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Special Issue on "Spatial Structure for Future Sustainable Cities in Asian Countries"
Guest Editor: Shichen Zhao and Akira Ohgai

Content

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Editorial Introduction

Special Issue on "Spatial Structure for Future Sustainable Cities in Asian Countries"

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Currently, Asia accounts for 40% of the world's urban population, which will increase to 56% by 2030. Urbanization is one of the biggest issues in Asian countries. In addition, in the economically developed countries such as Japan and South Korea, the aging problem has also emerged. In order to achieve a sustainable urban society, it is increasingly necessary to find urban design innovations and appropriate research methods and tools. Thus, this special issue focuses on spatial structure for future sustainable cities in Asian countries.

The first paper "Urbanization Patterns of China's Cities in 1990-2010" attempts to describe the urbanization patterns of China's cities during the period 1990–2010. The authors selected the eight most telling indicators of urbanization and 218 cities from China City Statistic Yearbook 1991, 1996, 2001, 2006 and 2011; and adopted a Principal Component Analysis to extract three comprehensive indicators from the sample database: Potential Capacity for Expansion of Tertiary Industry, the Degree of Urban Commercialization and the Potential Capacity for Population Growth. These three comprehensive indicators can describe the most important and remarkable features of a city during urbanization, namely the development of commercialization and the growth of population. China has experienced dramatic urbanization over the past 20 years. This is a dynamic set of multidimensional socio-spatial processes of several dimensions. Although, these comprehensive indicators cannot be considered as common ones for other similar research, the method was proved to be feasible and rational (He L. and Shichen Z., 2014).

Urbanization patterns in rapidly growing cities are complex. Such patterns reflect historic policy outcomes, economic characteristics and changing lifestyles. The second paper "Measuring the Urban Expansion Process of Yogyakarta City in Indonesia" examined urban growth in Yogyakarta City in Indonesia to understand its urban expansion process. The findings of this study show that the main urban area of Yogyakarta City is expanding faster than other parts of the urban region. The outward expansion of urban growth starts with small urban patches. Later, these patches expand

and merge to form larger urban patches. These large patches may have various levels of complexity, depending on the region. This fact is visible in urban extent data from 1997 to 2013 and the *COHESION* value for the corresponding periods. Expansion of the main urban area was visible particularly for the period 2002–2013 when the proportion of urban growth was less than the previous period (Prasanna D. and K. N. H. 2014).

Compact urban structure is one important government policy for local cities in Japan. The third paper "Study on a Method of Making a Concentrated Urban Structure Model Based on an Urban Master Plan" aimed to consider a new technical approach for the realization of compact cities. The authors made forecasting methods for future population and built future population distribution models. They then created the concentration urban structure models that applied the rules to evaluate population distribution and distance from urban facilities. This study is considered effective for planning aimed to satisfy a sustainable and compact urban structure (Shirou T., Shinji I. and Takeshi K., 2014).

The economy of Japan has matured since the beginning of the 21st century. However, decreasing population, birth rate and increase of the aging population are proceeding rapidly especially in local cities. As a result, it will become difficult to maintain functions of communities in future, and it is also forecasted that regional gaps between cities and villages will become larger. Being based on regional characteristics, strengthening a wide area in self-sufficiency and exchanges among regions might be called for. The fourth paper "Study on Regional Characteristics and Exchanges Among Regions in Fukuoka Wide Area" aims at clarifying the changes of regional characteristics and exchanges among the regions in the Fukuoka wide area, using statistical data and personal trip survey data over the recent decade, paying attention to a new structure of wide area including cities and villages. As the result, in the Fukuoka wide area, it was made clear that there were six groups which were classified with principal component analysis and cluster analysis, and they have spread concentrically and become complicated in the recent decade. This may have been influenced by the changes of population distribution and household composition. Moreover, the exchanges among the regions have been broadened in the recent decade. In the Fukuoka wide area, strengthening both self-sufficiency and exchanges among the regions will become important subjects in future (Shigeyuki K. and Ichiro M., 2014).

According to a 2006 report by the National Institute of Population and Social Security Research, Japan has been undergoing a long-term decline in population since 2005. The mid- and long-term vision of urban and regional planning regards the consolidation of residential areas and public service facilities, including their withdrawal, as necessary, for improving the quality of life for rural and suburban residents. From the point of view of provider's, such as the administrative and private sectors, consolidation of facilities is inevitable due to their profitability. Because of the decrease in the number of facility users and their lack of successors, brought about by population decline and aging, it is also difficult for the public administration to provide public services. The fifth paper "A Spatial Simulation Model to Explore Agglutination of Residential Areas and Public Service Facilities" is to produce suggestions for sustainable urban and regional spatial structures in Japan. A spatial simulation model was used as a multi-agent-based model to analyse the mid- and long-term changes in the agglutination of residential areas and public service facilities. At first, a multi-agent-based model was developed to quantitatively evaluate the agglutination of residential areas and public service facilities. Next, sensitivity analysis was conducted to adjust some of the crucial parameters that influenced simulation results. Finally, simulations were carried out based on several policy scenarios related to the sustainability and accessibility of the facilities. The results of the analysis indicated that public service facilities are likely to be concentrated in the city centre, but that financial support by the administration or non-profitable organizations (NPOs) enables facilities located outside of centres to sustain the provision of public services. (Kazuki K., Akira O. and Atsushi M., 2014).

The final paper "Overview: Study of Intercity Travel Characteristics in Chinese Urban Agglomeration" focuses on research of intercity travel characteristics. By investigating the travel characteristics of passengers and the intercity traffic demand forecast, the authors aim to discriminate the geographical spatial characteristics of the departure place and to establish a coupling law of city public transportation hubs and urban space which directly connects with the intercity rail station. The findings of this study can conclude that there are the following characteristics of urban agglomeration in the intercity transportation: 1) Intercity transportation is still primarily for business purposes; the future trend will adjust to meet the mutual demands of both commuter and business travelers. 2) The intercity rail has become the most popular transport mode for business purposes for its quick, convenient and safe characteristics. Because the cost is still the main influencing factor of the intercity rail, the users are still mainly high income groups. Therefore, further reducing the cost is needed to adapt to the travel demand of the majority of passengers. 3) Thanks to the increased speed, many long intercity MRT trips can be had back and forth within a day. The intercity rail shows a definite peak at a certain time in both the morning and evening, it also provides support and assurance for commuter travel (Zhuran L., Yan W. and Shichen Z., 2014).

This special issue is one of the outputs of the 9th International Symposium on City Planning and Environment Management in Asian Countries held on 11th -13th January 2014 at Horuto Hall OITA, Japan. We would like to express our sincere gratitude to the researchers who joined the symposium and submitted their works to our journal. We would also like to express our sincere gratitude to the reviewers who gave us their most generous support on reading and commenting on the papers. We hope all our efforts would contribute to a more sustainable world.

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Urbanization Patterns of China's Cities in 1990-2010

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Key words: Urbanization pattern, Comprehensive Indicator, PCA, Cluster Analysis, Discriminant Analysis

Abstract: This study attempts to describe the urbanization patterns of China's cities during the period 1990–2010. Firstly, we selected eight most telling indicators of urbanization for 218 cities from the China City Statistic Yearbook 1991, 1996, 2001, 2006 and 2011; secondly, we adopted Principal Component Analysis (PCA) to extract three comprehensive indicators from the sample database. They are: Potential Capacity for Expansion of Tertiary Industry (PCETI), the Degree of Urban Commercialization (DUC) and the Potential Capacity for Population Growth (PCPG); thirdly, these three comprehensive indicators were used to classify the 218 cities in 2010 into four groups by Cluster Analysis; fourthly, the same 218 cities in 1990 were classified into those four groups by Discriminant Analysis—Group 1: medium PCETI, remarkable DUC and limited PCPG. Group 2: medium PCETI, limited DUC and limited PCPG. Group 3: limited PCETI, medium DUC and medium PCPG. Group 4: remarkable PCETI, limited DUC and remarkable PCPG. On the basis of the cities' transition over 20 years and changes of three comprehensive indicators' levels, we determine ten urbanization patterns. The research could be useful and constructive for rethinking China's urbanization and new stages of development.

1. INTRODUCTION

Over the past several decades, continued urbanization has resulted in nearly half of the world's population living in urban areas. As the world's urban growth is expected to be concentrated in the developing countries in the next 30 years (Cohen, 2006), economic reforms have sped up urbanization in China since the early 1980s. Starting from 1990, when a frenzy of development zones and real estate construction swept across China**,** many cities have experienced dramatic growth of the urban area. Increased urban population, human activities and migration from rural areas are the main reasons for this growth. According to the general rule of global urbanization, urbanization levels between 30% and 70% are considered to indicate accelerated development (Northam, 1975). Now that the sixth census shows that the urbanization level in China is about 50% (Population Census Office under the State Council, Department of Population and Employment Statistics National Bureau of Statistics, 2010), China could be considered as being in a stage of accelerated development (Li et al., 2012). Because of the transformation from the planned economy to market economy, despite what is happening in China being superficially similar with what has already occurred in other countries, the process of urbanization in China is quite unique in terms of the scale and speed as well as the increasing number and size of cities (Chan and Yao, 1999). Evaluation on China's urbanization has aroused interest among scholars.

Many scholars have focused their attentions on the whole country's urbanization pattern. They usually consider the ratio of the urban population to total population as the proxy of urbanization and define its urbanization pattern based on the relationship between the level of urbanization and the economic development. Compared to other countries, the growth rate of the level of urbanization in China is much faster than that of economic development; economic reform since the early 1980s has revitalized the Chinese economy while accelerating the pace of resource consumption and environmental degradation. China's further plan should target on the quality of urbanization. (Chan and Yao, 1999; Chang and Brada, 2006; Chen et al., 2010; Chen et al., 2013; Li et al., 2012). The core of that - the development of urban areas - is the focus of this study, whose aim is to illustrate the picture of China's urbanization pattern on the city scale in a new way.

Previous studies concern the urbanization patterns of the region including a large area of suburbs. In this paper, we narrow down the objects to their urban area. We determine urbanization patterns of China's cities based on the degree of several comprehensive indicators of urbanization. Significant efforts about the comprehensive indicators of urbanization have been made toward: comprehensive analysis on the evolution of cities (Duo et al., 2000; Yang and Chen, 2010; Yuan and James, 2002); the sustainability of cities (Fang and Qi, 2010; Shen et al., 2012); the relationship between resource and environment with urbanization (Chen et al., 2010; Wang et al., 2011). Urbanization patterns proposed in this study are expected to be useful and constructive for rethinking China's urbanization.

2. STUDY AREAS AND INDICATORS

Urbanization is a dynamic socio-spatial process of several different and overlapping dimensions, each of which has its own vocabulary and traditions of scholarship. For this reason it has not been possible to identify a commonly agreed series of indicators. In this study, we focus on the dimensions of urbanization on population, space, and economy. To investigate on the transition of urbanization overtime, this study makes use of data from the China City Statistical Yearbook 1991, 1996, 2001, 2006 and 2011 to establish an indicator system.

Primarily, 43 same or similar indicators and 243 cities covered by the database of all five China City Statistical Yearbooks are picked out. Some of these 43 indicators' data have to be obtained by secondary calculation. During the period covered by this study, some cities have changed their names. While the initial information of these 243 cities is clear, these indicators are further selected according to the frequency of utilization in previous research (Chang and Brada, 2006; Chen et al., 2010; Chen et al., 2013; Duo et al., 2000; Fang and Qi, 2010; Henderson, 2000; Shen et al., 2012; Wang et al., 2011; Yang et al., 2012; Yang and Chen, 2010; Yuan and James, 2002). In this way, 17 of the 43 candidate indicators are selected. Then we exclude six indicators which do not characterize the dimensions of population, space, and economy: Public Transportation Vehicles per 10,000 Population and those to reduce the effect of information overlap (eg., Average Wage and Per Capita GDP; Percentage of Employment by secondary industry and The Contribution of Secondary Industry to GDP) from which we cut four indicators. Because of the close relationship between housing development and urbanization (Chen et al., 2011), we add one indicator—Per Capita Investment in Real Estate Development. The eventual system includes eight indicators, as shown in *Table 1*.

We sort out 218 cities with complete data of the eventual eight indicators in China City Statistical Yearbook 1991, 1996, 2001, 2006 and 2011 from the 243 cities. The 218 cities cover 25 provincial capitals in mainland China, except Tibet Autonomous Regions and Hainan Province; four municipalities directly under the Central Government (Beijing, Tianjin, Shanghai, Chongqing) and 189 prefecture-level cities.

Table 1. Raw indicator selected from China City Statistical Yearbooks
(Source: China City Statistical Yearbook (1991, 1996, 2001, 2006, 2011). Department of Urban Socio-economic Investigation, National Bureau of Statistics)

Indicator	Unit
Population Density	people/sq. km
The Percentage of Employment in The Primary Industry	%
The Percentage of Employment in The Secondary Industry	%
The Percentage of Employment in The Tertiary Industry	%
Per Capita GDP	Yuan
Per Capita Investment in Real Estate Development	Yuan
The Contribution of Built-up Area to Divisions of Administrative Areas	%
Per Capita Road Area	sq. m

2.1 Study Areas

There are two kinds of city data in the China City Statistical Yearbooks. One is data of all Divisions of Administrative Areas, including city urban areas, suburbs and counties or county-level cities under its jurisdiction. There is a considerable large area of suburb in counties or county-level cities. The other is data of city urban areas and suburbs. In this study, we use the latter as it more closely represents the data of the real urban area.

2.2 Indicators

Three of eight eventual indicators are calculated with the existing data.

Firstly, Per Capita Gross Domestic Product (GDP) is divided by the registered population at the Year-end. It is calculated without adjustments for inflation because a Z-score normalization was applied to the panel data in this study. Using this method Per capita GDP data can be compared in ways that reduce the influence of dimension and magnitude on research results. Per Capita GDP is calculated with the registered population only at the Year-end for a set of reliable and continuous data of Per Capita GDP that is not already available. Because China begin to calculate Per Capita GDP with Usual Resident Population since 2004 (Xu, 2006), only current data of Per capita GDP and Usual Resident Population exists for the areas under study in the China City Statistical Yearbooks, the earlier data is not available.

Secondly, Per Capita Investment in Real Estate Development is Investment in Real Estate Development divided by the registered population at the Year-end.

Thirdly, The Contribution of Built-up Area to Administrative Division Area is the area of built-up zone divided by the area of administrative divisions.

3. METHODS

3.1 Data Pre-processing

Eight raw indicators were standardized to eight new variables by using Z-score normalization to eliminate the influence of dimension and magnitude (Hardle and Simar, 2007; Wang, 2004).

3.2 Principal Component Analysis

Comprehensive indicators were generated with Principal Component Analysis (PCA).

Firstly, raw data were standardized by Z-score normalization. Standardized data is presented by $x'_{ij}, i = 1,2 \ldots p$ (p is the number of variables); $j = 1,2, .. q$ (q is the number of cities). Secondly, the $p \times p$ correlation matrix $\boldsymbol{R}$ of standardized data were calculated; thirdly, eigenvalue λ_i of $\boldsymbol{R}$ were figured out; then, eigenvector $\boldsymbol{e'}_{i'}$ of $\lambda_{i'}$ were calculated, $i' = 1,2, \ldots m, m (m \leq p)$ is the amount of extracted components, $e_{i'i}$ is the *ith* vector components of $\boldsymbol{e'}_{i'}$.

The loading of i' component $y_{i'}$ on i variable:

$$l_{i'i} = \sqrt{\lambda_{i'}} e_{i'i} \qquad (1)$$

The score of the $y_{i'}$ component of j city:

$$y_{i'j} = \sum_{i=1}^{p} e_{i'i} x'_{ij} \qquad (2)$$

The value of eigenvalue λ_i reflects the influence degree of a component on original random variables, meaning how much the components can explain the original random variables. There are two criteria for extracting principal components: Firstly, the value of eigenvalues λ_i must be greater than 1; secondly, the greater the value of cumulative percentage, the more information of original data is included in the extracted components; the extracted principal components are considered as comprehensive indictors. The value of $l_{i'i}$ is the basis for explaining the meaning of comprehensive indictors. The greater the value, the more information of i indicator on the i' comprehensive indictors (Hardle and Simar, 2007; Wang, 2004; Zhang, 2006).

3.3 Cluster Analysis

We input the standardized data of 2010 into formula (2) to get the scores of comprehensive indictors for each city. The scores were viewed as variables of cities when we employed a Hierarchical Cluster Analysis to classify them. The influence of dimension and magnitude was small enough so that it could be safely omitted. It was not necessary to normalize the score of comprehensive indictors for the cluster analysis.

Each city started in its own cluster. Firstly, sums of squared deviations of each cluster were calculated; secondly, the Squared Euclidean Distance between a sum of squared deviations of any two clusters were measured; thirdly, pairs of clusters with the closest distance were merged as one moves up the hierarchy; we repeated this computing process until getting four groups (Hardle and Simar, 2007; Wang, 2004).

3.4 Discriminant Analysis

First we employ Misclassification Probabilities on the data of classification from 2010 using a re-substitution method (Hardle and Simar, 2007; Wang, 2004) to predict the precision of dividing cities in 1990 into four groups. As shown in *Table 2*, the precision respectively was 80.4% for group 1, 90.6% for group 2, 91.2% for group 3 and 100.0% for group four. The errors were acceptable.

Table 2. The Misclassification Probabilities

	Group	Predicted Group Membership				Total
		1	2	3	4	
Count	1	37	6	3	0	46
	2	1	77	5	2	85
	3	4	2	62	0	68
	4	0	0	0	19	19
%	1	80.4	13.0	6.5	0	100.0
	2	1.2	90.6	5.9	2.3	100.0
	3	5.9	2.9	91.2	0	100.0
	4	0	0	0	100.0	100.0

Then we input the standardized data of 1990 into formula (2) to get the scores of comprehensive indicators of cities. These scores were viewed as variables' cities when we employed Bayes Discriminant Analysis to allocate new observations, i.e., cities in 1990 into four groups which were generated by applying Cluster Analysis to data of 2010, the result is shown in *Table 5*.

The whole computational process was accomplished using the software Statistic Package for Social Science.

Table 3. Extraction Sums of Squared Loadings

Component	Eigenvalues	Percentage of Variance	Cumulative Percentage
1	3.042	38.025	38.025
2	1.929	24.112	62.137
3	1.294	16.179	78.316

4. RESULTS AND DISCUSSIONS

4.1 Comprehensive Indicators

As shown in *Table 3,* according to Eigenvalues and values of Cumulative Percentage, the first three components are extracted as principal components. The value of Cumulative Percentage is nearly 80%. That means the three principal components explain the original random variables well.

As shown in *Table 4*, the loadings of the first principal component on the urban infrastructure variables (Per capita Road Area, The Contribution of Built-up Area to Divisions of Administrative Areas) and economy variables (Per capita GDP, Per capita Investment in Real Estate Development, and The Percentage of Employment in the Secondary Industry) are positive and relatively significant; the loading on The Percentage of Employment in the Tertiary Industry is negative, and the absolute value is significant. Therefore, the first principal component is best described by urban infrastructure and economy variables (Hardle and Simar, 2007; Zhang, 2006). The higher the score of the first principal component is, the more developed urban infrastructure and economic development are, and the more the support for the development of Tertiary Industry, which means the more the potential capacity for the expansion of Tertiary Industry. Consequently, the first comprehensive indicator is Potential Capacity for the Expansion of Tertiary Industry (PCETI).

Table 4. The Loadings of Components on Variables

Variable	Component 1	Component 2	Component 3
Population Density	0.550	0.610	-0.519
The Percentage of Employment in the Primary Industry	-0.390	0.090	0.243
The Percentage of Employment in the Secondary Industry	0.614	-0.722	-0.298
The Percentage of Employment in the Tertiary Industry	-0.570	0.737	0.267
Per capita GDP	0.679	-0.105	0.574
Per capita Investment in Real Estate Development	0.636	0.356	0.427
The Contribution of Built-up Area to Divisions of Administrative Areas	0.667	0.589	-0.368
Per capita Road Area	0.758	0.019	0.397

The loading of the second principal component on The Percentage of Employment in the Tertiary Industry is positive and relatively significant; the loading of The Percentage of Employment in the Secondary Industry is negative and the absolute value is significant. Hence, the second principal component is essentially the difference between the Tertiary Industry and Secondary Industry (Hardle and Simar, 2007; Zhang, 2006). The higher the score of the second principal component, the more developed the Tertiary Industry is; the lower the score, the more developed the Secondary Industry is. So, the second principal component reflects the economic structure. We have the second comprehensive indicator named as Degree of Urban Commercialization (DUC).

The loadings of the third principal component on economy variables (Per capita GDP and Per capita Investment in Real Estate Development) are positive and relatively significant; the loading on Population Density is negative and the absolute value is significant. For this reason, the third principal component is best described by economic variables and the Population Density variable (Hardle and Simar, 2007; Zhang, 2006). The higher the score of the third principal component, the more the support for Population Growth; the lower the score, the heavier the burden of population. Therefore, the third comprehensive indicator is Potential Capacity for Population Growth (PCPG).

4.2 Characteristics of Each Group

Group 1: As shown in *Table 5*, in 1990, there were 53 cities in Group 1; in 2010, there were 46 cities. The level of Potential Capacity for Expansion of Tertiary Industry is medium; the level of Degree of Urban Commercialization is remarkable; the level of Potential Capacity for Population Growth is low. Some developed cities are in Group 1 because of their developed urban infrastructure, tertiary industry and high population density. Coming to other cities, the urban fundamental infrastructure and economy are under-developed, while their tertiary industry is more developed than their secondary industry.

Group 2: As shown in *Table 5*, in 1990, there were 84 cities in Group 2; in 2010, there were 85 cities. The level of Potential Capacity for the Expansion of Tertiary Industry is medium; the level of Degree of Urban

Commercialization is low; the level of Potential Capacity for Population Growth is low. Some developed cities are in Group 2 because of their developed urban infrastructure, secondary industry and high population density. Coming to other cities, overall, their urban fundamental infrastructure and economy are under-developed, while their secondary industry is more developed.

Group 3: As shown in *Table 5*, in 1990, there were 72 cities in Group 3; in 2010, there were 68 cities. The level of Potential Capacity for the Expansion of Tertiary Industry is low; the level of Degree of Urban Commercialization is medium; the level of Potential Capacity for Population Growth is medium. There is no very developed city in Group 3. The urban infrastructure and economic development of cities in Group 3 are fair. The development of tertiary industry and secondary industry are balanced.

Table 5. The Classification and Character of Cities in 2010 and 1990

Group	PCETI	DUC	PCPG	Count	
				2010	1990
1	M	R	L	46	53
2	M	L	L	85	84
3	L	M	M	68	72
4	R	L	R	19	9
Total	----	----	----	218	218

Note : R----Remarkable M----Medium L----Limited

Group 4: As shown in *Table 5*, in 1990, there were nine cities in Group 4; in 2010, there were 19 cities. The level of Potential Capacity for the Expansion of Tertiary Industry is remarkable; the level of Degree of Urban Commercialization is limited; the level of Potential Capacity for Population Growth is remarkable. Overall, their urban fundamental infrastructure and economy are relatively developed, and the development of tertiary industry and secondary industry is balanced.

The number of cities in Groups 2 and 3 is steady; the number in Group 1 reduced from 53 in 1990 to 46 in 2010; the number in Group 4 doubled from nine in 1990 to 19 in 2010.

4.3 Urbanization Pattern of China's Cities 1990-2010 and their Distribution

As shown in *Table 7*, based on the transition of cities among groups and the change of three comprehensive indicators' levels, we determine ten urbanization patterns of China's cities during 1990-2010.

Pattern 1: As shown in *Table 7*, there are 125 cities—57.34% among all of the tested cities. These cities stay in the group with the same characteristics after 20 years of rapid development. There is no significant reform of cities' development model in this pattern.

Specifically, as shown in *Table 6,* 26 cities of Group 1 in 2010 came from Group 1in 1990. Combined with *Table 5* and *Table 7*, these 26 cities retained the same characteristics during the 20 year period: medium potential capacity for expansion of tertiary industry, remarkable degree of urban commercialization and limited potential capacity for population growth. This group includes cities such as Beijing, Shanghai, and Guangzhou.

As shown in *Table 6*, 49 cities of Group 2 in 2010 came from Group 2 in 1990. Combined with *Table 5* and *Table 7*, these 49 cities with medium potential capacity for expansion of tertiary industry, limited degree of urban commercialization and limited potential capacity for population growth retained the same characteristics during the 20 year period. This group includes cities such as Tianjin, Datong, and Jilin, cities with rich mineral resources or developed secondary industry.

As shown in *Table 6*, 44 cities of Group 3 in 2010 came from Group 3 in 1990. Combined with *Table 5* and *Table 7*, these 44 cities with limited potential capacity for expansion of tertiary industry, medium degree of urban commercialization and medium potential capacity for population growth retained the same characteristics during the 20 year period. This group includes cities such as Hengshui, Shuozhou and Yuncheng.

As shown in *Table 6*, six cities of Group 4 in 2010 came from Group 4 in 1990. Combined with *Table 5* and *Table 7*, these six cities with remarkable potential capacity for expansion of tertiary industry, limited degree of urban commercialization and remarkable potential capacity for population growth retained the same characteristics during the 20 year period. This group includes cities such as Daqing, Xiamen and Dongying.

China can be divided into three main economic areas: The Eastern Area, The Middle Area and The Western Area (Zhang, 2002). Cities in Pattern 1 are mainly located in the eastern and middle areas. A smaller number of cities are distributed in the western area. Specifically, there are 45 cities in the eastern area, 52 cities in the middle area and 28 cities in the western area, as shown in *Figure 1* and *Table 8*.

Pattern 2: As shown in *Table 7*, there are 23 cities, 10.55%, in Pattern 2, including one transition that was from Group 3 in 1990 to Group 2 in 2010. From *Table 5 and Table 7,* the potential capacity for expansion of tertiary industry for these cities increased from low to medium; the degree of urban commercialization and the capacity for population growth downgraded from medium to limited. Overall, over the 20 year period for this pattern, cities' economic growth and development of urban infrastructure was dramatic, and the emphasis of economic development was secondary industry. Urban population also grew dramatically. In this pattern, there are cities such as Putian, Quanzhou and Longyan. Six of the cities in Pattern 2 are distributed in the eastern area, ten are distributed in the middle area and seven cities are distributed in the western area, as shown in *Figure 1*and *Table 8*.

Pattern 3: As shown in *Table 7*, there are 16 cities, 7.34%, in Pattern 3, including one transition that was from Group 2 in 1990 to Group 1 in 2010. From *Table 5* and *Table 7,* the potential capacity for the expansion of tertiary industry and capacity for population growth of these 16 cities remained the same level. The emphasis of economic development transferred from secondary to tertiary industry during the 20 year period, so the degree of urban commercialization upgraded from low to remarkable. In this pattern, there are cities such as Shenyang, Anshan, Fushun and Fuxin. All of them were typical industrial cities. While their urban commercial development was dramatic during the 20 year period, they transitioned from Group 2 to Group 1. Ten of the cities in Pattern 3 are distributed in the eastern area; five are distributed in the middle area; and one city is distributed in the western area, as shown in *Figure 1* and *Table 8*.

