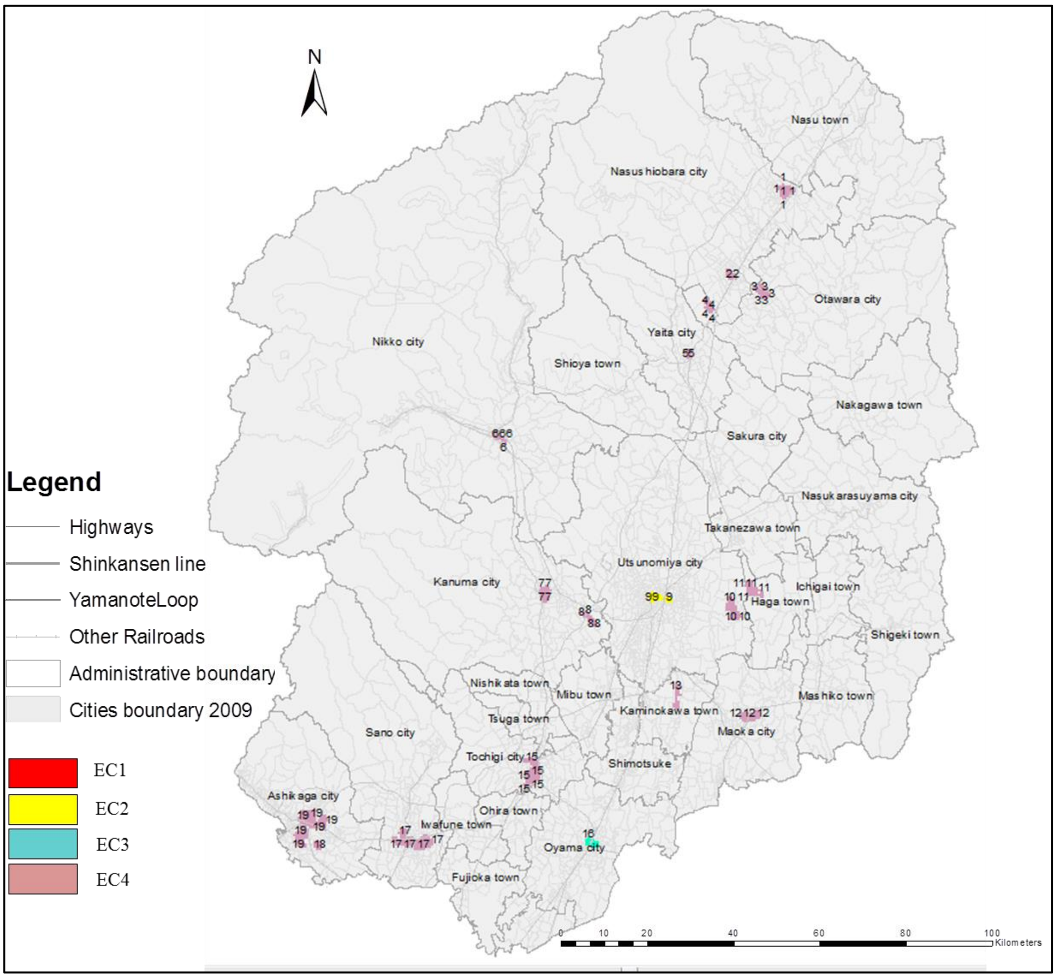

Figure 6.10: Center IDs of the ECs in different ranks and their distribution by cities (Tochigi prefecture).

Table 6.10: Center IDs and their distribution by cities (Tochigi prefecture).

Tochigi Prefecture				
City Name	**Center ID**			
Ashikaga city	18	19	-	-
Fujioka town	-	-	-	-
Haga town	11	-	-	-
Ichigai town	-	-	-	-
Iwafune town	-	-	-	-
Kaminokawa town	13	-	-	-
Kanuma city	7	8	-	-
Maoka city	12	-	-	-
Mashiko town	-	-	-	-
Mibu town	-	-	-	-
Nakagawa town	-	-	-	-
Nasu town	-	-	-	-
Nasukarasuyama city	-	-	-	-
Nasushiobara city	1	2	-	-
Nikko city	6	-	-	-
Nishikata town	-	-	-	-
Ohira town	-	-	-	-
Otawara city	3	4	-	-
Oyama city	16	-	-	-
Sakura city	-	-	-	-
Sano city	17	-	-	-
Shigeki town	-	-	-	-
Shimotsuke	-	-	-	-
Shioya town	-	-	-	-
Takanezawa town	-	-	-	-
Tochigi city	15	-	-	-
Tsuga town	-	-	-	-
Utsunomiya city	9	10	11	-
Yaita city	5	-	-	-

6.4 Change patterns analysis and the identified change patterns in TMA

The previous section suggests that the total employment and average density of the ECs in different ranks[18] have greatly changed in this ten-year period. In this next section, those ECs ≥ 1km^2 were further explored to analyze and identify the specific locations of the spatial pattern changes of employment between 1999 and 2009 at the ECs level. Research conducted by Kane, Hipp and Kim (2016) have used persistence score to identify the level of changes in boundary of centers between 1997 and 2014 calculated as-

$$P_i = \frac{C_{t-1} \cap C_t}{C_{t-1} \cup C_t} \qquad (11)$$

Where, the $C_{t-1} \cap C_t =$ the common grid-cells of the current and previous years of i-th center; and $C_{t-1} \cup C_t$= the total grid-cells of the i-th center of the current and previous years.

According to the authors the change in the boundary of centers are sensitive to size of the grid-cells that previously done tract level studies (e.g., Leslie 2010; Redfearn, 2009) have failed to recognize. Hence, a large number of employment centers were identified as unchanged in a given period. By using the persistence score, the authors have identified that out of 60 employment centers, five centers have shown no change with a persistence score of 1 (the highest score), 14 newly emerged centers and seven declined centers having a 0 (the minimum score) persistence score, and rest of the 34 employment centers were considered as changing with a persistence score ≤ 0.5. While the persistence

[18] The ECs in different ranks are termed as follows: rank1 ECs are considered as EC1, rank2 ECs as EC2, rank3 ECs as EC3 and rank4 ECs as EC4 for the analysis.

score has well identified the level of changes in the employment centers, it is unclear whether or not other types of change patterns exist among the employment centers. Although, Leslie (2010), using tracts rather than grid-cells to identify the employment centers as well as their differences in Phoenix metropolis, in fact, have identified new center, contiguous center, declined center, and unimportant center between 1995 and 2004. The author has found that since the differences in the employment centers are very small, area has increased in all identified employment centers. Additionally, the author has also investigated the dynamics of the economic system and found a great difference not only in the average employment but also in the density of employment and establishments of the identified centers. The author stated that “while there are important similarities among centers, they are hardly identical.” (page.229). Therefore, it is worthwhile investigating the identified ECs through this research to further reveal the change patterns between 1999 and 2009 in case of TMA to see whether all the identified ECs have increased or decreased in area as well as total employment and density, or stayed unchanged.

To identify the spatial pattern change of the ECs, the following equation was used:

$$C_i = ({G^t}_i - {G^{t-1}}_i) \qquad (12)$$

Where, i = Specific EC; G^t = number of Grid-cells of the current year and G^{t-1}= number of grid-cells of the previous year. Afterwards, the ECs were overlaid to explore the differences in the total number of grid-cells. The area of the grid-cells were then calculated to identify the change patterns of ECs in differnet ranks-

$$A_i = (G_i * A_{d_i}) \quad (13)$$

Where, G_i= the total number of grid-cells of i-th EC; and A_{d_i}= area of each grid-cell in i-th EC. Here, $A_i = 0$ is considered as no change, $A_i < 0$ is considered as decreased and $A_i > 0$ is considered as increased in the total number of grid-cells. Summary statistics of the ECs in different ranks and their total employment, average density and area are presented in Appendix B.

Between 1999 and 2009, nine specific spatial patterns in the ECs can be identified within the three change status – Extended; Emerged; Joined; and ranked Up ECs have increased in area whereas shrinking; decline, separated and ranked down the area of ECs have decreased. Affix to that, the area of ECs those have stayed static falls within the no change status (see table 6.11 for definitions).

Figure 6.11 visually illustrates the location of the identified nine spatial pattern types of the ECs in different ranks by prefectures for the ten-year period in distance bands, 40 ECs at 20km, 54 ECs at 30km, 102 ECs at 50km, 68 ECs at 100km and 27 ECs over 100km distance bands. In case of change patterns, a significant number of ECs of the no change, extended and shrinking were revealed in the suburban areas at the 50km-100km distance. Same was also identified at the 20km-30km distance. Although the mentioned three change patterns were simultaneously occurring in the core areas and suburban areas, no change and extended change patterns stands out.

Table 6.11: Change patterns of the ECs by prefectures, 1999-2009.

	Change patterns	Definitions
1	*Emerged*	*Non-center locations become a new center*
2	*Decline*	*ECs in 1999 became no longer ECs*
3	*Extended*	*ECs extended its area to previously non-center locations*
4	*Shrinking*	*ECs in 1999 became smaller in size*
5	*Joined*	*Consolidation of two neighboring ECs*
6	*Separated*	*One EC became disconnected*
7	*Rank up*	*The rank of EC became higher*
8	*Rank down*	*Higher ranked ECs become lower ranked ECs*
9	*No change*	*The size of the ECs remain unchanged*

Table 6.12: Total employment and average density of ECs ≥1km^2 and the rest of the identified ECs (i.e., the main center of EC2, EC3 and EC4, and those location that were surrounding the ECs ≥ 1km^2) (hereafter abbreviated as RECs).

Employment center ≥ 1km² ECs					Rest of the identified ECs				
Total Employment					Total Employment				
Year 1999	**EC1**	**EC2**	**EC3**	**EC4**	**Year 1999**	**REC1**	**REC2**	**REC3**	**REC4**
Tokyo-to	4,021,232	163,206	470,033	69,888	**Tokyo-to**	324,458	579,638	1,200,317	1,408,863
Saitama	58,736	71,021	179,437	404,685	**Saitama**	48,416	28,032	110,555	680,413
Kanagawa	315,257	108,780	364,068	359,743	**Kanagawa**	141,948	124,994	287,963	951,000
Chiba	58,681	88,460	108,135	377,564	**Chiba**	83,749	**-376**	117,340	316,034
Ibaraki	0	39,086	18,234	219,948	**Ibaraki**	8,679	**-8,858**	50,426	51,132
Tochigi	0	43,484	12,257	123,481	**Tochigi**	15,322	**-15,322**	16,034	146,265
Gunma	0	0	86,419	136,741	**Gunma**	0	28,791	**-9,542**	133,900
Year 2009	**EC1**	**EC2**	**EC3**	**EC4**	**Year 2009**	**REC1**	**REC2**	**REC3**	**REC4**
Tokyo-to	4,522,355	170,138	478,907	89,714	**Tokyo-to**	396,799	634,250	1,240,798	1,523,745
Saitama	72,885	61,821	182,292	391,982	**Saitama**	57,306	40,708	130,272	732,056
Kanagawa	360,282	150,689	417,604	381,127	**Kanagawa**	194,023	104,255	289,705	994,903
Chiba	62,840	97,459	118,705	387,448	**Chiba**	89,149	**-4,812**	115,485	337,518
Ibaraki	0	33,789	14,072	226,650	**Ibaraki**	10,802	**-7,256**	45,909	46,966
Tochigi	0	41,411	11,062	122,632	**Tochigi**	12,641	**-12,641**	15,986	145,425
Gunma	0	18,430	54,746	101,411	**Gunma**	0	10,546	10,553	155,498

Table 6.12: continued.

Average Density (ECs)					Average Density (RECs)				
Year 1999	**EC1**	**EC2**	**EC3**	**EC4**	**Year 1999**	**REC1**	**REC2**	**REC3**	**REC4**
Tokyo-to	58,544	23,739	9,593	3,251	**Tokyo-to**	32,244	14,312	7,760	3,087
Saitama	39,158	21,853	9,765	3,157	**Saitama**	35,212	10,194	5,896	2,851
Kanagawa	43,862	24,173	10,237	3,680	**Kanagawa**	32,915	13,513	6,160	2,844
Chiba	39,120	25,734	12,271	3,283	**Chiba**	35,263	**-201**	6,258	2,577
Ibaraki	0	22,335	11,221	3,355	**Ibaraki**	27,771	23,621	8,675	1,810
Tochigi	0	21,083	9,339	2,831	**Tochigi**	27,239	27,239	7,126	2,962
Gunma	0	0	10,887	3,325	**Gunma**	0	20,029	**-21,810**	2,719
Year 2009	**EC1**	**EC2**	**EC3**	**EC4**	**Year 2009**	**REC1**	**REC2**	**REC3**	**REC4**
Tokyo-to	66,383	24,974	10,082	3,476	**Tokyo-to**	39,190	15,034	7,973	3,300
Saitama	48,590	26,030	10,023	3,211	**Saitama**	38,204	12,771	6,724	3,020
Kanagawa	56,515	30,519	11,325	3,826	**Kanagawa**	37,858	12,356	6,197	2,962
Chiba	41,893	27,846	13,375	3,268	**Chiba**	35,659	**-3,208**	6,098	2,792
Ibaraki	0	20,023	8,660	3,444	**Ibaraki**	24,690	29,024	8,347	1,606
Tochigi	0	20,078	8,429	2,924	**Tochigi**	25,282	25,282	6,913	2,905
Gunma	0	18,430	8,422	2,847	**Gunma**	0	16,873	5,628	2,780

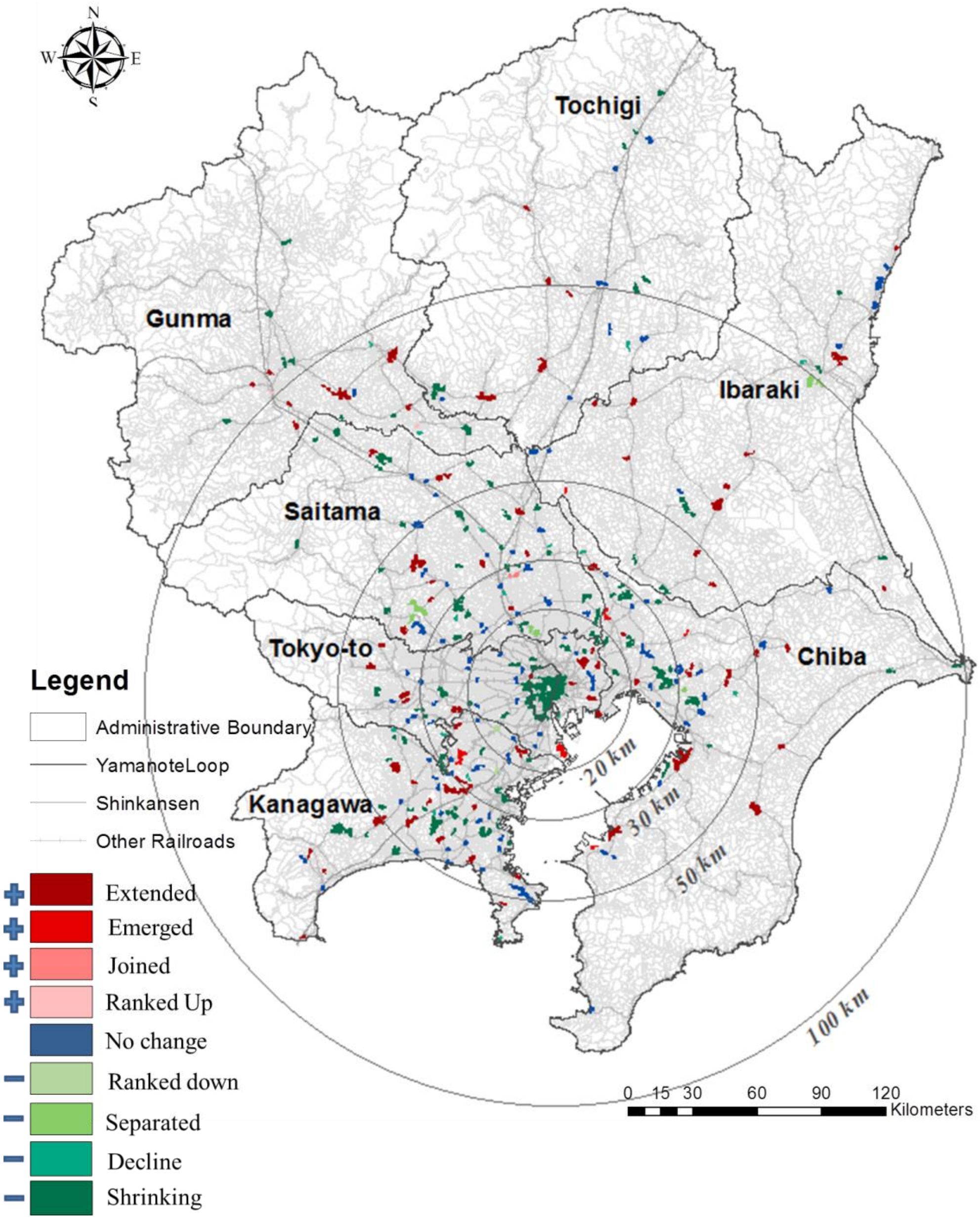

Figure 6.11: The detected nine change patterns of the ECs by prefectures, 1999-2009.

Table 6.13 gives the distribution of the ECs in these identified nine spatial pattern types by prefectures. The table illustrates that about 29% of the area in ECs have increased whereas 39% of the ECs have decreased in area. In addition, about 31% of the ECs stayed unchanged. Overall, between 1999 and 2009, 68%

of the area of ECs has changed (564.44 km^2) and a great number of ECs have lost areas (326.56 km^2); only 165.92 km^2 of area in the ECs showed no change. In prefecture level, area of the ECs have greatly change in Tokyo-to (121.08 km^2) followed by Saitama (109.82 km^2), Kanagawa (108.28km^2) and Chiba (97.42 km^2). In case of no change, Kanagawa stands out (39.6 km^2) followed by Chiba (35.09 km^2), Saitama (34.4km^2) and Tokyo-to (27.01 km^2). In case of Ibaraki, Tochigi and Gunma, a total of 127.84 km^2 areas in the ECs have changed compared to their unchanged areas (29.82 km^2). These signify that changes in the ECs have occurred in most of the prefectures between 1999 and 2009 and the proportion is higher than the unchanged areas. Regarding the change patterns, among the nine categories in the distribution of employment in the ECs, No change (31%), Shrinking (31%), and extended (25%) stands out between 1999 and 2009. Besides, a substantial number of ECs of the mentioned three categories were identified located in the prefectures of Saitama, Kanagawa, Chiba and Tokyo-to. In prefecture level, whereas Saitama holds most of the shrinking ECs, Kanagawa holds most of the extended and no change patterns of the ECs. Besides, Chiba has a great number of extended and no change patterns of the ECs than the Tokyo-to and Saitama. Also, 11 ECs were identified in Ibaraki, same as Tokyo-to. Additionally, three new ECs have emerged in Chiba. These indicates that although ECs in the prefecture level are shrinking, a substantial number of ECs become concentrated and denser as well as increased in area between 1999 and 2009 both in the core areas and in the suburban areas of TMA. The identified nine pattern changes in the ECs are discussed in the latter section.

Table 6.13: Change pattern types of the ECs by prefectures, 2009.

	Spatial pattern types of ECs in different ranks by prefectures										
Status	Pattern types	Tokyo-to	Saitama	Kanagawa	Chiba	Ibaraki	Tochigi	Gunma	Total	Percentage (%)	Percentage total (%)
Increased	*Extended*	11	10	16	13	11	5	8	74	25%	29%
	Emerged	1	0	1	3	1	0	0	6	2%	
	Joined	0	1(-1)	0	0	0	0	0	1(-1)	1%	
	Rank up	0	0	0	0	0	0	2	2	1%	
No Change	***No change***	**18**	**19**	**23**	**18**	**7**	**7**	**1**	**93**	**31%**	**31%**
Decreased	*Shrinking*	14	26	19	14	6	6	8	93	31%	39%
	Decline	2	4	4	2	1	1	2	16	5%	
	Separated	0	2(+2)	0	1(+1)	1(+1)	0	0	4(+4)	1% (+1%)	
	Rank down	0	0	2	0	0	0	0	2	1%	

6.5 Analysis of the change patterns

6.5.1 Emerged ECs

In the ten-year period, several non-center locations became new employment dense areas. These types of ECs were defined as emerged or new ECs, and added an area of +16.51km^2 in total to the TMA. Table 6.14 gives the type of new ECs in prefectures: out of 6 ECs, three are located in Chiba, one in Ibaraki, one in Tokyo-to, and another in Kanagawa. Additionally, the Emerged ECs show remarkable growth in employment as well as in average density. Furthermore, the emerged ECs became more concentrated and dense between 1999 and 2009. Appendix C presents the location of the emerged ECs where except Tokyo-to, new centers were appeared in suburban areas of Kanagawa, Chiba and Ibaraki at 30-50 km distance bands. Despite that the emerged ECs are small in number, they play an important role in attracting businesses to agglomerate and keeping further development prospects.

Table 6.14: Characteristics of the Emerged ECs by prefectures, 1999-2009.

Prefectures	Rank (ECs)	Center ID	Area(km^2)	Total employment	Average density
Tokyo-to	EC4	34	5.25	19,483	3,711
Kanagawa	EC4	12	5.00	22,610	4,522
Chiba	EC4	7	3.00	8,641	2,880
	EC4	15	1.13	5,502	4,890
	EC4	48	1.13	2,273	2,020
Ibaraki	EC4	17	1.00	2,718	2,718

6.5.2 Declined ECs

The declined ECs are those disappeared or P-value increased in this ten-year period. This type of ECs is found in most prefectures, and mean a total area of -18.32km^2 became extinct. Appendix C shows the specific ECs that have dropped out in the ten years of transition. A total of 16 ECs were found to have declined between 1999 and 2009. At the prefecture level, Saitama and Kanagawa lost eight ECs in total, Tokyo-to, Chiba, and Gunma lost six ECs in total, and Ibaraki, and Tochigi lost two ECs in total (Table 6.15). In addition, most of the declined ECs were identified in the suburban areas (Appendix C).

Table 6.15: The declined ECs by prefectures, 1999-2009.

Prefectures	Center ID	Rank (ECs)		Total employment		Area(km^2)		Average density	
		1999	2009	1999	2009	1999	2009	1999	2009
Tokyo-to	16	EC4	-	1,884	0	1	0	1,884	0
	35	EC3	-	15,533	0	1.06	0	14,619	0
Saitama	19	EC4	-	2,199	0	1.13	0	1,955	0
	22	EC4	-	3,137	0	1.06	0	2,952	0
	40	EC2	-	13,368	0	1	0	13,368	0
	50	EC4	-	1,759	0	1.25	0	1,407	0
Kanagawa	1	EC3	-	9,716	0	1	0	9,716	0
	23	EC4	-	3,130	0	1.38	0	2,277	0
	29	EC4	-	3,042	0	1	0	3,042	0
	64	EC4	-	4,901	0	1.38	0	3,564	0
Chiba	1	EC4	-	2,357	0	1.06	0	2,218	0
	32	EC4	-	2,387	0	1	0	2,387	0
Ibaraki	9	EC4	-	2,742	0	1.06	0	2,581	0
Gunma	3	EC4	-	2,651	0	1.06	0	2,495	0
	20	EC4	-	3,624	0	1.13	0	3,221	0
Tochigi	14	EC4	-	2,557	0	1.75	0	1,461	0

6.5.3 Extended ECs

Another type of EC was found to have expanded into nearby non-center locations. This type of spatial pattern in the ECs was found to be located in most of the prefectures in significant numbers. A total of 76 ECs were found to be of this type (table 6.16). Figure 6.12 shows the selection criteria of the extended ECs where total grid-cell > 0 is considered. Among the prefectures, the highest number of extended ECs was in Chiba followed by Kanagawa, Tokyo-to and Ibaraki, Saitama, Gunma and Tochigi. These ECs were extended in three ways and table 6.15 presents the three types of ECs that extended in the prefectures.

1) ECs that increased in area, total employment, and density: ECs those have shown an absolute increase in area, total employment and density were categorized as the 1st type of extended ECs. This type of ECs have concentrated and become denser and increased in size. In prefecture level, most of the extended ECs (1st type) appeared in Kanagawa, followed by Tokyo-to, Chiba and Saitama. Besides, appendix C represents the location of the ECs where a great number of extended ECs (1st type) were identified within the 20km distance band. On the other hand, most of the extended ECs (1st type) were found located in the 50km distance band in Kanagawa; and in case of Chiba most of the extended ECs (1st type) were found located within the 30-50 km distance bands. These indicate that while the core area of Tokyo-to becoming an important place for business to agglomerate, suburban locations of the Kanagawa and Chiba prefectures become important locations for businesses to flourish. On the other hand, although the number of extended ECs (1st type) are small in number and located at the suburban areas of Saitama, Ibaraki, Tochigi and Gunma, such ECs are the potential locations for employment concentration and future development in those areas.

2) ECs that grew in an area but decreased in employment and density: The 2nd type of emerging ECs was identified have lost both employment and density in the given period which illustrates a de-concentration trend in those ECs. In prefecture level, the extended ECs (2nd type) was identified in great numbers, specifically, in Ibaraki, Gunma and Tochigi. In Tokyo-to, the number of such ECs are less than its neighboring prefectures. Besides, most of the ECs (2nd type) were located within the 50km to 100km distance bands (appendix C) and near to the railway and highway corridors and junctions.

3) Either employment or density has decreased: the 3rd type of extended ECs was small in number and identified in five prefectures; Tokyo-to, Kanagawa, Saitama, Chiba and Gunma. This type of ECs was found located in the suburban areas of the mentioned five prefectures and shows an interesting growth trend. Most of the 3rd type of extended ECs becomes concentrated however density has decreased. These type of ECs are in the process of de-concentration of economic activities to its nearby ECs.

In addition, in most of the prefectures, the 2nd type of extended ECs increased more in area (0.06-1.13km^2) than the 1st type of extended ECs (0.06 to 0.75km^2) which signifies a high level of de-concertation of employment activities from those ECs to other locations.

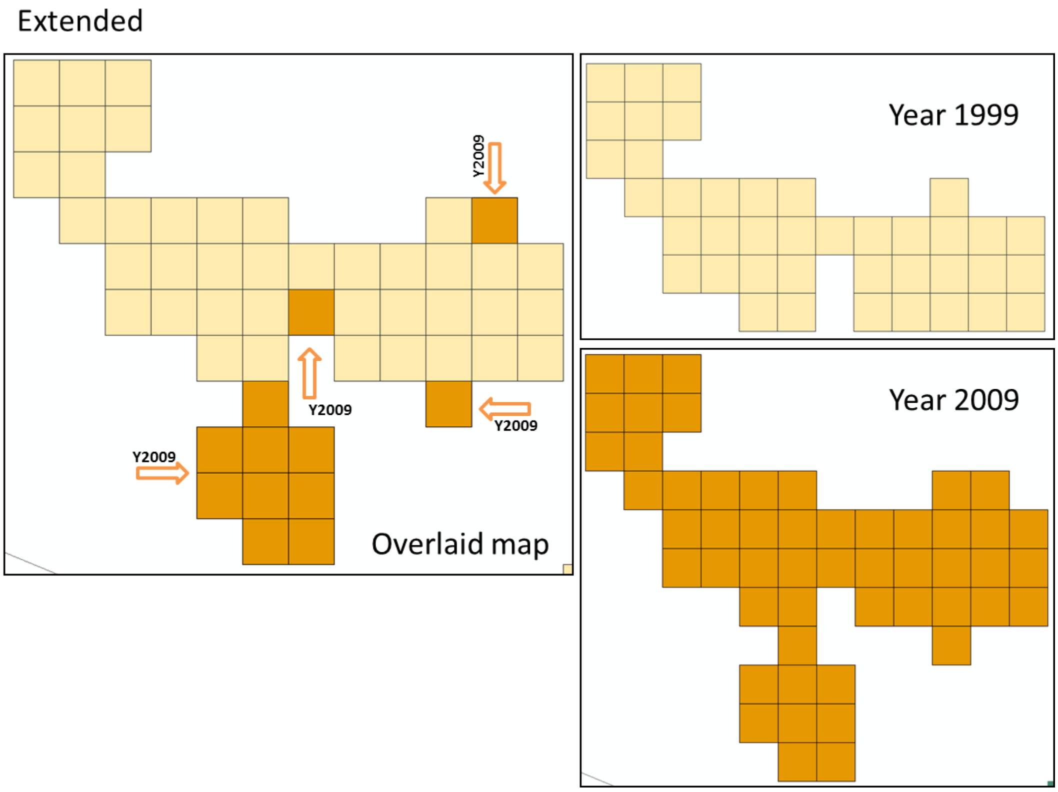

Figure 6.12: Selection criteria of extended ECs.

Table 6.16: the two types of extended ECs by prefectures, 1999-2009. (excluding New ECs)

Tokyo -to				
Center ID	Types	Total employment	Average density	Area (km^2)
1	2nd	**(3,114)**	**(2,289)**	0.06
2	3rd	867	**(73)**	0.31
7	2nd	**(822)**	**(910)**	0.06
8	1st	911	111	0.06
15	1st	629	90	0.13
31	1st	2,792	413	0.06
36	1st	10,163	5,446	0.06
37	1st	3,144	700	0.13
39	2nd	**(971)**	**(1,013)**	0.06
40	1st	776	162	0.06
41	1st	1,318	160	0.06
Saitama				
Center ID	Types	Total employment	Average density	Area (km^2)
3	2nd	**(1,051)**	**(473)**	0.06
8	2nd	**(537)**	**(181)**	0.06
17	3rd	161	**(100)**	0.13
24	2nd	**(487)**	**(483)**	0.06
28	1st	248	14	0.06
34	2nd	**(280)**	**(59)**	0.06
37	1st	909	312	0.19
43	2nd	**(1,620)**	**(2,352)**	0.13
45	2nd	**(525)**	**(3,076)**	0.13
48	1st	1,681	556	0.06
Kanagawa				
Center ID	Types	Total employment	Average density	Area (km^2)
4	1st	3,352	1,331	0.06
8	1st	9,962	1,118	0.75
18	1st	1,953	358	0.06
19	1st	263	88	0.06
24	1st	2,367	86	0.38
26	1st	2,397	1,414	0.06
30	1st	450	199	0.06
35	2nd	**(1,622)**	**(675)**	0.25
44	1st	341	0	0.13
45	2nd	**(610)**	**(298)**	0.25
55	3rd	1,324	**(584)**	0.44
57	2nd	**(3,135)**	**(3,304)**	0.13
58	2nd	**(1,361)**	**(853)**	0.06
60	1st	993	809	0.06
63	1st	431	227	0.06
65	2nd	**(312)**	**(481)**	0.06

Chiba				
Center ID	Types	Total employment	Average density	Area (km^2)
2	2nd	**(900)**	**(387)**	0.13
12	1st	522	166	0.13
17	1st	3,816	1,870	0.06
23	2nd	**(202)**	**(374)**	0.13
24	1st	1,360	449	0.13
26	1st	6,852	2,387	0.13
31	2nd	**(2,861)**	**(1,065)**	0.44
33	1st	554	210	0.06
35	2nd	**(1,013)**	**(1,889)**	0.19
41	1st	391	81	0.06
42	3rd	1,132	**(71)**	0.63
45	2nd	**(1,779)**	**(450)**	0.13
46	2nd	**(342)**	**(359)**	0.5
Ibaraki				
Center ID	Types	Total employment	Average density	Area (km^2)
1	2nd	**(616)**	**(943)**	0.13
7	2nd	**(1,180)**	**(250)**	0.13
10	2nd	**(93)**	**(347)**	0.19
11	2nd	**(679)**	**(357)**	0.06
12	2nd	**(667)**	**(691)**	0.13
13	2nd	**(365)**	**(360)**	0.06
19	1st	1,521	642	0.06
20	2nd	**(1,404)**	**(380)**	0.19
22	1st	1,305	573	0.06
24	2nd	**(90)**	**(135)**	0.06
26	1st	386	165	0.06

Gunma				
Center ID	Types	Total employment	Average density	Area (km^2)
4	2nd	**(1,431)**	**(281)**	0.13
7	1st	917	383	0.13
8	3rd	50	**(137)**	0.06
10	1st	178	14	0.06
11	2nd	**(51)**	**(157)**	0.06
12	2nd	**(2,134)**	**(326)**	0.06
15	2nd	**(42)**	**(114)**	0.06
18	2nd	**(5,417)**	**(3,610)**	0.06
Tochigi				
Center ID	Types	Total employment	Average density	Area (km^2)
6	2nd	**(505)**	**(527)**	0.06
7	2nd	**(347)**	**(425)**	0.13
8	1st	686	355	0.06
15	2nd	**(1,301)**	**(358)**	0.13
17	2nd	**(1,661)**	**(401)**	0.25

6.5.4 Shrinking ECs

In opposition to the extended ECs, several ECs decreased in size during the period 1999-2009, and were defined as shrinking ECs. Figure 6.13 illustrates the criteria used to define shrinking ECs those with an area < 0. A total of 93 shrinking ECs were found in the prefectures, but most were found located in the Saitama, Kanagawa, Chiba and Tokyo-to prefectures (Table 6.13). Appendix C gives the locations that decreased in the ten-year period. These data indicate that while some locations in the Tokyo-to, Kanagawa, Saitama and Chiba have increased in employment and became denser as previously mentioned, some locations are shrinking. Moreover, in the ECs, three types of shrinkage were found relating to total employment and density

Firstly, *the employment and density were increased despite shrinkage of the ECs in size:* This type of ECs become more concentrated and denser despite shrinkage in area. Most of the high ranked ECs specifically, EC1s and EC2s are located at the core areas of the TMA falls within this category. Note that compare to other types of ECs the shrinking ECs (1st type) are located within close distance. In prefecture level, Kanagawa has the highest number of shrinking ECs followed by Saitama and Tokyo-to. In contrary, Chiba, Ibaraki and Tochigi have fewer shrinking ECs of such type (table 6.18). Moreover, Tokyo-to has the highest number of shrinking ECs (1st type) and they were located within 20km distance. On the other hand, shrinking ECs (1st type) in Kanagawa, Saitama, Chiba and Ibaraki were found within the 30 to 50 km distance whereas over 100 km distance band in Tochigi. No shrinking ECs (1st type) were identified in Gunma between 1999 and 2009 (Appendix C).

Secondly, *the size of the EC as well as the average density and total employment were identified as simultaneously decreasing:* this type of ECs were considered as real shrinking areas in a given period. Note that, most of the shrinking ECs (2nd type) were located to nearby highly concentrated and dense ECs in prefectures such as Tokyo-to, Saitama, Kanagawa, Chiba and Ibaraki at the 30km to 50km distance bands (Appendix C). In addition to that, most of the 2nd type of ECs were located in the Saitama prefecture (13) followed by Gunma (7) and Kanagawa (6) (table 6.18).

And thirdly, *despite the shrinkage of the ECs in size, density or total employment were identified as either increasing or decreasing over the ten-year period*: this type of shrinking ECs are small in number and located in Tokyo-to, Kanagawa, Saitama, Chiba, Ibaraki and Gunma. Opposite to extended ECs (3rd type), rather than density, total employment has decreased in shrinking ECs (3rd type) as shown in the table 6.17. This may have been significantly affected by the composition change in different business sectors, which would also take into account the size of the ECs (Kane, Hipp, & Kim, 2016).

Table 6.17: The differences between Extended ECs (3rd type) and Shrinking ECs (3rd type), 1999-2009.

	Extended ECs (3rd type)	Shrinking ECs (3rd type)
Total Employment	+	-
Employment Density	-	+
Area (km^2)	+	-

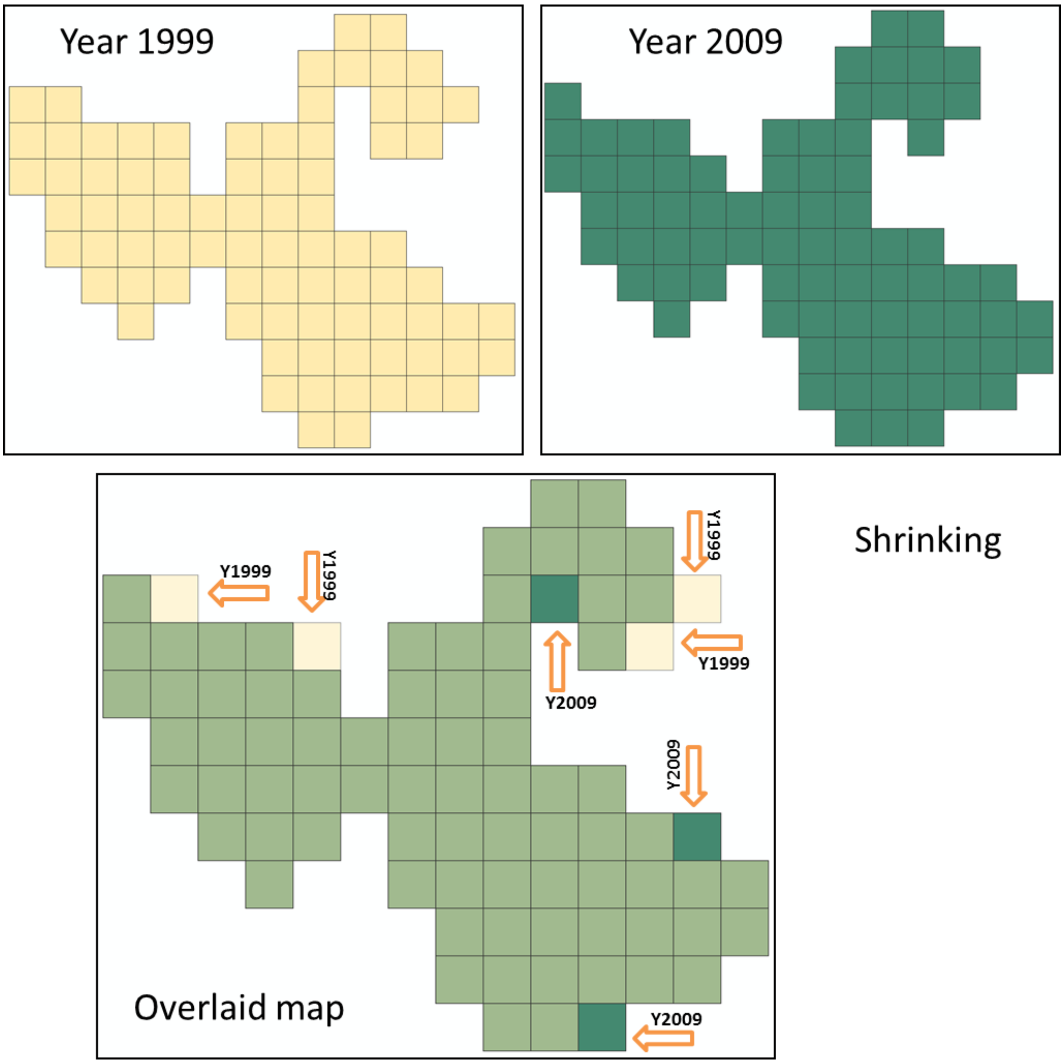

Figure 6.13: Selection criteria for the shrinking ECs over space.

Table 6.18: The number of ECs in two types of shrinkage by prefectures, 1999-2009.

Tokyo-to				
Center ID	Types	Total Employment	Density	Area (km^2)
3	2nd	**-495**	**-63**	**-0.13**
9	1st	127	768	**-0.25**
12	1st	3,678	3,327	**-0.06**
18	1st	3,196	3,357	**-0.13**
23	3rd	**-518**	346	**-0.13**
25	1st	648	822	**-0.13**
29	3rd	**-976**	45	**-0.06**
30	1st	26,559	12,576	**-0.19**
32	1st	4,138	3,010	**-0.01**
42	1st	425	1,372	**-0.13**
44	1st	2,942	1,235	**-0.13**
46	1st	449,212	7,918	**-0.5**
Saitama				
Center ID	Types	Total Employment	Density	Area(km^2)
1	2nd	**-1,750**	**-473**	**-0.06**
2	1st	106	338	**-0.13**
4	2nd	**-960**	**-96**	**-0.13**
5	2nd	**-1,748**	**-809**	**-0.19**
7	2nd	**-1,072**	**-343**	**-0.13**
11	2nd	**-952**	**-404**	**-0.06**
12	1st	552	224	**-0.06**
14	3rd	**-98**	526	**-0.38**
15	2nd	**-536**	**-123**	**-0.06**
16	2nd	**-328**	**-70**	**-0.06**
18	2nd	**-247**	**-24**	**-0.06**
20	1st	102	366	**-0.13**
23	3rd	**-1,071**	153	**-0.13**
26	3rd	**-91**	59	**-0.06**
29	2nd	**-324**	**-76**	**-0.06**
30	1st	716	630	**-0.13**
31	1st	258	699	**-0.25**

36	2nd	**-980**	**-606**	**-0.06**
42	1st	430	191	**-0.06**
44	1st	1,428	274	**-0.19**
46	2nd	**-1,427**	**-115**	**-0.25**
51	2nd	**-1,005**	**-387**	**-0.06**
52	1st	1,535	686	**-0.06**
57	1st	1,257	598	**-0.06**
59	1st	322	419	**-0.44**
60	2nd	**-1,483**	**-390**	**-0.06**
Kanagawa				
Center ID	Types	Total Employment	Density	Area(km^2)
2	2nd	**-4,099**	**-1,932**	**-0.25**
3	1st	171	689	**-0.13**
9	1st	16,029	14,554	**-0.06**
11	1st	8,042	5,925	**-0.06**
17	1st	104	238	**-0.06**
25	1st	65,311	18,133	**-0.69**
27	1st	2,103	450	**-0.06**
31	1st	587	721	**-0.06**
32	3rd	**-101**	49	**-0.06**
33	1st	666	963	**-0.06**
36	3rd	**-32**	99	**-0.19**
37	3rd	**-5**	141	**-0.06**
40	1st	4,087	2,440	**-0.13**
41	1st	3,354	2,362	**-0.13**
42	1st	708	410	**-0.38**
47	3rd	**-688**	281	**-0.13**
48	3rd	**-137**	39	**-0.06**
51	2nd	**-4,229**	**-351**	**-0.25**
52	1st	47	214	**-0.06**

Chiba				
Center ID	Types	Total Employment	Density	Area(km^2)
4	2nd	**-1,631**	**-717**	**-0.13**
5	3rd	**-113**	39	**-0.06**
6	1st	3,663	603	**-0.06**
10	3rd	296	**-117**	**0.13**
11	3rd	**-199**	834	**-0.13**
13	2nd	**-1,316**	**-257**	**-0.06**
16	1st	2,356	2,251	**-0.13**
19	1st	1,709	206	**-0.25**
21	1st	2,000	1,609	**-0.06**
28	3rd	**-1,021**	156	**-0.75**
37	2nd	**-571**	**-191**	**-0.06**
38	2nd	**-2,723**	**-982**	**-0.06**
40	1st	876	1,086	**-0.06**
43	1st	793	327	**-0.13**
Ibaraki				
Center ID	Types	Total Employment	Density	Area(km^2)
5	3rd	**-120**	142	**-0.13**
8	2nd	**-5,297**	**-2,312**	**-0.06**
17	3rd	**-540**	194	**-0.38**
21	1st	8,463	1,313	**-0.19**
23	1st	236	176	**-0.06**
25	2nd	**-697**	**-260**	**-0.06**

Tochigi				
Center	Types	Total Employment	Density	Area(km^2)
1	1st	466	295	**-0.06**
2	2nd	**-538**	**-325**	**-0.06**
4	1st	881	850	**-0.06**
10	1st	1050	565	**-0.19**
11	1st	4838	2083	**-0.06**
19	2nd	**-969**	**-73**	**-0.13**
Gunma				
Center ID	Types	Total Employment	Density	Area(km^2)
1	2nd	**-1,742**	**-657**	**-0.06**
2	2nd	**-1,068**	**-350**	**-0.06**
5	2nd	**-4,185**	**-1,623**	**-0.06**
6	2nd	**-2,192**	**-1,002**	**-0.06**
14	2nd	**-711**	**-534**	**-0.06**
16	2nd	**-1,172**	**-385**	**-0.13**
17	3rd	**-534**	11	**-0.19**
21	2nd	**-1,412**	**-294**	**-0.06**

6.5.5 Joined ECs

Another change pattern was detected in the ECs whereby two adjacent ECs joined together in this ten-year period. The joined-ECs increased in area by +1.13 km^2 and added +3035 in employment. However, despite the consolidation of center number 33 (EC4), a slight decrease in average density (-10) was noticed between 1999 and 2009 (Table 6.19). This type of change pattern type was only identified in Saitama prefecture at the 50km distance band (appendix C).

Table 6.19: Joined ECs between 1999 and 2009.

Center ID	Year	Rank(ECs)	Total employment	Area (km^2)	Average density
33	1999	EC4	3,227	1.19	2,717
	2009	EC4	6,262	2.31	2,708

6.5.6 Separated ECs

In contrasts to the joined-ECs, several ECs divided to become separate ECs in this ten-year period. Table 6.20 gives the distribution of such changes by prefectures, with Saitama holding two and Chiba and Ibaraki one. The Original ECs[19] of 1999 were separated into two in 2009. For example, in Saitama, center numbers 62 and 63 of the year 1999 were separated respectively into 62a & 62b, and 63a & 63b in 2009; center number 27 of Ibaraki separated into 27a & 27b; and in Chiba, center number 51 separated into 51a and 51b. Table 6.20 further shows the changes in the total employment, density and area in the original ECs (year 1999) and in the separated ECs[20] (year 2009). Moreover, this separation has occurred at both EC3 and EC4 levels. Moreover, table 6.19 also illustrates that the total employment, area, and average density has significantly decreased in the separated ECs between 1999 and 2009.

[19] Here the year 1999 was selected as the base year that was compared with the current year (2009) to detect the changes. Therefore, the ECs of 1999 were considered as original ECs.
[20] The ECs of the current year were considered as separated have also taken into account the changes in the area, total employment and average density.

Table 6.20: Original ECs of 1999 and separated ECs, 1999-2009.

Prefectures	Rank (ECs)	Year	ECs	Center ID	Area(km^2)	Total Employment	Density
Saitama	EC4	1999	Original EC	62	10.25	31,938	3,116
	EC3	1999	Original EC	63	4.25	41,252	9,706
	EC4	2009	Separated EC	62a	**(3.31)**	**(12,069)**	**(252)**
	EC3	2009	Separated EC	63a	**(1.75)**	**(14,670)**	926
	EC4	2009	Separated EC	62b	**(19,939)**	979	**(7.32)**
	EC3	2009	Separated EC	63b	**(14,671)**	926	**(1.75)**
Chiba	EC4	1999	Original EC	51	2.75	6,265	2,278
	EC4	2009	Separated EC	51a	**(1.38)**	**(2,188)**	687
	EC4	2009	Separated EC	51b	**(1.75)**	**(4,030)**	**(43)**
Ibaraki	EC4	1999	Original EC	27	6.75	21,268	3,151
	EC4	2009	Separated EC	27a	**(4.31)**	**(15,644)**	**(843)**
	EC4	2009	Separated EC	27b	**(2.44)**	**(4,883)**	648

6.5.7 Ranked up ECs

Another type of change pattern was detected where the rank of an EC became higher in the ten-year period. Hence, such change patterns were defined as *ranked up*. This type of change pattern was revealed in Gunma prefecture, where EC3 changed to EC2 and EC4 changed to EC3 (Table 6.21). Not only has the level of ECs changed but also their total employment, average density, and area. In the rank-up case, center number 9 (EC3 became EC2) and 19 (EC4 became EC3) have increased in total employment as well as in area, but their density has decreased between 1999 and 2009.

Table 6.21: Ranked-up ECs in the ten-year period.

Center ID	Ranked ECs		Total employment		Area (km^2)		Average density	
	1999	2009	1999	2009	1999	2009	1999	2009
9	EC3	EC2	29,092	18,430	2.38	1	12,249	18,430
19	EC4	EC3	19,644	9,211	3.31	1	5,930	9,211
	Change, 1999-2009							
Center ID	Ranked ECs		Total employment		Area (km^2)		Average density	
9	EC3	EC2	10,662		1.38		**(6,181)**	
19	EC4	EC3	10,433		2.31		**(3,281)**	

6.5.8 Ranked down ECs

In addition to the ranked up ECs, certain ranked down ECs were also identified. These ECs lost ranking from 1999 to 2009. Table 6.22 shows that such ECs were located in Kanagawa prefecture, where an EC2 changed to EC3, and an EC1 changed to EC2. Moreover, in the ranked-down case, center number 6 (EC2 became EC3), and center number 14 (EC1 became EC2) showed an exception in the case of total employment, area and average density. Note that despite the fact that an EC1 became a EC2 in the ten-year period, total employment and density increased in 2009. Also, total employment and area increased in center number 6 between 1999 and 2009. Such exceptional cases in total employment, density, and area appeared because of the ECs closeness to the CBD. Center number 14 was located at the 30km distance from the CBD at one of the major interchange railway stations of the TMA (Yokohama Station). In addition to that, a major railway line (Shinkansen) was found to pass through center number 14. Also, center number 6 was found to be close to the railway intersection within the 20km distance from the CBD, and experienced an increase in total employment and area. However, unlike center number 14, the average density of employment in center number 6 decreased.

Table 6.22: Rank-down ECs in the ten -year period.

		Level of ECs (Ranks)		1999-2009			
Prefectures	Types	Y1999	Y2009	Center ID	Area (km^2)	Total Employment	Density
Kanagawa	Rank down	EC2	EC3	6	1.13	12,372	**(4,108)**
		EC1	EC2	14	0.50	20,419	1,508

6.5.9 No Change in ECs

Lastly, the no change pattern was identified, where the size of the ECs remained unchanged. Figure 6.14 shows the selection criteria for such ECs. A total of 93 ECs were found to have remained unchanged, of which 23 were identified in the Kanagawa prefecture, followed by Tokyo-to (19), Saitama (19), Chiba (18), Ibaraki (7), Tochigi (7) and Gunma (1) (Table 6.12). Most of the no change ECs was found in the core as well as suburban areas. In this type of EC, total employment and average density have two variations. Firstly, *the total employment and average density increased*; and secondly, *either employment or density decreased even though the size of the EC showed no change between 1999 and 2009*. Table 6.23 shows the two types, and shows that a significant number of ECs of the 1st type were located in Kanagawa, followed by Tokyo-to, Saitama and Chiba. The first type of ECs was found in great numbers within the 20km to 30km distance bands in Kanagawa, Tokyo, Saitama and Chiba (appendix C). In the cases found in Ibaraki and Tochigi, the number of ECs of the 1st type was very small, and no ECs of the 1st type were found in Gunma. In prefecture level, out of 14 ECs, nine were located surrounding the central area of Tokyo-to which further contributes in densification of the core areas. Moreover, a very small number of ECs was found at the core areas of Kanagawa, Saitama and Chiba compared to their suburban areas.

Contrary to this pattern, the number of 2^{nd} type of ECs was considerably small in Kanagawa and Tokyo-to, where only 8 ECs of the 2^{nd} type were detected between 1999 and 2009. In the case of Saitama and Chiba, a total of 16 ECs of the

2nd type were identified, the highest among the prefectures, followed by Tochigi and Ibaraki. Only one EC of the 2nd type was identified in Gunma (Appendix C).