Pattern 4: As shown in *Table 7*, there are 13 cities, 5.96%, in Pattern 4, including one transition that was from Group 2 in 1990 to Group 3 in 2010. From *Table 5* and *Table 7,* the potential capacity for the expansion of tertiary industry downgraded from medium to limited; both the degree of urban commercialization and the capacity for population growth upgraded from limited to medium. Overall, in the 20 year period, the economic growth was dramatic. Especially, tertiary industry advanced more than secondary industry. In this pattern there are cities such as Chengde, Changzhi and Chifeng. Three of the cities in Pattern 4 are distributed in the eastern area, five cities are distributed in the middle area and five cities are distributed in the western area, as shown in *Figure 1* and *Table 8*.

Table 6. The Transition of Cities among Groups

	Group (2010)	Total (1990) 1	2	3	4	Total (2010)
Count	1	26	16	4	0	46
	2	10	49	23	3	85
	3	11	13	44	0	68
	4	6	6	1	6	19
	Total (1990)	53	84	72	9	218
%	1	56.52	34.78	8.70	0	100.00
	2	11.76	57.65	27.06	3.53	100.00
	3	16.18	19.12	64.70	0	100.00
	4	31.58	31.58	5.26	31.58	100.00

Pattern 5: As shown in *Table 7*, there are 11 cities, 5.05%, in Pattern 5 including one transition that was from Group 1 in 1990 to Group 3 in 2010. From *Table 5* and *Table 7,* the potential capacity for the expansion of tertiary industry downgraded from medium to limited; the degree of urban commercialization downgraded from remarkable to medium and the capacity for population growth upgraded from limited to medium. In the 20 year period, the development of tertiary industry was dramatic while the secondary industry advanced more than tertiary industry. Overall, the economic growth was dramatic. In this pattern, there are cities such as Harbin, Kaifeng and Shangqiu. One of the cities in Pattern 5 is distributed in the eastern area, five cities are distributed in the middle area and five cities are distributed in the western area, as shown in *Figure 1* and *Table 8*.

Pattern 6: As shown in *Table 7*, there are ten cities, 4.59%, in Pattern 6 including one transition that was from Group 1 in 1990 to Group 2 in 2010. From *Table 5* and *Table 7,* the potential capacity for the expansion of tertiary industry and capacity for population growth of these ten cities remained the same level. The secondary industry advanced more than the tertiary industry during the 20 year period, so the degree of urban commercialization downgraded from remarkable to limited. In this pattern, there are cities such as Taiyuan, Wenzhou and Nantong. Eight of the cities in Pattern 6 are distributed in the eastern area, two cities are distributed in the middle area and none are in the western area, as shown in *Figure 1* and *Table 8*.

Pattern 7: As shown in *Table 7*, there are seven cities, 3.21%, in Pattern 7, including two transitions of cities among groups. For this pattern, in the 20 year period, cities' economic growth and the development of urban infrastructure were dramatic; especially the development of tertiary industry, which advanced more than the Secondary Industry.

Specifically, as shown in *Table 6,* six cities, 31.58%, of Group 4 in 2010 came from Group 1 in 1990. From *Table 5* and *Table 7*, the potential capacity for the expansion of tertiary industry upgraded from medium to remarkable, the degree of urban commercialization downgraded from remarkable to limited and the capacity for population growth upgraded from limited to remarkable. This pattern included cities such as Qingdao and Wuxi.

As shown in *Table 6*, one city, 5.26%, of Group 4 in 2010 came from Group 3 in 1990. From *Table 5* and *Table 7*, the potential capacity for the expansion of tertiary industry upgraded from limited to remarkable, the degree of urban commercialization downgraded from medium to limited and the capacity for population growth upgraded from medium to remarkable. This city is Zhongshan.

Six of the cities in Pattern 7 distributed in the eastern area, one distributed in the middle area and none are in the western area, as shown in *Figure 1* and *Table 8*.

Table 7. Urbanization Pattern of Cities in China 1990-2010

Pattern	PCETI	DUC	PCPG	Transition	Count		%
1	R	R	R	1→1 2→2 3→3 4→4	26 49 44 6	125	57.34
2	U	D	D	3→2		23	10.55
3	R	U	R	2→1		16	7.34
4	D	U	U	2→3		13	5.96
5	D	D	U	1→3		11	5.05
6	R	D	R	1→2		10	4.59
7	U	D	U	1→4 3→4	6 1	7	3.21
8	U	R	U	2→4		6	2.75
9	U	U	D	3→1		4	1.83
10	D	R	D	4→2		3	1.38
Total	----	----	----	----		218	100

Note: R---- Remain U---- Upgrade D---- Downgrade

Pattern 8: As shown in *Table 7*, there are six cities, 2.75%, in Pattern 8 including one transition that was from Group 2 in 1990 to Group 4 in 2010. From *Table 5* and *Table 7,* the potential capacity for the expansion of tertiary industry upgraded from medium to remarkable, the degree of urban commercialization remained the same level on limited and the capacity for population growth upgraded from limited to remarkable. In the 20 year period, the economic growth and the development of urban infrastructure were dramatic and the development of tertiary industry and secondary industry were balanced. In this pattern, there are cities such as Baotou and Ningbo. Three of the cities in Pattern 8 are distributed in the eastern area, two are distributed in the middle area and one city is distributed in the western area, as shown in *Figure 1* and *Table 8*.

Pattern 9: As shown in *Table 7*, there are four cities, 1.83%, in Pattern 9, including one transition that was from Group 3 in 1990 to Group 1 in 2010. From *Table 5* and *Table 7,* the potential capacity for the expansion of tertiary industry upgraded from limited to medium, the degree of urban commercialization upgraded from medium to remarkable and the capacity for population growth downgraded from medium to limited. Overall, in the 20 year period, these four cities' economic growth and development of urban infrastructure was dramatic and the tertiary industry advanced more than the secondary industry. Urban population also grew dramatically. The four cities of this pattern are Langfang, Jincheng, Tieling and Sanya. Three of the cities in Pattern 9 are distributed in the eastern area, one city is distributed in the middle area and none are in the western area, as shown in *Figure 1* and *Table 8*.

Pattern 10: As shown in *Table 7*, there are three cities, 1. 38%, in Pattern 10, including one transition that is from Group 4 in 1990 to Group 2 in 2010. From *Table 5* and *Table 7,* the degree of urban commercialization remained on the level of limited, the remarkable potential capacity for the expansion of tertiary industry and the capacity for population growth respectively downgraded to medium and limited. Overall, in the 20 year period, the development of tertiary industry and secondary industry were dramatic and balanced and urban population grew dramatically. The three cities of this pattern are Shiyan, Jiayuguan and Jinchang. No city of Pattern 10 is in the eastern area, one city is distributed in the middle area and two cities are in the western area, as shown in *Figure 1* and *Table 8*.

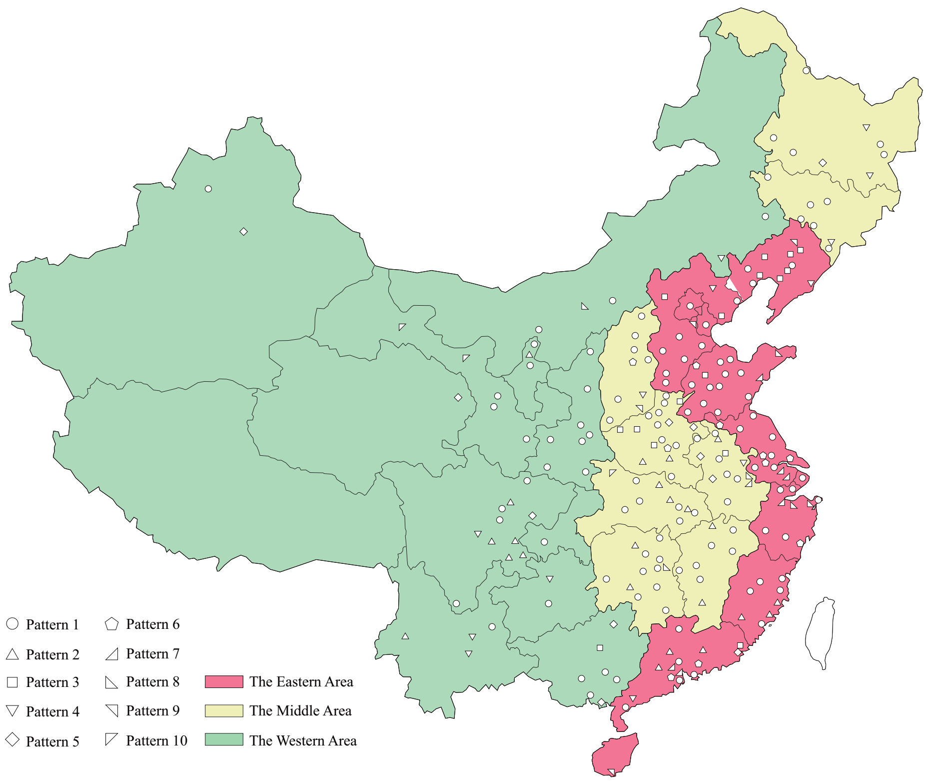

Figure 1. The Distribution of Cities in Three Main Economic Areas

Table 8. The Distribution of Urbanization Patterns in Three Main Economic Areas

Area	Pattern										Total	%
	1	2	3	4	5	6	7	8	9	10		
Eastern	45	6	10	3	1	8	6	3	3	0	85	38.99
Middle	52	10	5	5	5	2	1	2	1	1	84	38.53
Western	28	7	1	5	5	0	0	1	0	2	49	22.48
Total	125	23	16	13	11	10	7	6	4	3	218	100

The distribution of urbanization patterns in three main economic areas reveals the development feature of each economic area. Firstly, cities in Pattern 1 make a great percentage of the totality of the three economic areas. That means most cities in these three main economic areas have followed the same development mode during the 20 year period. Secondly, cities in Pattern 3 and Pattern 6 respectively are the second-most and the third-most in the eastern area, and the amounts are similar. That means development transformation has happened over time in the eastern area. Some cities explored new ways to develop the tertiary industry and some industrial cities improved their initial industrial development mode. Thirdly, cities in Pattern 2 are the second-most in the middle and western areas. That means there are some cities that have experienced primary urbanization over the 20 years period in these two areas where urban construction has been promoted, secondary industry has developed and the urban population has increased.

5. CONCLUSION

China experienced dramatic urbanization over the 20 year period from 1990 to 2010. This is a dynamic socio-spatial process of several dimensions. Signal indicators cannot state this complicated processes very well. Comprehensive indicators which are extracted form a reasonable indicator system would be more accurate. In this study, based on the eight most telling raw variables about urbanization, three comprehensive indicators are obtained by Principal Component Analysis. They are: Potential Capacity for the Expansion of Tertiary Industry, Degree of Urban Commercialization and Potential Capacity for Population Growth. These three comprehensive indicators can describe the most important and remarkable features of a city during urbanization, namely the development of commercialization and the growth of population. Although these comprehensive indicators cannot be considered as common ones for other similar research, the method was proven to be feasible and rational.

218 cities in both 2010 and 1990 can be respectively classified into four groups: Group 1 with medium PCETI, remarkable DUC and limited PCPG; Group 2 with medium PCETI, limited DUC and limited PCPG; Group 3 with limited PCETI, medium DUC and medium PCPG; Group 4 with remarkable PCETI, limited DUC and remarkable PCPG.

Ten urbanization patterns are proposed in this study. More than 50% of cities are in Pattern 1, with less than 50% in the other nine patterns. The results reveal that most cities in China kept the same development mode from 1990-2010, while the others already have tried to practice development transformation or reconsidered the development emphasis. The transformations mainly reflect development of urban infrastructure, industrial restructuring and growth of population.

The National New-type Urbanization Plan (2014-2020) admitted mistakes in China's urbanization, including sprawling cities, low efficiency in resource use, city disease and environmental disruption. These are among the problems China plans to avoid in the future. To achieve sustainable urban development in China, in a context of fast growing urbanization, government and policy makers should focus upon the reform and emphasis of development models. For cities in Patten 1, it is necessary to evaluate the sustainability of their development. The cities in other patterns could be the case base, providing examples for the same types of cities.

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Measuring the Urban Expansion Process of Yogyakarta City in Indonesia

Urban expansion process and spatial and temporal characteristics of growing cities

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Key words: spatial metrics, urban sprawl, urban growth, remote sensing

Abstract: Urbanization patterns in rapidly growing cities are complex. Such patterns reflect historic policy outcomes, economic characteristics and changing lifestyles. This research examined urban growth in Yogyakarta City in Indonesia to understand its urban expansion process. Several attributes of urbanization were measured to understand the city's urbanization pattern. Land-use data for 1997, 2002, and 2013 were derived from remote-sensing data; in addition, other supporting data of urbanization were measured with several spatial metrics. Analysis was performed for the whole city and for transections across the city to understand macro and local scale characteristics of the urbanization process. Urban land-use changes between 2002 and 2013 were studied to understand the land-use conversion process. Thereafter, the measurements were analyzed to understand temporal and spatial characteristics of urbanization in Yogyakarta City. It was observed that the urban expansion process in Yogyakarta has several distinct stages. Essentially, in the periphery of the city, urbanization has been fragmented. Over time, these fragmented urban patches develop into stable and less complex shapes.

1. INTRODUCTION

1.1 Urbanization Process

Cities are the engines of national development; they provide economics of scale and agglomeration, and allow many goods and services to be produced and traded more efficiently. Cities contribute to large shares of the national output of many Asian countries. By 2010, urban areas contributed 80% of the gross domestic product (GDP) of the Asia-Pacific region (UN-HABITAT, 2010). Migration into cities has increased the net productivity of economies by directing labor to locations where greater economic contributions are possible. Many rapidly expanding South East Asian countries have experienced an increasing rate of internal migration because of increased economic opportunities in urban areas (UN-HABITAT, 2010). In Southeast Asia, the proportion of urban population increased from 31.6% in 1990 to 42% in 2010 (ESCAP, 2013).

The outward urban expansion in Southeast Asian cities shows a distinct pattern compared to that of North American cities, where urban sprawl is considered as low-density suburbanization. Southeast Asian cities have maintained higher population densities while expanding (World Bank, 2015). In these cities, such urban expansion is not addressed adequately in planning practices. In addition, planning practices lack coordination for infrastructure provision to fragmented, expanding urban areas (Ooi, 2008).

Indonesia is a relatively urbanized country in the Southeast Asian region with 52% of the country's population living in urban areas (World Bank, 2014). Indonesia's urban population grew 3.5–3.7% annually between 2000 and 2010. The country's urban areas are fragmented spatially and across adjoining administrative districts. While population density is increasing, growth is uneven across the city. The objective of this research is to improve knowledge of this uneven urban expansion process.

1.2 Measuring urban expansion

Urban sprawl is defined as outgrowth of cities along their periphery. Although a clear definition is debatable, sprawl is accepted widely as unplanned and uneven growth driven by multiple processes that lead to inefficient use of resources (Bhatta, 2010). Often, sprawl is considered as undesirable by city authorities and policy measures are used in attempts to curb it. The "compact city" concept promotes high-density compact growth that is found in traditional Asian and European cities.

In the field of urban design, sprawl and scatter are conceded as unaesthetic. At the same time, these new developments are popular among people who like urban lifestyles in the periphery. These new growth areas provide affordable housing opportunities. Some of the short-term and long-term economic and environmental disadvantages of sprawl are infrastructure costs, conversion of valuable agricultural land, and deterioration of environmentally sensitive areas.

Decentralization of activities from the central core to the urban periphery is fundamental to sprawl. Therefore, sprawl is commonly linked with suburbanization of economic activities. In growing cities, this is connected with job creation in the form of industrial areas in the periphery. The other phenomenon that is unique to rapidly growing cities is the variability of infrastructure availability in sprawling areas and the spontaneous nature of growth.

There are numerous studies about sprawl in Northern American cities. These studies have examined sprawl from the perspectives of growth, social and aesthetic attributes (Calthorpe, 2001), decentralization (Galstera, 2001), accessibility (Hasse, 2004), density characteristics (Lang, 2003), fragmentation, loss of open space, and dynamics of sprawl. Some studies have proposed measuring the physical growth of sprawl quantitatively using multiple measurements (Torrens, 2008). In the Asian context, Murakami (2005) studied sprawl on a small scale. McGee (1995) explained expansion of Asian cities in the urban periphery as a new growth type and explained that it has a mixture of urban and rural features. There are several studies that attempt to understand this growth process as a demographic and social phenomenon in the Asian context.

Recent studies have attempted to compare the characteristics of sprawl in several regions of the world. Schneider and Curtis (2008) studied urban sprawl in 25 global cities to compare global characteristics and trends. They observed that only US cities and Montreal in Canada exhibit dispersed expansion with lower population densities. Huang et al. (2007) qualitatively examined urban form in metropolitan areas of Asia, the US, Europe, Australia, and Latin America. They observed a correlation between national wealth and urban form where wealthier cities demonstrate less compact and complex urban forms. In recent years, China has experienced large-scale urbanization in metropolitan areas and large regional cities. Several studies have measured urban expansion in these cities recently (Seto and Fragkias, 2005; Yu and Ng, 2007). Current research on measuring urban sprawl in the Asian region is concentrated mainly on Asian metropolitan regions and rapidly developing Indian and Chinese cities. The overwhelming proportion of urban growth will take place in developing countries in the next century (UN-HABITAT, 2010). In addition, most of this urban population will live in medium-sized cities (UN-HABITAT, 2010). Therefore, the question of the urban expansion process in such cities is especially relevant for policymaking.

The specific objectives of this study are to measure:

1. the urban expansion process in Yogyakarta City, Indonesia, and
2. the urban form of Yogyakarta City to understand how it varies across the city.

This study used spatial metrics, a class of metrics used originally in landscape ecology, to analyze the urban land use and expansion patterns in Yogyakarta City. Many metrics and statistical techniques are in use to measure sprawl. The metrics are numeric indicators that quantify spatial patterns of land-use patches. In the field of landscape ecology, such metrics are called landscape metrics and are used to describe, detect, and quantify characteristics of landscape patches to reveal properties of ecosystems in landscapes (McGarigal et al., 2002). These metrics are used widely in other fields, including urban studies, as quantitative indicators to describe the structures and patterns of landscape mosaics.

In recent studies, spatial metrics have been applied in the urban planning field to quantify urban growth, sprawl and fragmentation (Bereitschaft and Debbage, 2014; Lowry and Lowry, 2014; Ramachandra et al., 2015). Spatial metrics are a useful set of tools to quantify urban structure and patterns using data from thematic maps (Clarke and Couclelis, 2005). In recent years, the availability of historic remote-sensing images has enabled the combination of remote-sensing data with the application of spatial metrics as a potential method to study the spatial and temporal dynamics of urbanization.

Zipperer (2000) analyzed the applicability and uses of landscape metrics in urban studies. This study emphasized the validity of using ecological principles in land-use decisions. Recently, spatial metrics are being used to understand urban growth patterns and to validate urban growth models that represent complex social and environmental processes. Berling-Wolff and Wu (2004) used spatial metrics to assess the accuracy of urban growth simulation models. In addition, spatial metrics have been utilized widely recently to understand urban gradient and land fragmentation.

1.3 Study area

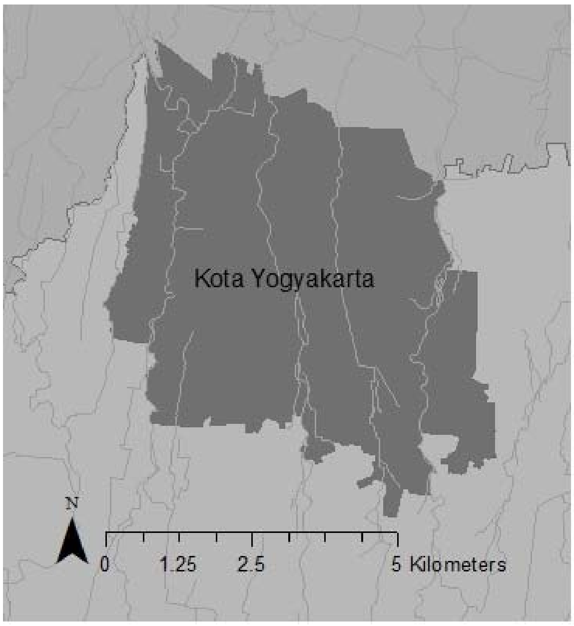

Figure 1. Yogyakarta City

During the last three decades, Indonesian urban areas have grown rapidly. Java Island, which has 59% of Indonesia's total population, recorded the highest consistent rate of urbanization among all Indonesian islands. For this study, Yogyakarta City was selected taking into account the city's rapid urbanization, dense population and medium size.

Yogyakarta City is the main urban center in the Yogyakarta Special Region of Daerah Istimewa Yogyakarta Province and is a hub of Javanese art and culture. In addition, the city is the second most important tourist destination in Indonesia. The average population density of Yogyakarta City in 2000 was 12,891/km^2. In addition, the conversion of agricultural land for construction is a major issue as the city has outgrown its urban boundaries and has spread to neighboring regions in recent decades. Specifically, the population of the large peri-urban areas that has spread to adjoining Sleman and Bantul is more than 1 million. Yogyakarta City and its peri-urban areas contain more than one third of the provincial population. Its high urban population growth and urbanization process has extended the city outwards and this trend is expected to continue. While the administrative area of Yogyakarta City is 33km^2, its large peri-urban area has expanded the functional urban area to 201km^2.

The urban growth process in Yogyakarta City is influenced by several significant aspects of transformation in administrative structure and infrastructural development. The outer ring road, which was completed in 1987, fostered outward expansion beyond the boundaries of the city. In 1999 and 2004, Indonesia changed its centralized administrative structure to a highly decentralized system. This process devolved significant power to local authorities with the intention of bringing services closer to the people. As a result, most government authority was transferred to the local authority, giving local authorities power equal to that of provincial governments in many areas. This created an environment for weaker central planning in matters related to regional planning.

While the outward expansion of Yogyakarta City has been prominent, the city has also expanded its densely-built areas along the periphery. Inevitably, this process has impacted on the environment and land use, which needs to be studied in a structured manner. The main objective of this research is to objectively and quantitatively analyze the expansion process of the densely built-up area.

2. METHOD AND DATA

2.1 Measuring urban expansion patterns

Sprawl is measured in relative and absolute scales by various researchers. Absolute measurements attempt to distinguish the growth process between compact cities and sprawling cities. Most of these studies have been undertaken for land-rich North American cities and some European cities. On the other hand, relative measures attempt to understand variations in growth patterns between different parts of a city or between different periods. The urban growth observed in rapidly growing cities occurs as a result of conversion of agricultural lands to developed land to accommodate growing populations. In Southeast Asian cities, urban population density has been observed to be increasing constantly in recent years (World Bank, 2015). Therefore, this study attempts to understand this growth process relative to time periods and among different parts of Yogyakarta City. This study does not attempt to define the threshold of sprawl and non-sprawl growth.

Angel et al. (2007) defined five attributes of growth by which urban expansion can be understood, such as urban extent, density, suburbanization, contiguity, and compactness. Torrens (2008) argued that sprawl must be measured in multiple scales.

In this study, the characteristics of urban expansion were examined by measuring the attributes of urbanization, both spatially and temporally. Measurements for spatial characteristics were carried out in two stages. First a land-use dataset derived from a series of satellite images was used to understand land-use conversion for the years 1997, 2002 and 2013. Later, changes in the urbanization pattern were measured for the whole city and for each period to understand the growth pattern. We measured five attributes of the growth pattern: urbanization, urban extent, scattered growth, suburbanization, and contiguity of the urban area. These attributes were measured using spatial metrics explained in *Table 1* and the extent of the built-up area.

PD measures the scattered growth of the urbanization pattern, which quantifies the number of urban patches per unit area (100ha). *COHESION* metrics and the proportion of urban footprint measure the suburbanization process. The contiguity metric (*CONTAG_MN*) measures the spatial connectedness of urban patches. Instead of population densities, this study used density of built-up area.

In the second stage of measuring spatial characteristics, the urbanization characteristic was measured using a transection across the city. The purpose of this method is to identify characteristics of urbanization using a section of the city. Each measurement was taken for five square tiles in a diagonal transection (*Figure 5*). The measurements were taken for all three periods. Five spatial metrics were employed to measure the characteristics of urbanization. The patch characteristics of tiles were measured using patch density (*PD*), number of patches in the landscape (*N*), and total landscape area (*A*). A landscape shape index (*LSI*) was measured to evaluate aggregation of urban patches. Perimeter-area fractal dimension (*PAFRAC*) measured the shape complexity of urban patches. Patch level *COHESION* metrics was employed to measure connectedness of corresponding patches.

Table 1. Spatial metrics and definitions

Number of patches (*NP*) NP = *N*
Patch density *(PD)* *N* = Total number of patches in the landscape, *A* = Total landscape area (m^2) $PD = \frac{n_i}{A}(10,000)(100)$ The number of patches in the landscape, divided by total landscape area m^2, multiplied by 10,000 and 100 (to convert to 100ha).
Perimeter-area fractal dimension (*PAFRAC*) at landscape level $PAFRAC = \frac{\left[n_i \sum_{j=1}^{n}(lnp_{ij} \cdot lna_{ij})\right] - \left[\left(\sum_{j=1}^{n} lnp_{ij}\right)\left(\sum_{j=1}^{n} lna_{ij}\right)\right]^{2}}{\left(n_i \sum_{j=1}^{n} lnp_{ij}^2\right) - \left(n_i \sum_{j=1}^{n} lnp_{ij}\right)^2}$ a_{ij} = area of (m^2)patch *ij*, p_{ij}= perimeter (*m*) of patch *ij*, N_i = number of patches in the landscape. Units: none. PAFRAC reflects shape complexity.
Landscape shape index (*LSI*) *E** = total length (*m*) edge in landscape, *A*= total landscape area. Units: None. *LSI* = 1 when the landscape consists of a single square patch. This provides a standardized measure of total edge or edge density that adjusts for the size of the landscape.
COHESION $COHESION = \left[1 - \frac{\sum_{j=1}^{n} P_{ij}^*}{\sum_{j=1}^{n} P_{ij}^* \sqrt{a_{ij}^*}}\right] \cdot \left[1 - \frac{1}{\sqrt{Z}}\right]^{-1} \cdot (100)$ P^*_{ij} = perimeter of patch *ij* in terms of the number of cell surfaces, a^*_{ij} = area of patch *ij* in terms of the number of cells, *Z* = the total number of cells in the landscape. Units: none. *COHESION* measures the physical connectedness of the patches.
Contiguity index (*CONTIG)* $CONTIG = \frac{\left[\frac{\sum_{r=1}^{z} c_{ijr}}{a_{ij}}\right] - 1}{v - 1}$ c_{ij} = contiguity value for pixel r in patch *ij*, *v* = sum of the values in a 3-by-3 cell template, a_{ij} = area of patch *ij* in terms of number of cells. *Contiguity index* assesses the spatial connectedness, or contiguity, of cells within a grid-cell patch to provide an index of patch boundary configuration. This research uses mean Contiguity Index Distribution *(CONTIG_MN)* in the landscape
Largest Patch Index (*LPI*) a_{ij} = area (m^2) of patch *ij*, *A* = total landscape area(m^2). Units = pecent. $LPI = \frac{max_{j=1}^{n} a_{ij}}{A}(100)$ *LPI* approches 0 when largest patch in the landscape is increasingly small. *LPI* quantifies the percentage of total landscape area comprised by largest patch.