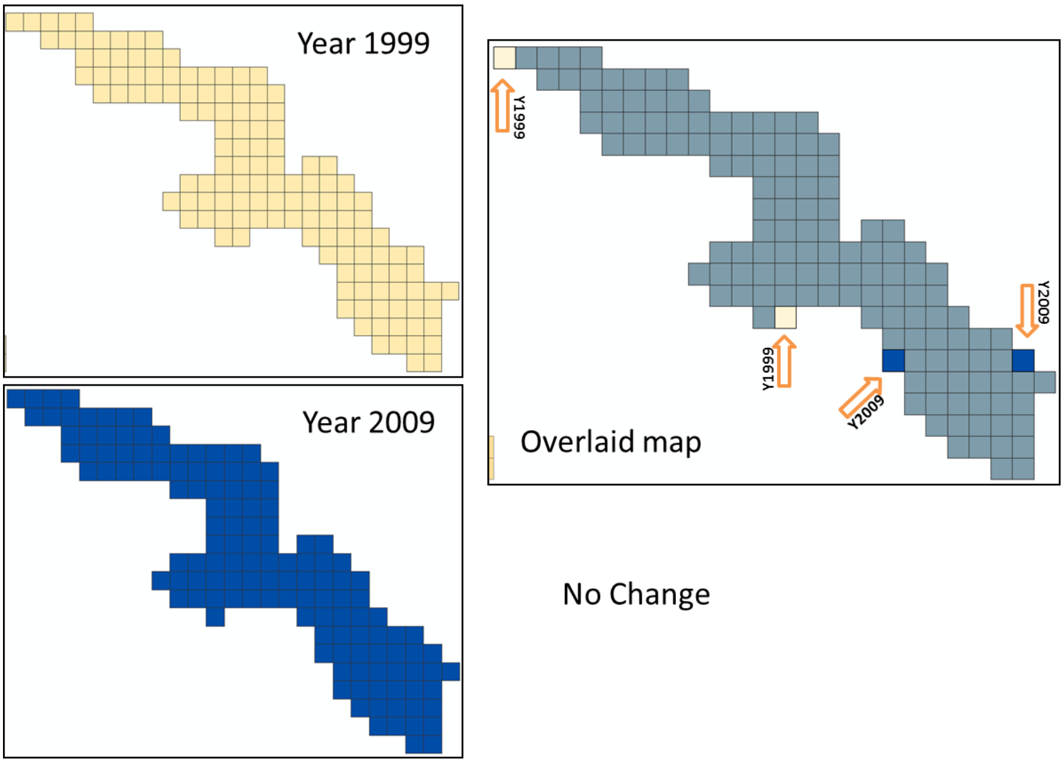

Figure 6.14: Selection criteria for the no change ECs.

Table 6.23: The number of ECs in two types of no change pattern by prefectures, 1999-2009.

Y1999-2009	1st type	2nd type
Tokyo-to	14	4
Saitama	10	8
Kanagawa	18	5
Chiba	10	8
Ibaraki	2	5
Gunma	0	1
Tochigi	1	6

6.6 Summary of the chapter

To summarize, the spatial pattern change analysis of the ECs signifies some interesting outcomes. The spatial pattern change analysis was conducted and presented in the chapter in two ways:

1) *Changes in the total employment and average density of the ECs between 1999 and 2009*: The analysis of the total employment and denisty have revealed that ECs became agglomerated; indicating that they became more attractive locations for business. Additionally, between 1999 and 2009 the total employment and average density in the ECs were found to have significantly varied at the prefecture level. In the case of total employment, whereas most of the ECs have showed an employment growth in Tokyo-to, a simultaneous increase and decrease in employment was found in Saitama, Ibaraki, Gunma and Tochigi prefectures. In the case of density, the ECs in different ranks of Tokyo-to, Saitama, Kanagawa, and Chiba became denser over the period. Added to that, Kanagawa, Saitama and Chiba became denser. Additionally, density has decreased in the ECs of Ibaraki and Tochigi, whereas the EC of Gunma recorded a great increase in density. These results indicate that not only the core areas of the TMA became denser; average density has also increased in some of the suburban areas.

2) Spatial pattern change analysis at the EC level, 1999-2009: Moreover, the spatial pattern change analysis revealed nine specific spatial patterns: (1) Emerged; (2) Declined; (3) Extended; (4) Shrinking; (5) ECs-Joined; (6) Separated; (7) Ranked-up; (8) Ranked-Down; and (9) No change. Such patterns signify that not only did the total employment, and density over time, but so did the spatial pattern at the ECs level. Additionally, no change (31%), shrinking (31%) and extended (25%) stands out among the nine change pattern types of the ECs. Besides, extended and no change patterns were found have the largest number of ECs those are located in the suburban areas between 1999 and 2009. Additionally, a significant number of shrinking ECs were found located in the Saitama, Kanagawa, Tokyo-to and Chiba prefectures, along with extended and no change ECs; in contrast to the pattern in Ibaraki, Tochigi and Gunma. Added to this, the highest number of shrinking ECs were detected in Saitama, whereas Kanagawa holds the highest number of extended and no change ECs. Although ECs in the prefecture level are found shrinking, ECs become concentrated and denser as well as increased in area between 1999 and 2009 both in the core areas and in the suburban areas of TMA. Further analysis of the nine change pattern types by prefectures revealed the locations of the specific change patterns of the ECs; specifically, different types of the no change, extended and shrinking change patterns between 1999 and 2009.

CHAPTER 7
SYNTHESIS AND CONCLUSIONS

7.1 Introduction

This chapter is divided into three sections. Section 7.2 presents a synthesis of the research findings discussed and analyzed in earlier chapters. The goal of this chapter is to summarize the insights derived from unveiling the spatial structure of employment in the TMA; specifically, to identify the spatial structure of employment and explore changes in the spatial pattern of the centers of employment in the Tokyo Metropolitan Area (TMA) between 1999 and 2009. This research proposed an alternative approach to studies of spatial structure that is generic and applicable to research studies in this field. Section 7.3 concludes the presentation of the achievements of the research study, and the limitations and future directions of the research are presented in Section 7.4.

7.2 Synthesis of the research findings

The results of this research are synthesized based on five aspects:

1) *Scale based analysis is more efficient in spatial structure studies as well as in selection of the employment centers*

The research investigated the spatial structure of employment in the Tokyo Metropolitan Area (TMA). In the beginning, a scale based analysis in combination with a LISA technique were used to address whether center size influences the spatial structure of employment in the TMA. A review of previous studies revealed that research on the identification and delineation of the spatial structure has neglected scale size issues. Therefore, this research selected five specific scale sizes (i.e., *250m by 250m or 0.0625* km^2*; 500m by 500m or 0.25* km^2*; 1000m by 1000m or 1* km^2*; 2000m by 2000m or 4* km^2*; and 3000m by 3000m or 9* km^2*),* and conducted center identification in one-order and second-order contiguity cases. It is revealed that employment centers can be identified effectively by comparing them with the immediate surrounding areas. Besides, this analysis found that the spatial structure is indeed sensitive to different scale sizes. That is, from a regional view the spatial structure of employment in Tokyo is observed to be monocentric, whereas the fine-scale view identified by this study showed a polycentric spatial structure in the TMA. Therefore, performing a scale size analysis beforehand would improve the research outcomes of spatial structure studies.

2) Grid Approach (GA) can better represent the spatial characteristics than the census tract boundaries (polygons)

Through this research not only the scale size issue could be investigated, but also the data analyzing process for the spatial structure studies could be tested. The research found that several scholarly articles identified fragmented spatial structure but did not undertake further investigation. A fragmented spatial structure was also revealed for the TMA by using census tract boundaries (polygons) as most previous studies did. Therefore, this research proposed a GA approach that represent these raw polygons as grid-cells. It was found that this method can better represent changes in the spatial trends of the distribution of employment as identified by the spatial boundaries of the employment centers, the growth directions of the employment structure, and the development of job centers over time than the use of census tracts

3) A rank based analysis can better understand the spatial structure of employment

In past studies, locations outside the CBD with high density and statistical significance were considered employment sub-centers of that area. And, a combination of methods was also used to identify employment centers. However, the criteria for center identification rarely changed (e.g., Small & Song, 1994, McMillen, 2003, Fernandez-Maldonado, Romein, Verkoren, & Perente Paula Pessoa, 2014). Thus, few studies were done based on rank hierarchies (i.e., on significance levels), and therefore most lacked the ability to explain the differences between each statistically significant area (Han, 2005; Riguelle, Thomas, & Verhetsel, 2007). This research fills the gap in the case where employment peaks are distributed inrank order over the region.

Moreover, development corridors were found to be multidirectional and located at the periphery of the historic downtown area of the TMA. Most of the upper ranked centers located outside 20km distance band were surrounded by lower ranked centers along the main railway networks and junctions. Besides, several high ranked centers were found to be located near to the CBD. This indicates that distance significantly influences the location of employment centers as well as the rank hierarchies involved.

4) The TMA's spatial structure of employment was unveiled by using fine scale and GA

The proposed scale based analysis using Grid-Approach (GA) analysis revealed the spatial structure of the TMA at different levels. The fine scale case showed that the regional spatial structure of the TMA was more polycentric than monocentric, and polycentric growth was visible both in the CBD and in the peripheral areas of the TMA. This was hardly recognized in earlier studies such as Fukuhara (1977), and Kikuchi and Obara (2004).

Moreover, a comparison of this study's identified employment centers ≥ $1km^2$ or ECs, and the centers decided by the 4th National Capital Region Development Plan (NCRDP) revealed differences in the number of centers, total employment, area, average density, employment share and rank hierarchies. Of the 32 recognized business centers in the 4th NCRDP, only 11 were found to be in the upper ranked centers with high concentration of employment found in this study which supports the use of GA. Moreover, the entire Waterfront sub metropolitan area and the area of Koshigaya were not recognized as ECs in 2009. Therefore, a scale based analysis in combination with GA can better capture the spatial structure of employment, and can therefore provide a better base for regional planning.

5) Different change patterns were identified systematically

To trace the change in each EC, the research provided identical numbers to each of them for the year 1999 and 2009. The analysis addressed nine specific spatial patterns among the ECs in different ranks, those of: (1) Emerged; (2) Declined; (3) Extended; (4) Shrinking; (5) ECs-Joined; (6) Separated; (7) Rank-up; (8) Rank-down; and (9) No change. Out of nine spatial patterns, a great numbere of ECs belong to no change, shrinking and extended ECs. Besides, a large number of shrinking ECs were located in the Saitama prefecture whereas Kanagawa holds most of the extended and no change ECs. In addition, further analysis has revealed different no change, shrinking and extended ECs between 1999 and 2009. The results can help local governments to recognize the dynamics of the centers, and can be further used to study the structure of the industrial sectors and their changes over time in a more precise manner (Goto & Okabe, 1998; Matsubara, 2014).

7.3 Conclusion: Research achievements

This research analyzed a significant problem related to urban structure studies. A careful review of the previous literature revealed that whereas a vast literature has focused on the identification and selection of employment centers based on thresholds, density peaks, commuting, and spatial econometrics as summarized in the paper of Garcia-López and Muñiz (2005), the impact of minimum center size as well as the range of surrounding areas that the observed location will be compared with has hardly been recognized. Moreover, research related to identification of employment centers in TMA has been limited. Therefore, through this research, a new approach considering the influence of scale sizes was proposed for spatial structure studies of areas like the TMA. Furthermore, the changes in the spatial pattern of the TMA employment centers between 1999 and 2009 were also explored.

The scale size analysis proved that an employment center is significantly influenced by the scale view, and thus it is very important to consider scale size analysis in spatial structure studies. Besides, the grid approach recommended in the identification of employment centers can better capture high-density employment peaks. The finest scale size and GA analysis revealed that both the traditional downtown area and the periphery are polycentric in the TMA, not monocentric. Also, the employment centers distributed in rank order are greatly influenced by distance from the CBD. Additionally, development corridors were revealed as being persistent in the high-ranked centers located in suburban areas. A comparison with the 4^{th}NCRDP identified centers further revealed the weaknesses in spatial planning in the TMA.

The identified employment centers were later investigated in terms of their change patterns. The analysis found dynamics of the ECs in TMA between 1999 and 2009.

The introduced GA approach can be applied to the metropolitan areas over the globe in employment distribution analysis. Besides, careful attention should be given in selection criteria of spatial scale sizes as well as in defining employment centers that differs based on the geographic location.

7.4 Limitations and future directions

This research further analyzed a very critical issue related to identifying changes in the intra-metropolitan spatial structure that has been highly discussed and debated since the post-war era. The characterization and delineation of employment centers has become necessary, and has been considered as the key geographic feature that will allow researchers and policy makers to understand an economic region. The research revealed that a scale size analysis in the selection of employment centers is necessary, and can improve spatial structure identification at the regional level.

However, the research is not final, and can be further extended in the following areas:

1) The research proposed an alternative approach to the selection of the employment centers that determine the spatial structure of a metropolitan area. The research proved that job centers are sensitive to scale size in the TMA at least. Although the employment distribution features the economic character of a region, further research should be extended to population distributions and other factors, so that a full picture of spatial structure can be revealed;

2) The research selected the ESDA technique to define the employment centers and their different ranks based on significance levels. Because the analysis focused on overall employment distribution in employment centers, information related to industry clusters has not been studied. Hence, further research should investigate further the agglomeration of specific industries in employment centers, as well as their specialization and co-located operations. For example, in the case

of the TMA, which industries have agglomerated in the top ranked centers and in other centers? Alternatively, which specific industry has the largest share in an identified employment center? Also, while the research found that distance from the CBD determined the location of the employment centers by rank hierarchy, it would be interesting to determine the relationships between specific industries and the rank of a center.

3) The research was conducted to identify employment centers and to reveal the distribution pattern of employment. Nine different spatial pattern changes were identified. However, this number is limited due to datasets being restricted to a short period of 10 years. Therefore, investigation of the spatial pattern of change should be conducted using a greater number of past and present census datasets on a longitudinal basis to observe whether the changes in spatial patterns that have occurred in the past years stand a real trend, or just a noise caused by the census system differences, etc., and how the speed of change has varied. In addition, it would be useful to identify which industry sectors tend to create particular spatial patterns. Nevertheless, this research provides a methodological exploration in analyzing spatial pattern changes.

To sum up, this study explored the pattern of employment centers that determine the intra-metropolitan spatial structure in the Tokyo Metropolitan Area. The complexity of urban dynamics needs careful and continuous observation for a precise understanding of the spatial structure at the regional level, thus the empirical approach proposed in this study and the findings of the present research can hopefully provide useful insights for both academic and regional planning practice, not only in the TMA but also across the world.

REFERENCES

Abe, Kazutoshi. (1996). Urban geography in postwar Japan. *Geographical Review of Japan, (Series B)*, 69 (1), 70-82.

Abe, Kazutoshi. (2008). The changing urban geography of Japan. *Geographical Review of Japan*, 81(5), 262-278.

Agarwal, Ajai, Giuliano, Genevieve, & Redfearn, Christian L. (2012). Strangers in our midst: The usefulness of exploring polycentricity. *The Annals of Regional Science*, 48(2), 433-450.

Ahlfeldt, Gabriel M., & Wendland, Nicolai. (2013). How polycentric is a monocentric city? Centers, spillovers, and hysteresis. *Journal of Economic Geography*, *13*(1), 53-83.

Alonso, William. (1964). *Location and land use: Towards a general theory of land rent*. Cambridge, MA: Harvard University Press.

Alpkokin, Pelin, Komiyama, Naohisa, Takeshita, Hiroyuki, & Kato, Hirokazu. (2007). Tokyo metropolitan area employment cluster formation in line with Its extensive rail network. *Journal of the Eastern Asia Society for Transportation Studies*, 7, 1403–1416.

Anas, Alex, Arnott Richard, & Small, Kenneth A. (1998). Urban spatial structure. *Journal of Economic Literature*, 36(3), 1426–1464.

An, Sang Kyung. (2008). Recentralization of central Tokyo and planning responses. *Journal of Regional Development Studies*, (11), 1–20.

Anselin, Luc. (1995). Local indicators of spatial association—LISA. *Geographical Analysis*, 27(2), 93–115.

Anselin, Luc. (1996). The moran scatterplot as an ESDA tool to assess local instability in spatial association. In Manfred Fischer, Henk J Scholten, & David Unwin (Eds.), *Spatial analytical perspectives on GIS: GISDATA 4* (pp. 111-125). London: Taylor & Francis.

Anselin, Luc, Syabri, Ibnu, & Kho, Youngihn. (2006). GeoDa: An introduction to spatial data analysis. *Geographical Analysis*, 38, 5-22.

Arbia, Giuseppe. (2001). The role of spatial effects in the empirical analysis of regional concentration. *Journal of Geographical Systems*, 3(3), 271-281.

Arribas-Bel, Daniel, & Sanz-Gracia, Fernando. (2014). The validity of the monocentric city model in a polycentric age: US metropolitan areas in 1990, 2000 and 2010. *Urban Geography*, 35(7), 980-997.

Ban, Jifei, Arnott, Richard, & Macdonald, Jacob L. (2017). Identifying employment subcenters: The method of exponentially declining cutoffs. *Land*, 6(17),1-33.

Baumont, Catherine, Ertur, Cem, & Le Gallo, Julie. (2004). Spatial analysis of employment and population density: The case of the agglomeration of Dijon 1999. *Geographical Analysis*, 36(2), 146–176.

Bertaud, Alain, & Malpezzi, Stephen. (2003). The spatial distribution of population in 48 world cities: Implications for economics in transition. Working Paper. Madison, WI: University of Wisconsin, Center for Urban Land Economics Research.

Berry, Brian J. L., & Kim, Hak-Min. (1993). Challenges to the monocentric model. *Geographical Analysis*, 25(1), 1-4.

Beaverstock, Jonathan V., Smith, Richard G., & Taylor, Peter J. (1999). A roster of world cities. *Cities*, 16(6), 445-458.

Bollinger, Christopher R., & Ihlanfeldt, Keith R. (2003). The intraurban spatial distribution of employment: which government interventions make a difference? *Journal of Urban Economics*, 53, 396-412.

Bontje, Marco, & Joachim, Burdack. (2005). Edge cities, European-style: Examples from Paris and the Randstad. *Cities*, 22(4), 317-330.

Böventer, Edwin. (1976). Transportation costs, accessibility, and agglomeration economies. *Papers in Regional Science*, 37(1), 167-183.

Brueckner, Jan K. (1979). A model of non-central production in a monocentric city. *Journal of Urban Economics*, 6, 444-463.

Burton, Ian. (1963). A Restatement of the dispersed city hypothesis. *Annals of the Association of American Geographers*, 53(3), 285-289.

Burgess, Ernest Watson. (1925). The growth of the city: an introduction to a research project. In Robert E. Park, Ernest W. Burgess & Roderick D. McKenzie (Eds.), *The city* (pp.47-62). Chicago: The University of Chicago Press.

Cervero, Robert, & Wu, Kang-Li. (1997). Polycentrism, commuting, and residential location in the San Francisco Bay area. *Environment and Planning A*, 29(5), 865-886.

Cervero, Robert, & Wu, Kang-Li. (1998). Sub-centering and commuting: evidence from the San Francisco Bay area, 1980-90. *Urban Studies*, 35(7), 1059-1076.

Cladera, Josep Roca, Duarte, Carlos R Marmolejo, & Moix, Montserrat. (2009). Urban structure and polycentrism: Towards a redefinition of the sub-centre concept. *Urban Studies*, 46(13), 2841-2868.

Coffey, William J., & Shearmur, Richard G. (2001). The identification of employment centres in Canadian metropolitan areas: The example of Montreal, 1996. *Canadian Geographer/ Le Geographe Canadien*, 45(3), 371-386.

Colby, Charles C. (1933). Centrifugal and centripetal forces in urban geography. *Annals of the Association of American Geographers*, 23(1), 1-20.

Craig, Steven G., & Ng, Pin T. (2001). Using quantile smoothing splines to identify employment subcenters in a multicentric urban area. *Journal of Urban Economics*, 49(1), 100–120.

Craig, Steven G., Kohlhase, Janet E., & Perdue, Adam W. (2016). Empirical polycentricity: The complex relationship between employment centers. *Journal of Regional Science*, 56(1), 25-52.

Cutsinger, Jackie, & Galster, George. (2006). There is no sprawl syndrome: A new typology of metropolitan land use patterns. *Urban Geography*, 27(3), 228-252.

De Dominicis, Laura, Arbia, Giuseppe, & De Groot, Henri LF. (2013). Concentration of manufacturing and service sector activities in Italy: Accounting for spatial dependence and firm size distribution. *Regional Studies*, 47(3), 405-418.

Doxiadis, Constantinos A. (1968). Ecumenopolis: Tomorrow's City. In Encyclopedia Britannica (Ed.), *Britannica book of the year 1968* (pp 14-38). Chicago: Encyclopedia Britannica, Inc.

Doxiadis, Constantinos A. (1969). The city (II): Ecumenopolis, world-city of tomorrow. *Impact of Science on Society*, 19(2), 179-193.

Ellickson, Bryan. (1971). Jurisdictional Fragmentation and Residential Choice. *The American Economic Review*, 61(2), 334-339.

Erickson, Rodney A., & Gentry, Marylynn. (1985). Suburban nucleations. *Geographical Review*, 75(1), 19-31.

Erickson, Rodney A. (1986). Multinucleation in metropolitan economies. *Annals of the Association of American Geographers*, 76(3), 331-346.

Escamilla, Jorge Montejano, Cos, Camilo Caudillo, & Cárdenas, Jose Silvan. (2015). Contesting Mexico City's alleged polycentric condition through a centrality-mixed land-use composite index. *Urban Studies*, 53(11), 2380-2396.

Fernandez-Maldonado, Ana Maria, Romein, Arie, Verkoren, Otto, & Parente Paula Pessoa, Renata. (2014). Polycentric structure in Latin American metropolitan areas: Identifying employment sub-centres. *Regional Studies*, 48(12), 1954-1971.

Forstall, Richard L., & Greene, Richard P. (1997). Defining job concentration: The Los Angeles case. *Urban Geography*, 18(8),705-739.

Fujita, Masahisha, & Kashiwadani, Masuo. (1989). Testing the efficiency of urban spatial growth: A case study of Tokyo. *Journal of Urban Economics*, 25(2), 156–192.

Fujita, Masahisa, & Ogawa, Hideki. (1982). Multiple equilibria and structural transition of non-monocentric urban configurations. *Regional Science and Urban Economics*, 12(2), 161–196.

Fujii, Tadashi, & Hartshorni, Truman Asa. (1995). The changing Metropolitan Structure of Atlanta, Georgia; Locations of Functional and Regional Structure in A Multinucleated urban Area. *Urban Geography*, 16(8), 680-707.

Fujita, Masahisa, Thisse, Jacques-François, & Zenou, Yves (1997). On the endogeneous formation of secondary employment centers in a city. *Journal of Urban Economics*, 41(3), 337-357.

Fukuhara, Masahiro. (1977). A study of regional structure of the Tokyo metropolitan regions. *Geography Journal*, 86(3), 158-173. (*In Japanese*)

Fulton, W. (1986). Offices in the dell. *Planning*, 52 (7), 13-17.

Garreau, Joel. (1991). *Edge City: Life on the new frontier*. New York, NY: Doubleday.

Garcia-López, Miquel-Àngel, & Muñiz, Ivan. (2005). Decentralization of employment: Polycentric, compaction or dispersion? The case of Barcelona, 1986-1996. Document de Treball 05.06. Department d' Economia Aplicada, Universidad Autonoma de Barcelona, 1-31.

Garcia-López, Miquel-Àngel, & Muñiz, Ivan. (2010). Employment decentralisation: Polycentricity or scatteration? The case of Barcelona. *Urban Studies*, 47(14), 3035-3056.

Giuliano, Genevieve, & Small, Kenneth A. (1991). Subcenters in the Los Angeles region. *Regional Science and Urban Economics*, 21(2), 163-182.

Giuliano, Genevieve, Redfearn, Christian, Agarwal, Ajay, Li, Chen, & Zhuang, Duan. (2007). Employment concentrations in Los Angeles, 1980–2000. *Environment and Planning A*, 39(12), 2935-2957.

Goto, Yutaka, & Okabe, Atsuyuki. (1998). City-center system in Tokyo metropolitan area: Distribution and characteristics of the agglomeration of employees. *Comprehensive Urban Studies*, 65, 35-44. (*In Japanese*)

Gordon, Peter, & Richardson, Harry W. (1996). Beyond policentricity: the dispersed metropolis, Los Angeles, 1970-1990. *Journal of the American Planning Association*, 62(3), 289-295.

Greene, David L. (1980). Recent trends in urban spatial structure. *Growth and Change*, 11(1), 29-40.

Griffith, Daniel A. (1992). What is spatial autocorrelation? Reflections on the past 25 years of spatial statistics. *L'Espace Géographique*, 21(3), 265–280.

Guillain, Rachel, Le Gallo, Julie, & Boiteux-Orain, Celine. (2006). Changes in spatial and sectoral patterns of employment in Ile-de-France, 1978-97. *Urban Studies*, 43(11), 2075–2098.

Guillain, Rachel, & Le Gallo, Julie. (2010). Agglomeration and dispersion of economic activities in and around Paris: An exploratory spatial data analysis. *Environment and Planning B: Planning and Design*, 37(6), 961-981.

Hackworth, Jason. (2005). Emergent urban forms or emergent post-modernisms? A comparison of large U.S. metropolitan areas. *Urban Geography*, 26(6), 484–519.

Hakim, Ikhwan, & Parolin, Bruno. (2009). Spaital structure and spatial impact of the Jakarta metropolitan area: A Southeast Asian EMR perspective. *International Journal of Human and Social Science*, 4(6), 397-405.

Hall, Peter. (1997). Modelling the post-industrial city. *Futures*, 29(4), 311-322.

Hamada, Hiroyuki. (2003). Makuhari shintoshin ni okeru office syuseki to kinou henka (Office agglomeration and its functional change in Makuhari new city). *Geographical Sciences (Chirikagaku)*, 58(4), 253–267. (*In Japanese*)

Hajrasouliha, Amir H., & Hamidi, Shima. (2016). The typology of the American metropolis: Monocentricity, polycentricity, or generalized dispersion? *Urban Geography*, 38(3), 420-444.

Han, Sun Sheng. (2005). Polycentric urban development and spatial clustering of condominium property values: Singapore in the 1990s. *Environment and Planning A*, 37(3), 463-481.

Harris, Chauncy D., & Ullman, Edward L. (1945). The nature of cities. *Annals of the American Academy of Political and Social Science*, 242, 7–17.

Hattori, Keijiro. (1965). Tokyo no chushinchigun to kankeiken ni tsuite (Concerning central places and tributary areas within Tokyo). *Geographical Review of Japan*, 38(3), 162–178. (*In Japanese*)

Hattori, Keijiro. (1966). Kyodai toshi ni okeru toshin fukutoshin ni tsuite (Concerning the civic center and the sub-centers of metropolis). *Japanese Journal of Human Geography*, 18(1), 21–47. (*In Japanese*)

Hebbert, Michael, & Nakai, Norihiro. (1988). *How Tokyo grows : land development and planning on the metropolitan fringe*. London: Suntory-Toyota International Centre for Economics and Related Disciplines : London School of Economics and Political Science.

Hein, Carola. (2010). Shaping Tokyo: Land development and planning practice in the early modern Japanese metropolis. *Journal of Urban History,* 36(4), 447–484.

Henderson, Vernon, & Mitra, Arindam. (1996). The new urban landscape: developers and edge cities. *Regional Science and Urban Economics*, 26, 613-643.

Helsley, Robert W., & Sullivan, Arthur M. (1991). Urban subcenter formation. *Regional Science and Urban Economics*, 21(2), 255-275.

Hino, Masateru, & Tsutsumi, Jun. (2015). *Urban geography of post-growth society*. Tohoku: Tohoku University Press.

Howard, Ebenezer. (1898). *To-morrow: A Peaceful Path to Real Reform*. London: Swan Sonnenschein & Co., Ltd.

Hoyt, Homer. (1939). *The Structure and Growth of Residential Neighborhood in American cities*. Washington, D.C.: Federal Housing Administration.

Huang, Daquan, Liu, Zhen, & Zhao, Xingshuo. (2015). Monocentric or Polycentric? The urban spatial structure of employment in Beijing. *Sustainability*, 7, 11632-11656.

Ichikawa, Hiroo. (1994). The evolutionary process of urban form in Edo/Tokyo to 1900. *The Town Planning Review*, 65(2), 179–196.

Ingram, Gregory K. (1998). Patterns of metropolitan development: What have we learned? *Urban Studies*, 35(7), 1019–1035.

Itsuki, Nakabayashi. (2006). Concentration and deconcentration in the context of the Tokyo capital regional plan and recent cross-border networking concepts. In Carola Hein and Philip Pelletier (Eds.), *Cities, autonomy, and decentralization in Japan* (pp.55-80). Abingdon, Oxon: Routledge.

Jun, Myung-Jin, & Ha, Seong-Kyu. (2002). Evolution of employment centers in Seoul. *Review of Urban & Regional Development Studies, 14*(2), 117-132.

Kagawa, Takashi, Koga, Shinji, & Neda, Katsuhiko. (2012). Research trends in Japanese urban geography since 1980 (Spatial issue: Progress of Human geography in Japan since 1980 (part 1)). *Japanese Journal of Human Geography*, 64(6), 497-520.

Kane, Kevin, Hipp, John. R., & Kim, Jae Hong. (2016). Los Angeles employment concentration in the 21st century. *Urban Studies*, 0042098016678341.

Keil, Roger, & Ronneberger, Klaus. (1994). Going up the country: Internationalization and urbanization on Frankfurt’s northern fringe. *Environment and Planning D: Society and Space*, 12(2), 137–166.

Kikuchi, Toshio, & Obara, Norihiro. (2004). Spatio-temporal changes of urban fringe in Tokyo metropolitan area. *Geographical Reports of Tokyo Metropolitan University*, 39, 57-69.

Kikuchi, Toshio, Inazaki, Tomio, Kumaki, Yohta, Kureha, Masaaki, Sano, Osam, & Sugai, Toshihiko. (2014). Overview of the special issue on “Tokyo: Past, present, and future (part III)”. *Journal of Geography*, 123(4), 634-641.

Kloosterman, Robert C., & Musterd, Sako. (2001). The polycentric urban region: Towards a research agenda. *Urban Studies*, 38(4), 623-633.

Kloosterman, Robert C., & Lambregts, Bart (2007). Between Accumulation and Concentration of Capital: Towards A Framework for Comparing Long-Term Trajectories of Urban Systems. *Urban Geography*, 28(1), 54-73.

Krugman, Paul (1993). On the number and location of cities. *European Economic Review*, 37(2), 293-298.

Krehl, Angelika. (2015). Urban spatial structure: An interaction between employment and built-up volumes. *Regional Studies, Regional Science*, 2(1), 290-308.

Krehl, Angelika. (2016). Urban subcentres in German city regions: Identification, understanding, comparison. *Papers in Regional Science*、1-26.

Lang, Robert E. (2003). *Edgeless cities: Exploring the elusive metropolis*. Washington, DC: Brookings Institution Press.

Lang, Robert E., & LeFurgy, Jennifer. (2003). Edgeless cities: Examining the noncentered metropolis. *Housing Policy Debate*, 14(3), 427-460.

Lee, Bumsoo. (2007). Edge or edgeless cities? Urban spatial structure in U.S. metropolitan areas, 1980 to 2000. *Journal of Regional Science*, 47(3), 479–515.

Le Gallo, Julie, & Ertur, Cem. (2003). Exploratory spatial data analysis of the distribution of regional per capita GDP in Europe, 1980–1995. *Papers in Regional Science*, *82*(2), 175-201.

Leslie, Timothy F. (2010). Identification and differentiation of urban centers in Phoenix through a multi-criteria kernel-density approach. *Journal of International Regional Science Review*, 33(2), 205-235.

Li, Yan, & Monzur, Tawhid. (2017). The spatial structure of employment in the metropolitan region of Tokyo: A scale-view. *Urban Geography*, Doi: 10.1080/02723638.2017.1308182.

Lynch, Kevin. (1961). The Pattern of the metropolis. *Daedalus*, 90(1), 79-98.

Maoh, Hanna, & Kanaroglou, Pavlos (2007). Geographic clustering of firms and urban form: A multivariate analysis. *Journal of Geographical Systems*, *9*(1), 29-52.

Martin, Ron, & Sunley, Peter. (2003). Deconstructing clusters: Chaotic concept or policy panacea? *Journal of Economic Geography*, 3(1), 5-35.

Machimura, Takashi. (1992). The urban restructuring process in Tokyo in the 1980s: Transforming Tokyo into a world city. *International Journal of Urban and Regional Research*, 16(1), 114–128.

Matsubara, Hiroshi. (2014). Industrial structural changes in the Tokyo metropolitan area. *Journal of Geography*, 123(2), 285-297. (*In Japanese*)

McDonald, John F. (1987). The identification of Urban employment subcenters. *Journal of Urban Economics*, 21, 242-258.

McMillen, Daniel P., & McDonald, John F. (1997). A nonparametric analysis of employment density in a polycentric city. *Journal of Regional Science*, 37(4), 591–612.

McMillen, Daniel P. (2001). Nonparametric employment subcenter identification.

Journal of Urban Economics, 50(3), 448–473.

McMillen, Daniel P. (2003). Identifying sub-centres using contiguity matrices. *Urban Studies*, 40(1), 57-69.

McMillen, Daniel P. (2004). Employment densities, spatial autocorrelation, and subcenters in large metropolitan areas. *Journal of Regional Science*, 44(2), 225-244.

METI. (2009). Japan's economic dynamism drawn from the vitality of the greater Kanto region. Kanto Bureau of Economy, Trade and Industry. Retrieved from: http://www.kanto.meti.go.jp/english/introduction/data/english_brochure_2009_09.pdf

MILT. (2006). *White Paper on national capital region development, 2006*. Tokyo: Ministry of Land, Infrastructure, and Transport.

Mills, Edwin S. (1972). *Studies in the structure of the urban economy*. Baltimore, MD: Johns Hopkins Press.

Modarres, Ali (2011). Policentricity, Commuting Pattern, Urban Form: The Case of Southern California. *International Journal of Urban and Regional Research*, 35(6), 1193-1211.

Morita, Tetsuo, Nakagawa, Yoshihide, Morimoto, Akinori, Maruyama, Masateru, & Hosokawa, Yoshimi. (2012). Changes and Issues in green space planning in the Tokyo metropolitan area: Focusing on the "capital region plan." *International Journal of GEOMATE: Geotechnique, Construction Materials and Environment*, 2(1), 191–196.

Muth, Richard F. (1969). *Cities and housing: The spatial pattern of urban residential land use*. Chicago, IL: University of Chicago Press.

Odland, John. (1976). The spatial arrangement of urban activities: A simultaneous local model. *Environment and Planning A*, 8(7), 779-791.

Odland, John. (1978). The Conditions for multi-center cities. *Economic Geography*, 54(3), 234-244.

Ogawa, Hideaki, and Fujita, Masahisa. (1980). Equilibrium land use patterns in a nonmonocentric city*. *Journal of Regional Science*, 20(4), 455–475.

Okata, Junichiro, & Murayama, Akiko. (2011). Tokyo's urban growth, urban form, and sustainability. In Andre Sorensen & Junichiro Okata (Eds.), *Megacities* (pp. 15–41). Japan: Springer.

Pacione, Michael. (2006). *Urban geography: A global perspective (Third edition)*. London and New York: Routledge.

Pernice, Raffaele. (2006). The transformation of Tokyo during the 1950s and early 1960s. *Journal of Asian Architecture and Building Engineering*, 5(2), 253–260.

Pernice, Raffaele. (2007). Urban sprawl in postwar Japan and the vision of the city based on the urban theories of the metabolists & prime projects. *Journal of Asian Architecture and Building Engineering*, 6(2), 237–244.

Pereira, Rafael Henrique Moraes, Nadalin, V., Monasterio, L., & Albuquerque, P. H. (2013). Urban centrality: A simple index. *Geographical Analysis*, 45(1), 77-89.

Pfister, Neil, Freestone, Robert, & Murphy, Peter. (2000). Polycentricity or dispersion? Changes in Center Employment in Metropolitan Sydney, 1981 to 1996. *Urban Geography*, 21(5), 428-442.

Phelps, Nicholas A. (2004). Clusters, dispersion and the spaces in between: For an economic geography of the banal. *Urban Studies*, 41(5-6), 971-989.

Pivo, Gray. (1990). The net of mixed beads: Suburban office development in six metropolitan regions. *Journal of American Planning Association*, 56(4), 457-469.

Real Estate Research Corporation. (1974). *The cost of sprawl: Environmental and economic costs of alternative residential development patterns at the urban fringe*. Washington D.C.: Portland Regional Planning History.

Redfearn, Christian L. (2007). The topography of metropolitan employment: Identifying centers of employment in a polycentric urban area. *Journal of Urban Economics*, 61(3), 519-541.

Redfearn, Christian L. (2009). Persistence in urban form: The long-run durability of employment centers in metropolitan areas. *Regional Science and Urban Economics*, 39, 224-232.

Reed, Howard Curtis. (1980). The ascent of Tokyo as an international financial center. *Journal of International Business Studies*, 11(3), 19-35.

Richardson, Harry W. (1971). *Urban economics*. Baltimore, Md: Penguin Books.

Riguelle, Francois, Thomas, Isabelle, & Verhetsel, Ann. (2007). Measuring urban polycentrism: A European case study and its implications. *Journal of Economic Geography*, 7 (2), 193-215.

Rodríguez-Gámez, Liz, & Dallerba, Sandy. (2012). Spatial distribution of employment in Hermosillo, 1999–2004. *Urban Studies*, 49(16), 3663-3678.

Sassen, Saskia. (1991). *The global city: New York, London, Tokyo*. Princeton, NJ: Princeton University Press.

Shearmur, Richard G., & Coffey, William J. (2002a). Urban employment subcenters and sectoral clustering in Montreal: Complementary approaches to the study of urban form. *Urban Geography*, 23(2), 103-130.

Shearmur, Richard G., & Coffey, William J. (2002b). A tale of four cities: intrametropolitan employment distribution in Toronto, Montreal, Vancouver, and Ottawa–Hull, 1981–1996. *Environment and Planning A*, 34(4), 575-598.

Shearmur, Richard, Coffey, William, Dube, Christian, & Barbonne, Remy. (2007). Intrametropolitan Employment Structure: Polycentricity, scatteration, dispersal and chaos in Toronto, Montreal and Vancouver, 1996-2001. *Urban Studies*, 44(9), 1713-1738.

Siebert, Loren. (2000). Urbanization transition types and zones in Tokyo and Kanagawa prefectures. *Geographical Review of Japan* (Series B), 73(2), 207–224.

Small, Kenneth A., & Song, Shunfeng. (1994). Population and employment densities: Structure and change. *Journal of Urban Economics*, 36, 292-313.

Sorensen, Andre. (2001a). Building suburbs in Japan: Continuous unplanned change on the urban fringe. *The Town Planning Review*, 247–273.

Sorensen, Andre. (2001b). Subcentres and satellite cities: Tokyo's 20th-century experience of planned polycentrism. *International Planning Studies*, 6(1), 9–32.

Sweet, Matthias N., Bullivant, Bronson, & Kanaroglou, Pavlos S. (2016). Are major Canadian city-regions monocentric, polycentric, or dispersed? *Urban Geography*, 38(3), 445-471.

Takeuchi, Tomoko, & Ishikawa, Mikiko. (2009). A Study on the effect of urban development projects on the open space environment in areas once designated as green districts. *Journal of the Japanese Institute of Landscape Architecture*, 72(5), 705–708.

TMG. (1994). *A hundred years of Tokyo city planning*. Tokyo: Tokyo Metropolitan Government.

TMG. (2011). Urban development in Tokyo, 2011. Bureau of Urban Development. Tokyo Metropolitan Government.

TMG. (2013). Urban development in Tokyo, 2013. Bureau of Urban Development. Tokyo Metropolitan Government.

Todokoro, Takashi. (2014). Decentralizing Tokyo’s capital functions. *Journal of Geography*, 123(4), 528-541. (*In Japanese*)

Tonuma, Koichi. (1998). Tokyo: Policies toward the 21st century. *Ekistics*, 65: 388-390.

Tomita, Kazuaki. (1975). Wagakuni daitoshiken ni okeru jinkou sangyou no doukou to sonopataan (Changing patterns of population and industries in the metropolitan areas of Japan). *Geographical Review of Japan*, 48(5), 331–350.

(*In Japanese*)

Tsubomoto, Hiroyuki. (1996). Tokyo daitoshiken ni okeru office kyokyu to gyoumu chiiki noseicho (Trend in office supply and the growth of business districts in the Tokyo metropolitan area). *Japanese Journal of Human Geography*, 48(4), 341–363. (*In Japanese*)

UN-Habitat. (2015). *The state of Asian and Pacific cities 2015: Urban transformations shifting from quantity to quality*. State of cities regional report. Nairobi: UN-Habitat.

UN-Habitat. (2016). *Urbanization and development: Emerging futures*. World cities report. Nairobi: UN-Habitat.

United Nations. (2014). *World urbanization prospects the 2014 revision, highlights*. New York: United Nations.

Veneri, Paolo. (2013). The identification of sub-centres in two Italian metropolitan areas: A functional approach. *Cities*, 31, 177-185.

Von Thunen, Johann H. (1826). *Der Isolierte Staat in Beziehung auf Landwirtschaftund National¨okonomie* (C. M. Wartenberg, *Von Thunen's Isolated State*, Oxford, English Trans., 1966). Hamburg: Pergamon Press.

Watanabe, Yoshio. (1972). Some aspects of recent Japanese metropolitan growth. *Geographical Reports of Tokyo Metropolitan University*, 6, 51–62.

Watanabe, Yoshio, Takeuchi, Kazuhiko, Nakabayashi, Itsuki, & Kobayashi, Akira. (1980). Urban growth and landscape change in the Tokyo metropolitan area.

Geographical Reports of Tokyo Metropolitan University, 14, 1–26.

Waley, Paul (2002). Moving the margins of Tokyo. *Urban Studies*, 39(9), 1533–1550.

Waley, Paul. (2007). Tokyo-as-world-city: Reassessing the role of capital and the state in urban restructuring. *Urban Studies*, 44(8), 1465–1490.

White, Michelle J. (1976). Firm suburbanization and urban subcenters. *Journal of Urban Economics*, 3, 323-343.

Wieand, Kenneth F. (1987). An extension of the monocentric urban spatial equilibrium model to a multicenter setting: The case of the two-center city. *Journal of Urban Economics*, 21(3), 259–271.

World Bank. (2015). *East Asia's changing urban landscape: Measuring a decade of spatial growth*. Urban Development Series. Washington DC: World Bank.

Yamaga, Seiji. (1967). *Tokyo daitoshiken no kenkyu (A study on the Tokyo metropolitan area)*. Tokyo: Taimeido. (*In Japanese*).

Yang, Jiawen, French, Steven, Holt, James, & Zhang, Xingyou. (2012). Measuring the structure of US metropolitan areas, 1970–2000: Spatial statistical metrics and an application to commuting behavior. *Journal of the American Planning Association*, 78(2), 197-209.

Yinger, John. (1992). City and suburb: Urban models with more than one employment center. *Journal of Urban Economics*, 31(2), 181–205.

Yue, Wenze, Liu, Yong, & Fan, Peilei (2010). Policentric urban development: the case of Hangzhou. *Environment and Planning A*, 42, 563-577.

Zhang, Yang, & Sasaki, Komei. (1997). Effects of subcenter formation on urban spatial structure. *Regional Science and Urban Economics*, 27(3), 297-324.

Zheng, Xiao-Ping. (1991). Metropolitan spatial structure and its determinants: A case-study of Tokyo. *Urban Studies*, 28(1), 87–104.

APPENDIX A

Table A-1: The Characteristics of the ECs in different ranks, 1999.

Note: EC1= Red color; EC2= Yellow color; EC3= Blue color; and EC4= Rose color

Different ranks (ECs)	Prefectures	Total employment (Largest to smallest)	Area (km^2)	Average density	Employment Share (%)	Land Share (%)
EC1	Tokyo-to	3,702,215	61.06	60,630	46.53%	8.13%
EC1	Kanagawa	233,519	5.81	40,175	2.94%	0.77%
EC1	Tokyo-to	156,736	3.06	51,179	1.97%	0.41%
EC1	Saitama	58,736	1.50	39,158	0.74%	0.20%
EC1	Chiba	58,681	1.50	39,120	0.74%	0.20%
EC3	Tokyo	48,539	4.19	11,591	0.61%	0.56%
EC1	Tokyo-to	45,846	1.44	31,893	0.58%	0.19%
EC1	Kanagawa	45,424	1.31	34,609	0.57%	0.17%
EC2	Tochigi	43,484	2.06	21,083	0.55%	0.27%
EC2	Tokyo-to	43,092	1.38	31,340	0.54%	0.18%
EC3	Tokyo-to	41,633	4.88	8,540	0.52%	0.65%
EC1	Tokyo-to	41,402	1.13	36,802	0.52%	0.15%
EC3	Saitama	41,252	4.25	9,706	0.52%	0.57%
EC4	Kanagawa	40,952	11.13	3,681	0.51%	1.48%
EC3	Tokyo-to	40,715	5.00	8,143	0.51%	0.67%
EC2	Ibaraki	39,086	1.75	22,335	0.49%	0.23%
EC4	Chiba	38,860	12.38	3,140	0.49%	1.65%
EC4	Kanagawa	38,761	8.50	4,560	0.49%	1.13%
EC2	Tokyo-to	37,943	1.25	30,355	0.48%	0.17%
EC4	Kanagawa	37,754	9.44	4,000	0.47%	1.26%
EC1	Tokyo-to	37,658	1.00	37,658	0.47%	0.13%
EC1	Tokyo-to	37,375	1.00	37,375	0.47%	0.13%
EC3	Kanagawa	37,057	3.44	10,780	0.47%	0.46%
EC2	Saitama	37,044	1.25	29,635	0.47%	0.17%
EC1	Kanagawa	36,315	1.00	36,315	0.46%	0.13%

EC4	Kanagawa	34,071	8.44	4,038	0.43%	1.12%
EC2	Chiba	33,251	1.19	28,001	0.42%	0.16%
EC2	Kanagawa	32,267	1.19	27,173	0.41%	0.16%
EC4	Saitama	31,938	10.25	3,116	0.40%	1.36%
EC2	Tokyo-to	31,883	1.50	21,255	0.40%	0.20%
EC4	Chiba	31,783	10.38	3,063	0.40%	1.38%
EC2	Tokyo-to	29,457	1.75	16,832	0.37%	0.23%
EC4	Saitama	29,265	8.38	3,494	0.37%	1.12%
EC2	Kanagawa	29,141	1.00	29,141	0.37%	0.13%
EC3	Gunma	29,092	2.38	12,249	0.37%	0.32%
EC3	Chiba	28,829	1.88	15,375	0.36%	0.25%
EC2	Chiba	28,083	1.19	23,649	0.35%	0.16%
EC3	Tokyo-to	27,813	2.56	10,854	0.35%	0.34%
EC4	Saitama	27,445	7.81	3,513	0.34%	1.04%
EC4	Ibaraki	27,200	5.81	4,680	0.34%	0.77%
EC2	Kanagawa	27,199	1.25	21,759	0.34%	0.17%
EC2	Chiba	27,126	1.06	25,531	0.34%	0.14%
EC3	Kanagawa	27,101	2.94	9,226	0.34%	0.39%
EC3	Kanagawa	26,828	2.63	10,220	0.34%	0.35%
EC3	Kanagawa	26,813	1.50	17,875	0.34%	0.20%
EC3	Tokyo-to	25,883	2.56	10,101	0.33%	0.34%
EC3	Gunma	25,766	2.19	11,779	0.32%	0.29%
EC3	Chiba	25,166	2.13	11,843	0.32%	0.28%
EC4	Kanagawa	24,322	5.50	4,422	0.31%	0.73%
EC4	Tochigi	24,321	8.25	2,948	0.31%	1.10%
EC3	Saitama	23,987	3.00	7,996	0.30%	0.40%
EC3	Tokyo-to	23,889	3.25	7,351	0.30%	0.43%
EC3	Chiba	23,294	1.81	12,852	0.29%	0.24%
EC4	Ibaraki	22,595	6.38	3,544	0.28%	0.85%
EC4	Gunma	22,549	6.50	3,469	0.28%	0.87%
EC4	Chiba	21,391	5.69	3,761	0.27%	0.76%
EC4	Ibaraki	21,283	7.06	3,014	0.27%	0.94%
EC4	Ibaraki	21,268	6.75	3,151	0.27%	0.90%
EC4	Gunma	21,147	7.06	2,994	0.27%	0.94%

EC3	Kanagawa	21,091	2.50	8,436	0.27%	0.33%
EC4	Chiba	21,022	5.00	4,204	0.26%	0.67%
EC2	Tokyo-to	20,832	1.00	20,832	0.26%	0.13%
EC2	Saitama	20,609	1.00	20,609	0.26%	0.13%
EC3	Tokyo-to	20,554	2.13	9,673	0.26%	0.28%
EC3	Kanagawa	20,539	2.13	9,665	0.26%	0.28%
EC3	Tokyo-to	20,370	1.56	13,037	0.26%	0.21%
EC2	Kanagawa	20,172	1.06	18,985	0.25%	0.14%
EC3	Saitama	19,939	1.69	11,816	0.25%	0.23%
EC4	Gunma	19,644	3.31	5,930	0.25%	0.44%
EC3	Kanagawa	19,487	1.56	12,472	0.24%	0.21%
EC3	Kanagawa	19,271	2.31	8,334	0.24%	0.31%
EC3	Kanagawa	19,176	1.38	13,946	0.24%	0.18%
EC4	Tokyo-to	18,890	4.75	3,977	0.24%	0.63%
EC4	Kanagawa	18,842	4.69	4,020	0.24%	0.62%
EC4	Chiba	18,786	6.44	2,918	0.24%	0.86%
EC4	Saitama	18,285	6.38	2,868	0.23%	0.85%
EC3	Ibaraki	18,234	1.63	11,221	0.23%	0.22%
EC4	Chiba	18,099	6.88	2,633	0.23%	0.92%
EC4	Tochigi	17,903	5.81	3,080	0.23%	0.77%
EC3	Gunma	17,545	1.63	10,797	0.22%	0.22%
EC4	Ibaraki	17,020	5.06	3,362	0.21%	0.67%
EC4	Kanagawa	16,959	5.13	3,309	0.21%	0.68%
EC3	Tokyo-to	16,885	1.56	10,806	0.21%	0.21%
EC3	Tokyo-to	16,680	1.56	10,675	0.21%	0.21%
EC3	Kanagawa	16,560	1.50	11,040	0.21%	0.20%
EC3	Kanagawa	16,310	1.44	11,346	0.20%	0.19%
EC4	Chiba	16,183	4.25	3,808	0.20%	0.57%
EC3	Kanagawa	15,849	1.31	12,075	0.20%	0.17%
EC3	Chiba	15,681	1.69	9,292	0.20%	0.23%
EC3	Tokyo-to	15,533	1.06	14,619	0.20%	0.14%
EC3	Tokyo-to	15,167	1.56	9,707	0.19%	0.21%
EC3	Chiba	15,166	1.31	11,555	0.19%	0.17%
EC3	Tokyo-to	15,153	1.38	11,020	0.19%	0.18%

EC3	Kanagawa	15,117	1.38	10,995	0.19%	0.18%
EC4	Kanagawa	14,949	2.13	7,035	0.19%	0.28%
EC3	Saitama	14,635	1.44	10,181	0.18%	0.19%
EC3	Tokyo-to	14,418	1.50	9,612	0.18%	0.20%
EC4	Chiba	14,405	2.94	4,904	0.18%	0.39%
EC3	Kanagawa	14,367	1.94	7,415	0.18%	0.26%
EC4	Saitama	14,282	3.94	3,627	0.18%	0.52%
EC3	Saitama	14,041	1.25	11,233	0.18%	0.17%
EC3	Gunma	14,016	1.75	8,009	0.18%	0.23%
EC3	Saitama	13,935	1.19	11,734	0.18%	0.16%
EC4	Tochigi	13,907	4.56	3,048	0.17%	0.61%
EC4	Saitama	13,783	4.06	3,393	0.17%	0.54%
EC4	Chiba	13,716	3.75	3,657	0.17%	0.50%
EC3	Tokyo-to	13,624	1.31	10,380	0.17%	0.17%
EC2	Saitama	13,368	1.00	13,368	0.17%	0.13%
EC4	Gunma	13,362	4.19	3,191	0.17%	0.56%
EC3	Kanagawa	13,332	1.13	11,850	0.17%	0.15%
EC4	Chiba	13,202	2.50	5,281	0.17%	0.33%
EC4	Saitama	12,950	2.88	4,504	0.16%	0.38%
EC3	Tokyo-to	12,699	1.19	10,694	0.16%	0.16%
EC4	Ibaraki	12,689	2.94	4,320	0.16%	0.39%
EC4	Kanagawa	12,557	2.00	6,279	0.16%	0.27%
EC3	Tochigi	12,257	1.31	9,339	0.15%	0.17%
EC4	Saitama	12,218	5.00	2,444	0.15%	0.67%
EC4	Chiba	12,203	5.06	2,410	0.15%	0.67%
EC3	Kanagawa	11,957	1.19	10,069	0.15%	0.16%
EC3	Saitama	11,945	1.13	10,618	0.15%	0.15%
EC4	Kanagawa	11,903	5.06	2,351	0.15%	0.67%
EC3	Tokyo-to	11,532	1.13	10,250	0.14%	0.15%
EC4	Chiba	11,404	3.31	3,443	0.14%	0.44%
EC3	Kanagawa	11,389	1.50	7,593	0.14%	0.20%
EC4	Saitama	11,304	3.31	3,413	0.14%	0.44%
EC3	Tokyo-to	11,186	1.25	8,949	0.14%	0.17%
EC3	Kanagawa	11,105	1.13	9,871	0.14%	0.15%