The calculation of spatial metrics was performed using public domain software FRAGSTAT version 3.3 (McGarigal et al., 2002). This software became available in 1995, and has been developed continuously. FRAGSTAT provides a large range of metrics for patch-level, class-level, and landscape-level measurements.

2.2 Data

Data used for this study were prepared for three time periods. The study utilized three cloud-free Landsat Thematic Mapper (TM) datasets from 1997, 2002 and 2013 with 30m resolutions to extract urban areas and land-use data. All three images were selected from the months of June and July of each year so that seasonal variation effects would be minimized. Since the study area is a predominantly agricultural area and the main crop is paddy rice, it was important to select images from the same season. Images were acquired from USGS open Landsat image libraries. Land-use data with reasonable and consistent data scales were not found for the study area.

Data preparation for the study involved three stages, namely, pre-processing of data; classification of data for land-use classes; and extracting

$$LSI = \frac{.25 \sum_{k=1}^{m} e_{ik}^{*}}{\sqrt{A}}$$

urban footprint and preparing overlay images to measure land-use changes. First, all the datasets were registered and geometrical corrections were carried out. An image for 2013 was selected as the reference dataset and all other datasets were co-registered with the 2013 image at pixel level. The image set for 2013 was selected as the reference owing to the availability of additional data from this period. Later, a dark object subtraction (DOS) method was used for atmospheric correction of the images. DOS is one of the simplest and widely used image-based absolute atmospheric correction approaches for classification. The DOS approach assumes the existence of dark objects (zero or small surface reflectance) throughout a Landsat TM scene and a horizontally homogeneous atmosphere. The minimum cell-value digital number value in the histogram of the entire scene was subtracted from all the pixels. Later, several composite images were created to visually compare the image datasets with land-use maps and Google Earth data.

Owing to the lack of reference data to verify the accuracy for the 1997 classification results, several experimental classifications were carried out for three image sets. First, all three datasets were classified using ISODATA unsupervised classification, which is a commonly used unsupervised image classification algorithm. The classification was useful enough to identify a few significant classes of land uses. Data were classified into 25 classes and identifiable classes were grouped into five class names. The first classifications separated water bodies, barren land, irrigated land, urban areas, and vegetated land. At this stage, dry paddy lands and deforested hillsides were not separated satisfactorily. Later, segmentation was used to identify recognizable classes in the unsupervised data and to develop a signature set for supervised classification. Thereafter, supervised classification was carried out using maximum likelihood classification. Classified data was filtered for unclassified pixels and for clear class separation using a segmentation classification method. The segmentation data were prepared using the same set of bands as the data (*Figures 2 and 3*).

The five land-use classes were:

(1) barren land; dry barren land, deforested hillsides, open grassland, golf courses.
(2) mixed built-up land; suburban land with significant vegetation cover, housing estates
(3) crop land; paddy rice land, irrigated crop land

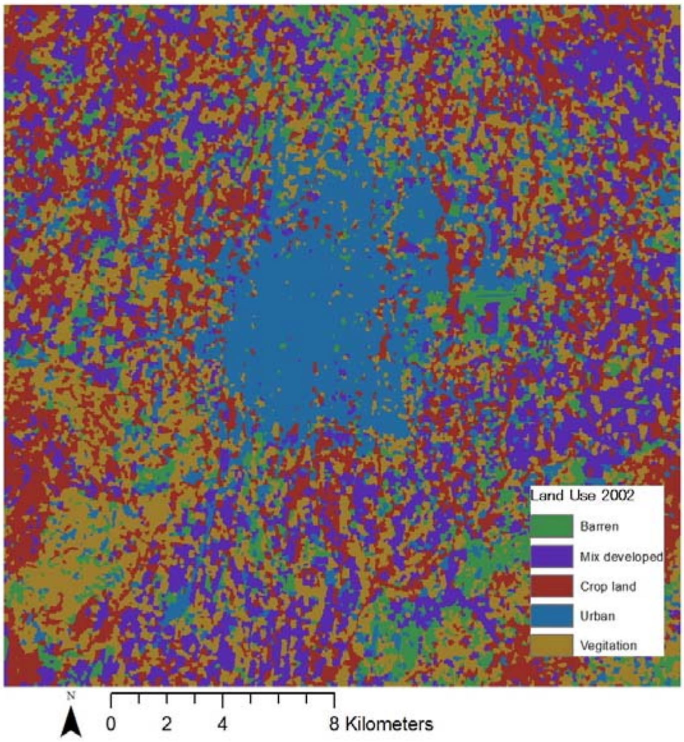

Figure 2. Land uses of 2002

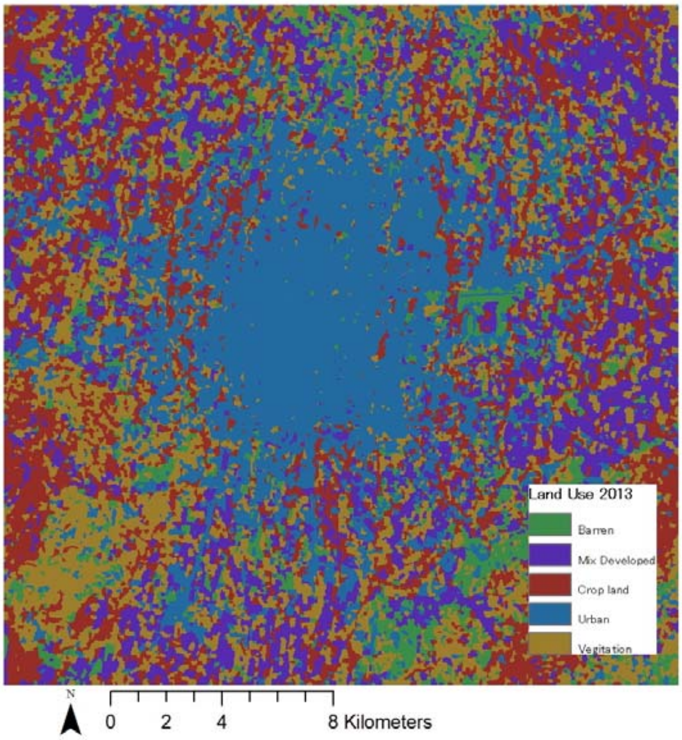

Figure 3. Land uses of 2013

(4) urban; built-up land, paved surfaces, streets
(5) vegetation; forest land, heavy vegetation.

On-screen digitization was utilized to rectify errors in classification. The classification of 1997 was verified against a scanned and projected GIS map of 1995. All datasets were transformed into 30m grid data on the proprietary geographic information system platform ArcGIS, and the built-up areas were extracted from the classified datasets for subsequent analysis.

3. MEASURING CHARACTERISTICS OF URBAN EXPANSION

3.1 Land-use change detection

The urban land-use changes *(Table 2)* detected from land-use classification indicate a high proportion of land-use conversion from vegetation land to urban activities. This phenomenon is due to the gap-filling growth pattern that converts existing green areas between 2002 urban patches. A large portion of vegetation land that was visible in the southeast hillsides and fragmented vegetation land in the northeast does not show extensive urbanization during 2002–2013 (*Figures 2 and 3*).

The crop land class consists of paddy rice land, both irrigated and barren, and other irrigated land visible in the classified image. Crop land is resistant to high-density urbanization during this period. In particular, crop land in the south of the city remained unchanged during this period. The eastern and northern crop land is observed to have been converted to high-density urban areas at a higher rate compared to the crop land of other regions (*Figures 2 and 3*).

The conversion of barren land to urban activities was also relatively high (*Table 2*). The barren land class consists of dry barren land, deforested hillsides, open grassland and golf courses (*Figures 2 and 3*). Some of the land classified as barren has urban land-use characteristics. In addition, vacant patches in or near the main urban center are classified in the barren land-use class.

3.2 Macro scale characteristics of urban expansion

Macro scale measurements show how urbanization has been progressing toward the countryside. The urbanized area in *Table 2* shows rapid expansion of urban land. The percentage of land urbanized during each period rapidly expanded the existing urban areas. The largest patch index (LPI) at the class level quantifies the percentage of the largest urban patch in the total landscape area *(Table 6 and Figure 4)*.

Widespread land-use changes prompted by rapid urbanization have led to fundamental changes in landscape pattern in the last decade. Other researchers have observed wide-scale peri-urbanization in the Yogyakarta region further away from the main urban centers (Richard, 2014). While peri-urbanization remains the dominant form of growth, expansion of existing urban centers is equally visible. The growth process observable in

Table 2. Urban land conversion estimated from other land uses to urban for the period 2002 to 2013. Key: 1. Barren, 2. Mixed developed, 3. Crop land, 4. Urban, 5. Vegetation.

Land use class		2013 land use area hectare					% change
		1	2	3	4	5	
2002 land use area hectares	1	5021.28	-	-	784.35	-	13.5
	2	-	11082.42	-	1198.44	-	9.7
	3	-	-	12578.85	1180.71	-	8.5
	4	-	-	-	10030.41	-	
	5	-	-	-	2313.36	12897.36	15.2

Table 3. Patch density for 1997, 2002 and 2013

Year	*PD*
1997	1.1158
2002	1.7264
2013	1.7296

Table 4. Proportion of suburbanization and COHESION

Year	Proportion of sub urban growth	*COHESION*
1997	42%	98.6729
2002	47%	98.7517
2013	34%	99.2085

Table 5. Contiguity

Year	*CONTIG_MN*
1997	0.7138
2002	0.7130
2013	0.6931

Table 6. Urbanized areas of 1997, 2002 , 2013 and *LPI*

Year	Total Area	% of land	LPI
1997	7832	12%	7.2433
2002	11409	18%	10.0833
2013	16932	27%	17.8341

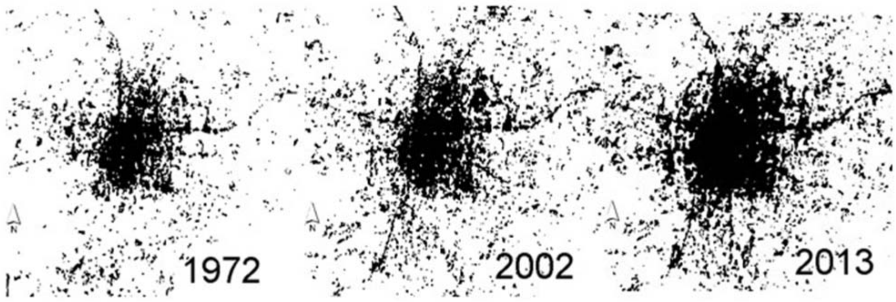

Figure 4. Urban area of 1997, 2002 and 2013

this data shows two growth patterns from 1997 to 2002 and from 2002 to 2013. No significant increase in patch density value was observed between 2002 and 2013 (*Table 3*).

The *COHESION* index (*Table 4*) measures the physical connectedness of the corresponding patch type. The *COHESION* value reaches zero if the focal class (in this case, urban patches) is increasingly scattered and less connected. From 1997 to 2013, the *COHESION* value (*Table 4*) increases, indicating an increase of connectedness of built-up patches. The proportion of the suburban area increased between 1997 and 2002. Later, between 2002 and 2013, the proportion of suburbanization decreased (*Table 4*). This indicates that in the last decade, there has been a significant expansion of the main urban area rather than new urban areas in the periphery. This observation is similar to the relative increase of the LPI value for identical periods (*Table 6*).

Visual observation of urbanization data for both periods shows that the most prominent expansion is observable in the west of the city (*Figures 2 and 3*). Most of the visible urban patches in the 2002 images were merged into larger urban patches in the 2013 images (*Figure 3*). Growth towards the east formed a strip of continuous urban stretch during 2002–2013 (*Figures 2 and 3*). Growth towards the west and north indicates a gap-filling trend. Larger patches are observable close to the main urban center (*Figure 3*).

Growth in the south corridor is not as prominent as other regions during 2002–2013 (*Figures 2 and 3*).

The contiguity index provides the connectedness of cells of a given land-cover class. Urban cells are less connected if the value of the contiguity index reaches zero. The value reaches one if urban cells are more connected. The contiguity index value decreased from 1997 to 2013 (*Table 5*). This indicates that there was an increase in the number of suburban built-up patches that are isolated and less connected. *PD*, the number of patches for a unit area, increased from 1997 to 2013 (*Table 3*). Increasing patch density and a decreasing contiguity index indicate a trend of isolated leapfrog growth of small urban patches in the landscape (*Tables 3 and 5*).

3.3 Local characteristics of urban expansion

The local characteristics of urbanization were measured by applying several spatial metrics to tiles in *Figure 4*. Five spatial metrics, *NP*, *PD*, *LSI*, *PAFRAC* and *COHESION*, were measured for all three datasets (*Table 1*). Tile 3 in Figures 4a–4e corresponds to the main urban area. Tiles 2 and 4 are outside the main urban area while tiles 1 and 5 are furthest from the main urban area.

The main finding of this analysis was the observation of characteristics of urbanization along an intersection through the main urban area (*Figures 5 and 6*). While the *NP* value of Tile 3 has the smallest value owing to it being fully urbanized, the highest numbers of urban patches were observed in Tiles 2 and 5 in all three datasets (*Figure 6a*).

The *NP* value varies from year to year. Tile 2 has the large increase in the number of urban patches between 1979 and 2002 (*Figure 6a*). Later, between 2002 and 2013, the number of urban patches decreased (*Figure 6a*) in tile 2. One possible explanation is that the original increase from 1997 to 2002 expanded and resulted in a small number of larger patches merging in 2013. Another possibility involves outward expansion of the main urban area. This observation is consistent with the behavior of the *COHESION* value observed for the total study area, as explained in Subsection 3.3 (*Table 4*). In addition, it is possible that both outward expansion and merging of

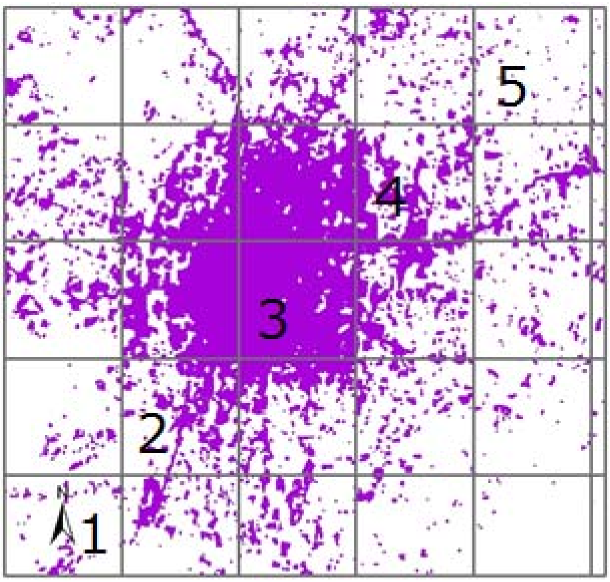

Figure 5. Tiles 1 – 5 of diagonal transection

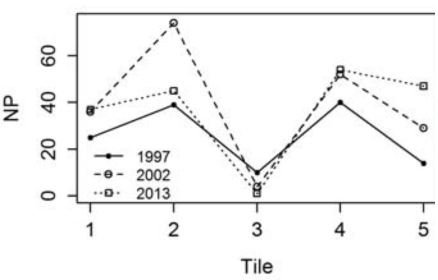

Figure 6a. NP

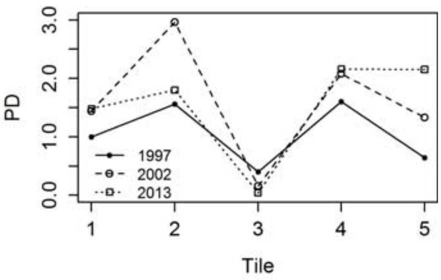

Figure 6b. PD

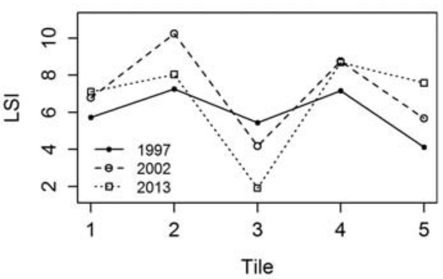

Figure 6c. LSI

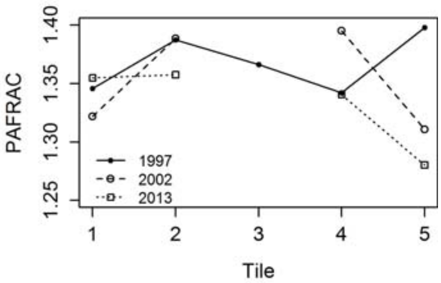

Figure 6d. PAFRAC

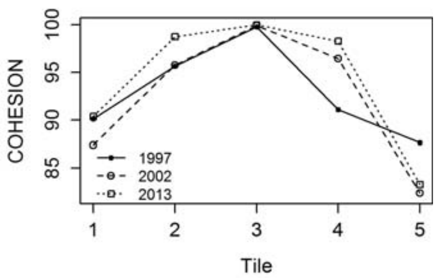

Figure 6e. COHESION

Figure 6. Spatial metrics measurements for Tiles 1-5 of diagonal transect

patches occurred at the same time to varying degrees.

The *NP* value changes in the core urban area for the same period (Tile 3). The value of *NP* decreased continuously from 1997 to 2013 (Tile 3). This may be because of infill growth in the main urban areas. The *NP* value is steadily increasing in Tile 5 (*Figure 6a*). The values of *PD* closely follow the corresponding value of *NP* (*Figure 6b*). The observation of land-use changes between 2002 and 2013 shows large-scale urbanization of the vegetation land class (Table 2). This observation can explain the urbanization of small vegetation land-use patches locked between urban patches.

The *LSI* provides a standardized measure of total edge or edge density adjusted for the size of the landscape (*Table 1*). The *LSI* reaches one when the landscape comprises a single square (or almost square) patch. The *LSI* increases without limit as the landscape shape becomes more irregular and/or as the length of edges within the landscape increases. The *LSI* has a close relationship with the *NP* and *PD* values. In Tile 3, the *LSI* value decreases with the value of the number of patches (*Figure 6c*). In Tiles 2 and 4, the LSI values again closely follow the *NP* and *PD* values. In 1997, there were large numbers of urban patches and they had complex shapes. Later, in 2002 and in 2013, the number of patches dropped and fewer urban patches with less complex shapes were observed in 2013.

PAFRAC reflects shape complexity across a range of spatial scales or patch sizes (*Table 1*). *PAFRAC* is undefined and reported as “N/A” if all patches are the same size or there are less than 10 patches. Therefore, the calculation of PAFRAC for 2013 was not possible for the main urban center. The urban area of 2002 shows the highest level of complexity. Local variation of shape complexity of urban patches can be identified by comparing the *NP* and *PAFRAC* values (*Figure 6d*). Urban data of 2002 shows high *NP* values in Tile 2 and those closest to the main urban center *(Figure 5a)*. In the northeastern part of the city there are fewer patches compared to the southwestern part (*Figures 2 and 3*). In addition, the northeastern urban patches (Tile 5) show more complex shapes than the urban patches of the southwest (Tiles 1 and 2) in 1997 and 2002. In 2013, urban patches lost the shape complexity of Tile 5 (*Figure 6c*). Distinct growth patterns can be observed for the northeastern and southwestern corners of the city.

The landscape *COHESION* index measures the physical connectedness of the corresponding patches. It approaches zero as the proportion of the landscape comprising the focal class decreases and the patch becomes increasingly subdivided and less physically connected. The *COHESION* values of Tiles 1 and 5 are low for all three years. Tiles 2 and 4 show increases in *COHESION* values (*Figure 6e*).

The *NP* and *PD* show increases from 1997 to 2013, indicating an increase of urban patches in Tiles 2 and 4. The *COHESION* index for both Tiles 2 and 4 shows increases during the same period. This observation can be explained as new urbanization in peripheral areas being an essentially fragmented process. In addition, with the progress of urbanization, these fragmented patches are interconnected, forming ever larger patches that tend to have complex shapes in certain areas. In particular, in the northeastern part of the city, urban patches have more complex shapes than those of the southeastern corner (Tile 1 and Tile 5).

4. CONCLUSION

The findings of this study show that the main urban area of Yogyakarta City is expanding faster than other parts of the urban region. The outward expansion of urban growth starts with small urban patches. Later, these patches expand and merge to form larger urban patches. These large patches may have various levels of complexity, depending on the region. This fact is visible in urban extent data from 1997 to 2013 and the *COHESION* value for the corresponding periods. Expansion of the main urban area was visible particularly for the period 2002–2013, when the proportion of urban growth was less than the previous period.

From these observations, several urban expansion patterns can be identified. The first comprises initially small urban patches in rural areas and along roads. The second involves expansion of the main urban area by encroaching into the surrounding area. The third is urban infill growth, which can be identified in the patterns of the *NP* and *PD* data between 1997 and 2013. The fourth observation is the complexity of urban patches in the outskirts of the city. Urban expansion within already developed areas are happening in the form of infill development in existing undeveloped green areas. Loss of green areas inside cities is one of the undesirable effects of densification. The LPI value shows that the core urban area is has been growing at an increasing rate in the recent decade. The city of Yogyakarta needs to develop methods that can preserve green open spaces within the city that are vital for vibrant and healthy city environments. While current research provides evidence of such growth, more detailed research is needed to understand the functions, extent and distribution of such open areas.

Yogyakarta City has experienced several stages of urbanization during the past decades. The completion of the city's outer ring road in 1987 prompted urbanization between the ring road and urban agglomeration. Decentralization of the Indonesian government's decision-making processes has accelerated the growth of peri-urban areas, which are expanding to adjoining administrative areas. Although the peri-urban areas are more attractive for living, Yogyakarta City's main urban agglomeration also has been growing steadily during the last decade. Observations from this study based on land-use data between 2002 and 2013 show that the main agglomeration is not occurring as low-density suburbs. There is more urban growth observed on agricultural and non-urban land, such as vegetation areas. This may be due to the availability of affordable land as well as weakness in land regulations to protect agricultural land. Thus, it is important to study the role of decentralization of administrative functions and decision making in order to understand the urbanization process in Yogyakarta City.

This research highlighted the regional and local trends in the urbanization process of Yogyakarta City. The methodology used in this research is useful to study temporal and spatial trends of urbanization to understand future priorities of land use planning. It is important to examine the current planning practice and economic trends of the city against findings of this study to recommend suitable measures for future planning.

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Study on a Method of Making a Concentrated Urban Structure Model Based on an Urban Master Plan

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Key words: Local City, Compact City, Future Population, Concentrated Urban Structure, Master Plan

Abstract: In this study, we created concentrated urban structure models based on the scenarios that demonstrate a compact city. We investigated urban districts, suburban sprawl areas and rural community areas. Moreover, we aimed to show a way to control land use and develop a future urban structure for local cities. The target area is the city of Yamaguchi, a non-area divided city[1)] and the city of Hofu, an area divided city[1)]. First, using 100 meter mesh data, we analysed urban structures by using district and population distribution. Then, we built future population distribution models from 2010 to 2060 for the target area. Moreover, we produced a "Knowledge Base of Planning Policy" in order to realize a compact city based on each master plan of the target area. Additionally, we set the "Rules of Population Migration" based on it. We created concentration urban structure models that applied the rules to future population distribution models. Lastly, we evaluated the concentrated urban structure models using the population distribution and the distance from urban facilities.

1. INTRODUCTION

1.1 Background and purpose of this study

The world population is continually increasing, however the Japanese population is decreasing (*Table 1*). As shown in *Table 1*, the Japanese population in 2050 is less than 100 million people. Also, *Figure 1* showed the age structure of 2010 and 2060 in Japan. 40% of the people were over the age of 65 for the year 2060. The data shows that declining birth rate and population aging rate are progressing. Formations of urban structures are needed to solve such problems. The local government is considering a compact city project, which can recover the vitality of the central district and life base for residents.

Yamaguchi Prefecture, which is our target area, has their idea of a compact city of urban structure that is multi-core and multi-layer. However, the urban structure has been sprawling, with unplanned developments in the suburbs and a decline of the central district. Due to this, a planning method is needed for the formation of a concentrated urban structure. This will begin to address the issues of a declining population, birth rate and central district by local government.

Therefore, in this study, we set "Rules of Population Migration" based on future population, sprawling areas in suburbs and urban planning basic policy such as a general plan and urban master plan. Then, using these rules, we formed concentrated urban structure models and evaluated it. We aimed to consider a technical approach for the realization of a compact city.

Table 1. World population and Japanese population

	2010 Population	2020 Population	2030 Population
World	6,916,183,000	7,716,749,000	8,424,937,000
Japan	128,057,000	124,100,000	116,618,000
	2040 Population	2050 Population	2060 Population
World	9,038,687,000	9,550,944,000	9,957,398,000
Japan	107,276,000	97,076,000	86,737,000

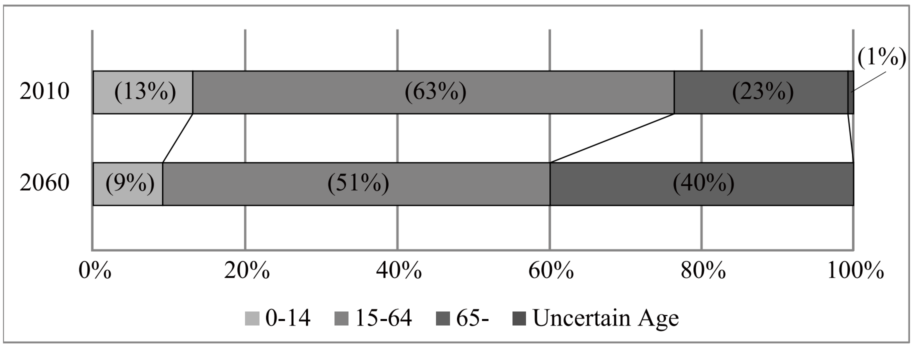


Figure 1. Age structure of 2010 and 2060 in Japan

1.2 Review of related studies

There are many studies about compact cities worldwide. For example, there are studies that have focused on the form of a compact city as a result of the population density of elementary school zones (Kim, et al., 2010), those that have proposed a direction of urban regeneration (Jung Geun, et al., 2014), those that have been verified from carbon dioxide emissions (Gao, et al., 2013) and those that have verified compact cities according to public transport factors (Boquet, 2014).