EC3	Saitama	10,888	1.31	8,295	0.14%	0.17%
EC3	Kanagawa	10,835	1.25	8,668	0.14%	0.17%
EC3	Saitama	10,798	1.00	10,798	0.14%	0.13%
EC4	Ibaraki	10,745	2.44	4,408	0.14%	0.32%
EC3	Tokyo-to	10,501	1.13	9,334	0.13%	0.15%
EC4	Kanagawa	10,384	3.31	3,135	0.13%	0.44%
EC4	Saitama	10,292	3.94	2,614	0.13%	0.52%
EC3	Saitama	10,264	1.13	9,124	0.13%	0.15%
EC4	Saitama	10,223	3.38	3,029	0.13%	0.45%
EC3	Tokyo-tō	10,026	1.00	10,026	0.13%	0.13%
EC4	Ibaraki	10,020	2.69	3,728	0.13%	0.36%
EC4	Saitama	9,846	2.75	3,580	0.12%	0.37%
EC3	Kanagawa	9,716	1.00	9,716	0.12%	0.13%
EC4	Saitama	9,671	2.69	3,599	0.12%	0.36%
EC4	Saitama	9,378	3.25	2,886	0.12%	0.43%
EC3	Kanagawa	9,370	1.19	7,890	0.12%	0.16%
EC4	Saitama	9,346	2.56	3,647	0.12%	0.34%
EC4	Saitama	9,309	3.31	2,810	0.12%	0.44%
EC4	Saitama	9,299	2.63	3,543	0.12%	0.35%
EC4	Saitama	9,244	2.13	4,350	0.12%	0.28%
EC4	Tokyo-to	9,229	1.94	4,763	0.12%	0.26%
EC3	Kanagawa	9,191	1.00	9,191	0.12%	0.13%
EC4	Saitama	9,083	2.56	3,545	0.11%	0.34%
EC3	Tokyo-to	8,791	1.06	8,274	0.11%	0.14%
EC3	Kanagawa	8,709	1.19	7,334	0.11%	0.16%
EC4	Chiba	8,656	3.44	2,518	0.11%	0.46%
EC4	Tochigi	8,630	3.00	2,877	0.11%	0.40%
EC4	Gunma	8,558	2.50	3,423	0.11%	0.33%
EC4	Tokyo-to	8,508	2.88	2,959	0.11%	0.38%
EC4	Gunma	8,435	2.38	3,552	0.11%	0.32%
EC4	Ibaraki	8,313	2.44	3,410	0.10%	0.32%
EC4	Tokyo-to	8,276	2.94	2,817	0.10%	0.39%
EC4	Tochigi	8,236	2.50	3,294	0.10%	0.33%
EC4	Saitama	8,041	2.88	2,797	0.10%	0.38%

EC4	Chiba	8,024	2.38	3,378	0.10%	0.32%
EC4	Chiba	8,008	3.44	2,330	0.10%	0.46%
EC4	Kanagawa	8,007	1.94	4,133	0.10%	0.26%
EC4	Tokyo-to	7,836	2.31	3,389	0.10%	0.31%
EC3	Tokyo-to	7,783	1.06	7,325	0.10%	0.14%
EC3	Saitama	7,753	1.00	7,753	0.10%	0.13%
EC4	Chiba	7,468	1.38	5,431	0.09%	0.18%
EC4	Saitama	7,455	2.44	3,058	0.09%	0.32%
EC4	Chiba	7,453	2.06	3,613	0.09%	0.27%
EC4	Saitama	7,440	2.56	2,903	0.09%	0.34%
EC4	Tokyo-to	7,421	2.88	2,581	0.09%	0.38%
EC4	Chiba	7,305	1.88	3,896	0.09%	0.25%
EC3	Tokyo-to	7,113	1.06	6,694	0.09%	0.14%
EC4	Saitama	7,027	2.13	3,307	0.09%	0.28%
EC4	Tochigi	6,911	1.81	3,813	0.09%	0.24%
EC4	Chiba	6,881	1.69	4,078	0.09%	0.23%
EC4	Gunma	6,822	2.13	3,210	0.09%	0.28%
EC4	Tochigi	6,814	2.31	2,947	0.09%	0.31%
EC4	Chiba	6,729	1.94	3,473	0.08%	0.26%
EC4	Chiba	6,640	1.63	4,086	0.08%	0.22%
EC4	Saitama	6,485	1.94	3,347	0.08%	0.26%
EC4	Ibaraki	6,479	2.06	3,141	0.08%	0.27%
EC3	Tokyo-to	6,445	1.13	5,729	0.08%	0.15%
EC4	Saitama	6,366	2.19	2,910	0.08%	0.29%
EC4	Saitama	6,290	2.25	2,796	0.08%	0.30%
EC4	Chiba	6,285	1.75	3,592	0.08%	0.23%
EC4	Chiba	6,265	2.75	2,278	0.08%	0.37%
EC4	Chiba	6,264	1.69	3,712	0.08%	0.23%
EC4	Chiba	6,242	2.06	3,027	0.08%	0.27%
EC4	Saitama	6,045	1.69	3,582	0.08%	0.23%
EC4	Kanagawa	6,034	1.13	5,364	0.08%	0.15%
EC4	Saitama	5,995	1.94	3,094	0.08%	0.26%
EC4	Saitama	5,925	1.88	3,160	0.07%	0.25%
EC4	Ibaraki	5,855	1.88	3,122	0.07%	0.25%

EC4	Ibaraki	5,815	2.06	2,819	0.07%	0.27%
EC4	Chiba	5,794	1.63	3,565	0.07%	0.22%
EC4	Gunma	5,781	1.94	2,984	0.07%	0.26%
EC4	Saitama	5,770	2.13	2,715	0.07%	0.28%
EC4	Saitama	5,655	1.19	4,762	0.07%	0.16%
EC4	Tochigi	5,633	2.19	2,575	0.07%	0.29%
EC4	Kanagawa	5,615	2.06	2,722	0.07%	0.27%
EC4	Chiba	5,574	1.44	3,878	0.07%	0.19%
EC4	Saitama	5,460	1.44	3,798	0.07%	0.19%
EC4	Ibaraki	5,419	2.25	2,409	0.07%	0.30%
EC4	Chiba	5,332	1.63	3,281	0.07%	0.22%
EC4	Chiba	5,324	1.75	3,043	0.07%	0.23%
EC4	Kanagawa	5,205	1.75	2,974	0.07%	0.23%
EC4	Kanagawa	5,201	1.94	2,684	0.07%	0.26%
EC4	Ibaraki	5,197	2.06	2,520	0.07%	0.27%
EC4	Chiba	5,188	1.63	3,192	0.07%	0.22%
EC4	Kanagawa	5,169	1.81	2,852	0.06%	0.24%
EC4	Kanagawa	5,166	1.50	3,444	0.06%	0.20%
EC4	Saitama	5,049	1.44	3,512	0.06%	0.19%
EC4	Ibaraki	5,014	1.69	2,971	0.06%	0.23%
EC4	Kanagawa	4,901	1.38	3,564	0.06%	0.18%
EC4	Saitama	4,806	1.69	2,848	0.06%	0.23%
EC4	Ibaraki	4,748	1.44	3,303	0.06%	0.19%
EC4	Ibaraki	4,743	1.81	2,617	0.06%	0.24%
EC4	Kanagawa	4,664	1.13	4,146	0.06%	0.15%
EC4	Ibaraki	4,455	1.31	3,394	0.06%	0.17%
EC4	Saitama	4,347	1.44	3,024	0.05%	0.19%
EC4	Ibaraki	4,284	1.06	4,032	0.05%	0.14%
EC4	Chiba	4,276	1.19	3,601	0.05%	0.16%
EC4	Tochigi	4,266	2.44	1,750	0.05%	0.32%
EC4	Kanagawa	4,260	1.19	3,587	0.05%	0.16%
EC4	Gunma	4,211	1.19	3,546	0.05%	0.16%
EC4	Saitama	4,209	1.25	3,367	0.05%	0.17%
EC4	Kanagawa	4,173	1.44	2,903	0.05%	0.19%

EC4	Tokyo-to	4,148	1.81	2,289	0.05%	0.24%
EC4	Gunma	4,007	1.38	2,914	0.05%	0.18%
EC4	Ibaraki	4,005	1.44	2,786	0.05%	0.19%
EC4	Kanagawa	3,888	1.31	2,962	0.05%	0.17%
EC4	Saitama	3,817	1.75	2,181	0.05%	0.23%
EC4	Tochigi	3,803	1.31	2,898	0.05%	0.17%
EC4	Ibaraki	3,784	1.50	2,523	0.05%	0.20%
EC4	Tochigi	3,771	1.63	2,321	0.05%	0.22%
EC4	Tochigi	3,751	1.25	3,001	0.05%	0.17%
EC4	Tokyo-to	3,695	1.00	3,695	0.05%	0.13%
EC4	Gunma	3,624	1.13	3,221	0.05%	0.15%
EC4	Kanagawa	3,608	1.25	2,886	0.05%	0.17%
EC4	Kanagawa	3,593	1.38	2,613	0.05%	0.18%
EC4	Chiba	3,566	1.06	3,357	0.04%	0.14%
EC4	Gunma	3,544	1.50	2,362	0.04%	0.20%
EC4	Tochigi	3,527	1.44	2,454	0.04%	0.19%
EC4	Chiba	3,516	1.31	2,679	0.04%	0.17%
EC4	Kanagawa	3,416	1.25	2,733	0.04%	0.17%
EC4	Ibaraki	3,415	1.13	3,036	0.04%	0.15%
EC4	Saitama	3,284	1.44	2,284	0.04%	0.19%
EC4	Tochigi	3,275	1.19	2,758	0.04%	0.16%
EC4	Gunma	3,229	1.38	2,348	0.04%	0.18%
EC4	Saitama	3,227	1.19	2,717	0.04%	0.16%
EC4	Saitama	3,226	1.06	3,037	0.04%	0.14%
EC4	Chiba	3,193	1.25	2,555	0.04%	0.17%
EC4	Tochigi	3,151	1.19	2,654	0.04%	0.16%
EC4	Kanagawa	3,150	1.00	3,150	0.04%	0.13%
EC4	Saitama	3,137	1.06	2,952	0.04%	0.14%
EC4	Kanagawa	3,130	1.38	2,277	0.04%	0.18%
EC4	Kanagawa	3,108	1.19	2,617	0.04%	0.16%
EC4	Gunma	3,108	1.25	2,486	0.04%	0.17%
EC4	Saitama	3,102	1.31	2,363	0.04%	0.17%
EC4	Gunma	3,054	1.19	2,572	0.04%	0.16%
EC4	Kanagawa	3,042	1.00	3,042	0.04%	0.13%

EC4	Saitama	3,039	1.19	2,559	0.04%	0.16%
EC4	Tochigi	3,024	1.00	3,024	0.04%	0.13%
EC4	Gunma	3,016	1.06	2,839	0.04%	0.14%
EC4	Saitama	2,980	1.19	2,509	0.04%	0.16%
EC4	Saitama	2,949	1.00	2,949	0.04%	0.13%
EC4	Ibaraki	2,860	1.30	2,288	0.04%	0.17%
EC4	Kanagawa	2,813	1.20	2,369	0.04%	0.16%
EC4	Kanagawa	2,793	1.10	2,629	0.04%	0.15%
EC4	Chiba	2,765	1.10	2,602	0.03%	0.15%
EC4	Kanagawa	2,753	1.10	2,448	0.03%	0.15%
EC4	Ibaraki	2,742	1.10	2,581	0.03%	0.15%
EC4	Gunma	2,651	1.10	2,495	0.03%	0.15%
EC4	Tochigi	2,557	1.80	1,461	0.03%	0.24%
EC4	Chiba	2,552	1.00	2,552	0.03%	0.13%
EC4	Kanagawa	2,473	1.10	2,328	0.03%	0.15%
EC4	Chiba	2,466	1.40	1,793	0.03%	0.19%
EC4	Saitama	2,440	1.00	2,440	0.03%	0.13%
EC4	Chiba	2,387	1.00	2,387	0.03%	0.13%
EC4	Chiba	2,357	1.10	2,218	0.03%	0.15%
EC4	Saitama	2,199	1.10	1,955	0.03%	0.15%
EC4	Kanagawa	2,128	1.00	2,128	0.03%	0.13%
EC4	Tokyo-to	1,884	1.00	1,884	0.02%	0.13%
EC4	Saitama	1,759	1.30	1,407	0.02%	0.17%

Table A-2: The Characteristics of the ECs in different ranks, 2009.

Different ranks (ECs)	Prefectures	Total employment (Largest to smallest)	Area (km^2)	Average density	Employment share (%)	Land Share (%)
EC1	Tokyo-to	4,151,427	60.56	68,548	48.44%	8.30%
EC1	Kanagawa	298,829	5.13	58,308	3.49%	0.70%
EC1	Tokyo-to	183,295	2.88	63,755	2.14%	0.39%
EC1	Saitama	72,885	1.50	48,590	0.85%	0.21%
EC1	Chiba	62,840	1.50	41,893	0.73%	0.21%
EC1	Kanagawa	61,453	1.25	49,162	0.72%	0.17%
EC2	Kanagawa	56,734	1.50	37,822	0.66%	0.21%
EC1	Tokyo-to	56,008	1.50	37,339	0.65%	0.21%
EC1	Tokyo-to	55,127	1.13	49,002	0.64%	0.15%
EC3	Tokyo-to	48,666	3.94	12,360	0.57%	0.54%
EC2	Tokyo-to	47,230	1.38	34,349	0.55%	0.19%
EC4	Kanagawa	43,319	11.50	3,767	0.51%	1.58%
EC3	Tokyo-to	42,508	4.88	8,719	0.50%	0.67%
EC3	Tokyo-to	42,034	5.06	8,303	0.49%	0.69%
EC2	Tochigi	41,411	2.06	20,078	0.48%	0.28%
EC4	Chiba	40,569	12.13	3,346	0.47%	1.66%
EC1	Tokyo-to	40,451	1.06	38,071	0.47%	0.15%
EC4	Kanagawa	38,729	8.31	4,659	0.45%	1.14%
EC2	Tokyo-to	38,352	1.25	30,682	0.45%	0.17%
EC3	Kanagawa	37,104	3.38	10,994	0.43%	0.46%
EC2	Saitama	36,520	1.38	26,560	0.43%	0.19%
EC1	Tokyo-to	36,046	1.00	36,046	0.42%	0.14%
EC2	Chiba	35,385	1.19	29,798	0.41%	0.16%
EC2	Ibaraki	33,789	1.69	20,023	0.39%	0.23%
EC4	Kanagawa	33,525	9.19	3,649	0.39%	1.26%
EC4	Chiba	32,915	11.00	2,992	0.38%	1.51%
EC2	Kanagawa	32,884	1.19	27,691	0.38%	0.16%
EC3	Kanagawa	32,543	2.19	14,877	0.38%	0.30%

EC4	Kanagawa	32,276	8.44	3,825	0.38%	1.16%
EC2	Tokyo-to	32,235	1.50	21,490	0.38%	0.21%
EC3	Chiba	32,018	2.25	14,230	0.37%	0.31%
EC2	Chiba	31,898	1.25	25,519	0.37%	0.17%
EC3	Kanagawa	31,053	3.25	9,555	0.36%	0.45%
EC2	Kanagawa	31,005	1.00	31,005	0.36%	0.14%
EC2	Chiba	30,175	1.06	28,400	0.35%	0.15%
EC2	Kanagawa	30,067	1.25	24,054	0.35%	0.17%
EC4	Ibaraki	29,746	6.88	4,327	0.35%	0.94%
EC3	Tokyo-to	29,028	2.69	10,801	0.34%	0.37%
EC4	Saitama	28,985	8.44	3,435	0.34%	1.16%
EC4	Saitama	28,873	7.63	3,787	0.34%	1.04%
EC2	Tokyo-to	28,481	1.69	16,877	0.33%	0.23%
EC3	Tokyo-to	28,461	2.44	11,676	0.33%	0.33%
EC3	Tokyo-to	28,012	3.00	9,337	0.33%	0.41%
EC3	Chiba	27,816	2.06	13,486	0.32%	0.28%
EC3	Kanagawa	26,843	2.63	10,226	0.31%	0.36%
EC3	Tokyo-to	26,831	3.13	8,586	0.31%	0.43%
EC3	Saitama	26,582	2.50	10,633	0.31%	0.34%
EC4	Ibaraki	25,796	6.00	4,299	0.30%	0.82%
EC2	Saitama	25,302	1.00	25,302	0.30%	0.14%
EC3	Saitama	25,245	2.94	8,594	0.29%	0.40%
EC2	Tokyo-to	23,840	1.00	23,840	0.28%	0.14%
EC4	Kanagawa	23,712	5.75	4,124	0.28%	0.79%
EC3	Kanagawa	23,678	1.63	14,571	0.28%	0.22%
EC3	Tokyo-to	23,565	1.44	16,393	0.27%	0.20%
EC4	Tochigi	23,351	8.13	2,874	0.27%	1.11%
EC3	Chiba	23,095	1.69	13,686	0.27%	0.23%
EC4	Kanagawa	22,610	5.00	4,522	0.26%	0.68%
EC4	Chiba	22,449	6.38	3,521	0.26%	0.87%
EC3	Gunma	21,582	2.13	10,156	0.25%	0.29%
EC4	Ibaraki	21,415	6.50	3,295	0.25%	0.89%
EC4	Gunma	21,117	6.63	3,188	0.25%	0.91%
EC3	Kanagawa	21,087	1.31	16,066	0.25%	0.18%

EC4	Chiba	21,049	6.19	3,402	0.25%	0.85%
EC4	Kanagawa	20,795	4.75	4,378	0.24%	0.65%
EC3	Kanagawa	20,710	2.00	10,355	0.24%	0.27%
EC3	Kanagawa	20,153	1.50	13,435	0.24%	0.21%
EC3	Tokyo-to	20,037	2.00	10,018	0.23%	0.27%
EC3	Kanagawa	20,013	2.31	8,654	0.23%	0.32%
EC4	Saitama	19,869	6.94	2,864	0.23%	0.95%
EC3	Tokyo-to	19,847	1.56	12,702	0.23%	0.21%
EC3	Kanagawa	19,565	1.44	13,610	0.23%	0.20%
EC4	Tokyo-to	19,483	5.25	3,711	0.23%	0.72%
EC3	Kanagawa	19,431	1.44	13,517	0.23%	0.20%
EC4	Chiba	19,243	5.13	3,755	0.22%	0.70%
EC4	Gunma	19,013	7.13	2,668	0.22%	0.98%
EC3	Tokyo-to	18,831	1.31	14,347	0.22%	0.18%
EC3	Saitama	18,825	1.69	11,156	0.22%	0.23%
EC3	Saitama	18,629	1.25	14,903	0.22%	0.17%
EC2	Gunma	18,430	1.00	18,430	0.22%	0.14%
EC4	Kanagawa	18,301	2.19	8,366	0.21%	0.30%
EC3	Kanagawa	18,252	1.50	12,168	0.21%	0.21%
EC3	Chiba	18,036	1.56	11,543	0.21%	0.21%
EC3	Kanagawa	17,940	1.38	13,047	0.21%	0.19%
EC3	Chiba	17,739	1.31	13,516	0.21%	0.18%
EC3	Kanagawa	17,721	1.81	9,777	0.21%	0.25%
EC4	Kanagawa	17,667	4.75	3,719	0.21%	0.65%
EC4	Tokyo-to	17,598	4.63	3,805	0.21%	0.63%
EC4	Saitama	17,325	6.25	2,772	0.20%	0.86%
EC4	Chiba	17,077	6.13	2,788	0.20%	0.84%
EC4	Ibaraki	16,632	5.06	3,285	0.19%	0.69%
EC4	Ibaraki	16,385	4.31	3,799	0.19%	0.59%
EC4	Tochigi	16,242	6.06	2,679	0.19%	0.83%
EC3	Tokyo-to	16,090	1.31	12,259	0.19%	0.18%
EC3	Tokyo-to	15,913	1.63	9,793	0.19%	0.22%
EC4	Chiba	14,867	4.19	3,550	0.17%	0.57%
EC3	Kanagawa	14,704	1.38	10,694	0.17%	0.19%

EC4	Chiba	14,552	5.06	2,875	0.17%	0.69%
EC3	Kanagawa	14,355	1.25	11,484	0.17%	0.17%
EC3	Ibaraki	14,072	1.63	8,660	0.16%	0.22%
EC3	Kanagawa	14,071	1.13	12,507	0.16%	0.15%
EC4	Kanagawa	14,006	5.00	2,801	0.16%	0.68%
EC4	Kanagawa	13,881	2.44	5,695	0.16%	0.33%
EC4	Chiba	13,662	2.94	4,651	0.16%	0.40%
EC3	Tokyo-to	13,596	1.56	8,701	0.16%	0.21%
EC3	Saitama	13,564	1.31	10,334	0.16%	0.18%
EC3	Tokyo-to	13,290	1.19	11,192	0.16%	0.16%
EC4	Saitama	13,246	4.13	3,211	0.15%	0.57%
EC4	Saitama	13,204	5.00	2,641	0.15%	0.68%
EC4	Saitama	13,127	3.94	3,334	0.15%	0.54%
EC3	Saitama	13,065	1.63	8,040	0.15%	0.22%
EC4	Ibaraki	12,925	2.88	4,496	0.15%	0.39%
EC4	Tochigi	12,606	4.69	2,689	0.15%	0.64%
EC3	Saitama	12,314	1.31	9,382	0.14%	0.18%
EC3	Gunma	12,129	1.69	7,187	0.14%	0.23%
EC3	Tokyo-to	12,053	1.63	7,417	0.14%	0.22%
EC4	Saitama	12,000	2.94	4,085	0.14%	0.40%
EC4	Gunma	11,950	4.13	2,897	0.14%	0.57%
EC3	Saitama	11,908	1.31	9,073	0.14%	0.18%
EC4	Tokyo-to	11,842	2.88	4,119	0.14%	0.39%
EC3	Gunma	11,824	1.69	7,007	0.14%	0.23%
EC3	Tokyo-to	11,611	1.13	10,321	0.14%	0.15%
EC4	Saitama	11,523	2.63	4,390	0.13%	0.36%
EC3	Kanagawa	11,424	1.13	10,155	0.13%	0.15%
EC3	Saitama	11,420	1.13	10,151	0.13%	0.15%
EC3	Saitama	11,360	1.13	10,098	0.13%	0.15%
EC3	Tokyo-to	11,321	1.13	10,063	0.13%	0.15%
EC3	Tokyo-to	11,277	1.19	9,496	0.13%	0.16%
EC3	Kanagawa	11,111	1.19	9,357	0.13%	0.16%
EC3	Tochigi	11,062	1.31	8,429	0.13%	0.18%
EC4	Chiba	10,854	4.19	2,592	0.13%	0.57%

EC4	Saitama	10,764	2.63	4,100	0.13%	0.36%
EC4	Ibaraki	10,697	2.44	4,388	0.12%	0.33%
EC3	Saitama	10,645	1.00	10,645	0.12%	0.14%
EC4	Saitama	10,615	3.5	3,033	0.12%	0.48%
EC4	Chiba	10,504	3.44	3,056	0.12%	0.47%
EC4	Chiba	10,478	2.44	4,299	0.12%	0.33%
EC3	Kanagawa	10,430	1.00	10,430	0.12%	0.14%
EC3	Tokyo-to	10,041	1.06	9,450	0.12%	0.15%
EC3	Tokyo-to	10,007	1.00	10,007	0.12%	0.14%
EC4	Saitama	10,006	2.88	3,481	0.12%	0.39%
EC4	Saitama	9,961	2.00	4,980	0.12%	0.27%
EC4	Saitama	9,860	3.25	3,034	0.12%	0.45%
EC4	Saitama	9,808	3.19	3,077	0.11%	0.44%
EC4	Tochigi	9,681	2.81	3,442	0.11%	0.39%
EC4	Saitama	9,554	3.25	2,940	0.11%	0.45%
EC3	Tokyo-to	9,326	1.06	8,778	0.11%	0.15%
EC4	Kanagawa	9,288	1.81	5,125	0.11%	0.25%
EC3	Gunma	9,211	1.00	9,211	0.11%	0.14%
EC4	Ibaraki	9,178	2.69	3,415	0.11%	0.37%
EC4	Tochigi	9,104	2.38	3,833	0.11%	0.33%
EC4	Saitama	8,995	2.88	3,129	0.10%	0.39%
EC4	Saitama	8,974	2.50	3,590	0.10%	0.34%
EC3	Tokyo-to	8,954	1.13	7,960	0.10%	0.15%
EC4	Tokyo-to	8,905	3.06	2,908	0.10%	0.42%
EC4	Chiba	8,832	3.44	2,569	0.10%	0.47%
EC4	Saitama	8,810	2.50	3,524	0.10%	0.34%
EC4	Chiba	8,801	3.31	2,657	0.10%	0.45%
EC4	Kanagawa	8,763	3.56	2,460	0.10%	0.49%
EC4	Saitama	8,740	3.31	2,639	0.10%	0.45%
EC3	Saitama	8,735	1.00	8,735	0.10%	0.14%
EC4	Tokyo-to	8,704	2.63	3,316	0.10%	0.36%
EC3	Kanagawa	8,682	1.06	8,171	0.10%	0.15%
EC4	Chiba	8,641	3.00	2,880	0.10%	0.41%
EC4	Saitama	8,463	2.69	3,149	0.10%	0.37%

EC4	Saitama	8,249	2.69	3,069	0.10%	0.37%
EC4	Chiba	8,135	2.38	3,425	0.09%	0.33%
EC4	Chiba	8,089	2.06	3,922	0.09%	0.28%
EC4	Tokyo-to	8,081	1.94	4,171	0.09%	0.27%
EC4	Ibaraki	7,634	2.50	3,053	0.09%	0.34%
EC3	Tokyo-to	7,608	1.06	7,161	0.09%	0.15%
EC4	Tochigi	7,561	2.50	3,025	0.09%	0.34%
EC4	Gunma	7,490	2.44	3,073	0.09%	0.33%
EC4	Saitama	7,208	2.38	3,035	0.08%	0.33%
EC4	Ibaraki	7,160	1.94	3,695	0.08%	0.27%
EC4	Tochigi	7,069	2.31	3,057	0.08%	0.32%
EC4	Chiba	7,031	1.69	4,166	0.08%	0.23%
EC4	Chiba	6,997	1.75	3,998	0.08%	0.24%
EC4	Chiba	6,973	2.06	3,381	0.08%	0.28%
EC4	Tokyo-to	6,927	2.75	2,519	0.08%	0.38%
EC3	Kanagawa	6,736	1.00	6,736	0.08%	0.14%
EC4	Ibaraki	6,718	2.13	3,162	0.08%	0.29%
EC4	Gunma	6,694	2.31	2,895	0.08%	0.32%
EC4	Chiba	6,683	1.69	3,960	0.08%	0.23%
EC4	Chiba	6,573	1.63	4,045	0.08%	0.22%
EC4	Tochigi	6,563	1.94	3,387	0.08%	0.27%
EC4	Chiba	6,503	1.88	3,468	0.08%	0.26%
EC4	Kanagawa	6,474	1.13	5,755	0.08%	0.15%
EC4	Chiba	6,345	1.38	4,615	0.07%	0.19%
EC4	Saitama	6,293	1.75	3,596	0.07%	0.24%
EC4	Saitama	6,262	2.31	2,708	0.07%	0.32%
EC4	Tochigi	6,100	2.13	2,870	0.07%	0.29%
EC4	Saitama	6,070	1.94	3,133	0.07%	0.27%
EC4	Saitama	6,022	2.06	2,920	0.07%	0.28%
EC4	Saitama	5,962	2.19	2,725	0.07%	0.30%
EC4	Kanagawa	5,956	2.19	2,723	0.07%	0.30%
EC4	Kanagawa	5,939	1.94	3,065	0.07%	0.27%
EC4	Saitama	5,843	1.88	3,116	0.07%	0.26%
EC4	Kanagawa	5,812	1.50	3,875	0.07%	0.21%

EC4	Chiba	5,741	1.69	3,402	0.07%	0.23%
EC4	Gunma	5,739	2.00	2,869	0.07%	0.27%
EC4	Saitama	5,672	1.75	3,241	0.07%	0.24%
EC4	Chiba	5,671	2.00	2,836	0.07%	0.27%
EC4	Gunma	5,650	2.00	2,825	0.07%	0.27%
EC4	Ibaraki	5,625	2.44	2,308	0.07%	0.33%
EC4	Kanagawa	5,545	1.81	3,059	0.06%	0.25%
EC4	Chiba	5,502	1.13	4,890	0.06%	0.15%
EC4	Ibaraki	5,467	1.25	4,374	0.06%	0.17%
EC4	Saitama	5,382	1.75	3,075	0.06%	0.24%
EC4	Saitama	5,294	2.06	2,567	0.06%	0.28%
EC4	Chiba	5,275	1.75	3,015	0.06%	0.24%
EC4	Chiba	5,251	1.56	3,360	0.06%	0.21%
EC4	Ibaraki	5,125	2.06	2,485	0.06%	0.28%
EC4	Ibaraki	5,118	2.00	2,559	0.06%	0.27%
EC4	Saitama	5,043	1.88	2,690	0.06%	0.26%
EC4	Ibaraki	5,005	1.31	3,813	0.06%	0.18%
EC4	Saitama	4,973	1.50	3,315	0.06%	0.21%
EC4	Ibaraki	4,921	1.88	2,624	0.06%	0.26%
EC4	Ibaraki	4,880	1.88	2,602	0.06%	0.26%
EC4	Kanagawa	4,847	1.13	4,308	0.06%	0.15%
EC4	Saitama	4,725	1.38	3,436	0.06%	0.19%
EC4	Tochigi	4,685	1.25	3,748	0.05%	0.17%
EC4	Saitama	4,675	1.13	4,156	0.05%	0.15%
EC4	Saitama	4,663	1.25	3,730	0.05%	0.17%
EC4	Ibaraki	4,652	1.88	2,481	0.05%	0.26%
EC4	Chiba	4,615	1.63	2,840	0.05%	0.22%
EC4	Chiba	4,572	1.31	3,484	0.05%	0.18%
EC4	Kanagawa	4,560	1.25	3,648	0.05%	0.17%
EC4	Chiba	4,466	1.31	3,403	0.05%	0.18%
EC4	Gunma	4,461	1.63	2,745	0.05%	0.22%
EC4	Saitama	4,449	1.31	3,390	0.05%	0.18%
EC4	Chiba	4,442	1.00	4,442	0.05%	0.14%
EC4	Tokyo-to	4,433	1.00	4,433	0.05%	0.14%

EC4	Kanagawa	4,406	1.25	3,525	0.05%	0.17%
EC4	Kanagawa	4,352	1.19	3,665	0.05%	0.16%
EC4	Gunma	4,261	1.25	3,408	0.05%	0.17%
EC4	Kanagawa	4,240	1.44	2,949	0.05%	0.20%
EC4	Tochigi	4,214	1.50	2,809	0.05%	0.21%
EC4	Ibaraki	4,082	1.56	2,612	0.05%	0.21%
EC4	Chiba	4,078	1.38	2,966	0.05%	0.19%
EC4	Kanagawa	4,043	1.44	2,813	0.05%	0.20%
EC4	Saitama	3,948	1.38	2,871	0.05%	0.19%
EC4	Kanagawa	3,845	1.81	2,121	0.04%	0.25%
EC4	Ibaraki	3,801	1.19	3,201	0.04%	0.16%
EC4	Kanagawa	3,751	1.25	3,001	0.04%	0.17%
EC4	Tokyo-to	3,741	1.69	2,217	0.04%	0.23%
EC4	Ibaraki	3,668	1.19	3,089	0.04%	0.16%
EC4	Ibaraki	3,665	1.38	2,665	0.04%	0.19%
EC4	Ibaraki	3,640	1.50	2,426	0.04%	0.21%
EC4	Tochigi	3,591	1.63	2,210	0.04%	0.22%
EC4	Saitama	3,542	1.19	2,983	0.04%	0.16%
EC4	Gunma	3,473	1.19	2,925	0.04%	0.16%
EC4	Chiba	3,314	1.44	2,306	0.04%	0.20%
EC4	Chiba	3,295	1.44	2,292	0.04%	0.20%
EC4	Chiba	3,287	1.19	2,768	0.04%	0.16%
EC4	Saitama	3,246	1.06	3,055	0.04%	0.15%
EC4	Tochigi	3,246	1.31	2,473	0.04%	0.18%
EC4	Kanagawa	3,244	1.25	2,595	0.04%	0.17%
EC4	Gunma	3,232	1.25	2,586	0.04%	0.17%
EC4	Kanagawa	3,212	1.13	2,855	0.04%	0.15%
EC4	Saitama	3,208	1.19	2,702	0.04%	0.16%
EC4	Kanagawa	3,121	1.06	2,937	0.04%	0.15%
EC4	Chiba	3,080	1.19	2,594	0.04%	0.16%
EC4	Saitama	3,059	1.50	2,039	0.04%	0.21%
EC4	Gunma	3,057	1.31	2,329	0.04%	0.18%
EC4	Kanagawa	3,057	1.13	2,717	0.04%	0.15%
EC4	Gunma	2,969	1.38	2,159	0.03%	0.19%

EC4	Tochigi	2,955	1.00	2,955	0.03%	0.14%
EC4	Tochigi	2,928	1.19	2,465	0.03%	0.16%
EC4	Saitama	2,889	1.13	2,568	0.03%	0.15%
EC4	Tochigi	2,736	1.13	2,432	0.03%	0.15%
EC4	Kanagawa	2,730	1.00	2,730	0.03%	0.14%
EC4	Ibaraki	2,718	1.00	2,718	0.03%	0.14%
EC4	Kanagawa	2,653	1.06	2,497	0.03%	0.15%
EC4	Saitama	2,606	1.00	2,606	0.03%	0.14%
EC4	Chiba	2,529	1.00	2,529	0.03%	0.14%
EC4	Kanagawa	2,469	1.00	2,469	0.03%	0.14%
EC4	Gunma	2,306	1.00	2,306	0.03%	0.14%
EC4	Chiba	2,273	1.13	2,020	0.03%	0.15%
EC4	Chiba	2,235	1.00	2,235	0.03%	0.14%

APPENDIX B

Table B-1: The center ID of the ECs in different ranks and their employment characteristics (Tokyo-to) in the year 1999 and 2009.

Tokyo-to	Note: EC1= Red color; EC2= Yellow color; EC3= Blue color; and EC4= Rose color							
Center ID	ECs (different ranks)		Total employment		Area(km^2)		Average density	
	1999	2009	1999	2009	1999	2009	1999	2009
1	EC3	EC3	15,167	12,053	1.56	1.62	9,707	7,417
2	EC4	EC4	7,836	8,704	2.31	2.62	3,389	3,316
3	EC4	EC4	7,421	6,927	2.87	2.75	2,581	2,519
4	EC2	EC2	37,943	38,352	1.25	1.25	30,355	30,682
5	EC3	EC3	11,532	11,321	1.12	1.12	10,250	10,063
6	EC1	EC1	41,402	55,127	1.12	1.12	36,802	49,002
7	EC3	EC3	14,418	13,596	1.5	1.56	9,612	8,701
8	EC3	EC3	27,101	28,012	2.93	3	9,226	9,337
9	EC3	EC3	48,539	48,666	4.18	3.93	11,591	12,360
10	EC3	EC3	16,680	19,847	1.56	1.56	10,675	12,702
11	EC4	EC4	4,148	3,741	1.81	1.68	2,289	2,217
12	EC3	EC3	15,153	18,831	1.37	1.31	11,020	14,347
13	EC4	EC4	8,508	11,842	2.87	2.87	2,959	4,119
14	EC4	EC4	3,695	4,433	1	1	3,695	4,433
15	EC4	EC4	8,276	8,905	2.93	3.06	2,817	2,908
16	EC4	-	1,884	0	1	0	1,884	0
17	EC4	EC4	18,890	17,598	4.75	4.62	3,977	3,805

18	EC3	EC3	20,370	23,565	1.56	1.43	13,037	16,393
19	EC3	EC3	8,791	9,326	1.06	1.06	8,274	8,778
20	EC2	EC2	20,832	23,840	1	1	20,832	23,840
21	EC3	EC3	12,699	13,290	1.18	1.18	10,694	11,192
22	EC4	EC4	9,229	8,081	1.93	1.93	4,763	4,171
23	EC3	EC3	20,554	20,037	2.12	2	9,673	10,018
24	EC3	EC3	7,113	7,608	1.06	1.06	6,694	7,161
25	EC3	EC3	27,813	28,461	2.56	2.43	10,854	11,676
26	EC2	EC2	31,883	32,235	1.5	1.5	21,255	21,490
27	EC3	EC3	13,624	16,090	1.31	1.31	10,380	12,259
28	EC3	EC3	6,445	8,954	1.12	1.12	5,729	7,960
29	EC2	EC2	29,457	28,481	1.75	1.68	16,832	16,877
30	EC1	EC1	156,736	183,295	3.06	2.87	51,179	63,755
31	EC1	EC1	37,658	40,451	1	1.06	37,658	38,071
32	EC2	EC2	43,092	47,230	1.38	1.37	31,340	34,349
33	EC1	EC1	37,375	36,046	1	1	37,375	36,046
34	-	EC4	0	19,483	0	5.25	0	3,711
35	EC3	-	15,533	0	1.06	0	14,619	0
36	EC1	EC1	45,846	56,008	1.43	1.5	31,893	37,339
37	EC3	EC3	25,883	29,028	2.56	2.68	10,101	10,801
38	EC3	EC3	41,633	42,508	4.87	4.87	8,540	8,719
39	EC3	EC3	16,885	15,913	1.56	1.62	10,806	9,793
40	EC3	EC3	10,501	11,277	1.12	1.18	9,334	9,496
41	EC3	EC3	40,715	42,034	5	5.06	8,143	8,303

42	EC3	EC3	11,186	11,611	1.25	1.12	8,949	10,321
43	EC3	EC3	10,026	10,007	1	1	10,026	10,007
44	EC3	EC3	23,889	26,831	3.25	3.12	7,351	8,586
45	EC3	EC3	7,783	10,041	1.06	1.06	7,325	9,450
46	EC1	EC1	3,702,215	4,151,427	61.06	60.56	60,630	68,548

Table B-2: The center ID of the ECs in different ranks and their employment characteristics (Saitama prefecture) in the year 1999 and 2009.

Saitama								
Center ID	ECs (different ranks)		Total employment		Area(km^2)		Average density	
	1999	2009	1999	2009	1999	2009	1999	2009
1	EC4	EC4	11,304	9,554	3.31	3.25	3,413	2,940
2	EC4	EC4	3,102	3,208	1.31	1.19	2,363	2,702
3	EC4	EC4	9,299	8,249	2.62	2.69	3,543	3,069
4	EC4	EC4	18,285	17,325	6.38	6.25	2,868	2,772
5	EC4	EC4	4,806	3,059	1.69	1.5	2,848	2,039
6	EC3	EC3	19,939	18,825	1.69	1.69	11,816	11,156
7	EC4	EC4	6,366	5,294	2.19	2.06	2,910	2,567
8	EC4	EC4	13,783	13,246	4.06	4.13	3,393	3,211
9	EC4	EC4	4,209	4,663	1.25	1.25	3,367	3,730
10	EC4	EC4	2,949	2,606	1	1	2,949	2,606
11	EC4	EC4	5,995	5,043	1.94	1.88	3,094	2,690
12	EC3	EC4	9,309	9,860	3.31	3.25	2,810	3,034
13	EC4	EC4	14,282	13,127	3.94	3.94	3,627	3,334
14	EC4	EC4	5,770	5,672	2.13	1.75	2,715	3,241
15	EC4	EC4	9,346	8,810	2.56	2.5	3,647	3,524
16	EC4	EC4	6,290	5,962	2.25	2.19	2,796	2,725
17	EC4	EC4	9,846	10,006	2.75	2.88	3,580	3,481

18	EC4	EC4	7,455	7,208	2.44	2.38	3,058	3,035
19	EC4	-	2,199	0	1.13	0	1,955	0
20	EC4	EC4	4,347	4,449	1.44	1.31	3,024	3,390
21	EC4	EC4	5,925	5,843	1.88	1.88	3,160	3,116
22	EC4	-	3,137	0	1.06	0	2,952	0
23	EC3	EC3	14,635	13,564	1.44	1.31	10,181	10,334
24	EC4	EC4	5,460	4,973	1.44	1.5	3,798	3,315
25	EC4	EC4	3,226	3,246	1.06	1.06	3,037	3,055
26	EC4	EC4	2,980	2,889	1.19	1.13	2,509	2,568
27	EC3	EC3	11,945	11,420	1.13	1.13	10,618	10,151
28	EC4	EC4	6,045	6,293	1.69	1.75	3,582	3,596
29	EC4	EC4	5,049	4,725	1.44	1.38	3,512	3,436
30	EC4	EC4	9,244	9,961	2.13	2	4,350	4,980
31	EC4	EC4	3,284	3,542	1.44	1.19	2,284	2,983
32	EC4	EC4	9,671	8,463	2.69	2.69	3,599	3,149
33	EC4	EC4	3,227	6,262	1.19	2.31	2,717	2,708
34	EC4	EC4	29,265	28,985	8.38	8.44	3,494	3,435
35	EC4	EC4	6,485	6,070	1.94	1.94	3,347	3,133
36	EC4	EC4	5,655	4,675	1.19	1.13	4,762	4,156
37	EC4	EC4	3,039	3,948	1.19	1.38	2,559	2,871
38	EC2	EC2	20,609	25,302	1	1	20,609	25,302
39	EC1	EC1	58,736	72,885	1.5	1.5	39,158	48,590

40	EC2	-	13,368	0	1	0	13,368	0
41	EC4	EC4	8,041	8,995	2.88	2.88	2,797	3,129
42	EC4	EC4	9,378	9,808	3.25	3.19	2,886	3,077
43	EC3	EC3	13,935	12,314	1.19	1.31	11,734	9,382
44	EC4	EC4	27,445	28,873	7.81	7.63	3,513	3,787
45	EC2	EC2	37,044	36,520	1.25	1.38	29,635	26,560
46	EC4	EC4	12,950	11,523	2.88	2.63	4,504	4,390
47	EC4	EC4	12,218	13,204	5	5	2,444	2,641
48	EC4	EC4	9,083	10,764	2.56	2.63	3,545	4,100
49	EC3	EC3	14,041	18,629	1.25	1.25	11,233	14,903
50	EC4	-	1,759	0	1.25	0	1,407	0
51	EC4	EC4	7,027	6,022	2.13	2.06	3,307	2,920
52	EC4	EC4	7,440	8,974	2.56	2.5	2,903	3,590
53	EC3	EC3	10,798	10,645	1	1	10,798	10,645
54	EC3	EC3	10,888	11,908	1.31	1.31	8,295	9,073
55	EC3	EC3	7,753	8,735	1	1	7,753	8,735
56	EC3	EC3	10,264	11,360	1.13	1.13	9,124	10,098
57	EC3	EC3	23,987	25,245	3	2.94	7,996	8,594
58	EC4	EC4	3,817	5,382	1.75	1.75	2,181	3,075
59	EC4	EC4	10,292	10,615	3.94	3.5	2,614	3,033
60	EC4	EC4	10,223	8,740	3.38	3.31	3,029	2,639
61	EC4	-	2,440	0	1	0	2,440	0

62	EC4	EC4	31,938		10.25		3,116	
62a		EC4		19,869		6.94		2,864
62b		EC4		12,000		2.94		4,085
63	EC3	EC3	41,252		4.25		9,706	
63a		EC3		26,582		2.5		10,633
63b		EC3		13,065		1.63		8,040

Table B-3: The center ID of the ECs in different ranks and their employment characteristics (Kanagawa prefecture) in the year 1999 and 2009.

Kanagawa								
Center ID	ECs (different ranks)		Total employment		Area(km^2)		Average density	
	1999	2009	1999	2009	1999	2009	1999	2009
1	EC3	-	9,716	0	1	0	9,716	0
2	EC3	EC3	10,835	6,736	1.25	1	8,668	6,736
3	EC3	EC3	20,539	20,710	2.13	2	9,665	10,355
4	EC4	EC4	14,949	18,301	2.13	2.19	7,035	8,366
5	EC3	EC3	9,191	10,430	1	1	9,191	10,430
6	EC2	EC3	20,172	32,543	1.06	2.19	18,985	14,877
7	EC2	EC2	27,199	30,067	1.25	1.25	21,759	24,054
8	EC3	EC3	21,091	31,053	2.5	3.25	8,436	9,555
9	EC1	EC1	45,424	61,453	1.31	1.25	34,609	49,162
10	EC3	EC3	19,271	20,013	2.31	2.31	8,334	8,654
11	EC3	EC3	11,389	19,431	1.5	1.44	7,593	13,517
12	-	EC4	0	22,610	0	5	0	4,522
13	EC3	EC3	26,828	26,843	2.63	2.63	10,220	10,226
14	EC1	EC2	36,315	56,734	1	1.5	36,315	37,822
15	EC4	EC4	3,416	4,406	1.25	1.25	2,733	3,525
16	EC3	EC3	13,332	14,071	1.13	1.13	11,850	12,507
17	EC4	EC4	3,108	3,212	1.19	1.13	2,617	2,855
18	EC4	EC4	18,842	20,795	4.69	4.75	4,020	4,378
19	EC4	EC4	2,793	3,057	1.06	1.13	2,629	2,717
20	EC3	EC3	8,709	11,111	1.19	1.19	7,334	9,357
21	EC4	EC4	5,169	5,545	1.81	1.81	2,852	3,059
22	EC3	EC3	15,117	14,704	1.38	1.38	10,995	10,694
23	EC4	-	3,130	0	1.38	0	2,277	0
24	EC4	EC4	40,952	43,319	11.13	11.5	3,681	3,767

25	EC1	EC1	233,519	298,829	5.81	5.13	40,175	58,308
26	EC3	EC3	11,957	14,355	1.19	1.25	10,069	11,484
27	EC4	EC4	11,903	14,006	5.06	5	2,351	2,801
28	EC4	EC4	4,173	4,240	1.44	1.44	2,903	2,949
29	EC4	-	3,042	0	1	0	3,042	0
30	EC4	EC4	3,593	4,043	1.38	1.44	2,613	2,813
31	EC4	EC4	4,260	4,847	1.19	1.13	3,587	4,308
32	EC4	EC4	2,753	2,653	1.13	1.06	2,448	2,497
33	EC3	EC3	19,487	20,153	1.56	1.5	12,472	13,435
34	EC4	EC4	5,166	5,812	1.5	1.5	3,444	3,875
35	EC4	EC4	10,384	8,763	3.31	3.56	3,135	2,460
36	EC4	EC4	38,761	38,729	8.5	8.31	4,560	4,659
37	EC4	EC4	2,473	2,469	1.06	1	2,328	2,469
38	EC2	EC2	32,267	32,884	1.19	1.19	27,173	27,691
39	EC3	EC3	15,849	21,087	1.31	1.31	12,075	16,066
40	EC4	EC4	5,201	9,288	1.94	1.81	2,684	5,125
41	EC3	EC3	14,367	17,721	1.94	1.81	7,415	9,777
42	EC4	EC4	16,959	17,667	5.13	4.75	3,309	3,719
43	EC3	EC3	16,310	19,565	1.44	1.44	11,346	13,610
44	EC4	EC4	5,615	5,956	2.06	2.19	2,722	2,723
45	EC4	EC4	24,322	23,712	5.5	5.75	4,422	4,124
46	EC4	EC4	3,608	4,560	1.25	1.25	2,886	3,648
47	EC3	EC3	9,370	8,682	1.19	1.06	7,890	8,171
48	EC4	EC4	3,888	3,751	1.31	1.25	2,962	3,001
49	EC2	EC2	29,141	31,005	1	1	29,141	31,005
50	EC3	EC3	11,105	11,424	1.13	1.13	9,871	10,155
51	EC4	EC4	37,754	33,525	9.44	9.19	4,000	3,649
52	EC3	EC3	37,057	37,104	3.44	3.38	10,780	10,994
53	EC3	EC3	16,560	18,252	1.5	1.5	11,040	12,168
54	EC4	EC4	3,150	2,730	1	1	3,150	2,730
55	EC4	EC4	12,557	13,881	2	2.44	6,279	5,695
56	EC4	EC4	6,034	6,474	1.13	1.13	5,364	5,755

57	EC3	EC3	26,813	23,678	1.5	1.63	17,875	14,571
58	EC4	EC4	5,205	3,845	1.75	1.81	2,974	2,121
59	EC4	EC4	8,007	5,939	1.94	1.94	4,133	3,065
60	EC4	EC4	2,128	3,121	1	1.06	2,128	2,937
61	EC4	EC4	34,071	32,276	8.44	8.44	4,038	3,825
62	EC3	EC3	19,176	17,940	1.38	1.38	13,946	13,047
63	EC4	EC4	2,813	3,244	1.19	1.25	2,369	2,595
64	EC4	-	4,901	0	1.38	0	3,564	0
65	EC4	EC4	4,664	4,352	1.13	1.19	4,146	3,665

Table B-4: The center ID of the ECs in different ranks and their employment characteristics (Chiba prefecture) in the year 1999 and 2009.

Chiba								
Center ID	ECs (Different ranks)		Total employment		Area(km^2)		Average density	
	1999	2009	1999	2009	1999	2009	1999	2009
1	EC4	—	2,357	0	1.06	0	2,218	0
2	EC4	EC4	11,404	10,504	3.31	3.44	3,443	3,056
3	EC4	EC4	5,574	3,295	1.44	1.44	3,878	2,292
4	EC4	EC4	6,881	5,251	1.69	1.56	4,078	3,360
5	EC4	EC4	3,193	3,080	1.25	1.19	2,555	2,594
6	EC4	EC4	18,786	22,449	6.44	6.38	2,918	3,521
7	-	EC4	0	8,641	0	3	0	2,880
8	EC2	EC2	27,126	30,175	1.06	1.06	25,531	28,400
9	EC4	EC4	5,794	6,573	1.63	1.63	3,565	4,045
10	EC4	EC4	4,276	4,572	1.19	1.31	3,601	3,484
11	EC3	EC3	23,294	23,095	1.81	1.69	12,852	13,686
12	EC4	EC4	2,765	3,287	1.06	1.19	2,602	2,768
13	EC4	EC4	16,183	14,867	4.25	4.19	3,808	3,550
14	EC4	EC4	12,203	14,552	5.06	5.06	2,410	2,875
15	-	EC4	0	5,502	0	1.13	0	4,890
16	EC3	EC3	15,681	18,036	1.69	1.56	9,292	11,543
17	EC2	EC2	28,083	31,898	1.19	1.25	23,649	25,519
18	EC3	EC3	15,166	17,739	1.31	1.31	11,555	13,516
19	EC4	EC4	38,860	40,569	12.38	12.13	3,140	3,346
20	EC4	EC4	7,468	6,345	1.38	1.38	5,431	4,615
21	EC4	EC4	2,466	4,466	1.38	1.31	1,793	3,403
22	EC4	EC4	8,656	8,832	3.44	3.44	2,518	2,569
23	EC4	EC4	3,516	3,314	1.31	1.44	2,679	2,306
24	EC4	EC4	6,729	8,089	1.94	2.06	3,473	3,922

25	EC4	EC4	5,324	5,275	1.75	1.75	3,043	3,015
26	EC3	EC3	25,166	32,018	2.13	2.25	11,843	14,230
27	EC2	EC2	33,251	35,385	1.19	1.19	28,001	29,798
28	EC4	EC4	18,099	17,077	6.88	6.13	2,633	2,788
29	EC4	EC4	6,285	6,997	1.75	1.75	3,592	3,998
30	EC4	EC4	8,024	8,135	2.38	2.38	3,378	3,425
31	EC4	EC4	13,716	10,854	3.75	4.19	3,657	2,592
32	EC4	-	2,387	0	1	0	2,387	0
33	EC4	EC4	5,188	5,741	1.63	1.69	3,192	3,402
34	EC4	EC4	14,405	13,662	2.94	2.94	4,904	4,651
35	EC3	EC3	28,829	27,816	1.88	2.06	15,375	13,486
36	EC4	EC4	7,305	6,503	1.88	1.88	3,896	3,468
37	EC4	EC4	6,242	5,671	2.06	2	3,027	2,836
38	EC4	EC4	13,202	10,478	2.5	2.44	5,281	4,299
39	EC1	EC1	58,681	62,840	1.5	1.5	39,120	41,893
40	EC4	EC4	3,566	4,442	1.06	1	3,357	4,442
41	EC4	EC4	6,640	7,031	1.63	1.69	4,086	4,166
42	EC4	EC4	31,783	32,915	10.38	11	3,063	2,992
43	EC4	EC4	8,008	8,801	3.44	3.31	2,330	2,657
44	EC4	EC4	5,332	4,615	1.63	1.63	3,281	2,840
45	EC4	EC4	21,022	19,243	5	5.13	4,204	3,755
46	EC4	EC4	21,391	21,049	5.69	6.19	3,761	3,402
47	-	EC4	0	2,273	0	1.13	0	2,020
48	EC4	EC4	6,264	6,683	1.69	1.69	3,712	3,960
49	EC4	EC4	2,552	2,529	1	1	2,552	2,529
50	EC4	EC4	7,453	6,973	2.06	2.06	3,613	3,381
51	EC4	EC4	6,265		2.75		2,278	
51a		EC4		4,078		1.38		2,966
51b		EC4		2,235		1		2,235

Table B-5: The center ID of the ECs in different ranks and their employment characteristics (Ibaraki prefecture) in the year 1999 and 2009.