Also, there are many studies about compact cities in Japan. For example, there are studies that have verified compact cities by using the cost of the formation effect (Takahashi and Deguchi, 2007), have verified from the carbon dioxide emissions (Uchida, et al.,2009; Kobayashi and Ikaruga, 2012; Kobayashi, et al., 2010) or have verified from the effect of the behaviour patterns of consumers (Yamane, et al., 2007).

However, there are few studies that have examined the formation method of a compact city in detail for a targeted local city in Japan.

1.3 Study methods

In this study, the target area is the city of Yamaguchi which is the capital of Yamaguchi Prefecture and the city of Hofu which has over 100,000 people. At first, using 100 meter mesh data, we analysed urban structures by using district and population distribution. Next, we forecast the future population by using a primary factors cohort. We also, built future population distribution models from 2010 to 2060 in our target area. Moreover, we made "Knowledge Base of Planning Policy" for the realization of a compact city based on each master plan for the target area. We also set “Rules of Population Migration” based on it. We created concentrated urban structure models by applying the rules and future population distribution models. Then, we evaluated the models using the population distribution and the distance from urban facilities. Lastly, we show knowledge on building methods and evaluation of the models.

2. SUMMARY OF THE TARGET AREA

As previously mentioned, the target area is the city of Yamaguchi which is a non-area divided city and the city of Hofu which is an area divided city.

2.1 Land use

Urban structures in the target area were analysed using land use with 100 meter mesh data[2)]. The land use was classified into 14 categories of “Rice Area”, “Growth Area”, “Mountain Area”, “Water Area”, “Other Nature Area”, “Residential Area”, “Commercial Area”, “Industrial Area”, “Public Institution Area”, “Traffic Facility Area”, “Public Vacant Area”, “Other Public Institution Area”, “Other Vacant Area”, and “Road Area”. *Table 2* shows the number of the land use mesh. For Inside Use District, “Residential Area” has largest number of meshes. On the other hand, Outside Use District, “Mountain Area” is the largest.

Table 2. Number of Land Use Meshes

Land Use	Target Area	
	Inside Use District	Outside Use District
Rice Area	1,162 (14.9%)	8,751 (15.1%)
Growth Area	117 (1.5%)	1,101 (1.9%)
Mountain Area	781 (10.0%)	41,293 (71.5%)
Water Area	96 (1.2%)	924 (1.6%)
Other Nature Area	217 (2.8%)	1,658 (2.9%)
Residential Area	2,662 (34.1%)	1,256 (2.2%)
Commercial Area	425 (5.5%)	228 (0.4%)
Industrial Area	920 (11.8%)	286 (0.5%)
Public Institution Area	562 (7.2%)	489 (0.8%)
Traffic Facility Area	56 (0.7%)	75 (0.1%)
Public Vacant Area	211 (2.7%)	371 (0.5%)
Other traffic facility area	48 (0.6%)	317 (0.5%)
Other Vacant Area	394 (5.1%)	879 (1.5%)
Road Area	145 (1.9%)	156 (0.3%)
Total	7,796 (100.0%)	57,787 (100.0%)

2.2 Population distribution

Urban structures in target areas were analysed using population distribution with 100 meter mesh data[3)]. Population distribution was classified into seven categories of “0 people”, “1-20 people”, “20-40 people”, “40-100 people”, “100-200 people”, “200-300 people”, and “over 300 people”. *Figure 2* and *Table 3* show the number of mesh for the population distribution. For Inside Use District, “40-100 people” have the largest number of mesh. On the other hand, Outside Use District, "0 people" is largest.

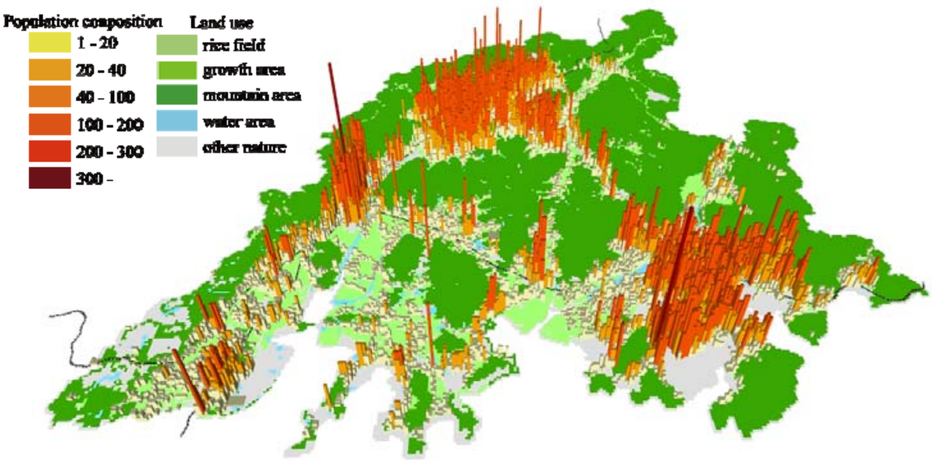


Figure 2. Population Distribution in the Target Area

Table 3. Number of the Mesh of the Population

Population	Target Area	
	Inside Use District	Outside Use District
0	2,123 (27.2%)	49,080 (84.9%)
1-20	1,825 (23.4%)	7,376 (12.8%)
20-40	1,441 (18.5%)	970 (1.7%)
40-100	2,190 (28.1%)	340 (0.6%)
100-200	211 (2.7%)	19 (0.0%)
200-300	5 (0.1%)	1 (0.0%)
300-	1 (0.0%)	1 (0.0%)
Total	7,796 (100.0%)	57,787 (100.0%)

3. CALCULATION OF FUTURE POPULATION AND BUILDING OF FUTURE POPULATION DISTRIBUTION MODELS

In this section, we explain how to build the future population distribution models for the target area. At first, we calculated the future population by using a primary factors cohort. Then, we made parameters of population distribution using number of Tele-point[4)] and built the 100 meter mesh population distribution models. Finally, we evaluated future population distribution models.

3.1 Calculation of future population

At first, we calculated the future population of 2020, 2030, 2040, 2050 and 2060 by using a primary factors cohort based on the 5-year age group and population composition of 2000, 2005 and 2010. *Table 4* shows the future population. When comparing the population in 2010 to that of 2060, it is possible to see that the population of Yamaguchi City will decrease by 62.4% and Hofu by 65.9%.

Table 4. Future Population

	2010 Population	2020 Population	2030 Population
Target Area	284,772	261,792 (91.9)	238,162 (83.6)
Yamaguchi City	183,223	167,612 (91.5)	154,317 (84.2)
Hofu City	101,549	94,180 (92.7)	83,845 (82.6)
	2040 Population	2050 Population	2060 Population
Target Area	223,705 (78.6)	200,194 (70.3)	181,358 (63.7)
Yamaguchi City	144,079 (78.6)	128,248 (70.0)	114,403 (62.4)
Hofu City	79,626 (78.4)	71,947 (70.8)	66,955 (65.9)

( ) shows the change rate for 2010 population

3.2 The building of future population distribution models

The 100 meter mesh future population distribution models are referenced in *Figure 1*. We calculated the population distribution parameter according to the number of the Tele-point in the target area. Then, we distributed the population to each mesh by parameter. *Formula 1* shows how to calculate the population distribution parameter.

$$\text{Distribution Parameter} = \frac{\text{Number of the Tele-point on each 100 meter mesh}}{\text{Number of the Tele-point on the target area}} \quad \textit{Formula 1}$$

3.3 Evaluation of future population distribution models

Finally, we evaluated the future population distribution models. *Table 5* shows the number of mesh. In the 2010 urban structure, “1-20 people” has 9,201 (14.0%). On the other hand, in 2060 urban structure has 10,387 (15.8%). Also, in the 2010 urban structure, over 100 people has 238, on the other hand, 2060 urban structure has 19.

Table 5. Number of the Mesh of the Future Population

	2010 Population	2020 Population	2030 Population
0	51,203 (78.1%)	51,683 (78.8%)	51,733 (78.9%)
1-20	9,201 (14.0%)	9,429 (14.4%)	9,728 (14.8%)
20-40	2,411 (3.7%)	2,415 (3.7%)	2,386 (3.6%)
40-100	2,530 (3.9%)	1,970 (3.0%)	1,680 (2.6%)
100-200	230 (0.4%)	82 (0.1%)	53 (0.1%)
200-300	6 (0.0%)	4 (0.0%)	3 (0.0%)
300-	2 (0.0%)	0 (0.0%)	0 (0.0%)
	2040 Population	2050 Population	2060 Population
0	51,749 (78.9%)	51,820 (79.0%)	51,983 (79.3%)
1-20	9,916 (15.1%)	10,204 (15.6%)	10,387 (15.8%)
20-40	2,408 (3.7%)	2,424 (3.7%)	2,342 (3.6%)
40-100	1,471 (2.2%)	1,110 (1.7%)	852 (1.3%)
100-200	37 (0.1%)	25 (0.0%)	19 (0.0%)
200-300	2 (0.0%)	0 (0.0%)	0 (0.0%)
300-	0 (0.0%)	0 (0.0%)	0 (0.0%)

4. THE BUILDING OF CONCENTRATED URBAN STRUCTURE MODELS

In this section, at first, we made the "Knowledge Base of Planning Policy" based on the master plan of Yamaguchi Prefecture and the cities of Yamaguchi and Hofu. Then, we set "Rules of Population Migration" based on the "Knowledge Base of Planning Policy". Finally, we created concentrated urban structure models based on the rules.

4.1 The making of the "Knowledge Base of Planning Policy"

We made the "Knowledge Base of Planning Policy" to build concentrated urban structure models, applicable though government plans. At first, we used the six categories of "Environmental Protection", "Residential Area", "Commercial and Business Area", "Public Transportation", "Roadside", and "Suburban" as referenced in the "Yamaguchi National Land Use Plan -The Fourth- (Yamaguchi Prefecture, 2010)" [5), "Yamaguchi City Planning Master Plan (Yamaguchi City, 2012)" [5)], "Basic Policy for City Planning in Hofu (Hofu City, 1999)" [5)] and "Yamaguchi Prefecture Master Plan Revised Version (Yamaguchi Civil Building Department, City Planning Division, 2008)" [6)].

4.2 Setting of the "Rules of Population Migration"

We set the "Rules of Population Migration" based on the "Knowledge Base of Planning Policy". In this study, we set eight rules of "Environmental Protection", "Concentration of population to Use District", "Keeping of Public Transportation", "Advanced Use of Central District", "High Density Residential District", "Urban Development of Roadsides", "Population Concentration to Suburban Base" and "Maintenance and Preservation for Suburban Village". *Figure 3* shows a flow chart on Rules of Population Migration. Further information on the rules is as follows.

Rule 1: Environmental Protection

This rule is important for the preservation of the natural and agricultural environment. The basic philosophy is to control the conversion from green fields such as farmland and timberland to other urban land use. If the land use of the mesh is "Rice Area", "Growth Area", "Mountain Area", "Water Area" or "Other Nature Area", the mesh is designated as a non-inhabitable area. In this case, the population in the meshes move to the other transmigration area.

Rule 2: Concentration of Population to Use District

According to the future population in the target area, the population density is thought to expand with low density. Therefore, the population outflow to the loose regulation area might become lower in population density. Consequently, if the mesh is in the loose regulation area, except "the suburban location (Rule 7)" and "the suburban villages (Rule 8)", the mesh is designated as a non-inhabitant area. In this case, the population in the meshes move to the other transmigration area.

Rule 3: Keeping of Public Transportation

Declining use of public transport is a serious problem in local cities. In this study, the area within a 1 kilometer radius of a train station and a 500 meter radius of a bus stop is designated as a utility circle for public transportation. The minimum population density of the mesh is set at 40 people/ha for the preservation of sustainable public transportation.

Rule 4: Advanced Use of Central District

Formation of a central urban area is needed for the concentration of urban functions and the increasing of the residential population. Therefore, the target population density in the commercial district should be set as the maximum accumulable population. The maximum accumulable population is calculated based on the area of vacant land, area of the site, and the legal floor area ratio. Also, if the use district is either low-rise exclusive residential districts or industrial districts, the population of the mesh does not move.

Rule 5: High Density Residential District

The residential district around the central business district is designated as land use for high population density. In this study, the target population density of the residential districts, except for low exclusive residential

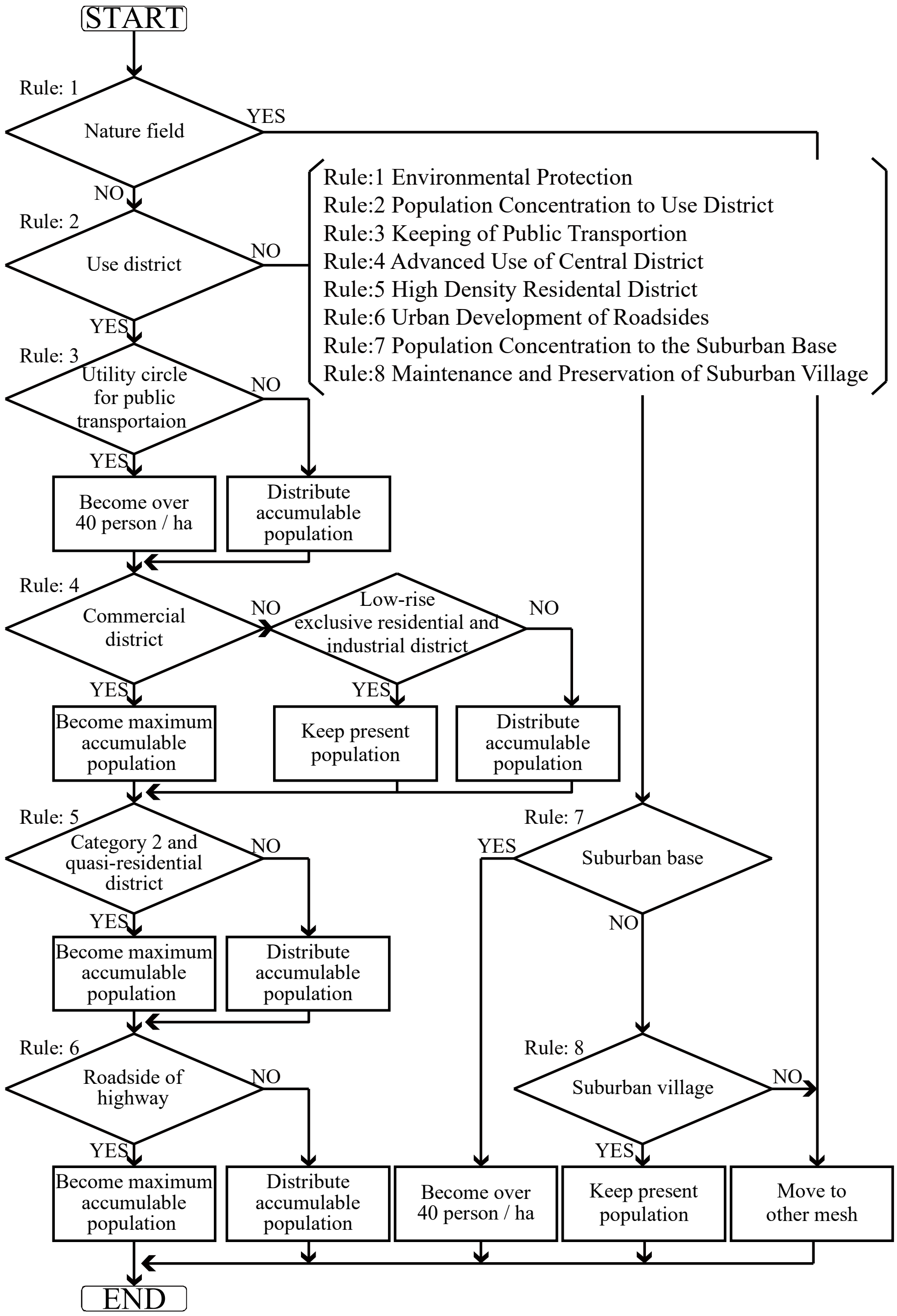


Figure 3. Flow chart on Rules of Population Migration

districts, is set as the maximum accumulable population.

Rule 6: Urban Development of Roadsides

Roadside districts accommodate a concentration of urban functions. Meshes of roadside define floor area as 200% ratio. The target population density is set as the maximum accumulable population.

Rule 7: Population Concentrated in Suburban Base

A certain population of Outside Use District is needed to keep the urban structure. In this study, the area within a 1 kilometer radius of JR Tonomi, JR Daidou, JR Azisu and the Aio government office are designated as the utility circle for the suburban base. The minimum population density of the mesh is set at 40 people/ha.

Rule 8: Maintenance and Preservation of Suburban Villages

A resident population of Outside Use District is needed to preserve and maintain the natural environment. In this rule, the mesh where the population under 55 years old is over 50% is designated as a suburban village. The mesh population becomes multiplied by the present population and the rate of change.

4.3 Creation of the concentrated urban structure models

We created the concentrated urban structure models on 2010 and 2040 population distribution based on Rules of Population Migration. In the target area, the master plan was made by assuming a 20-year destination. However, in this study, we selected by assuming a 30-year destination where the changes of the future population is largest. *Figure 4* shows the 2040 urban structure and the 2040 concentrated urban structure model.

5. EVALUATION OF THE CONCENTRATED URBAN STRUCTURE MODELS

We evaluated the concentrated urban structure models using the population distribution and the distance from urban facilities.

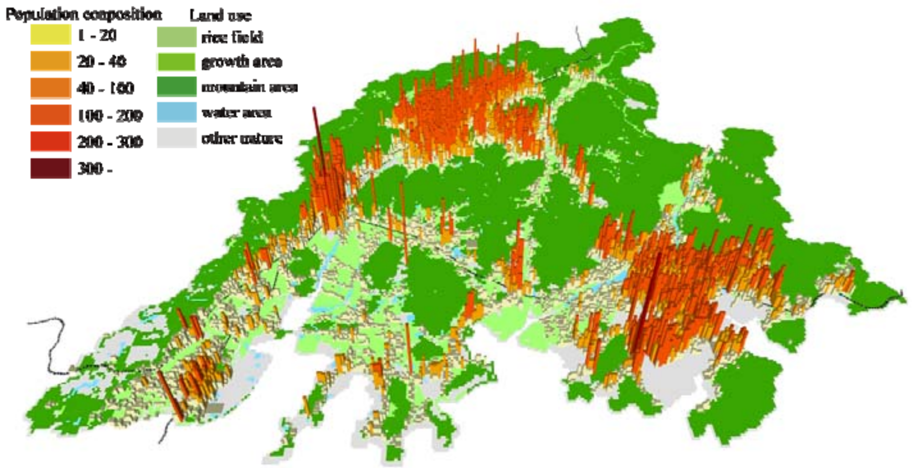
5.1 Evaluation by population distribution

Table 6 shows the concentrated urban structure models based on number of meshes of the population distribution. *Table 7* shows the models based on the population by use district.

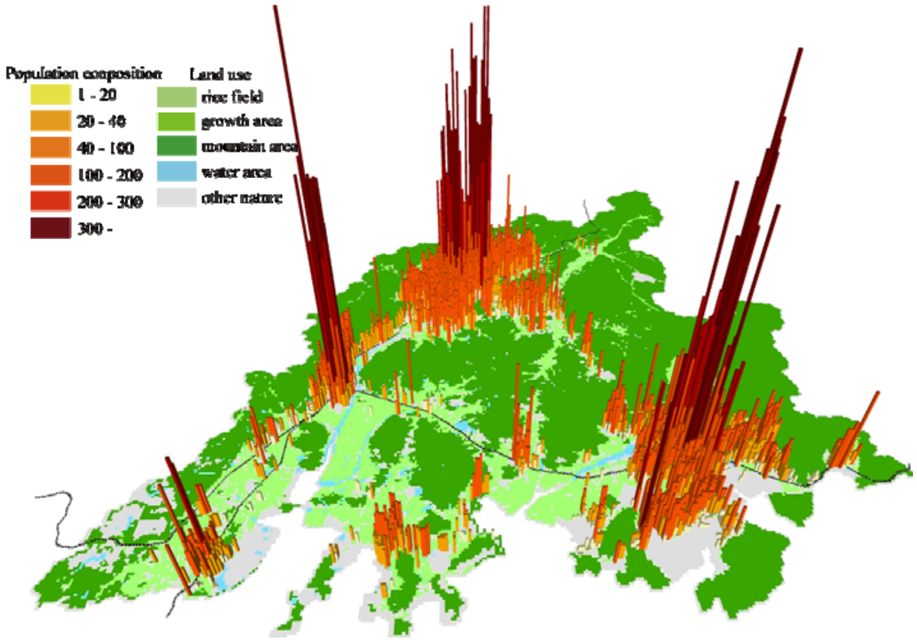
As shown in the number of meshes of the population distribution in the 2010 urban structure, “1-20 people” has 9,201 (14.0%) and the 2040 urban structure has 9,916 (15.1%). On the other hand, the 2010 concentrated urban structure model has 1,408 (2.2%) and the 2040 concentrated urban structure model has 1,039 (1.6%).

In the 2010 urban structure, over 200 people have 8 and the 2040 urban structure has 2. On the other hand, the 2010 concentrated urban structure model has 262 and the 2040 concentrated urban structure model has 172.

Next, as shown in the population by use district population, for commercial districts, the 2010 urban structure has 14,839 (5.2%) and the 2040 urban structure has 11,646 (5.2%). On the other hand, the 2010 concentrated urban structure model has 54,794 (19.2%) and the 2040 concentrated urban structure model has 60,296 (27.0%).



2040 Urban Structure



2040 Concentrated Urban Structure Model

Figure4. 2040 Urban Structure and Concentrated Urban Structure Model

Moreover, for the population of Outside Use District, the 2010 urban structure has 88,944 (28.8%) and the 2040 urban structure has 70,036 (30.7%). On the other hand, the 2010 concentrated urban structure model has 28,160 (9.8%) and the 2040 concentrated urban structure model has 20,403 (9.1%).

5.2 Evaluation by distance from urban facilities

The distance from urban facilities was classified into six categories "0-1,000 meters", "1,000–2,000 meters", "2,000-3,000 meters", "3,000-4,000 meters", "4,000-5,000 meters" and "over 5,000 meters". *Table 8* shows

Table 6. Number of the Mesh by Population distribution

Population	2010 Urban Structure	2010 Concentration Urban Structure
0	51,203 (78.1%)	60,317 (92.0%)
1-20	9,201 (14.0%)	1,408 (2.1%)
20-40	2,411 (3.7%)	1,033 (1.6%)
40-100	2,530 (3.9%)	2,062 (3.1%)
100-200	230 (0.4%)	501 (0.8%)
200-300	6 (0.0%)	174 (0.3%)
300-	2 (0.0%)	88 (0.1%)
Population	2040 Urban Structure	2040 Concentration Urban Structure
0	51,749 (78.9%)	61,203 (93.3%)
1-20	9,916 (15.1%)	1,039 (1.6%)
20-40	2,408 (3.7%)	1,399 (2.1%)
40-100	1,471 (2.2%)	1,583 (2.4%)
100-200	37 (0.1%)	187 (0.3%)
200-300	2 (0.0%)	87 (0.1%)
300-	0 (0.0%)	85 (0.1%)

Table 7. Population by Use District

Use District	2010 Urban Structure	2010 Concentration Urban Structure
Residential 1	47,941 (16.8%)	30,818 (10.8%)
Residential 2	780 (0.3%)	626 (0.2%)
Residential 3	35,068 (12.3%)	39,911 (14.0%)
Residential 4	7,775 (2.7%)	8,629 (3.0%)
Residential 5	51,858 (18.2%)	61,906 (21.7%)
Residential 6	10,026 (3.5%)	21,644 (7.6%)
Residential 7	3,894 (1.4%)	6,986 (2.5%)
Commercial 1	5,112 (1.8%)	15,911 (5.6%)
Commercial 2	14,839 (5.2%)	54,794 (19.2%)
Industrial 1	17,614 (6.2%)	14,548 (5.1%)
Industrial 2	657 (0.2%)	381 (0.1%)
Industrial 3	263 (0.1%)	457 (0.2%)
Outside Use District	88,944 (31.2%)	28,160 (9.9%)
Use District	2040 Urban Structure	2040 Concentration Urban Structure
Residential 1	40,761 (18.2%)	28,795 (12.9%)
Residential 2	660 (0.3%)	563 (0.3%)
Residential 3	28,430 (12.7%)	22,882 (10.2%)
Residential 4	6,209 (2.8%)	2,129 (1.0%)
Residential 5	42,368 (18.9%)	36,914 (16.5%)
Residential 6	7,859 (3.5%)	16,014 (7.2%)
Residential 7	3,083 (1.4%)	5,604 (2.5%)
Commercial 1	4,135 (1.8%)	16,479 (7.4%)
Commercial 2	11,646 (5.2%)	60,296 (27.0%)
Industrial 1	7,775 (3.5%)	13,208 (5.9%)
Industrial 2	518 (0.2%)	306 (0.1%)
Industrial 3	224 (0.1%)	111 (0.0%)
Outside Use District	70,036 (31.3%)	20,403 (9.1%)

the distance to the nearest train station and *Table 9* shows the distance to the nearest general hospital.

As shown in the "less than 1,000 meters" category of the distance to the train station, the 2010 urban structure has 100,875 people (31.5%) and the 2040 urban structure has 74,952 people (33.5%). On the other hand, the

Table 8. Population by distance to a train station

Distance to Train Station	2010 Urban Structure	2010 Concentration Urban Structure
0-1000	100,875 (31.5%)	152,413 (47.6%)
1000-2000	88,218 (27.5%)	84,863 (26.5%)
2000-3000	50,831 (15.9%)	34,409 (10.7%)
3000-4000	40,608 (12.7%)	25,777 (8.0%)
4000-5000	17,788 (5.6%)	12,004 (3.7%)
5000-	21,982 (6.9%)	10,955 (3.4%)
Distance to Train Station	2040 Urban Structure	2040 Concentration Urban Structure
0-1000	74,952 (33.5%)	114,946 (51.4%)
1000-2000	64,709 (28.9%)	58,462 (26.1%)
2000-3000	36,934 (16.5%)	20,514 (9.2%)
3000-4000	23,024 (10.3%)	14,873 (6.6%)
4000-5000	9,793 (4.4%)	6,918 (3.1%)
5000-	14,483 (6.5%)	7,983 (3.6%)

Table 9. Population by distance to a general hospital

Distance to a General Hospital	2010 Urban Structure	2010 Concentration Urban Structure
0-1000	86,935 (27.1%)	73,873 (24.0%)
1000-2000	91,766 (28.6%)	84,166 (26.3%)
2000-3000	57,230 (17.9%)	53,771 (16.8%)
3000-4000	28,343 (8.8%)	43,924 (13.7%)
4000-5000	18,529 (5.8%)	34,374 (10.7%)
5000-	37,500 (11.7%)	27,313 (8.5%)
Distance to a General Hospital	2040 Urban Structure	2040 Concentration Urban Structure
0-1000	27,609 (12.3%)	63,321 (28.3%)
1000-2000	44,846 (20.0%)	58,637 (26.2%)
2000-3000	39,798 (17.8%)	36,940 (16.5%)
3000-4000	39,560 (17.7%)	27,795 (12.4%)
4000-5000	34,794 (15.6%)	22,285 (10.0%)
5000-	37,098 (16.6%)	14,717 (6.6%)

2010 concentrated urban structure model has 152,413 people (47.6%) and the 2040 concentrated urban structure model has 114,946 people (51.4%).