Ibaraki								
Center ID	ECs (Different ranks)		Total employment		Area(km^2)		Average density	
	1999	2009	1999	2009	1999	2009	1999	2009
1	EC4	EC4	4,284	3,668	1.06	1.19	4,032	3,089
2	EC3	EC3	18,234	14,072	1.63	1.63	11,221	8,660
3	EC4	EC4	17,020	16,632	5.06	5.06	3,362	3,285
4	EC4	EC4	10,745	10,697	2.44	2.44	4,408	4,388
5	EC4	EC4	3,784	3,665	1.5	1.38	2,523	2,665
6	EC4	EC4	6,479	5,125	2.06	2.06	3,141	2,485
7	EC4	EC4	22,595	21,415	6.38	6.5	3,544	3,295
8	EC2	EC2	39,086	33,789	1.75	1.69	22,335	20,023
9	EC4	-	2,742	0	1.06	0	2,581	0
10	EC4	EC4	5,014	4,921	1.69	1.88	2,971	2,624
11	EC4	EC4	8,313	7,634	2.44	2.5	3,410	3,053
12	EC4	EC4	4,748	4,082	1.44	1.56	3,303	2,612
13	EC4	EC4	4,005	3,640	1.44	1.5	2,786	2,426
14	EC4	EC4	4,455	5,005	1.31	1.31	3,394	3,813
15	EC4	EC4	10,020	9,178	2.69	2.69	3,728	3,415
16	-	EC4	0	2,718	0	1	0	2,718
17	EC4	EC4	5,419	4,880	2.25	1.88	2,409	2,602
18	EC4	EC4	2,860	5,467	1.25	1.25	2,288	4,374
19	EC4	EC4	5,197	6,718	2.06	2.13	2,520	3,162
20	EC4	EC4	27,200	25,796	5.81	6	4,680	4,299
21	EC4	EC4	21,283	29,746	7.06	6.88	3,014	4,327
22	EC4	EC4	5,855	7,160	1.88	1.94	3,122	3,695
23	EC4	EC4	12,689	12,925	2.94	2.88	4,320	4,496
24	EC4	EC4	4,743	4,652	1.81	1.88	2,617	2,481
25	EC4	EC4	5,815	5,118	2.06	2	2,819	2,559

26	EC4	EC4	3,415	3,801	1.13	1.19	3,036	3,201
27	EC4	EC4	21,268		6.75		3,151	
27a		EC4		5,625		2.44		2,308
27b		EC4		16,385		4.31		3,799

Table B-6: The center ID of the ECs in different ranks and their employment characteristics (Tochigi prefecture) in the year 1999 and 2009.

Tochigi									
Center ID	ECs (Different ranks)		Total employment		Area(km^2)		Average density		
	1999	2009	1999	2009	1999	2009	1999	2009
1	EC4	EC4	5,633	6,100	2.19	2.13	2,575	2,870
2	EC4	EC4	3,275	2,736	1.19	1.13	2,758	2,432
3	EC4	EC4	6,814	7,069	2.31	2.31	2,947	3,057
4	EC4	EC4	3,803	4,685	1.31	1.25	2,898	3,748
5	EC4	EC4	3,151	2,928	1.19	1.19	2,654	2,465
6	EC4	EC4	3,751	3,246	1.25	1.31	3,001	2,473
7	EC4	EC4	6,911	6,563	1.81	1.94	3,813	3,387
8	EC4	EC4	3,527	4,214	1.44	1.5	2,454	2,809
9	EC2	EC2	43,484	41,411	2.06	2.06	21,083	20,078
10	EC4	EC4	8,630	9,681	3	2.81	2,877	3,442
11	EC4	EC4	4,266	9,104	2.44	2.38	1,750	3,833
12	EC4	EC4	8,236	7,561	2.5	2.5	3,294	3,025
13	EC4	EC4	3,771	3,591	1.63	1.63	2,321	2,210
14	EC4	-	2,557	0	1.75	0	1,461	0
15	EC4	EC4	13,907	12,606	4.56	4.69	3,048	2,689
16	EC3	EC3	12,257	11,062	1.31	1.31	9,339	8,429
17	EC4	EC4	17,903	16,242	5.81	6.06	3,080	2,679
18	EC4	EC4	3,024	2,955	1	1	3,024	2,955
19	EC4	EC4	24,321	23,351	8.25	8.13	2,948	2,874

Table B-7: The center ID of the ECs in different ranks and their employment characteristics (Gunma prefecture) in the year 1999 and 2009.

Gunma								
Center ID	ECs (Different ranks)		Total employment		Area(km^2)		Average density	
	1999	2009	1999	2009	1999	2009	1999	2009
1	EC4	EC4	8,435	6,694	2.38	2.31	3,552	2,895
2	EC4	EC4	8,558	7,490	2.5	2.44	3,423	3,073
3	EC4	-	2,651	0	1.06	0	2,495	0
4	EC4	EC4	22,549	21,117	6.5	6.63	3,469	3,188
5	EC3	EC3	25,766	21,582	2.19	2.13	11,779	10,156
6	EC3	EC3	14,016	11,824	1.75	1.69	8,009	7,007
7	EC4	EC4	3,544	4,461	1.5	1.63	2,362	2,745
8	EC4	EC4	4,211	4,261	1.19	1.25	3,546	3,408
9	EC3	EC2	29,092	18,430	2.38	1	12,249	18,430
10	EC4	EC4	3,054	3,232	1.19	1.25	2,572	2,586
11	EC4	EC4	3,108	3,057	1.25	1.31	2,486	2,329
12	EC4	EC4	21,147	19,013	7.06	7.13	2,994	2,668
13	EC4	EC4	3,229	2,969	1.38	1.38	2,348	2,159
14	EC4	EC4	3,016	2,306	1.06	1	2,839	2,306
15	EC4	EC4	5,781	5,739	1.94	2	2,984	2,869
16	EC4	EC4	6,822	5,650	2.13	2	3,210	2,825
17	EC4	EC4	4,007	3,473	1.38	1.19	2,914	2,925
18	EC3	EC3	17,545	12,129	1.63	1.69	10,797	7,187
19	EC4	EC3	19,644	9,211	3.31	1	5,930	9,211
20	EC4	-	3,624	0	1.13	0	3,221	0
21	EC4	EC4	13,362	11,950	4.19	4.13	3,191	2,897

APPENDIX C

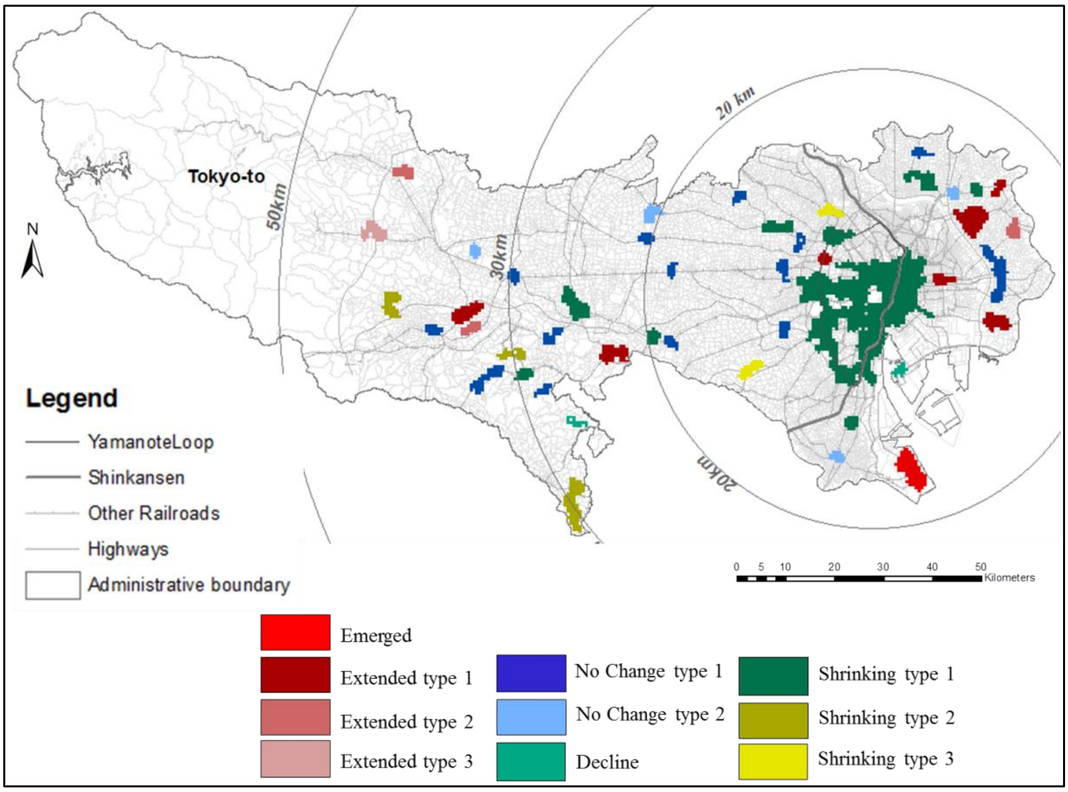

Figure C-1: Location of the change patterns of the ECs (Tokyo-to), 1999-2009.

Table C-1: The change patterns of the ECs in Tokyo-to, 1999-2009.

Tokyo-to	Note: EC1= Red color; EC2= Yellow color; EC3= Blue color; and EC4= Rose color				
Center ID	ECs (Different ranks)		Employment change	Density change	Area(km^2) change
	1999	2009	1999-2009	1999-2009	1999-2009
1	EC3	EC3	**(3,114)**	**(2,289)**	0.06
2	EC4	EC4	867	**(73)**	0.31
3	EC4	EC4	**(495)**	**(63)**	**(0.13)**
4	EC2	EC2	409	327	0.00
5	EC3	EC3	**(211)**	**(187)**	0.00
6	EC1	EC1	13,725	12,200	0.00
7	EC3	EC3	**(822)**	**(910)**	0.06
8	EC3	EC3	911	111	0.06
9	EC3	EC3	127	768	**(0.25)**
10	EC3	EC3	3,167	2,027	0.00
11	EC4	EC4	**(407)**	**(72)**	**(0.13)**
12	EC3	EC3	3,678	3,327	**(0.06)**
13	EC4	EC4	3,334	1,160	0.00
14	EC4	EC4	738	738	0.00
15	EC4	EC4	629	90	0.13
16	EC4	-	**(1,884)**	**(1,884)**	**(1.00)**
17	EC4	EC4	**(1,292)**	**(172)**	**(0.13)**
18	EC3	EC3	3,196	3,357	**(0.13)**
19	EC3	EC3	536	504	0.00

20	EC2	EC2	3,008	3,008	0.00
21	EC3	EC3	591	498	0.00
22	EC4	EC4	**(1,148)**	**(592)**	0.00
23	EC3	EC3	**(518)**	346	**(0.13)**
24	EC3	EC3	496	466	0.00
25	EC3	EC3	648	822	**(0.13)**
26	EC2	EC2	352	235	0.00
27	EC3	EC3	2,466	1,879	0.00
28	EC3	EC3	2,510	2,231	0.00
29	EC2	EC2	**(976)**	45	**(0.06)**
30	EC1	EC1	26,559	12,576	**(0.19)**
31	EC1	EC1	2,792	413	0.06
32	EC2	EC2	4,138	3,010	**(-0.01)**
33	EC1	EC1	**(1,329)**	**(1,329)**	0.00
34	-	EC4	19,483	3,711	5.25
35	EC3	-	**(15,533)**	**(14,619)**	**(1.06)**
36	EC1	EC1	10,163	5,446	0.06
37	EC3	EC3	3,144	700	0.13
38	EC3	EC3	874	179	0.00
39	EC3	EC3	**(971)**	**(1,013)**	0.06
40	EC3	EC3	776	162	0.06
41	EC3	EC3	1,318	160	0.06
42	EC3	EC3	425	1,372	**(0.13)**
43	EC3	EC3	**(19)**	**(19)**	0.00

44	EC3	EC3	2,942	1,235	**(0.13)**
45	EC3	EC3	2,258	2,125	0.00
46	EC1	EC1	449,212	7,918	**(0.50)**

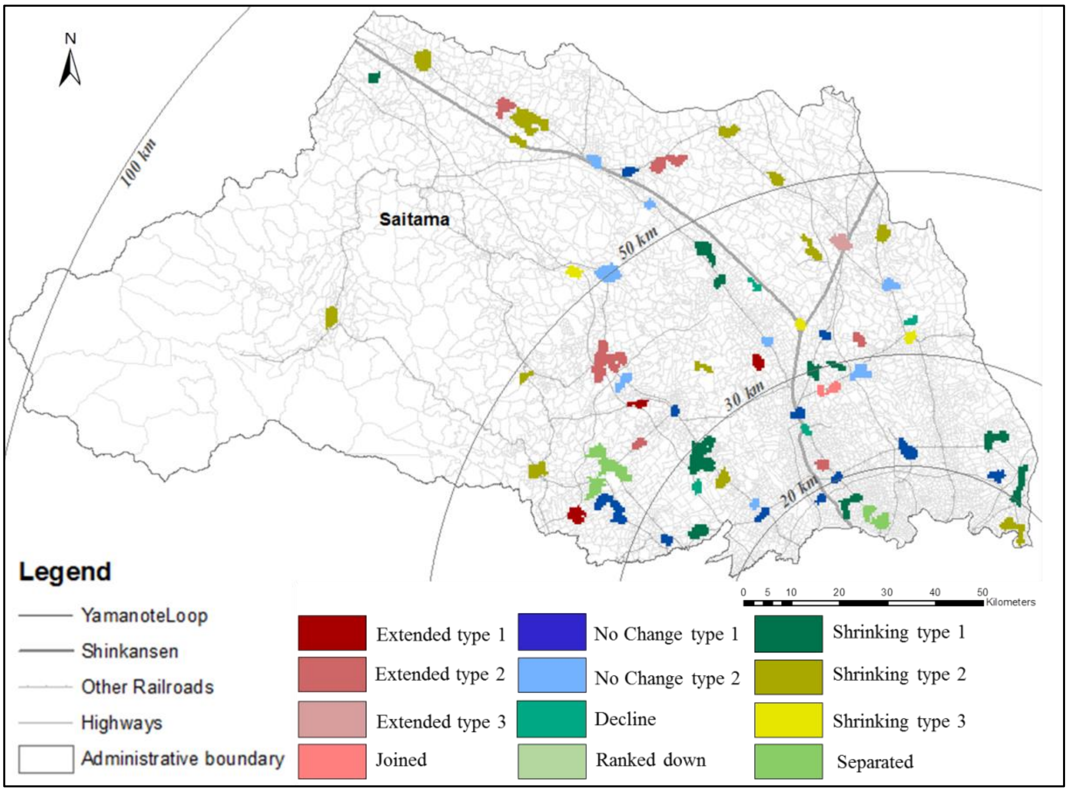

Figure C-2: Location of the change patterns of the ECs (Saitama prefecture), 1999-2009.

Table C-2: The change patterns of the ECs in Saitama prefecture, 1999-2009.

Saitama					
Center ID	ECs (Different ranks)		Employment change	Density change	Area(km^2) change
	1999	2009	1999-2009	1999-2009	1999-2009
1	EC4	EC4	**(1,750)**	**(473)**	**(0.06)**
2	EC4	EC4	106	338	**(0.13)**
3	EC4	EC4	**(1,051)**	**(473)**	0.06
4	EC4	EC4	**(960)**	**(96)**	**(0.13)**
5	EC4	EC4	**(1,748)**	**(809)**	**(0.19)**
6	EC3	EC3	**(1,113)**	**(660)**	0.00
7	EC4	EC4	**(1,072)**	**(343)**	**(0.13)**
8	EC4	EC4	**(537)**	**(181)**	0.06
9	EC4	EC4	454	363	0.00
10	EC4	EC4	**(343)**	**(343)**	0.00
11	EC4	EC4	**(952)**	**(404)**	**(0.06)**
12	EC4	EC4	552	224	**(0.06)**
13	EC4	EC4	**(1,155)**	**(293)**	0.00
14	EC4	EC4	**(98)**	526	**(0.38)**
15	EC4	EC4	**(536)**	**(123)**	**(0.06)**
16	EC4	EC4	**(328)**	**(70)**	**(0.06)**
17	EC4	EC4	161	**(100)**	0.13
18	EC4	EC4	**(247)**	**(24)**	**(0.06)**
19	EC4	-	**(2,199)**	**(1,955)**	**(1.13)**
20	EC4	EC4	102	366	**(0.13)**
21	EC4	EC4	**(82)**	**(44)**	0.00
22	EC4	-	**(3,137)**	**(2,952)**	**(1.06)**
23	EC3	EC3	**(1,071)**	153	**(0.13)**
24	EC4	EC4	**(487)**	**(483)**	0.06
25	EC4	EC4	20	19	0.00

26	EC4	EC4	**(91)**	59	**(0.06)**
27	EC3	EC3	**(526)**	**(467)**	0.00
28	EC4	EC4	248	14	0.06
29	EC4	EC4	**(324)**	**(76)**	**(0.06)**
30	EC4	EC4	716	630	**(0.13)**
31	EC4	EC4	258	699	**(0.25)**
32	EC4	EC4	**(1,208)**	**(449)**	0.00
33	EC4	EC4	3,035	**(10)**	1.13
34	EC4	EC4	**(280)**	**(59)**	0.06
35	EC4	EC4	**(415)**	**(214)**	0.00
36	EC4	EC4	**(980)**	**(606)**	**(0.06)**
37	EC4	EC4	909	312	0.19
38	EC2	EC2	4,693	4,693	0.00
39	EC1	EC1	14,149	9,432	0.00
40	EC2	-	**(13,368)**	**(13,368)**	**(1.00)**
41	EC4	EC4	953	332	0.00
42	EC4	EC4	430	191	**(0.06)**
43	EC3	EC3	**(1,620)**	**(2,352)**	0.13
44	EC4	EC4	1,428	274	**(0.19)**
45	EC2	EC2	**(525)**	**(3,076)**	0.13
46	EC4	EC4	**(1,427)**	**(115)**	**(0.25)**
47	EC4	EC4	986	197	0.00
48	EC4	EC4	1,681	556	0.06
49	EC3	EC3	4,588	3,671	0.00
50	EC4	-	**(1,759)**	**(1,407)**	**(1.25)**
51	EC4	EC4	**(1,005)**	**(387)**	**(0.06)**
52	EC4	EC4	1,535	686	**(0.06)**
53	EC3	EC3	**(152)**	**(152)**	0.00
54	EC3	EC3	1,020	777	0.00
55	EC3	EC3	982	982	0.00
56	EC3	EC3	1,096	974	0.00
57	EC3	EC3	1,257	598	**(0.06)**

58	EC4	EC4	1,564	894	0.00
59	EC4	EC4	322	419	**(0.44)**
60	EC4	EC4	**(1,483)**	**(390)**	**(0.06)**
62a	EC4	EC4	**(12,069)**	**(252)**	**(3.31)**
62b	EC4	EC4	**(19,939)**	979	**(7.32)**
63a	EC3	EC3	**(14,670)**	926	**(1.75)**
63b	EC3	EC3	**(14,671)**	926	**(1.75)**

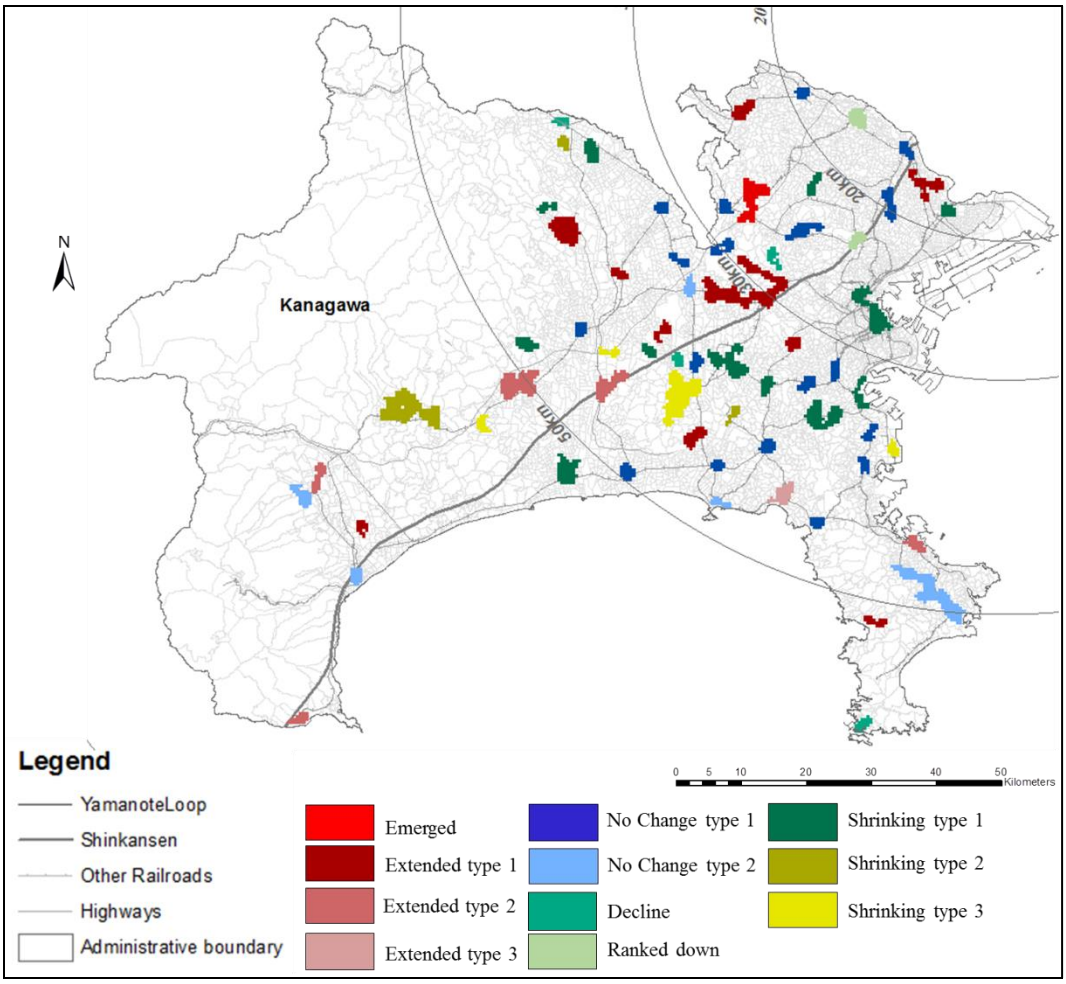

Figure C-3: Location of the change patterns of the ECs (Kanagawa prefecture), 1999-2009.

Table C-3: The change patterns of the ECs in Kanagawa prefecture, 1999-2009.

Kanagawa					
Center ID	ECs (different ranks)		Employment change	Density change	Area(km^2) change
	1999	2009	1999-2009	1999-2009	1999-2009
1	EC3	-	**(9,716)**	**(9,716)**	**(1.00)**
2	EC3	EC3	**(4,099)**	**(1,932)**	**(0.25)**
3	EC3	EC3	171	689	**(0.13)**
4	EC4	EC4	3,352	1,331	0.06
5	EC3	EC3	1,239	1,239	0.00
6	EC2	EC3	12,372	**(4,108)**	1.13
7	EC2	EC2	2,868	2,295	0.00
8	EC3	EC3	9,962	1,118	0.75
9	EC1	EC1	16,029	14,554	**(0.06)**
10	EC3	EC3	742	321	0.00
11	EC3	EC3	8,042	5,925	**(0.06)**
12	-	EC4	22,610	4,522	5.00
13	EC3	EC3	15	6	0.00
14	EC1	EC2	20,419	1,508	0.50
15	EC4	EC4	990	792	0.00
16	EC3	EC3	739	657	0.00
17	EC4	EC4	104	238	**(0.06)**
18	EC4	EC4	1,953	358	0.06
19	EC4	EC4	263	88	0.06
20	EC3	EC3	2,402	2,023	0.00
21	EC4	EC4	377	208	0.00
22	EC3	EC3	**(414)**	**(301)**	0.00
23	EC4	-	**(3,130)**	**(2,277)**	**(1.38)**
24	EC4	EC4	2,367	86	0.38
25	EC1	EC1	65,311	18,133	**(0.69)**
26	EC3	EC3	2,397	1,414	0.06

27	EC4	EC4	2,103	450	**(0.06)**
28	EC4	EC4	67	47	0.00
29	EC4	-	**(3,042)**	**(3,042)**	**(1.00)**
30	EC4	EC4	450	199	0.06
31	EC4	EC4	587	721	**(0.06)**
32	EC4	EC4	**(101)**	49	**(0.06)**
33	EC3	EC3	666	963	**(0.06)**
34	EC4	EC4	646	431	0.00
35	EC4	EC4	**(1,622)**	**(675)**	0.25
36	EC4	EC4	**(32)**	99	**(0.19)**
37	EC4	EC4	**(5)**	141	**(0.06)**
38	EC2	EC2	616	519	0.00
39	EC3	EC3	5,238	3,991	0.00
40	EC4	EC4	4,087	2,440	**(0.13)**
41	EC3	EC3	3,354	2,362	**(0.13)**
42	EC4	EC4	708	410	**(0.38)**
43	EC3	EC3	3,255	2,264	0.00
44	EC4	EC4	341	0	0.13
45	EC4	EC4	**(610)**	**(298)**	0.25
46	EC4	EC4	953	762	0.00
47	EC3	EC3	**(688)**	281	**(0.13)**
48	EC4	EC4	**(137)**	39	**(0.06)**
49	EC2	EC2	1,863	1,863	0.00
50	EC3	EC3	319	284	0.00
51	EC4	EC4	**(4,229)**	**(351)**	**(0.25)**
52	EC3	EC3	47	214	**(0.06)**
53	EC3	EC3	1,692	1,128	0.00
54	EC4	EC4	**(419)**	**(419)**	0.00
55	EC4	EC4	1,324	**(584)**	0.44
56	EC4	EC4	440	391	0.00
57	EC3	EC3	**(3,135)**	**(3,304)**	0.13
58	EC4	EC4	**(1,361)**	**(853)**	0.06
59	EC4	EC4	**(2,069)**	**(1,068)**	0.00

60	EC4	EC4	993	809	0.06
61	EC4	EC4	**(1,794)**	**(213)**	0.00
62	EC3	EC3	**(1,236)**	**(899)**	0.00
63	EC4	EC4	431	227	0.06
64	EC4	-	**(4,901)**	**(3,564)**	**(1.38)**
65	EC4	EC4	**(312)**	**(481)**	0.06

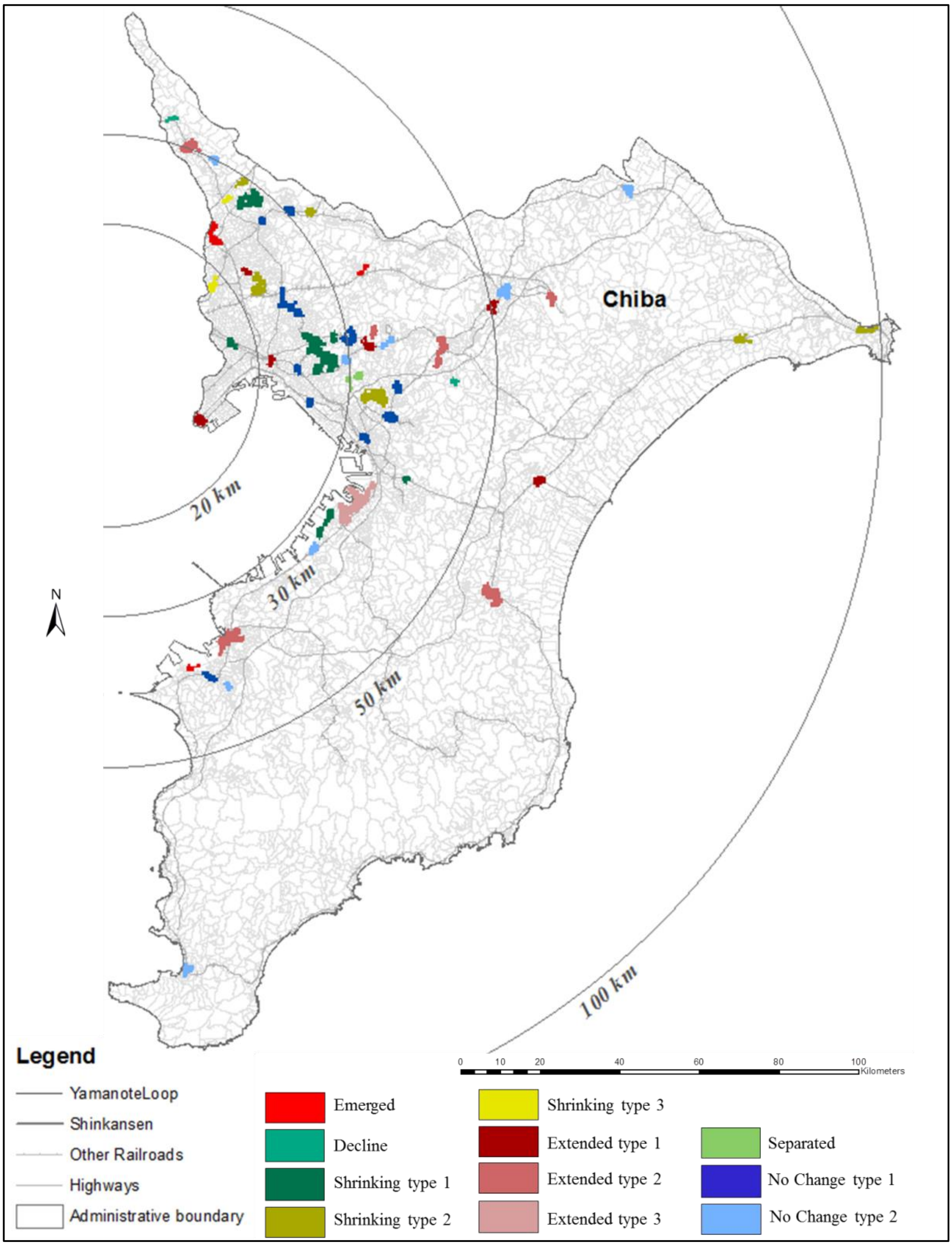

Figure C-4: Location of the change patterns of the ECs (Chiba prefecture), 1999-2009.

Table C-4: The change patterns of the ECs in Chiba prefecture, 1999-2009.

Chiba					
Center ID	ECs (Different ranks)		Employment change	Density change	Area(km^2) change
	1999	2009	1999-2009	1999-2009	1999-2009
1	EC4	—	**(2,357)**	**(2,218)**	**(1.06)**
2	EC4	EC4	**(900)**	**(387)**	0.13
3	EC4	EC4	**(2,279)**	**(1,586)**	0.00
4	EC4	EC4	**(1,631)**	**(717)**	**(0.13)**
5	EC4	EC4	**(113)**	39	**(0.06)**
6	EC4	EC4	3,663	603	**(0.06)**
7	-	EC4	8,641	2,880	3.00
8	EC2	EC2	3,049	2,870	0.00
9	EC4	EC4	779	479	0.00
10	EC4	EC4	296	**(117)**	**0.13**
11	EC3	EC3	**(199)**	834	**(0.13)**
12	EC4	EC4	522	166	0.13
13	EC4	EC4	**(1,316)**	**(257)**	**(0.06)**
14	EC4	EC4	2,350	464	0.00
15	-	EC4	5,502	4,890	1.13
16	EC3	EC3	2,356	2,251	**(0.13)**
17	EC2	EC2	3,816	1,870	0.06
18	EC3	EC3	2,574	1,961	0.00
19	EC4	EC4	1,709	206	**(0.25)**
20	EC4	EC4	**(1,123)**	**(816)**	0.00
21	EC4	EC4	2,000	1,609	**(0.06)**
22	EC4	EC4	175	51	0.00
23	EC4	EC4	**(202)**	**(374)**	0.13
24	EC4	EC4	1,360	449	0.13
25	EC4	EC4	**(49)**	**(28)**	0.00
26	EC3	EC3	6,852	2,387	0.13

27	EC2	EC2	2,135	1,798	0.00
28	EC4	EC4	**(1,021)**	156	**(0.75)**
29	EC4	EC4	712	407	0.00
30	EC4	EC4	112	47	0.00
31	EC4	EC4	**(2,861)**	**(1,065)**	0.44
32	EC4	-	**(2,387)**	**(2,387)**	**(1.00)**
33	EC4	EC4	554	210	0.06
34	EC4	EC4	**(743)**	**(253)**	0.00
35	EC3	EC3	**(1,013)**	**(1,889)**	0.19
36	EC4	EC4	**(802)**	**(428)**	0.00
37	EC4	EC4	**(571)**	**(191)**	**(0.06)**
38	EC4	EC4	**(2,723)**	**(982)**	**(0.06)**
39	EC1	EC1	4,159	2,773	0.00
40	EC4	EC4	876	1,086	**(0.06)**
41	EC4	EC4	391	81	0.06
42	EC4	EC4	1,132	**(71)**	0.63
43	EC4	EC4	793	327	**(0.13)**
44	EC4	EC4	**(717)**	**(441)**	0.00
45	EC4	EC4	**(1,779)**	**(450)**	0.13
46	EC4	EC4	**(342)**	**(359)**	0.50
47	-	EC4	2,273	2,020	1.13
48	EC4	EC4	418	248	0.00
49	EC4	EC4	**(23)**	**(23)**	0.00
50	EC4	EC4	**(480)**	**(233)**	0.00
51a	EC4	EC4	**(2,188)**	687	**(1.38)**
51b	EC4	EC4	**(4,030)**	**(43)**	**(1.75)**

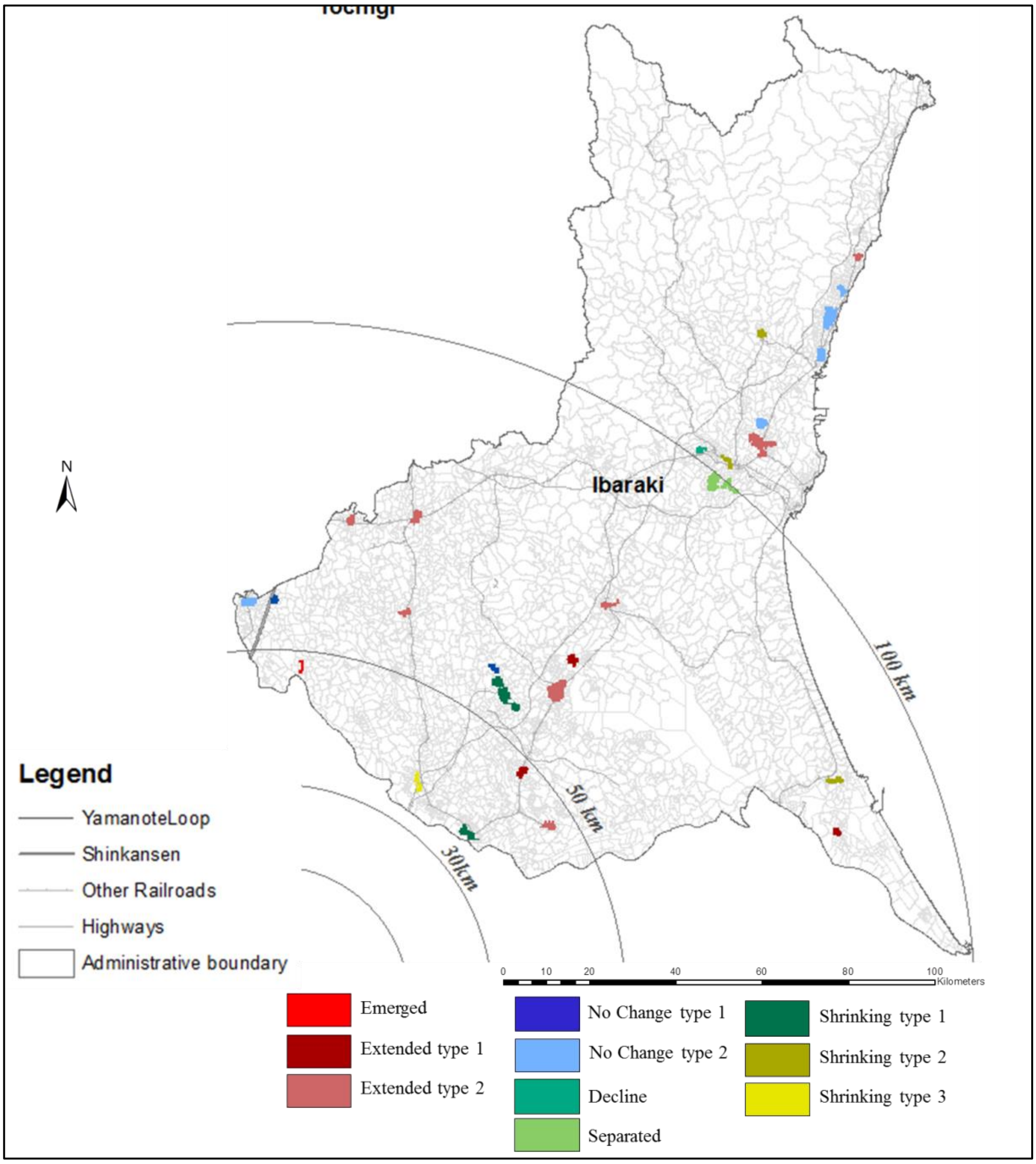

Figure C-5: Location of the change patterns of the ECs (Ibaraki prefecture), 1999-2009.

Table C-5: The change patterns of the ECs in Ibaraki prefecture, 1999-2009.

Ibaraki					
Center ID	ECs (Different ranks)		Employment change	Density change	Area(km^2) change
	1999	2009	1999-2009	1999-2009	1999-2009
1	EC4	EC4	**(616)**	**(943)**	0.13
2	EC3	EC3	**(4,162)**	**(2,561)**	0.00
3	EC4	EC4	**(388)**	**(77)**	0.00
4	EC4	EC4	**(48)**	**(20)**	0.00
5	EC4	EC4	**(120)**	142	**(0.13)**
6	EC4	EC4	**(1,355)**	**(657)**	0.00
7	EC4	EC4	**(1,180)**	**(250)**	0.13
8	EC2	EC2	**(5,297)**	**(2,312)**	**(0.06)**
9	EC4	-	**(2,742)**	**(2,581)**	**(1.06)**
10	EC4	EC4	**(93)**	**(347)**	0.19
11	EC4	EC4	**(679)**	**(357)**	0.06
12	EC4	EC4	**(667)**	**(691)**	0.13
13	EC4	EC4	**(365)**	**(360)**	0.06
14	EC4	EC4	550	419	0.00
15	EC4	EC4	**(842)**	**(313)**	0.00
16	-	EC4	2,718	2,718	1.00
17	EC4	EC4	**(540)**	194	**(0.38)**
18	EC4	EC4	2,607	2,086	0.00
19	EC4	EC4	1,521	642	0.06
20	EC4	EC4	**(1,404)**	**(380)**	0.19
21	EC4	EC4	8,463	1,313	**(0.19)**
22	EC4	EC4	1,305	573	0.06
23	EC4	EC4	236	176	**(0.06)**
24	EC4	EC4	**(90)**	**(135)**	0.06
25	EC4	EC4	**(697)**	**(260)**	**(0.06)**
26	EC4	EC4	386	165	0.06
27a	EC4	EC4	**(15,644)**	**(843)**	**(4.31)**
27b	EC4	EC4	16,385	3,799	4.31

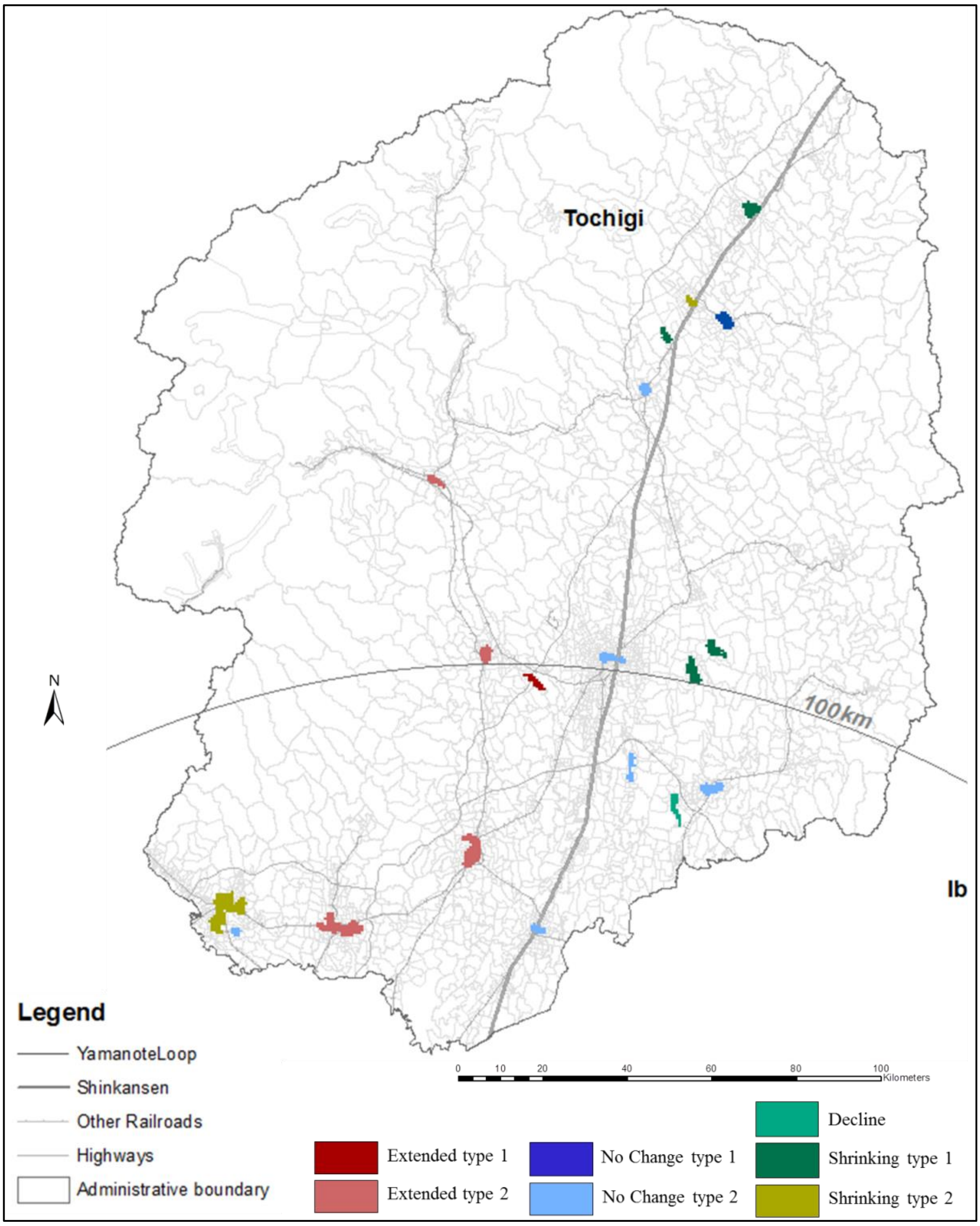

Figure C-6: Location of the change patterns of the ECs (Tochigi prefecture), 1999-2009.

Table C-6: The change patterns of the ECs in Tochigi prefecture, 1999-2009.

Tochigi					
Center ID	ECs (Different ranks)		Employment change	Density change	Area(km^2) change
	1999	2009	1999-2009	1999-2009	1999-2009
1	EC4	EC4	466	295	**(0.06)**
2	EC4	EC4	**(538)**	**(325)**	**(0.06)**
3	EC4	EC4	254	109	0.00
4	EC4	EC4	881	850	**(0.06)**
5	EC4	EC4	**(223)**	**(188)**	0.00
6	EC4	EC4	**(505)**	**(527)**	0.06
7	EC4	EC4	**(347)**	**(425)**	0.13
8	EC4	EC4	686	355	0.06
9	EC2	EC2	**(2073)**	**(1005)**	0.00
10	EC4	EC4	1050	565	**(0.19)**
11	EC4	EC4	4838	2083	**(0.06)**
12	EC4	EC4	**(674)**	**(269)**	0.00
13	EC4	EC4	**(179)**	**(110)**	0.00
14	EC4	-	**(2557)**	**(1461)**	**(1.75)**
15	EC4	EC4	**(1301)**	**(358)**	0.13
16	EC3	EC3	**(1194)**	**(910)**	0.00
17	EC4	EC4	**(1661)**	**(401)**	0.25
18	EC4	EC4	**(69)**	**(69)**	0.00
19	EC4	EC4	**(969)**	**(73)**	**(0.13)**

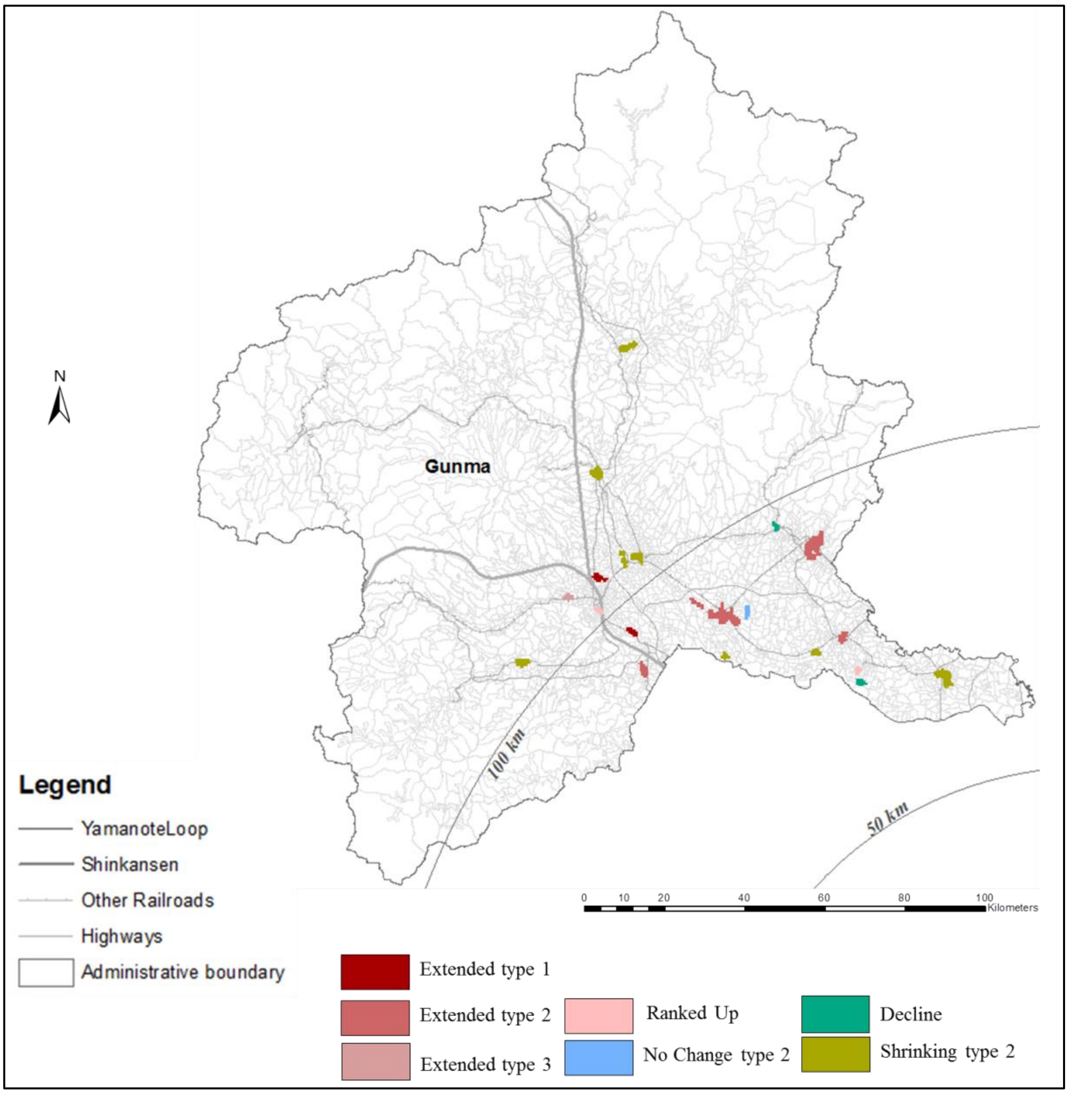

Figure C-7: Location of the change patterns of the ECs (Gunma prefecture), 1999-2009.

Table C-7: The change patterns of the ECs in Gunma prefecture, 1999-2009.

Gunma					
Center ID	ECs (Different ranks)		Employment change	Density change	Area(km^2) change
	1999	2009	1999-2009	1999-2009	1999-2009
1	EC4	EC4	**(1,742)**	**(657)**	**(0.06)**
2	EC4	EC4	**(1,068)**	**(350)**	**(0.06)**
3	EC4	-	**(2,651)**	**(2,495)**	**(1.06)**
4	EC4	EC4	**(1,431)**	**(281)**	0.13
5	EC3	EC3	**(4,185)**	**(1,623)**	**(0.06)**
6	EC3	EC3	**(2,192)**	**(1,002)**	**(0.06)**
7	EC4	EC4	917	383	0.13
8	EC4	EC4	50	**(137)**	0.06
9	EC3	EC2	**(10,662)**	6,181	**(1.38)**
10	EC4	EC4	178	14	0.06
11	EC4	EC4	**(51)**	**(157)**	0.06
12	EC4	EC4	**(2,134)**	**(326)**	0.06
13	EC4	EC4	**(259)**	**(189)**	0.00
14	EC4	EC4	**(711)**	**(534)**	**(0.06)**
15	EC4	EC4	**(42)**	**(114)**	0.06
16	EC4	EC4	**(1,172)**	**(385)**	**(0.13)**
17	EC4	EC4	**(534)**	11	**(0.19)**
18	EC3	EC3	**(5,417)**	**(3,610)**	0.06
19	EC4	EC3	**(10,432)**	3,281	**(2.31)**
20	EC4	-	**(3,624)**	**(3,221)**	**(1.13)**
21	EC4	EC4	**(1,412)**	**(294)**	**(0.06)**