Also, for the “over 5,000m” category, the 2010 urban structure has 21,982 people (6.9%) and the 2040 urban structure has 14,483 people (6.5%). On the other hand, the 2010 concentrated urban structure model has 10,955 people (3.4%) and the 2040 concentrated urban structure model has 7,983 people (3.6%).

As shown in the “less than 1,000 meters” category, of the distance to the general hospital, the 2010 urban structure has 86,935 people (27.1%) and the 2040 urban structure has 61,229 people (27.4%). On the other hand, in 2010, the concentrated urban structure model has 145,373 people (45.4%) and the 2040 concentrated urban structure model has 113,267 people (50.6%).

Also, for the “over 5,000m” category, the 2010 urban structure has 37,500 people (11.7%) and the 2040 urban structure has 25,865 people (11.6%). On the other hand, the 2010 concentrated urban structure model has 21,463 people (6.7%) and the 2040 concentrated urban structure model has 12,401 people (5.5%).

As shown in the distance to both facilities, the closer population increased and the faraway population decreased.

6. CONCLUSION

In this study, we made a forecasting method of future population and built future population distribution models. Then, we made "Knowledge Base of Planning Policy" references for a government plan on our target area and made the "Rules of Population Migration". We created the concentrated urban structure models that applied the rules and the future population models. Lastly, we evaluated the population distribution and the distance from urban facilities. This study is considered effective for planning aimed toward sustainable and compact urban structure. The results are as follows:

(1) In comparing the population from 2010 to 2060, the mesh of "1-20 people" is increasing and the mesh of "over 100 people" is decreasing.
(2) For the number of meshes according to population distribution, the mesh of "1-20 people" is decreasing and the mesh of "over 200 people" is increasing.
(3) For the population by use district, the population in commercial districts is increasing and the population of Outside Use District is decreasing.
(4) For the distance from the train station, the population of "less than 1,000 meters" is increasing and the population of "over 5,000 meters" is decreasing.
(5) For the distance from the general hospital, the population of "less than 1,000 meters" is increasing and the population of "over 5,000 meters" is decreasing.

ENDNOTE

1) An area divided city is a city that has been established as a use district. A use district according to the City Planning Law of Japan aims to prevent mixed building use. It has been classified into 12 categories "Category 1 low-rise exclusive residential district", "Category 2 low-rise exclusive residential district", "Category 1 medium-to-high-exclusive residential district", "Category 2 medium-to-high-exclusive residential district", "Category 1 residential district", "Category 2 residential district", "Quasi-residential district", "Neighborhood commercial district", "Commercial district", "Quasi-industrial district", "Industrial district" and "Exclusive industrial district"
2) Land use has been determined from a 2005 aerial photo.
3) The present population has been distributed to each 100 meter mesh according to the number of the Tele-point from 500 meter mesh data.
4) Tele-point shows the address point that has a phone number. It has excluded company points and same location points.
5) Urban master plans such as the "Yamaguchi National Land Use Plan -The Fourth-", "Yamaguchi City Planning Master Plan" and "Basic Policy for City Planning in Hofu" are legal government plans for basic urban planning.
6) "Yamaguchi Prefecture Master Plan Revised Version" is a voluntary plan for making urban master plans for basic policy based on the urban master plan.

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Study on Regional Characteristics and Exchanges Among Regions in Fukuoka Wide Area

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Key words: Spatial strategy, Regional characteristic, Fukuoka wide area, Exchange, Self-sufficiency

Abstract: The economy of Japan has been maturing in the beginning of the 21st century. However, the decrease of population, birth rate, and increase of the aging population are proceeding rapidly especially in local cities. As a result, it will become difficult to maintain functions of communities in the future, and it is also forecasted that regional gaps between cities and villages will become large. Being based on regional characteristics, strengthening a wide area in self-sufficiency and exchanges among regions might be called for. This study aims at clarifying the changes of regional characteristics and exchanges among the regions in the Fukuoka wide area, using statistical data and personal trip survey data over the recent decade, paying attention to a new structure of a wide area including cities and villages. As a result, in the Fukuoka wide area, it was made clear that there were six groups which were classified with principal component analysis and cluster analysis, and they have spread concentrically, and become complicated in the recent decade. It might have been influenced by the changes of population distribution and household composition. Moreover, the exchanges among the regions have been broadened in the recent decade. In the Fukuoka wide area, strengthening both self-sufficiency and exchanges among the regions will become important subjects in future.

1. INTRODUCTION

The economy of Japan has been maturing in the beginning of the 21st century. However, the decrease of population, birthrate, and increase of the aging population are proceeding rapidly especially in local cities. As a result, it will become difficult to maintain functions of communities in the future, and it is also forecasted that the regional gap between cities and villages will become large. The Ministry of Land, Infrastructure, Transport and Tourism of Japan published “The grand design of 21st century national land” in 1998. In this report, it is described that the structure of national land should be changed from the structure supported by a center and dependence, to a structure supported by autonomy and interdependence. Following this, in 2008, “National spatial planning” was published. In this plan, it is suggested that a spatial plan for a wide area should be made in collaboration with national, local government, and private sector. Thinking of problems in Japan, such as regional gaps, decrease of population, birthrate, and increase of its aging population, we must consider a new structure for a local wide area including cities and villages as a spatial strategy. Being based on regional characteristics, strengthening self-sufficiency and exchanges among regions in a wide area might be called for.

This study aims at clarifying the changes of regional characteristics and exchanges among the regions in the Fukuoka wide area, using statistical data (national population census, census of commerce, census of manufacturing industry) and personal trip surveys, paying attention to a new structure of a wide area including cities and villages.

There are some previous papers which have analyzed plural cities in wide areas of Asian countries. For example, 42 Korean cities were analyzed by using principle component analysis and cluster analysis. As a result, 42 Korean cities were classified into six groups (Mitsuyoshi & Hagishima et al., 1988).

On the other hand, from the view point of exchanges, mobility in the life of inhabitants who live in 26 Japanese cities located in the prefecture edges was analyzed by using national census data (Kanie, 1997). In Japan, populations of Tokyo, Osaka, and Nagoya regions are much bigger than local regions. 91 local small population regions were analyzed using national census data (1960-1995) from the view point of fluctuation factors (Saitou & Yamagata, 1999).

Asian capital cities recently have grown, especially Bangkok metropolis, a typical one which has been formed over a wide area. 60 districts of Bangkok metropolis were analyzed by using principle component analysis (Nishiura et al., 2011). Based on these previous papers, our paper is developed.

To this end, this paper is organized as follows. Firstly, we show the background of this paper, especially the Japanese situation. Secondly, the study area is introduced. Thirdly, the methodology is discussed. Fourthly, an analysis by using statistical data is discussed. Next, an analysis by using personal trip survey data is discussed. Finally, conclusions are drawn and some avenues for future research are discussed.

2. STUDY AREA

The study area of this paper is the Fukuoka wide area, which is one of the four areas (that is, Fukuoka area, North Kyushu area, Chikugo area and Chikuho area) of Fukuoka prefecture (see Figure 1). We chose the Fukuoka area as the study area and call it the Fukuoka wide area in this paper because this area is very important not only for Fukuoka prefecture but also for the whole Kyushu area. It includes Fukuoka, Chikushino, Kasuga, Onojyo, Munakata, Dazaifu, Koga, Fukutsu, Asakura, Itoshima City, Nakagawa, Umi, Sasaguri, Shime, Sue, Shingu, Hisayama, Kasuya, Chikuzen Town, and Touhou Village. It consists of 20 municipalities. However, Fukuoka City is extremely bigger than the others; we then divided Fukuoka City into seven wards, that is, Higashi, Hakata, Chuou, Minami, Nishi, Jyonan and Sawara wards, resulting in 26 regions being analyzed (seven wards, nine cities, nine towns and one village).

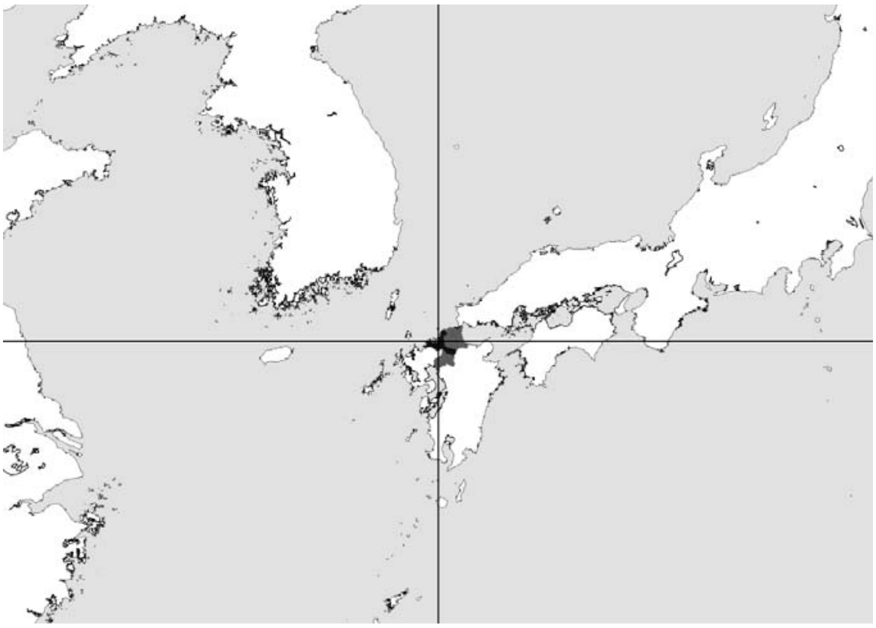

Figure 1. Study Area on Map

3. METHODOLOGY

We grasped and analyzed the changes of characteristics of regions in the Fukuoka wide area from 1995 to 2005 in principle by using the statistical data (national population census, census of commerce, census of manufacturing industry). The data were collected in 1995, 2000 and 2005. However, the census of commerce was taken in 1994, 1999 and 2004. Next, we used the third north Kyushu personal trip survey data, called 3PT (collected in 1993) and the fourth north Kyushu personal trip survey data, called 4PT (collected in 2005) in order to analyze the change of exchanges among the 26 regions (seven wards, nine cities, nine towns and one village) in the Fukuoka wide area.

3.1 Flow of analyses using statistical survey data

In this paragraph, we describe about the flow of analyses using statistical survey data.

Stage 1: We chose 18 indices to evaluate characteristics of regions from population census, census of manufacturing industry and census of commerce.

Stage 2: We analyzed these indices with principal component analysis and extracted evaluation axes in order to evaluate regions synthetically from the indices chosen in Stage 1.

Stage 3: Using scores which were obtained by principal component analysis we classified regions into six groups by using cluster analysis method.

3.2 Flow of analyses using personal trip survey data

In this paragraph, we described about the flow of analyses using personal trip survey data.

Stage 1: We removed samples of personal trip surveys where the trip number was 0 in order to grasp the exchanges among regions.

Stage 2: We extracted samples where origin and destination were both in the Fukuoka wide area and enlarged those samples by enlargement coefficients.

Stage 3: We made the OD trip table in the Fukuoka wide area by using those enlarged samples.

4. ANALYSES USING STATISTICAL SURVEY DATA

4.1 Selection of indices

Selected indices extracted from statistical data were population indices, household indices, business facility indices and so on. We selected 18 indices (see Table 1)which were transferred to proportional data or density data, except for the population and area data.

Table 1. Evaluation Index

	Index	Definition
1	Population	
2	Youth population ratio	Population of under 15 years old / population (%)
3	Productive age population ratio	Population of over 15 years old and under 65 years old / population (%)
4	Old age population ratio	Population of over 65 years old / population (%)
5	Area	
6	Population density	Population / area
7	Number of persons per household	Number of persons / number of general household
8	Nuclear family household ratio	Number of nuclear family household / number of general household (%)
9	Non-nuclear family household ratio	Number of non-nuclear family household / number of general household (%)
10	Non-relative household ratio	Number of non-relative family household / number of general household (%)
11	Single household ratio	Number of single household / number of general household (%)
12	Owned house ratio	Number of owned house / number of general household (%)
13	Public rental house ratio	Number of public rental house / number of general household (%)
14	Private rental house ratio	Number of private rental house / number of general household (%)
15	Wage house ratio	Number of wage house / number of general household (%)
16	Rental room ratio	Number of rental room / number of general household (%)
17	Enterprise density (Manufacturing industry)	Number of enterprise / area
18	Enterprise density (Commerce)	Number of enterprise / area

Source of 1～16 : National population census, 17 : Census of manufacturing industry, 18 : Census of commerce

4.2 Extraction evaluation axes with principal component analysis

In order to evaluate 18 indices synthetically, we extracted some synthetic components by using principal component analysis. The contribution value of the first principal component was 52.46% and that of the second principal component was 16.20%, the accumulated value of both was 68.66%. From this result, we judged these two principal components are important (see Table 2).

The first principal component showed bigger positive load values in the indices of population, productive age population ratio, population density, single household ratio, private rental house ratio, wage house ratio and business facility density, which were from the censuses of the manufacturing industry and commerce, and showed negative load values in the indices of the number of persons per household, the other related family household ratio and owned house ratio. Then we interpreted the first principal component as an urbanized grade criterion.

The second principal component showed positive load values in the indices of youth population ratio, nuclear family household ratio, which were from the censuses of the manufacturing industry and commerce, and showed negative load values in the indices of the old age population ratio. Then we interpreted the second principal component as the child-rearing household dwelling grade criterion.

Table 2. Principal Component Value, Eigenvalue, Contribution

Index	First synthetic component	Second synthetic component	Third synthetic component
Population	0.705	-0.221	0.568
Youth population ratio	-0.338	0.791	0.242
Productive age population ratio	0.811	0.436	0.116
Old age population ratio	-0.594	-0.721	-0.207
Area	-0.441	-0.279	0.571
Population density	0.865	-0.156	-0.097
Number of persons per household	-0.945	0.161	-0.061
Nuclear family household ratio	-0.465	0.788	0.048
Non-nuclear family household ratio	-0.823	-0.399	-0.144
Non-relative household ratio	0.558	0.160	-0.291
Single household ratio	0.923	-0.337	0.072
Owned house ratio	-0.968	-0.092	-0.111
Public rental house ratio	0.506	-0.424	0.531
Private rental house ratio	0.929	0.171	-0.033
Wage house ratio	0.676	0.359	0.157
Rental room ratio	0.571	0.162	-0.441
Enterprise density (Manufacturing industry)	0.677	-0.065	-0.415
Enterprise density (Commerce)	0.796	-0.327	-0.222
Eigenvalue	9.44	2.92	1.63
Contribution	52.46%	16.20%	9.03%
Accumulation	52.46%	68.66%	77.69%

4.3 Classification of regions with cluster analysis method

We classified 26 regions using a cluster analysis method by using principal component scores which were obtained by the principal component analysis. Distances between samples were calculated in Euclidean distances and distances between clusters were calculated with Ward method. In this analysis we had 26 regions and each region had three years' data (1995, 2000 and 2005). We used 78 samples. As a result, we could classify 78 samples into six groups (see Figure 2). Table 3 showed the names of regions, divided numbers and group numbers for each year. Next, we described each characteristic of six groups by using average values of evaluation indices (Table 4) and average values of principal components (Table 5).

Table 3. Group Composition

1995		
Region name	Number of 50 division	Number of group
Hakata ward	2	1
Chuou ward	3	
Higashi ward	1	2
Minami ward	4	
Jyonan ward	6	
Kasuga city	9	3
Onojyo city	10	
Nakagawa town	17	
Umi town	18	
Shime town	10	
Shingu town	20	
Kasuya town	22	
Nishi ward	5	4
Sawara ward	7	
Chikushino city	8	
Dazaifu city	12	
Koga city	13	
Sasaguri town	19	
Sue town	19	
Munakata city	11	5
Fukutsu city	14	
Itoshima city	16	
Hisayama town	21	
Chikuzen town	23	
Asakura city	15	6
Touhou village	24	

2000		
Region name	Number of 50 division	Number of group
Hakata ward	26	1
Chuou ward	27	
Higashi ward	25	2
Minami ward	6	
Jyonan ward	29	
Kasuga city	32	3
Nakagawa town	20	
Shingu town	38	
Kasuya town	10	
Nishi ward	28	4
Sawara ward	30	
Chikushino city	31	
Onojyo city	33	
Dazaifu city	5	
Koga city	8	
Umi town	8	
Sasaguri town	13	
Shime town	37	
Munakata city	34	5
Fukutsu city	35	
Itoshima city	21	
Sue town	11	
Hisayama town	21	
Chikuzen town	23	
Asakura city	36	6
Touhou village	39	

2005		
Region name	Number of 50 division	Number of group
Hakata ward	26	1
Chuou ward	41	
Higashi ward	40	2
Minami ward	29	
Jyonan ward	42	
Nakagawa town	48	3
Shingu town	22	
Kasuya town	32	
Nishi ward	28	4
Sawara ward	43	
Chikushino city	44	
Kasuga city	33	
Onojyo city	37	
Koga city	44	
Umi town	31	
Sasaguri town	8	
Shime town	7	
Munakata city	45	5
Dazaifu city	46	
Fukutsu city	45	
Itoshima city	47	
Sue town	34	
Hisayama town	47	
Chikuzen town	49	
Asakura city	36	6
Touhou village	50	

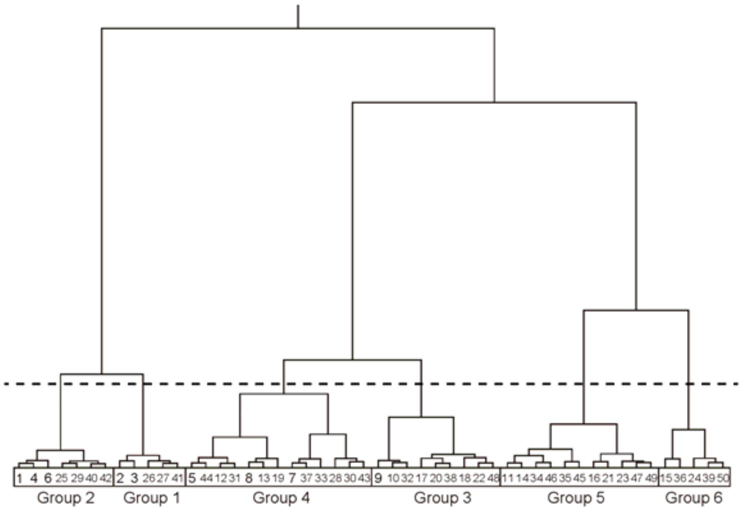

Figure 2. Dendrogram

Table 4. Average Value of Evaluation Index

1995

	Population (persons)	Youth population ratio (%)	Productive age population ratio (%)	Old age population ratio (%)	Area (km^2)	Population density (persons/ km^2)	Number of persons per household (persons)	Nuclear family household ratio (%)	Non-nuclear family household ratio (%)	Non-relative household ratio (%)	Single household ratio (%)	Owned house ratio (%)	Public rental house ratio (%)	Private rental house ratio (%)	Wage house ratio (%)	Rental room ratio (%)	Enterprise density (manufacturing industry) (/km^2)	Enterprise density (commerce) (/km^2)
G1	154,458	13.19	74.52	11.83	23.31	7300.34	2.00	41.41	6.03	0.55	52.01	25.83	10.66	50.53	7.60	1.09	16.62	313.89
G2	208,139	16.04	73.09	10.54	37.11	6507.99	2.32	51.37	6.95	0.38	41.30	35.04	10.26	45.77	5.40	0.74	5.30	73.36
G3	49,730	19.54	69.99	10.36	26.85	2754.46	3.00	67.23	12.45	0.41	19.91	55.40	2.87	32.51	5.77	0.93	5.40	32.18
G4	85,721	17.64	69.71	12.44	56.33	1484.26	2.94	65.31	13.12	0.28	21.29	59.90	6.62	26.48	3.83	0.67	2.25	13.08
G5	52,872	17.48	66.52	15.96	98.60	1105.73	3.32	63.58	22.33	0.16	13.93	79.24	4.62	12.40	1.82	0.58	0.72	5.48
G6	32,855	16.59	58.98	24.43	149.33	447.68	3.53	46.07	38.71	0.06	15.15	84.72	5.39	7.08	1.68	0.51	0.77	2.56

2000

	Population (persons)	Youth population ratio (%)	Productive age population ratio (%)	Old age population ratio (%)	Area (km^2)	Population density (persons/ km^2)	Number of persons per household (persons)	Nuclear family household ratio (%)	Non-nuclear family household ratio (%)	Non-relative household ratio (%)	Single household ratio (%)	Owned house ratio (%)	Public rental house ratio (%)	Private rental house ratio (%)	Wage house ratio (%)	Rental room ratio (%)	Enterprise density (manufacturing industry) (/km^2)	Enterprise density (commerce) (/km^2)
G1	166,162	11.55	74.80	13.30	23.32	7871.40	1.88	38.76	5.20	0.71	55.33	26.91	10.61	51.45	5.96	1.31	14.24	299.16
G2	212,938	14.37	72.13	13.03	37.69	6605.37	2.22	50.25	6.14	0.65	42.97	36.47	9.91	45.46	4.64	1.15	4.73	70.31
G3	52,002	18.33	69.90	11.55	30.53	2924.38	2.82	66.58	10.18	0.69	22.55	52.34	1.71	36.04	6.19	1.15	3.36	30.48
G4	86,631	16.24	69.63	13.88	49.32	2045.63	2.78	65.45	10.88	0.49	23.18	57.93	5.71	29.50	3.87	1.10	3.41	22.46
G5	50,754	15.51	66.67	17.63	84.89	1220.77	3.12	64.76	19.16	0.28	15.80	77.86	4.41	13.63	1.80	0.75	1.94	6.51
G6	32,328	14.43	57.35	28.19	149.33	433.45	3.31	47.32	34.76	0.06	17.86	83.11	5.16	8.16	1.50	0.67	0.71	2.52

2005

	Population (persons)	Youth population ratio (%)	Productive age population ratio (%)	Old age population ratio (%)	Area (km^2)	Population density (persons/ km^2)	Number of persons per household (persons)	Nuclear family household ratio (%)	Non-nuclear family household ratio (%)	Non-relative household ratio (%)	Single household ratio (%)	Owned house ratio (%)	Public rental house ratio (%)	Private rental house ratio (%)	Wage house ratio (%)	Rental room ratio (%)	Enterprise density (manufacturing industry) (/km^2)	Enterprise density (commerce) (/km^2)
G1	181,406	10.70	72.15	14.25	23.32	8620.70	1.82	37.22	4.65	1.13	57.00	28.28	9.78	53.44	4.64	1.16	10.15	279.32
G2	216,504	13.57	70.43	15.30	38.09	6688.27	2.18	50.76	5.92	0.79	42.52	38.53	9.86	45.10	3.79	1.10	3.40	61.10
G3	36,035	17.47	69.00	13.50	36.01	1511.73	2.78	66.83	10.33	1.26	21.57	53.98	0.67	38.04	4.50	0.95	2.88	16.90
G4	94,922	15.86	68.19	15.59	47.60	2736.77	2.68	65.35	9.58	0.68	24.39	56.49	5.85	31.69	3.45	0.97	2.95	27.03
G5	53,957	14.23	65.73	19.99	77.00	1074.17	2.91	64.60	16.20	0.42	18.78	73.91	3.74	19.18	1.70	0.59	1.66	8.68
G6	31,067	12.67	56.22	31.07	149.33	380.00	3.16	49.34	31.90	0.26	18.50	82.55	5.85	8.74	1.22	0.64	0.65	2.62

Table 5. Average Value of Principal Component

1995

	First principal component (urbanized grade criterion)	Second principal component (child-rearing household dwelling grade criterion)
G1	20.191	-2.905
G2	10.946	-0.404
G3	0.034	3.995
G4	-2.238	1.689
G5	-9.780	0.004
G6	-14.934	-4.923

2000

	First principal component (urbanized grade criterion)	Second principal component (child-rearing household dwelling grade criterion)
G1	20.911	-4.035
G2	11.946	-1.355
G3	1.836	3.804
G4	0.336	1.398
G5	-7.902	-0.556
G6	-14.030	-6.153

2005

	First principal component (urbanized grade criterion)	Second principal component (child-rearing household dwelling grade criterion)
G1	20.261	-4.867
G2	10.965	-2.167
G3	0.626	3.319
G4	0.817	0.749
G5	-6.751	-1.320
G6	-13.483	-7.090

Group 1 was estimated as high economic activity and high density central regions because population density, business facility density (manufacturing industry and commerce) and the first principal component score were high.

Group 2 was estimated as urbanized and specialized in single household dwelling regions because of the productive population ratio, population density, single house hold ratio, business facility density (commerce) and the first principal component score showed the urbanized grade was high.

Group 3 was estimated as intermediate density and specialized in child-rearing household dwelling regions because population, business facility density (manufacturing industry and commerce) were intermediate, and the second principal component score which showed the child-rearing household dwelling grade was high.

Group 4 was estimated as intermediate density and specialized in nuclear house hold dwelling regions because population density, business facility density (manufacturing industry and commerce) were intermediate and the nuclear household ratio was high.

Group 5 was estimated as low density and specialized in nuclear household dwelling regions because population, business facility density (manufacturing industry and commerce) were intermediate and the nuclear household ratio was high.

Group 6 was estimated as low urbanized regions, where conservative lifestyles are kept, because the other related household ratio and owned house ratio were very high and population density, business facility density (manufacturing industry and commerce) were very low.

Next, we described the relationships of two principal components and six group geographical positions by using the distribution of the six groups (Figure 3) and the changes of the scattering patterns of regions (Figure 4). Each group was distributed in the shape of the circles which shares the same center. Group 1 which was in the central position shows the highest value of the first principal component score. The greater the distance from the center becomes, the lower the first principal component score of the group becomes.

Figure 4 showed that in the changing of time (1995-2000-2005), Kasuga, Onojyou City, and Umi and Shime towns moved from Group 3 to Group 4 and Dazaifu City and Sue Town moved from Group 4 to Group 5.

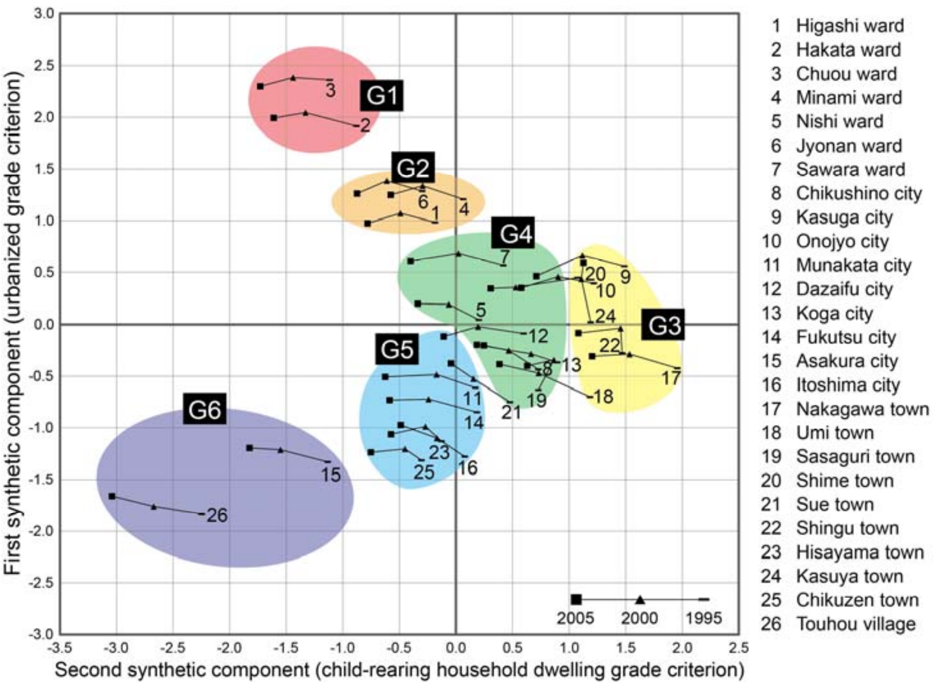

Figure 3. Geographical Distribution of Group

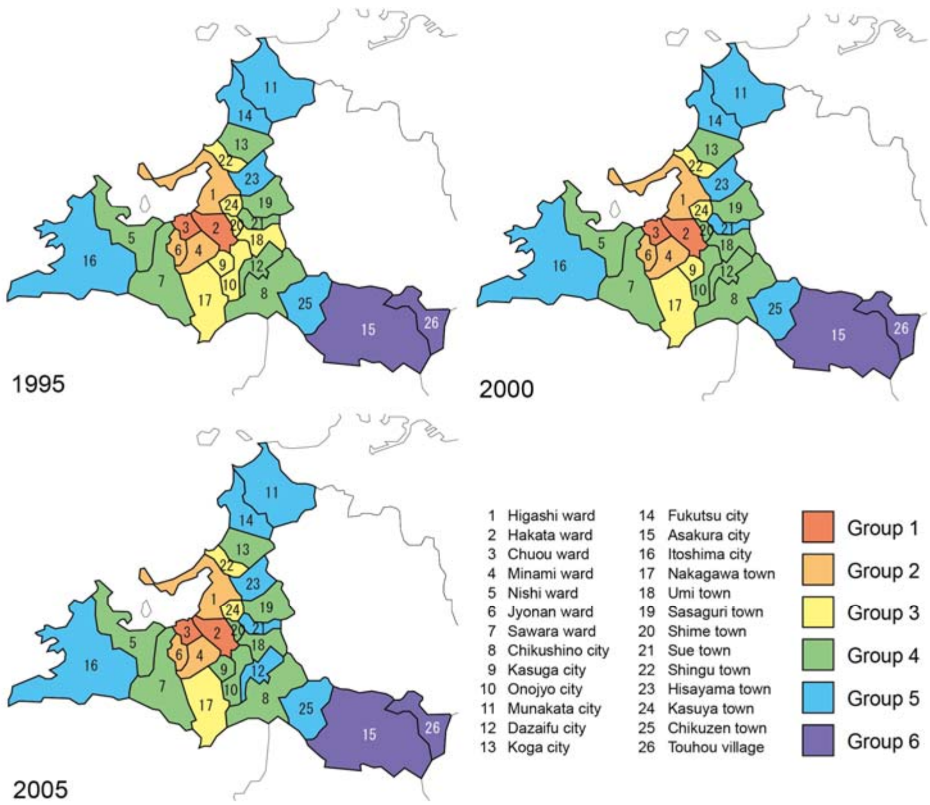

Figure 4. Change of Scattering Pattern of Region

5. ANALYSES USING PERSONAL TRIP SURVEY DATA

In this chapter, we made the OD table where values are transferred to the ratios for all in 3PT and 4PT and showed the change of exchanges among regions clear. Table 6 and Table 7 show the OD trip ratio for the sum of all generated trips of 3PT and 4PT. If the value of each cell was more than the average (1.70% in 3PT and 1.81% in 4PT), they were shown as emphasized cells. We counted the emphasized cells in each horizontal line and defined the number which showed the generation grade. In the same way, we counted the emphasized cells in each vertical column and defined the number which shows the attraction grade.

Table 6 and Table 7 show the generation grade in vertical columns, and attraction grade in horizontal lines. If Hisayama Town had an attraction grade of 1 and a generation grade of 10 it was positioned at the coordinate (1, 10), as shown in Figure 5. The region name with an underline means 4PT, otherwise the region is 3PT. In this figure, we classified 26 regions in four quadrants, that is, self sufficient type (small both in generation and attraction grade), absorbent type (small in generation grade and big in attraction grade), divergent type (small in attraction grade and big in generation grade) and central type (big both in generation and attraction grade). In the Fukuoka wide area, regions of divergent type were the most and that of absorbent type were the least. Only one absorbent type was identified, Higashi ward. It seemed that the generation grade became higher and many regions came to exchange with each other more from 1993 to 2005. Sasaguri and Sue town increased in both generation and attraction grade, meaning that they strengthened their centrality grade. Toho village decreased in generation grade and changed from divergent type to self-sufficient type.

Table 6. OD Table of 3PT

		1 Higa-shi ward	2 Hakata ward	3 Chuou ward	4 Mina-mi ward	5 Nishi ward	6 Jyonan ward	7 Sawa-ra ward	8 Chiku-shino city	9 Kasu-ga city	10 Ono-jyo city	11 Muna-kata city	12 Dazai-fu city	13 Koga city	14 Fuku-tsu city	15 Asaku-ra city	16 Itoshi-ma city	17 Naka-gawa town	18 Umi town	19 Sasa-guri town	20 Shime town	21 Sue town	22 Shingu town	23 Hisa-yama town	24 Kasu-ya town	25 Chiku-zen town	26 Tou-hou village
1	Higashi ward	66.22	9.89	5.84	2.06	0.96	1.07	1.33	0.40	0.56	0.64	1.02	0.47	1.50	0.99	0.07	0.31	0.20	0.66	0.56	0.79	0.54	1.63	0.48	1.72	0.09	0.00
2	Hakata ward	8.13	46.63	10.55	7.53	2.79	2.46	3.80	1.41	2.87	2.86	0.90	1.36	0.85	0.66	0.25	0.80	0.86	0.78	0.53	1.58	0.54	0.45	0.20	1.02	0.19	0.00
3	Chuou ward	5.46	11.33	45.34	8.84	4.32	6.03	8.00	1.21	1.51	1.28	0.60	1.19	0.49	0.43	0.16	1.19	0.54	0.27	0.24	0.39	0.21	0.25	0.06	0.48	0.18	0.00
4	Minami ward	2.28	9.97	10.51	61.76	0.93	3.09	1.76	0.99	2.70	1.41	0.19	0.95	0.13	0.10	0.11	0.29	1.74	0.20	0.08	0.25	0.15	0.06	0.06	0.23	0.08	0.00
5	Nishi ward	1.99	6.26	8.66	1.63	62.55	2.09	9.85	0.11	0.22	0.25	0.08	0.27	0.09	0.11	0.01	5.26	0.08	0.05	0.02	0.10	0.06	0.04	0.04	0.13	0.03	0.00
6	Jyonan ward	2.24	6.61	14.40	6.00	2.34	54.19	9.63	0.46	0.57	0.46	0.24	0.52	0.13	0.17	0.06	0.71	0.39	0.05	0.13	0.29	0.10	0.11	0.04	0.11	0.05	0.00
7	Sawara ward	1.95	6.13	11.20	2.03	6.96	5.64	62.41	0.30	0.28	0.34	0.16	0.35	0.12	0.14	0.07	1.08	0.25	0.03	0.08	0.11	0.04	0.08	0.04	0.17	0.04	0.00
8	Chikushino city	1.47	6.13	4.77	3.17	0.29	0.75	0.77	61.10	2.83	3.33	0.15	10.61	0.13	0.02	0.75	0.12	0.62	0.31	0.13	0.15	0.21	0.06	0.06	0.21	1.86	0.00
9	Kasuga city	1.82	10.03	4.44	7.09	0.37	0.77	0.71	2.29	58.68	7.57	0.10	1.99	0.08	0.04	0.13	0.19	2.70	0.18	0.06	0.31	0.20	0.01	0.01	0.11	0.11	0.00
10	Onojyo city	2.00	11.34	4.63	4.02	0.47	0.79	0.87	3.07	8.68	53.42	0.12	6.37	0.11	0.14	0.26	0.05	1.18	1.00	0.15	0.45	0.23	0.09	0.02	0.24	0.30	0.00
11	Munakata city	3.69	3.84	2.28	0.52	0.15	0.36	0.34	0.05	0.15	0.19	78.28	0.15	2.44	6.00	0.00	0.11	0.09	0.06	0.12	0.03	0.13	0.80	0.07	0.16	0.00	0.00
12	Dazaifu city	2.05	6.71	5.49	3.74	0.53	0.95	1.05	12.51	2.77	7.97	0.18	51.13	0.18	0.16	0.62	0.15	0.87	0.76	0.18	0.52	0.40	0.04	0.07	0.40	0.56	0.02
13	Koga city	7.89	5.01	2.67	0.56	0.28	0.37	0.44	0.19	0.10	0.21	3.56	0.26	65.04	6.98	0.10	0.06	0.07	0.27	0.69	0.09	0.31	3.61	0.47	0.74	0.03	0.00
14	Fukutsu city	5.41	4.28	2.34	0.48	0.27	0.47	0.59	0.08	0.10	0.16	9.34	0.29	6.98	67.23	0.00	0.20	0.02	0.07	0.04	0.12	0.06	1.16	0.08	0.20	0.03	0.00
15	Asakura city	0.29	1.33	0.92	0.58	0.02	0.13	0.23	1.17	0.17	0.37	0.00	0.62	0.07	0.02	86.81	0.06	0.08	0.12	0.03	0.05	0.02	0.00	0.00	0.05	6.70	0.16
16	Itoshima city	0.99	3.42	4.23	0.87	9.29	1.09	2.89	0.07	0.19	0.09	0.08	0.12	0.07	0.10	0.03	76.22	0.07	0.05	0.02	0.01	0.00	0.07	0.00	0.05	0.00	0.00
17	Nakagawa town	1.69	7.38	4.23	11.94	0.47	1.50	1.27	1.27	7.17	2.98	0.19	1.57	0.10	0.03	0.00	0.24	56.93	0.11	0.09	0.17	0.17	0.03	0.04	0.23	0.20	0.00
18	Umi town	5.37	7.85	2.09	1.58	0.24	0.18	0.33	0.45	0.53	2.27	0.09	1.52	0.46	0.11	0.16	0.12	0.12	61.13	0.91	5.72	4.00	0.25	0.32	4.11	0.08	0.00
19	Sasaguri town	6.77	7.55	3.02	0.77	0.20	0.71	0.88	0.47	0.28	0.62	0.35	0.48	1.45	0.16	0.00	0.00	0.19	0.91	64.41	1.35	1.59	0.70	2.17	4.97	0.00	0.00
20	Shime town	5.71	13.81	3.03	1.58	0.35	1.15	0.57	0.29	0.79	1.02	0.11	0.91	0.27	0.25	0.04	0.00	0.07	6.04	0.69	52.56	6.05	0.33	0.32	3.85	0.20	0.00
21	Sue town	6.36	7.64	2.55	1.47	0.40	0.69	0.29	0.64	0.57	1.03	0.48	0.88	0.63	0.20	0.06	0.00	0.37	6.10	1.53	9.59	52.82	0.31	0.54	4.52	0.36	0.00
22	Shingu town	20.09	6.18	3.18	0.45	0.25	0.71	0.73	0.14	0.09	0.19	3.10	0.27	9.39	3.08	0.07	0.20	0.05	0.45	0.66	0.63	0.47	48.03	0.91	0.65	0.06	0.00
23	Hisayama town	13.57	7.03	2.47	1.46	0.59	0.67	0.69	0.54	0.00	0.63	0.58	0.64	2.37	0.29	0.10	0.00	0.00	0.89	5.31	2.14	1.68	2.13	51.10	5.11	0.00	0.00
24	Kasuya town	14.29	9.69	4.30	1.56	0.45	0.35	1.07	0.47	0.54	0.63	0.30	0.86	1.09	0.35	0.04	0.17	0.25	4.17	3.51	4.17	3.27	0.53	1.49	46.29	0.13	0.00
25	Chikuzen town	1.18	2.63	2.45	1.02	0.10	0.35	0.35	5.44	0.36	1.00	0.00	1.80	0.06	0.00	15.89	0.00	0.37	0.11	0.06	0.26	0.23	0.05	0.04	0.24	65.73	0.27
26	Touhou village	0.00	0.00	0.00	0.00	0.00	5.33	7.69	0.00	6.80	6.21	0.00	6.80	0.00	0.00	32.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	34.32	0.00

Table 7. OD Table of 4PT

		1 Higa-shi ward	2 Hakata ward	3 Chuou ward	4 Mina-mi ward	5 Nishi ward	6 Jyonan ward	7 Sawa-ra ward	8 Chiku-shino city	9 Kasu-ga city	10 Ono-jyo city	11 Muna-kata city	12 Dazai-fu city	13 Koga city	14 Fuku-tsu city	15 Asaku-ra city	16 Itoshi-ma city	17 Naka-gawa town	18 Umi town	19 Sasa-guri town	20 Shime town	21 Sue town	22 Shingu town	23 Hisa-yama town	24 Kasu-ya town	25 Chiku-zen town	26 Tou-hou village
1	Higashi ward	63.69	9.95	6.27	1.90	1.12	0.92	1.80	0.47	0.59	0.59	1.04	0.60	1.84	0.93	0.10	0.39	0.24	0.40	0.68	0.80	0.56	2.49	0.82	1.75	0.04	0.00
2	Hakata ward	9.10	42.69	11.01	7.43	3.08	2.38	4.21	1.88	3.06	2.84	1.06	1.34	0.96	0.80	0.18	0.94	1.01	1.06	0.53	1.90	0.46	0.43	0.17	1.33	0.15	0.00
3	Chuou ward	5.45	10.16	44.27	9.23	4.29	6.59	7.50	1.58	1.66	1.46	0.71	1.27	0.58	0.44	0.17	1.14	0.75	0.43	0.34	0.70	0.20	0.22	0.10	0.61	0.15	0.00
4	Minami ward	2.37	10.52	13.45	55.82	1.08	3.53	2.17	0.89	3.31	1.49	0.18	0.71	0.12	0.07	0.11	0.31	2.36	0.27	0.12	0.27	0.14	0.12	0.05	0.40	0.12	0.00
5	Nishi ward	2.05	5.88	8.21	1.49	61.23	2.42	10.74	0.13	0.19	0.26	0.06	0.33	0.06	0.08	0.07	6.01	0.19	0.07	0.07	0.23	0.03	0.03	0.01	0.13	0.03	0.00
6	Jyonan ward	2.35	6.49	18.11	6.92	3.38	46.53	10.73	0.58	0.69	0.53	0.34	0.64	0.52	0.13	0.07	0.48	0.71	0.03	0.15	0.19	0.10	0.09	0.06	0.13	0.06	0.00
7	Sawara ward	2.53	6.49	11.72	2.35	8.69	5.91	57.66	0.31	0.43	0.40	0.23	0.32	0.09	0.14	0.06	1.37	0.43	0.14	0.07	0.16	0.09	0.11	0.03	0.24	0.02	0.00
8	Chikushino city	1.57	6.23	5.34	2.04	0.23	0.80	0.60	61.12	2.46	4.18	0.10	10.10	0.12	0.14	0.78	0.06	0.56	0.58	0.13	0.19	0.07	0.05	0.10	0.20	2.27	0.00
9	Kasuga city	1.90	9.98	5.29	7.33	0.37	1.01	0.82	2.57	54.31	8.63	0.24	2.29	0.11	0.06	0.12	0.07	3.52	0.37	0.12	0.27	0.09	0.00	0.06	0.35	0.12	0.00
10	Onojyo city	1.96	10.19	5.34	3.87	0.51	0.74	1.10	4.42	9.13	52.76	0.16	5.35	0.16	0.18	0.35	0.20	1.04	0.77	0.10	0.59	0.29	0.07	0.04	0.46	0.19	0.02
11	Munakata city	3.34	3.75	2.57	0.42	0.18	0.49	0.48	0.12	0.23	0.16	77.92	0.20	2.78	5.45	0.00	0.11	0.07	0.15	0.21	0.16	0.13	0.72	0.04	0.21	0.06	0.01
12	Dazaifu city	2.53	6.63	6.75	2.78	1.00	1.08	1.19	15.32	3.42	7.40	0.29	46.45	0.51	0.14	0.73	0.32	0.76	0.87	0.25	0.30	0.39	0.05	0.08	0.27	0.51	0.00
13	Koga city	9.03	5.32	3.31	0.38	0.19	1.02	0.41	0.20	0.18	0.36	4.20	0.57	59.25	9.21	0.00	0.18	0.11	0.15	0.57	0.11	0.39	4.01	0.35	0.49	0.00	0.00
14	Fukutsu city	5.19	4.83	2.63	0.40	0.25	0.31	0.61	0.28	0.11	0.28	9.35	0.16	10.29	61.96	0.02	0.13	0.07	0.23	0.19	0.14	0.12	1.93	0.19	0.31	0.00	0.00
15	Asakura city	0.37	0.85	0.79	0.38	0.17	0.11	0.25	1.27	0.13	0.46	0.00	0.65	0.00	0.00	87.86	0.00	0.07	0.03	0.00	0.03	0.10	0.11	0.05	0.02	6.11	0.19
16	Itoshima city	1.03	2.78	3.57	0.58	9.47	0.64	2.79	0.06	0.07	0.17	0.06	0.22	0.14	0.05	0.00	78.06	0.09	0.02	0.01	0.06	0.01	0.04	0.05	0.05	0.00	0.00
17	Nakagawa town	1.70	7.28	5.37	11.48	0.69	1.50	1.73	1.06	7.59	2.12	0.05	1.05	0.16	0.05	0.15	0.23	56.75	0.38	0.03	0.15	0.10	0.00	0.00	0.21	0.17	0.00
18	Umi town	3.42	10.55	4.00	1.81	0.42	0.19	0.86	1.70	0.92	2.32	0.36	1.41	0.32	0.32	0.00	0.02	0.56	51.96	1.65	5.27	6.38	0.58	0.80	4.14	0.05	0.00
19	Sasaguri town	8.04	6.43	4.55	1.12	0.40	0.70	1.08	0.48	0.30	0.33	0.59	0.72	1.17	0.38	0.13	0.09	0.06	2.33	56.29	2.76	1.77	1.12	3.15	5.94	0.07	0.00
20	Shime town	5.96	15.29	5.42	1.77	0.55	0.60	0.80	0.52	0.80	1.00	0.40	0.30	0.34	0.22	0.00	0.13	0.20	4.49	1.71	46.44	4.51	0.61	0.35	7.59	0.00	0.00
21	Sue town	6.23	5.77	2.42	1.58	0.14	0.40	1.01	0.31	0.21	0.93	0.55	1.39	1.26	0.26	0.20	0.05	0.32	8.62	1.90	8.09	48.07	0.83	1.12	8.32	0.00	0.00
22	Shingu town	24.30	4.97	2.37	0.81	0.20	0.38	0.53	0.16	0.00	0.20	2.24	0.30	8.07	3.09	0.24	0.10	0.00	0.60	0.77	0.71	0.69	47.57	0.94	0.77	0.00	0.00
23	Hisayama town	23.82	5.68	4.40	1.38	0.25	0.79	0.57	0.76	0.38	0.78	0.57	0.52	2.74	0.49	0.00	0.55	0.00	2.75	7.52	1.99	2.68	3.03	32.39	5.94	0.00	0.00
24	Kasuya town	11.35	9.60	4.37	1.73	0.52	0.34	1.16	0.43	0.54	1.00	0.49	0.21	0.64	0.48	0.03	0.22	0.16	3.03	3.39	7.23	4.41	0.60	1.09	46.90	0.08	0.00
25	Chikuzen town	0.57	2.43	2.30	1.12	0.20	0.36	0.17	9.55	0.61	1.01	0.00	1.37	0.00	0.00	17.85	0.00	0.36	0.08	0.17	0.00	0.00	0.00	0.00	0.23	61.62	0.00
26	Touhou village	0.00	0.00	6.58	0.00	0.00	0.00	0.00	0.00	0.00	7.34	0.00	0.00	0.00	0.00	64.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.77

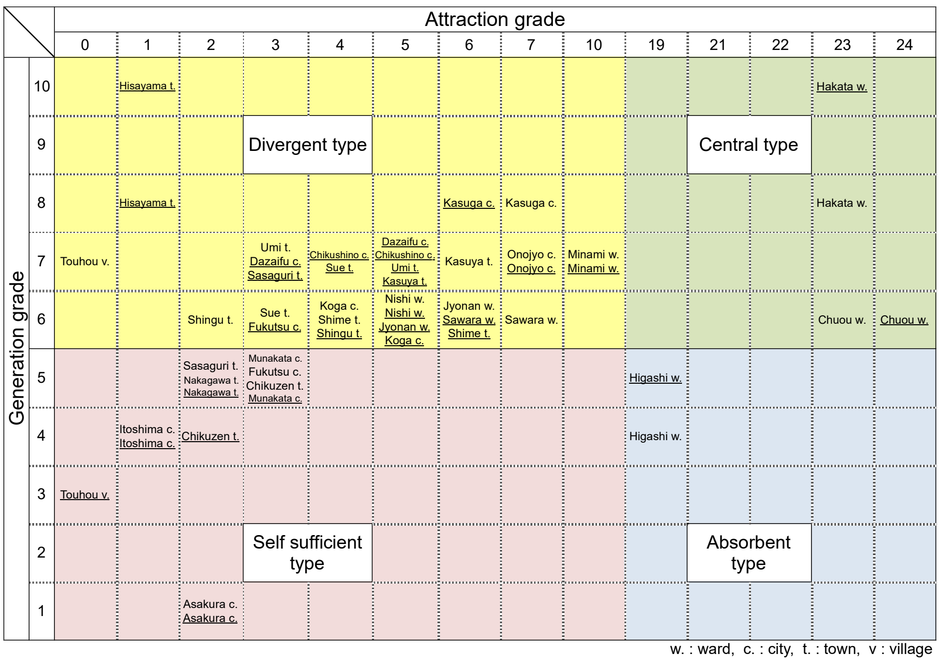

*Figure 5.*Generation Grade and Attraction Grade (3PT and 4PT)

6. CONCLUSIONS

In this study, we have classified characteristics of regions into six groups with principal component analysis and cluster analysis and made the changes of them clear from 1995 to 2005. Next, we have clarified the change of exchanges among regions in the Fukuoka wide area by using personal trip survey data from 1993 to 2005.

In the Fukuoka wide area, we identified six groups of regions in a circular distribution pattern and Hakata and Chuo ward were the center of these regional groups. In the decade from 1995 to 2005, some regions which were located in the intermediate band of the circular distribution pattern moved from one group to another group and the circular distribution pattern was distorted to a complicated pleated shape. As a whole, urbanization has matured and child-rearing households have decreased, resulting in the urbanized grade becaming high in many regions, however the child-rearing household living grade did not become high in any region.

In the exchanges among regions we classified 26 regions to four types and made it clear that there were many divergent types with high generation grades and low attraction grades in the Fukuoka wide area.

In addition, as a whole, the generation grades became higher and almost every region has had exchanges among more regions from 3PT (1993) to 4PT (2005).

Problems to be solved in the Fukuoka wide area might be that according to the changing characteristics of the regions and exchanges among them, from the view of wide regional planning, optimally locating main public facilities like educational and medical facilities and business facilities is important and diverse and flexible regional policies are needed. As future research, keeping analyses on changes of characteristics of regions and exchanges among regions, facility allocation and the traffic networks of the wide area might be important.

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A Spatial Simulation Model to Explore Agglutination of Residential Areas and Public Service Facilities

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Key words: Spatial Agglutination, Residential Areas, Public Service Facilities, Multi-agent based Model, Simulation

Abstract: According to a 2006 report by the National Institute of Population and Social Security Research, Japan has been undergoing a long-term decline in population since 2005. The mid-term and long-term vision of urban and regional planning regards the consolidation of residential areas and public service facilities, including their withdrawal, as necessary for improving the quality of life for rural and suburban residents. From the point of view of provider's such as the administrative and private sectors, consolidation of facilities is inevitable due to their profitability. Because of the decrease in the number of facility users and their lack of successors, brought about by population decline and aging, it is also difficult for the public administration to provide public services. The purpose of this study is to produce suggestions for sustainable urban and regional spatial structures in Japan. A spatial simulation model was used as a multi-agent-based model to analyze the mid- and long-term changes in the agglutination of residential areas and public service facilities. At first, a multi-agent-based model was developed to quantitatively evaluate the agglutination of residential areas and public service facilities. Next, sensitivity analysis was conducted to adjust some of the crucial parameters that influenced simulation results. Finally, simulations were carried out based on several policy scenarios related to the sustainability and accessibility of the facilities. The results of the analysis indicated that public service facilities are likely to be concentrated in the city center, but that financial support by the administration or non-profitable organizations (NPO) enables facilities located outside of centers to sustain the provision of public service.

1. INTRODUCTION

1.1 Background and Purpose

According to a 2006 report by the National Institute of Population and Social Security Research, Japan has been undergoing a long-term decline in population since 2005. As a result of the population decline, decreasing birth rate and aging population, it would be difficult for local residents to sustainably receive the primary services that are necessary for daily life (for example, medical, sales, financial services, etc.) because the mid-term and long-term vision of urban and regional planning considers the consolidation of residential areas and public service facilities, including their withdrawal, as necessary to improve quality of life for rural area and suburban residents. In addition, from the point of view of provider, such as the administration and private sectors, the consolidation of the facilities is inevitable due to their profitability. Because of the decrease in the number of facility-users and their lack of successors caused by population decline and aging, it is also difficult for the public administration to provide public services.

The purpose of this study is to produce suggestions for sustainable urban and regional spatial structures in Japan. A multi-agent-based spatial simulation model is used for analyzing the mid- and long-term locational changes in residential areas and service facilities.

1.2 Related Studies

At present, sustainability is a popular term. It is often used in the context of global environmental issues, for example, greenhouse gases, in referring to climate change and energy problems. In the field of urban planning, one of the concepts for creating a sustainable urban form, that is, a "compact city," is widely spreading. For example, Jenks et al. (1996) describe the concept of compact cities. This concept is reflected in many policies and practices globally.

In recent years, some countries, including Japan, have faced long-term depopulation as a sustainability issue. Many researchers have focused on the issue of urban shrinkage, a multidimensional phenomenon encompassing regions, cities and parts of cities or metropolitan areas that are experiencing population loss and a dramatic decline in their economic and social base. For example, Pallagst et al. (2014) and Richardson and Nam (2014) describe the concept of the shrinking city. A recent international debate on urban shrinkage has ensued due to the enhanced scholarly understanding of urban shrinkage, which reflects governance and policy. For example, Großmann et al. (2013) organized various studies related to urban shrinkage to augment and improve the international urban shrinkage research agenda. Rall and Haase (2011) evaluated the utility of a program in Leipzig, an example of a shrinking city that began to revitalize its declining neighborhoods. Kabisch and Grossmann (2013) focused on how a declining and aging population impacts the population composition within a particular estate, how residential satisfaction in the estate changed over time, and which target groups are attracted to the estates, using the results from a unique long-term sociological survey that was carried out for over 30 years in a large housing estate in Leipzig, eastern Germany. Schetke and Haase (2008) developed and applied a multi-criteria assessment scheme (MCA) to assess the socio-environmental impact of shrinkage. Frazier et al. (2013) examined the association between building demolition and crime, a human-environment interaction that is fostered by the presence of vacant and abandoned properties, through a comparative statistical analysis.

While studies that clarify the issue of urban planning and the actual conditions such as those mentioned above, are accumulating, exploring the vision and urban structure that corresponds to the issue is essential. Therefore, studies that explore the vision and urban structure through the use of spatial simulation techniques are also essential.

A review of prior studies regarding spatial simulation demonstrates that there are various methods of simulating a virtual urban structure. For example, Gonzales et al. (2013) used a decision-support system (DSS) that systematically integrates urban metabolism components into impact assessment processes with the aim of accurately quantifying the potential effects of difficult proposed planning interventions. Xu and Coors (2012) developed the integration of GIS, SD models and 3D visualization, called the GISSD system, which can better explain the interaction and variation between residential development sustainability indicators. Barredo et al. (2003) asserted that one of the most potentially useful applications of cellular automata (CA) from the point of view of spatial planning is their use in simulations of urban growth at the local and regional levels. Lagarias (2012) proposed a CA-based model linking macro-scale processes to micro-dynamics to simulate the urban sprawl process.

One of the most popular methods is the multi-agent system (MAS). Uhrmacher and Weyns (2009) described how MAS has been used to understand the interaction both among agents and between agents and their dynamic environment. For example, Ligtenberg et al. (2004) demonstrated a MAS that consists of agents representing organizations and interest groups involved in an urban allocation problem during a land use planning process. Ligtenberg et al. (2001) also described a spatial planning model combining a multi-agent simulation (MAS) approach with cellular automata (CA). Tian et al. (2011) developed an agent-based model of urban growth for the Phoenix metropolitan region in the United States, which simulates the behavior of regional authorities, real estate developers, residents, and environmentalists.

Among the studies that focus on the exploration of sustainable urban forms, one example is Zellner et al. (2008), who developed a simple agent-based model of a hypothetical urbanizing area that integrates data on spatial economic and policy decisions, energy and fuel use, and air pollution emissions and assimilation to test how residential and policy decisions affect urban forms, consumption and pollution. To assess the sustainability of urban area socio-ecological systems, Gaube and Remesch (2013) developed an agent-based decision model to simulate new residential patterns for different household types based on demographic development and migration scenarios. Cavari et al. (2011) developed a model to understand and draw conclusions concerning a planner's options in developing a plan that reflects a sustainable built environment in terms of transportation, distribution of facilities and minimization of pollution from vehicles.

Other studies focused on the exploration of the urban form as it corresponds to long-term depopulation. For example, Haase et al. (2012) demonstrated that a selective demolition of the vacant housing stock in Leipzig could counteract the vast supply of dwellings and balance the demand for housing with the number of available flats. He employed the spatially explicit simulation model RESMOBcity. Haase et al. (2012) also provided the initial results of a joint SD (system dynamics)-CA (cellular automata) model and an ABM (agent-based model), both of which operationalized social science data regarding urban shrinkage, using Leipzig, Germany, as a case study.

This paper is unique because it attempts the simulation of future trends of assumed urban shrinkage focusing on residential areas and public service facilities to obtain suggestions for creating sustainable urban and regional structures.

1.3 Study Method

The study procedure is as follows.

First, a spatial simulation model is developed using multi-agent-based modeling. We define service facilities and households as agents. The service facility agents perform withdrawal (agglutination), and the household agents use the facilities and relocate their residences.

Second, sensitivity analysis is conducted to extract the crucial parameters that influence the agglutination of residential areas and service facilities.

Third, based on the results mentioned above, simulations are carried out to simulate policy scenarios related to the sustenance and accessibility of the facilities. Finally, we analyze the results and examine the potential suggestions for sustainable spatial structure in the future.

2. MODEL DEVELOPMENT

2.1 Virtual Spatial Model

The multi-agent-based model is a useful technique for analysing unexpected phenomena. It can show the effects of an individual agent's activities or the interactions between agents and their environment. With this model, users can demonstrate dynamic and complex changes in an urban or regional area. This type of model is very useful for visually expressing the changes that occur in urban and regional areas over time.

In this paper, a spatial simulation model was developed in order to quantitatively evaluate the agglutination of residential areas and service facilities. This model contains a hierarchical system of service facility agents and household agents. These agents are generated in a virtual space consisting of grid cells under certain conditions.

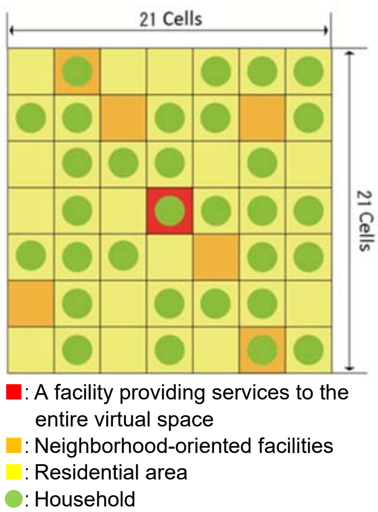

Figure 1. Conceptual diagram of virtual space

The virtual space is composed of grid cells where one cell is defined as a community (village) which roughly equals 1km^2 of "real space". The virtual space contains 441 (21 x 21) cells in total. This virtual space is a closed space with no socio-economic interaction with external forces, such as migration. Statistical data taken from Japan were used. One step in the simulation is equal to one year and lasts for 100 steps, starting in 2005 and ending in 2105.

2.2 Facility Agent

The facility agents are classified into two types; a facility which provides service to the entire virtual space and those that are neighbourhood oriented. The former is placed in the center of the virtual space, where it represents a central area in a real world region. The neighborhood-oriented facilities are randomly allocated throughout the virtual space before the initiation of the simulation. The facilities (agents) choose withdrawal (extinction) by comparing the number of users (households) present during the previous step to the minimum number of users needed for the facility to maintain service. If the number of users is lower than the requirement, the facility will either withdraw or combine with another facility. This process is based on the idea that the loss of sustainable service, as a result of declining users, can result in the withdrawal or agglutination of a facility.

2.3 Residential Area Agent

Residential area agents are placed in each of the 441 cells, which have variables indicating the maximum number of households that can occupy a cell (*MHC*), land price, the number of residents, and the number of households. Each cell is randomly assigned an *MHC* value between 1 and 20 before the simulation's initiation. The distribution of *MHC* values mirrors the different distributions of population density found in the real world.

The land price of a cell is determined by the cell's population density and the attractiveness and accessibility of the nearest facility. A regression analysis using formulas (1) and (2) was conducted using data on land prices from Toyohashi city. A multiple correlation coefficient was given the highest value when β=0.8 and the value of the constant term=0. In this model, we adopt a=271.3, b=7.7, and β=0.8 when the multiple correlation coefficient is the highest.

$$y_i = a x_{1i} + b x_{2i} \qquad (1)$$
$$x_{2i} = D_j \exp(-\beta C_{ij}) \qquad (2)$$

Where y_i is the land price of cell i, x_{1i} is the population density, x_{2i} is the convenience of the facilities, D_j is the attractiveness of the nearest facility j (determined by the number of users in the previous step), β is a parameter of the distance decay function, a and b are parameters and C_{ij} is the distance from cell i to the nearest facility j.

Every facility is given the same initial value for attractiveness.

2.4 Household Agent

The household agents are initially placed at random within the virtual space. Each household agent has four attributes; household type, age, income and house type. The household agent can decide which facility to use and can also decide to relocate to any other cell. The choice of whether to relocate is based on the distance to the nearest facility, the number of neighboring households in the current cell and the head of the household's age. When relocating to any other cell, the household agent decides on a new residential cell based on the new cell's land price, their income and the distance from the new cell to the nearest facility. However, the number of households that can relocate to any given cell is limited by the cell's *MHC*.

2.4.1 Attributes

(1) Household type

We defined household type as being one of the following three types: single-resident, couple, or couple with 1-3 children. In Japan, approximately 90% of households are either nuclear families or single residents, with households having more than four children making up less than 10% of the population. Therefore, the household agent assumes a maximum of three children. The ratio of household types was set based on a comprehensive survey on living conditions conducted by the Ministry of Health, Labor and Welfare (MHLW) (2005a).

(2) Ages of the household members

The ages of the household members are stochastically assigned by applying the age structure values of Japan. The population of the age structure was set based on an annual report on population estimates conducted by the Ministry of Internal Affairs and Communications (MIAC) (2005a).

(3) Income

The income of a household agent is stochastically assigned using the ratio between income and the head of the household's age in Japanese households. The data for this ratio is based on a national survey on family income and expenditure conducted by the MIAC (2004). In the simulation, the income of a household increases at a constant ratio each step as the head of the household ages.

(4) House type

We defined two house types: owner-occupied and rental. The housing type of a household agent was stochastically assigned using the ratio between the housing type and the head of the household's age. The data for this ratio is based on the housing and land survey conducted by the MIAC (2003).

2.4.2 Change of a Household Agent

(1) Generation

When a household agent's child reaches 20 years of age, that child becomes an independent household agent. Constant responsibility and authority are given to children when they reach 20 years of age in the real world, so the model assumes that children become adult household agents at the age of 20.

(2) Marriage

Based on a national census conducted by the Statistics Bureau of MIAC (2005b), marriage is stochastically assigned to each independent household agent between 20 and 49 years of age. If the age of a male agent is near that of a female agent, female agent's age is added to an attribute of the male agent and the female agent disappears, indicating a marriage. In addition, it is statistically likely that a bachelor older than 50 years old will be a bachelor for life. Therefore, this model assumes that unmarried agents older than 50 will not marry.

(3) Birth

A newborn child is added to the household agents when the wife of a coupled household agent reaches 20 to 39 years of age, in accordance with the birth rate calculated at the beginning of each step. The number of births is estimated using a cohort model.

(4) Death

The death of a person in a household agent is probabilistically assigned using the death rate and person's age at the end of each step. The death rate by age is based on a monthly report on an outline of vital statistics conducted by the MHLW (2005b).

2.4.3 Choice of a Service Facility

The determination of which service facility a household agent would use was carried out by using the spatial interaction model shown in equation (3).

$$P_{ij} = \frac{D_j \exp(-\beta C_{ij})}{\sum_j D_j \exp(-\beta C_{ij})} \quad (3)$$

Where P_{ij} is the probability that a household agent from cell i uses facility j, D_j is the attractiveness of facility j (determined by the number of users in the previous step), C_{ij} is the distance from cell i to facility j and β is a distance decay parameter.

Every facility is given an equal level of attractiveness at the first step.

2.4.4 Choice of Relocation by a Household Agent

In this model, the probability that a household agent would relocate to any other place (cell) is calculated using the three elements below. (A critical assumption for calibrating this probability is that residents generally have a strong intention to settle in a given location.)

(1) Distance to the facility

This is the distance between the cell a household agent currently lives in and the facility that the agent uses. The probability of relocation due to distance (P_1) is determined using equation (4). This means that the desire to relocate becomes stronger as the distance to the facility becomes farther.

$$P_1 = \alpha_1 C_{ij} \quad (4)$$

α_1: coefficient (arbitrary value)

(2) The number of household agents in the neighborhood

The probability of relocation, due to the number of household agents in the neighborhood (P_2), is determined by equation (5). When the number of household agents in the neighborhood (N) is lower than the minimum number of neighboring households (a), the probability takes on a value greater than 0. The neighborhood is defined as the cells adjacent to the one in question.

$$P_2 = \begin{cases} -\alpha_2 N + \beta_2, & N < a \\ 0, & N \geq a \end{cases} \quad (5)$$

α_2, β_2: coefficients (arbitrary values)

(3) Age

The third probability (P_3) is determined by the head of the household's age as shown in Figure 2. This is based on Japanese lifestyle trends. Because heads of households that are between 20 and 30 years old can be regarded as having a higher possibility to relocate than any other age group, the value of P_3 was set the highest among all age groups for 20-30 year olds. Conversely, elderly residents have a strong desire to remain at their current place of residence. Therefore, agents over 70 years old were given the lowest probability to relocate.

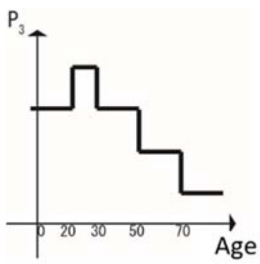

Figure 2. Conceptual diagramof P_3

2.4.5 Probability of Relocation

Considering some factors that can affect relocation, apart from the three elements mentioned above, we introduced a stochastic disturbance term (v) in the probability calculation for relocation P. As shown in equation (6), the value of v takes approximately 1 for random numbers (*rand*) from 0-1 while n takes approximately 0-0.5. Therefore, this disturbance term does not have a large effect on the influence of the three main elements. In addition, the individual difference between the influences from other elements is determined by providing a random number to each household agent. As a result, the probability of relocation P is calculated using equation (7). Household agents choose whether to relocate to any other place (cell) by using this equation.

$$v = [\ln(rand)]^n \qquad (6)$$

$$P = vP_3\{(P_1 + P_2)/2\} \qquad (7)$$

2.4.6 Choice of a New Address

Once a household agent decides to relocate, they must choose between a new cell where a desired facility is located or a cell neighboring that facility which is as close as possible to the cell where they currently live. The choice of a new address is based on socio-economic conditions. It was assumed that a household agent could relocate to a new cell if the head of the household's income exceeded the minimum standard allowing him/her to either purchase or rent housing, so long as the population density of the new cell is lower than its *MHC*. If neither condition mentioned above is satisfied, the household agent will search other cells until they can find a new cell satisfying the necessary conditions.

(1) Purchase of a house

It is assumed that if the cost of purchasing a house at a new address (cell) is less than five times the household agent's income, then that household agent can relocate to the cell of its choice. In the real world, almost all heads of households receive loans to purchase a house. Generally, a person receives a housing loan that is lower than five times their income. Therefore, using equation (8), we define the condition in which an agent can purchase a house. The house site area was fixed at 170 square meters, which is the average in Toyohashi City. The construction cost was set at 0.5 million yen per 3.3 square meters and the total floor area was set at 120 square meters.

$$\text{(5 times income)} \geqq \text{(land price at a cell} * 170\ \text{m}^2 + 0.5\ \text{million yen} * 120\ \text{m}^2/3.3\text{m}^2) \qquad (8)$$

(2) Rental housing

When the annual rental price of a house at a new address (cell) is less than 30% of a household head's income, a household agent can relocate to that cell using equation (9). One method of real estate appraisal is used as the estimation method for annual rent. Generally speaking, the average annual rent in Japan is less than 30% of a renter's income. Therefore, the limit on the annual rent of a house was set below 30% of an agent's income. The area of a rental house was set at 50 square meters, which is the average in Toyohashi City. The construction cost was set at 0.5 million yen per 3.3 square meters and the capitalization rate was set at the net yield, which is generally 6-8%. The annual maintenance cost was set at 120,000 yen.

$$\text{(30\% of income)} \geqq \text{(land prices at a cell} * 50\ \text{m}^2$$

$$+ 0.5 \text{ million yen} * 50 \text{ m}^2/3.3\text{m}^2) * \text{net yield} + 120{,}000 \text{ yen} \quad (9)$$

2.5 Simulation Flow

The simulation flow is as follows (Figure 3). Step 1 is the initial setting of the simulation. Steps 2-7 represent the flow for one year, and these steps

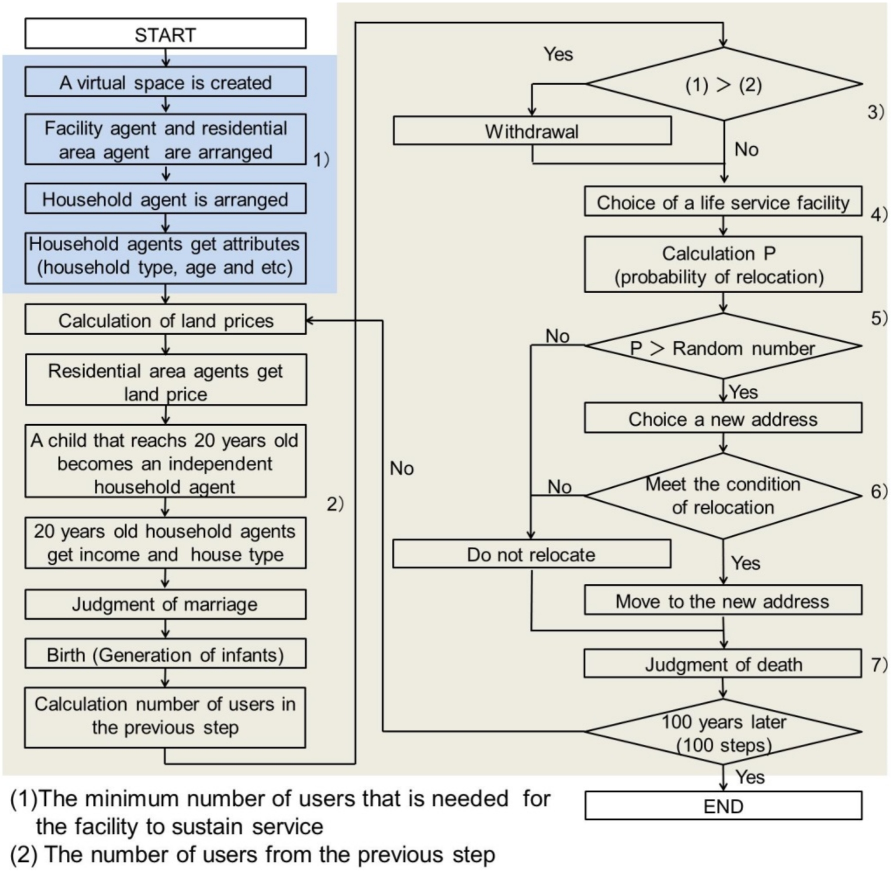

Figure 3. Simulation flow

are repeated 100 times to quantitatively evaluate the agglutination of residential areas and service facilities over a 100 year period.

In Step 1, a virtual space is created in accordance with the concepts mentioned in Section 2.1. Facility agents, residential area agents and household agents are arranged within the virtual space. Each household agent is then randomly assigned attributes (household type, household member ages, income, and house type).

In Step 2, each residential area agent is given a land price, and the attributes of each household agent are then changed. According to the change, each household agent undergoes generation, marriage, birth and death based on the concepts mentioned in Sections 2.2 - 2.4(1).

In Step 3, facility agents choose whether or not to withdrawal by comparing the number of users (households) in the previous step with the minimum number of users needed for the facility to sustain service based on the concepts mentioned in Section 2.2.

In Step 4, each household agent chooses a service facility by using a spatial interaction model, based on the concepts mentioned in Section 2.4 (4).

In Step 5, the household agents judge whether to relocate.

In Step 6, household agents that decide to relocate, choose a new cell where there is either a desired facility located or one of its neighboring cells is as close as possible to their cell of origin.

In Step 7, the mortality rate is used to calculate the household agents most likely to die.

3. SENSITIVITY ANALYSIS

3.1 Analysis Method

The following four elements are defined as indices for analyzing the results of the simulation.

(1) Total distance to facilities

This value shows the total travel distance between the cell a household agent lives in and the facility that the household agent uses in each step.

(2) Number of facilities

This value shows the number of facility that provide services to the entire simulation area and the number of neighborhood-oriented facilities in each step.

(3) Residential area ratio

This value shows the ratio between the number of cells in which a household agent is living and the total number of cells in each step.

(4) Compact degree

This value shows the ratio between the number of cells where a household agent currently lives and the number of facilities in each step. A smaller compact degree value indicates that a more compact urban structure is formed.

Table 1. Base case

Item	Set value	Item	Set value
Number of Step	100	α_1	0.0476
Number of the Facility Providing Life Services to the Whole Area	1	α_2	0.05
Number of Neighborhood-oriented Facilities	20	β_2	1
Number of Households	2000		
Minimum Number of Users that is Needed for the Facility to Sustain Service	20	P_3	Fig. 4
A Distance Decay Parameter	0.5	MHC	Random
The Minimum Number of Neighboring Households	20		

3.2 Parameter Setting

The average relocation rate after 10 full simulations was 4.46%. This value is approximately equal to the 4.45% relocation rate found in the report on internal migration conducted by the MIAC (2005c). Therefore, the values in Table 1 were used for the base case of this model.

3.3 Simulation Result Using the Base Case

The results of the simulation using the base case are shown in Figure 5 and lead to the following observations.

The agglutination of residential areas arose from cells that were more than 4km from the nearest facility. The land prices around a facility that had many users were higher than those around a facility with few users. In addition, land prices in a cell became cheaper when the distance between two facilities was short because of the dispersion of the residents and users. Household agents tended to choose the facility nearest to their cell of origin. Facilities that were close to other facilities and facilities located in the suburbs tended to withdraw. In the case of the former, household agents that lived around the facility tended to relocate to the cells around the more attractive facility.

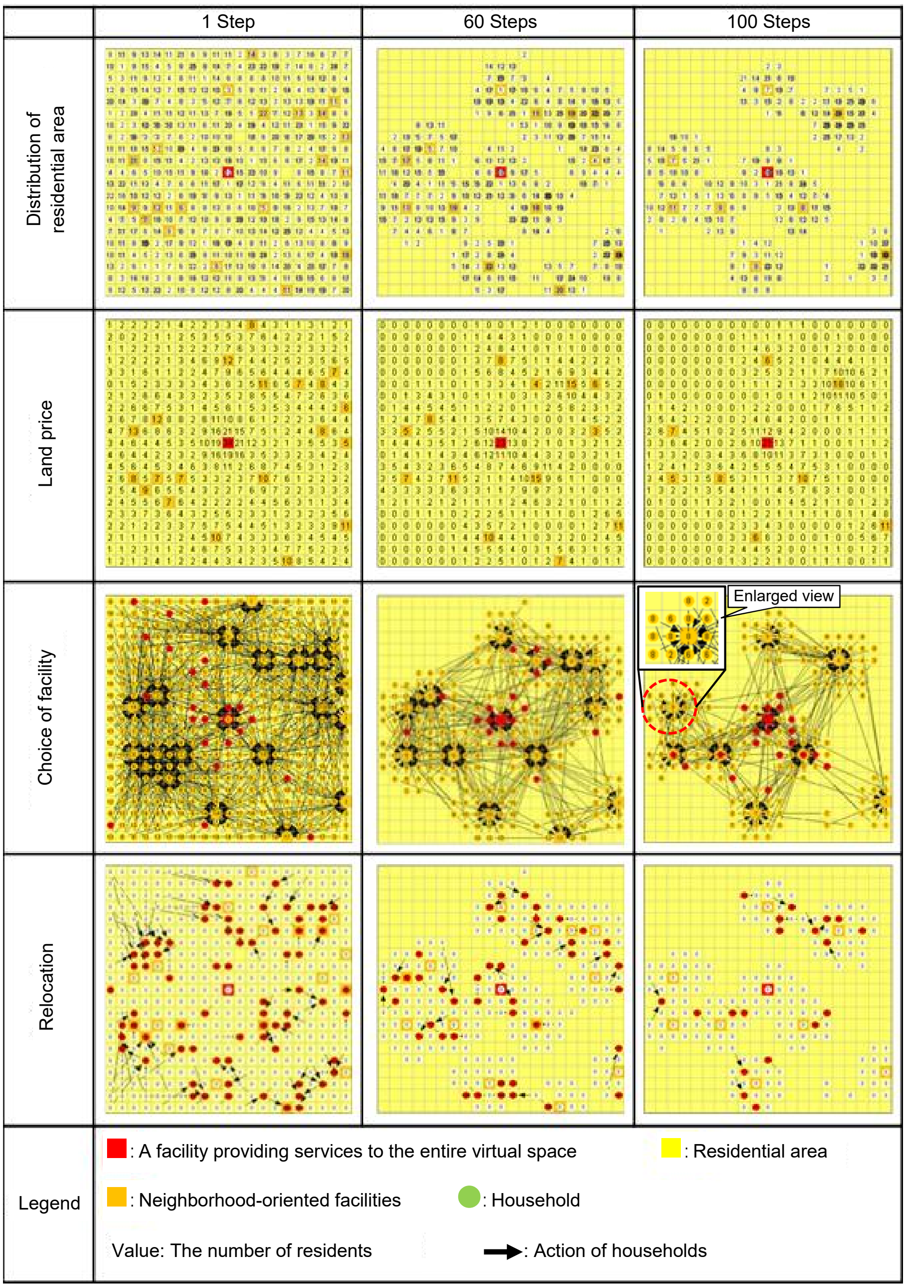

Figure 5. Simulation result

3.4 Sensitivity Analysis

A sensitivity analysis of the parameters influencing the results of the simulation was performed using the base case. The following six scenarios were analyzed. 1) A scenario where the P_1, P_2 and P_3, which influence P (the probability that a household agent relocates to any other cell), are changed. 2) A scenario in which the minimum number of users needed for the facility to sustain service, which affects the withdrawal of facilities, is changed. 3) A scenario in which the parameter of the distance decay function β, which influences the household agent's facility choice, is changed. 4) A scenario in which the number of facilities is changed. 5) A scenario in which the MHC is fixed. 6) A scenario in which the placement of elderly residents is restricted.

The values in Table 2 show which values changed compared to the base

Table 2. The changed values from base case (The blank means same value as a base case)

	Item			Changed value						
				$\alpha 1$	a	$\alpha 2$	Age	2	β	4
1	Distance to Facilities	P_1: Low	case1	0.0286						
		P_1: Slightly Low	case2	0.0357						
		P_1: High	case3	0.0714						
	The Minimum Number of Neighboring Households	P_2: High	case4		30	0.0333				
		P_2: Slightly Low	case5		10	0.1				
		P_2: Low	case6		5	0.2				
	Age	P_3: High	case7				Fig. 4			
		P_3: Slightly Low	case8				Fig. 4			
		P_3: Low	case9				Fig. 4			
2	Minimum Number of Users that is Needed for the Facility to Sustain Service	Extremely easy	case10					5		
		Easy	case11					10		
		Slightly difficult	case12					30		
		Difficult	case13					40		
		Extremely difficult	case14					80		
3	A Distance Decay Parameter (Accessibility)	Extremely easy	case15						0.1	
		Easy	case16						0.3	
		Difficult	case17						0.8	
		Extremely difficult	case18						1.0	
4	Number of Facilities	Low	case19							10
		Slightly high	case20							30
		High	case21							40
5	MHC-fixting	Central area: high Suburban area: low	case22							
6	Restricting Placement of Elderly Person.	Central area: high Suburban area: low Edge: high	case23							

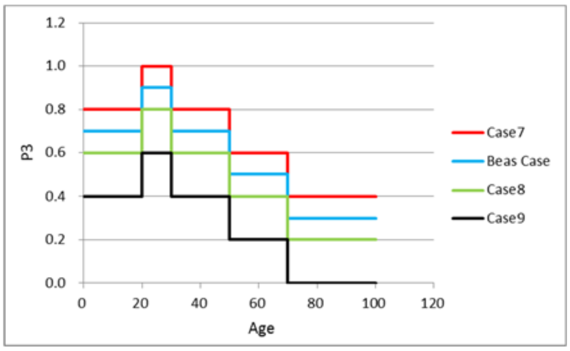

Figure 4. Relations between Age and P_3

case in each scenario.

Figures 6, 7, 8 and 9 show the results for each scenario. These results indicate that the element with the greatest influence on the total distance is accessibility, such as the parameter of the distance decay function. When facility accessibility is low, household agents tended to choose the nearest facility and the total distance was shortened. Focusing on Case 15, which has the lowest number of facilities, household agents could use every facility because facility accessibility was high. However, the total distance to facilities in this case was the greatest of all of the cases.

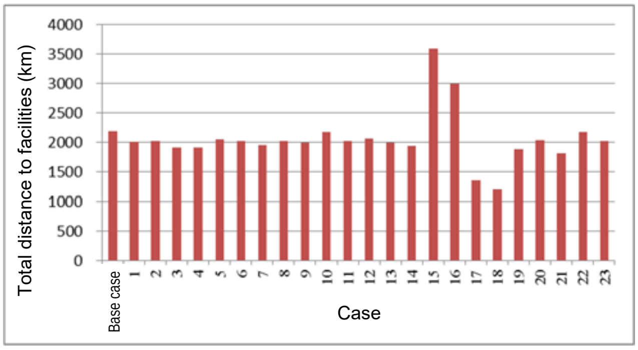

Figure 6. Total distance to facilities (100 Steps)

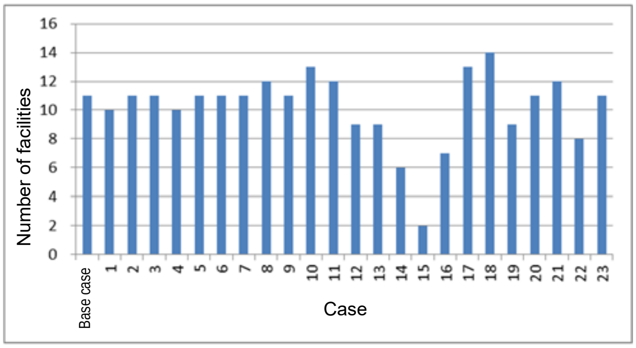

Figure 7. Number of facilities (100 Steps)

Figure 8. Residential area ratio (100 Steps)

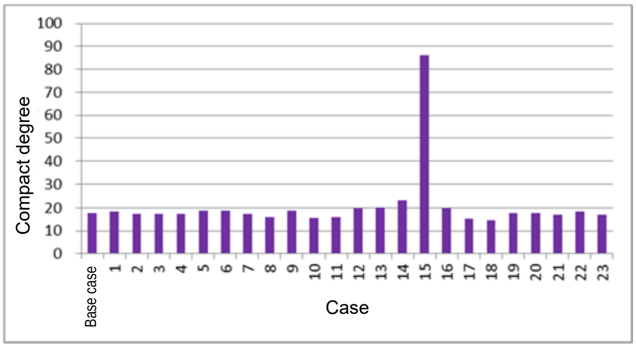

Figure 9. Compact degree (100 Steps)

Case 14 shows a market mechanism in which highly attractive facilities have remained. It seems that when there is no support from the local government or non-profitable organizations (NPO), facilities will consolidate naturally. Focusing on Cases 14, 15 and 19, the consolidation of residential areas occurred earlier than it did in other cases. These results indicate that the agglutination of residential areas is heavily dependent on the number of facilities. Therefore, the number of facilities suited for a given population and the early agglutination of facilities are the two most influential elements in the creation of a compact urban structure. Focusing on Figure 9, which shows the degree of compactness, Cases 10 and 18 have low values. These results show that the ease of facility maintenance depends on the number of residential areas and facilities.

From the results mentioned above, the key elements influencing the agglutination of residential areas and facilities are the distance decay function and the minimum number of users needed for a facility to sustain service. The minimum number of users indicates the 'strength of the degree of support for service facilities provided by policies'. The fact that facilities with few users naturally consolidated in accordance with market mechanisms in the absence of any support promotes the agglutination of facilities. However, it is hard to say that a lack of support from administrations or NPOs leads to the creation of a compact urban structure because the number of facilities decreases and the quality of social services are low. In addition, the distance decay function means the 'accessibility that attracts household agents to use a facility'. As the parameter becomes smaller, the attractiveness of facilities becomes a key factor in the household agents' facility choice. Therefore, small (low attractiveness) facilities naturally agglutinate. However, residential areas are widely dispersed throughout the whole area, and the distance to the facility increases. In contrast, when the accessibility of facilities decreases, facility maintenance is easier. Because of this, the possibility of creating a compact urban structure increases.

4. POLICY SIMULATION

4.1 Setting of the Policy Scenarios

Based on the results of the sensitivity analysis, the developed model was adjusted to simulate a more realistic urban and regional spatial structure. Specifically, this model was set up as follows: 1) in the central area, there is a high population density with a high aging rate; 2) in areas where the distance to the central area is greater (suburbs), the population density and the ratio of young people decreases; and 3) in areas closer to the edge of virtual space, the aging rate is higher. These are the initial settings for population placement in this model. Using the adjusted model, two simulations were conducted according to the assumed policy scenarios regarding residents and social service facilities. The two assumed scenarios are as follows: 1) the case in which a mean of transportation leading to high accessibility is developed through innovation (changing a parameter of the distance decay function); and 2) the case in which policies aimed at the maintenance of facilities with the support of the local government or NPOs are implemented (changing the minimum number of users necessary for the facility to sustain service). The results of these policy simulations are shown in Table 3 and Figure 10.

4.2 Analysis of the Policy Simulation Result

(1) The case in which a parameter of the distance decay function is changed

When comparing each index value in Table 3, focusing on 30 steps, there are fewer facilities and a higher compactness compared to the base case. In contrast, the total distance to facilities is greater than in the base case in each step. In addition, the distribution of residential areas in Figure 10 shows that the population density of the central area is high and residential areas are agglutinated in the central area.

In Japan, which is facing long-term population decline, the future development of innovations that allow elderly residents to move easily and safely would result in the residents' ability to use any facility freely. Therefore, residents would use the most attractive facility in the central area. Other facilities would also be agglutinated in the central area. Although a compact urban structure would be created, leaving only a few facilities. From the perspective of offering social services, it seems that this case is not

Table 3. Index value of each step

Item		Total distance to facilities (km)	Number of facilities	Residential area ratio	Compact degree
1 Step	Base Case	7663	31	99.86%	14.21
	1)	7733	31	99.91%	14.21
	2)	7686	31	99.91%	14.21
10 Step	Base Case	7688	18	82.15%	20.43
	1)	7774	18	83.56%	20.16
	2)	7673	18	83.70%	21.29
20 Step	Base Case	7270	16	69.37%	20.13
	1)	7685	15	72.52%	21.38
	2)	7368	15	70.86%	21.37
30 Step	Base Case	6558	14	58.84%	18.34
	1)	7735	12	61.95%	22.43
	2)	6544	14	61.52%	20.05
40 Step	Base Case	5686	14	50.79%	16.79
	1)	6570	11	52.00%	21.95
	2)	5646	13	52.97%	18.93
50 Step	Base Case	4954	12	45.60%	16.56
	1)	5968	10	43.81%	20.65
	2)	4857	12	46.69%	17.31
60 Step	Base Case	4209	10	41.86%	15.55
	1)	5216	8	37.41%	22.09
	2)	4182	11	43.63%	16.93
70 Step	Base Case	3495	10	39.23%	15.81
	1)	4331	6	31.75%	23.10
	2)	3536	11	40.95%	16.90
80 Step	Base Case	3106	10	37.89%	15.41
	1)	3625	5	27.03%	26.40
	2)	3078	10	39.07%	16.86
90 Step	Base Case	2727	9	36.35%	15.91
	1)	3012	4	23.29%	34.68
	2)	2672	10	37.10%	16.82
100 Step	Base Case	2400	8	34.99%	15.81
	1)	2543	3	20.02%	34.05
	2)	1246	10	35.62%	16.17

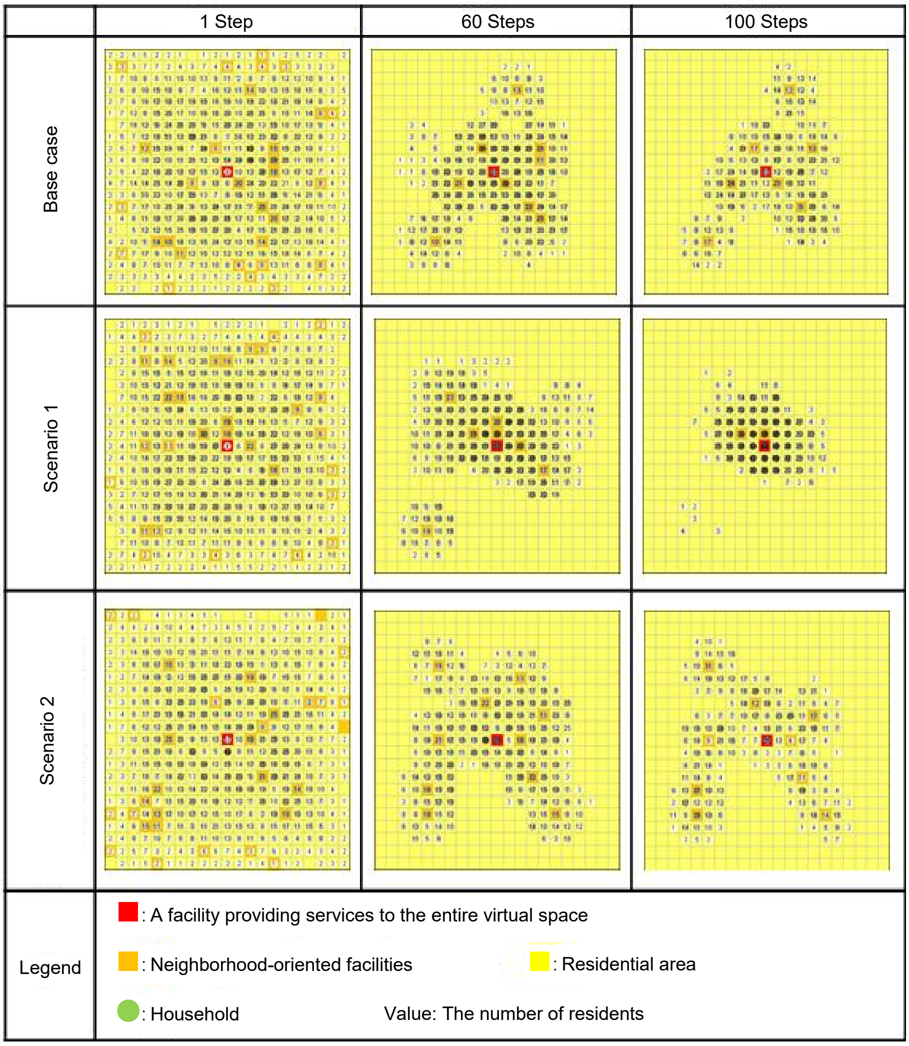

Figure 10. Distribution of residential areas

realistic. From the perspective of conserving natural environments in suburban areas, it also seems that this case is not realistic.

(2) The case in which the minimum number of users is changed

When comparing each of the index values in Table 3, the total distance to facilities and the residential area ratio are almost the same as in the base case. After 20 steps, almost every facility has been retained in stark contrast to the results of Scenario 1. In addition, Figure 10 shows the distribution of both the residential areas as well as the facilities that have been retained and that residential areas are dispersed throughout the entire virtual space when the minimum number of users is changed.

From these results, the following findings are indicated when some support is in place, such as grant money from the administration or NPOs. Some low-revenue facilities will be able to remain and neighborhood-oriented facilities tend to not consolidate in the central area. Instead, they are dispersed throughout the entire virtual space. Similar to the dispersion of facilities, agglutinated residential areas are also dispersed throughout the entire virtual space. Although the number of facilities after 100 steps is greater than in the base case, the degree of compaction is almost the same. In other words, a compact urban structure is formed while retaining the number of facilities that can moderately provide social services to residents. Thus, the following two policy scenarios are deemed important: 1) the promotion of the agglutination of public service facilities within the central area and 2) the maintenance of public service facilities outside of the core area with the support of local government or NPOs.

5. CONCLUSION

This study developed a multi-agent-based spatial simulation model for analyzing the intermediate and long-term locational changes to residential areas and service facilities by the progress of a long standing depopulation due to aging and a low birth rate.

Although the results are in a virtual space, the minimum number of facility users needed to sustain a service and a parameter of the distance decay function (accessibility) were suggested as the elements that have a strong effect on the agglutination of residential areas and public service facilities. Based on the results, the simulations that reflected the following scenarios were performed: 1) the case in which a transportation mode leading to high accessibility is developed through innovation (changing a parameter of the distance decay function) and 2) the case where policies aimed at the maintenance of facilities with the support of the local government or NPOs have been implemented (changing the minimum number of users necessary for the facility to sustain service).

As a result, the following findings were obtained: The policy to promote a user-friendly mode of public transportation can lead to the creation of a compact urban structure. However, almost all of the facilities will be agglutinated in the central area with only a few facilities remaining outside of the central area. From the aspect of offering a social service, it seems that this case is not realistic.

Therefore, the policy to maintain public service facilities outside of the core area with support from the local government or NPO is deemed important.

As mentioned above, the results of this study can provide information for the creation of an intensive urban structure.

The goal of future research is to attempt to simulate real urban and regional areas.

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Study of Intercity Travel Characteristics in Chinese Urban Agglomeration

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Abstract : Due to rapid urban development in china, traffic problems are fast becoming considerably serious. In this study, we focus on intercity travel characteristics' research. By investigating the travel characteristics of passengers and the intercity traffic demand forecast, we aim to discriminate the geographical spatial characteristics of departure places and to establish coupling law of city public transportation hubs and urban space which directly connect with the intercity rail station. In future research, we will try to determine theoretical research methods of node location choice in the urban transfer system. We will determine the location of the key hub node and form a transfer service for intercity public network system to improve the efficiency of residential travel.

1. INTRODUCTION

Urban agglomeration is a special kind of geographical space organization in the urbanization process. It takes one or two metropolises as the core area of regional economic development, relying on certain natural environmental conditions, modern transport and high accessibility of its integrated transport network, in order to expand the urban geographical scope and increase the number of cities, thus constituting an integrated urban area composed of economy, society and technology. China currently has three emergent urban agglomerations: Yangtze River Delta, Pearl River Delta and Beijing-Tianjin-Tangshan area. Other areas such as Liaoning Peninsula urban agglomeration, Shandong Peninsula urban agglomeration and Bashu urban agglomeration have been rising.

Intercity transportation is a representation of a healthily developed urban agglomeration. It includes two parts: passenger transportation and freight flow. For commute and leisure purposes, passenger traffic is the most important part of intercity transportation. Passenger travel flow forecast is important for two main reasons:

1) To understand the intercity travel characteristics inside the urban agglomeration, and make reasonable arrangements for the travelers' itineraries. A reasonable passenger flow forecast can obtain intercity travel characteristics such as average daily traffic flow and rush hour traffic flow, with that travelers can select an appropriate way to travel according to their travel destination and travel needs, as well as saving travel time.

2) To guide the construction of intercity transportation networks and avoid blind construction. The intercity transportation network is mainly composed of intercity railway and intercity highways, both of which need huge material input and long payback periods are required; once started it cannot be reversed. Reasonable flow forecasts could assist decision-making and reduce investment risk and optimize transportation network source configuration.

2. RELATED WORKS

Among the research of intercity travel, Yusak and Ryuichi (2008) make a comparative study of private car and public transport commuters in the Osaka metropolitan area based on a traffic survey during 1980-2000, finding that both kinds of commute have increased in distance during the past thirty years. On the contrary, the travel time has declined. In addition, with the increase of social and leisure travel demand, private car commuters are more willing to increase the number of trips rather than increase the number of trip nodes, while the condition for bus commuters is the opposite. From the aspect of trip influencing factors, based on an analysis of a UK domestic travel survey during 1995 -2006, Dargay et al. (2012) analyzed nine influential factors for long-distance travel, including income, age, gender, occupation and family status. They found that for long-distance travel, the most influential factor is income. Moreover, income, gender and age have important influences on the long distance transportation type selection. Compared with developed countries, income has a more important and straightforward influence on travel in China because of the relatively low income per capital. Corradino (2000) studied the regional travel characteristics of southeast Florida, by investigating 5200 samples, including family and personal travel times and travel methods. In China, this number should be greater to ensure the accuracy of the experiment because of the larger population density than that of the United States. Khandker et al. (2009) researched the travel characteristics of the Toronto metropolitan area based on a hybrid discrete-continuous model, and combined travel time with travel mode rather than the separated survey of the two indicators. In the field of Chinese intercity travel characteristics research, Zhou et al. (2007) compared city residents' travel modes of China with several foreign countries. They found that for the distribution of domestic city residents' trip purpose, commuter travel has dropped, corresponding to the proportional increase of daily travel. Through comparing the travel characteristics of three huge urban agglomerations of China (Yangtze River Delta, Pearl River Delta and Beijing-Tianjin-Hebei), Song (2010) found that city residents' average trip frequency increased with the growth of urban economy, and that residents in developed cities have increased the number of their living and recreational trips. Li (2006) analyzed travel time distribution, travel purpose and type of intercity travel in the Changsha-Zhuzhou-Xiangtan urban agglomeration.

Intercity travel can be regarded as an amplification of a city group's travel within a geographical area, therefore, there are similarities between the intercity and city groups' travel characteristics. Within the city groups, distribution of the nodes would be more elastic. Consequently, in the case of absence of research on domestic intercity travel characteristics, we can learn from travel characteristics research for city groups. In the field of intercity passenger traffic flow forecasts, Feng (2006) proposed a feedback forecast model of regional traffic demand for the Jabodetabek metropolitan area in

Indonesia. This model can be used in Transcad software, and the forecast is more precise than the traditional non-feedback model. Zhang et al. (2000) have also introduced a demand forecast model based on multiple variable feedback mechanisms, and applied it for New York City. They found that to control the iteration process, the use of road flow is more superior to travel time or speed. Chandra and Sujit (2000) have established a travel generation forecast model for commuters based on the activity and travel mode. The model framework is constituted of the workers' commuting trip in two cities of the Boston metropolitan area. Zhang et al. (2006) used the principal component analysis to extract the factors that affected the port throughput and took Nanjing port as an example to verify the model. The results show that the model can well reflect the actual case and is effective for system fitting. Gao (2011) obtained the key impact factor and selected it as the variable for a gravity forecast model. He used the sensitivity analysis to measure the impact factor of the passenger special line flow. He also determined the total passenger volume from origin to destination of the previous years and earmarked the parameters of a passenger special line flow gravity forecast model.

3. METHODOLOGY

This research attempts to introduce the gravity model to forecast the demand of intercity traffic with inter-regional economic and social parameters. Gravity function is a generalized distance function to measure the attenuation law with distance of the gravity between two regions. The model considers geometric distance, transportation costs, transportation time, economic exchanges and the linear combination of these factors. Based on the investigation of residents' travel and social economic development levels, we try to rank each impact factor by the analytical hierarchy process that combines the travel characteristics. For flow calibration, field investigation was carried out in the intercity traffic hubs.

The technology roadmap of this study is as shown in *Figure 1*.

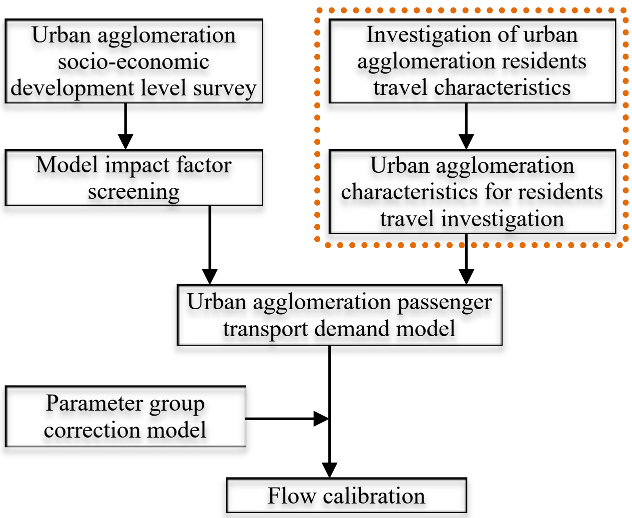

Figure 1. Research technology roadmap

In the steps which are surrounded by the dotted frame, we first investigate the characteristics of residents' travel, and try to find and induce the other characteristics of urban agglomeration from the investigation. They are important sources of information.

This paper focuses on the survey of resident travel characteristics in two typical Chinese urban agglomerations. In the subsequent studies we will use the research results to modify and check a travel demand forecast model of urban agglomeration. Intercity travel characteristics mainly include the travel purpose, travel mode, trip distance/time consumption and other basic travel characteristics, as well as the associations with traveler income, occupation, age, gender and other factors, in order to determine the traveler's expected travel mode, travel time and delivery speed of each class. In this paper, we select Beijing-Tianjin and Beijing-Zhengzhou intercity railway line as the research objects to analyze the travel characteristics of each line.

4. CASE STUDY OF INTERCITY TRAVEL CHARACTERISTICS

4.1 Analysis of Beijing-Tianjin intercity high speed rail travel characteristics

Beijing-Tianjin Intercity High Speed Rail quickly won the intercity passenger market with its advanced and reliable technology and equipment, human services system, efficient and convenient transport product and transit-oriented mode of transport. This research will analyze the characteristics of Beijing-Tianjin intercity passenger flow with the investigation data of passenger flow and historical information of passenger tickets from the Beijing South Railway Station.

4.1.1 Passenger flow structure analysis

For travel purposes, among the passengers of Beijing-Tianjin Intercity High Speed Rail, business trips accounted for the largest proportion, 35.3%, followed by visiting relatives' passenger flow, which accounted for 27.3%. For the occupation of passengers, company staff accounted for the largest proportion, 37.3%, followed by institution staff and freelancers, respectively accounting for 18.7% and 14%.

4.1.2 Travel purposes and passenger age

Table 1. Passengers of different ages (%)

age	Total
21-30-year-old	47.00
31-40-year-old	26.50
>60-year-old	1.50
others	25.00
Total	100.00

Among the passengers of the railway line, 21-30 year-old passengers accounted for the largest proportion, 47%, followed by 31-40 year-old passengers, who accounted for 26.5%, and; people over 50 years old accounted for the smallest proportion, 6.6%, among them, over 60s only accounted for 1.3%. Among the passengers of 21-40 year-olds, the purpose of business trip and visiting relatives accounted for the largest proportion, 17.9% and 15.9% respectively, and is higher than the average; other non-key-age travelers' private travel proportions were significantly higher than the average.

4.1.3 Source of expense and travel purposes

Passenger's sources of expense and travel purpose are as follows:

Table2. Relation of source of expense and travel purpose (%)

	Public Expense	Own Expense	Total
Visiting Relatives	1.90	24.70	26.60
Public Affairs	29.10	5.10	34.20
Tourism	0.00	12.70	12.70
Business	1.90	4.40	6.30
Employment	0.70	0.50	1.20
Study	0.00	3.20	3.20
Others	2.50	13.30	15.80
Total	36.10	63.90	100.00

According to *Table 2*, private travel expense accounted for 63.9%, which is significantly more than public travel expense. In this case, passengers will make their travel plans based on their own income. These two kinds of people are completely different for the purpose of node selection.

4.1.4 Passenger monthly per capita income structure

Table 3. Passenger monthly per capita income（%）

Income	Total
<$160	6.80
$160 — $320	9.60
$320 — $480	24.70
$480 — $800	26.70
>$800	32.20
Total	100.00

Among the passengers of Beijing-Tianjin Intercity Railway line, personal monthly income over $320 accounted for 84%, over $480 accounted for 59%, while the proportion of passengers is proportional to income. This result supports the influence of income and concludes the trend of travel rate is in the range of less than $800.

4.1.5 The main factors of rail line choice

The main factors for choosing Beijing-Tianjin Intercity Railway line include fares, safety, convenience, comfort etc. Speed is the primary reason for choosing this line, as 57.5% of passengers think the most important factor is travel time, followed by convenience—51% of passengers think that this line is convenient with efficient ticket service and high-frequency departure.

The percentage of reasons for line selection, such as safety, comfort and punctuality is not high, compared to other means of transport in this area, Beijing-Tianjin Intercity Railway's advantages are not obvious. Most travelers think the fare is expensive; only fewer than 15% of travelers think the current fare is reasonable.

4.1.6 Travel frequency

70% of passengers will travel between Beijing and Tianjin more than once per month, and more than 40% of passengers will travel more than three times, thus it can be seen that most passengers are frequent travelers. These frequent experiences reflect the objectivity of evaluation from passengers.

4.1.7 Round-trip weekly distribution

Table 4. Date of travel statistics

Date	Monday	Tuesday—Thursday	Friday	Saturday—Sunday
%	19.50%	30.82%	43.40%	38.99%

As shown in the table, the passenger flow volume between Beijing and Tianjin is comparatively larger from Friday to Monday, especially on Friday, which means a lot of passengers choose departing on Friday, and returning back on Saturday/Sunday or Monday. Weekend trip flow is commonly busier, while daily working time, for example Tuesday, Wednesday and Thursday, is subjectively smaller. It is consistent with the necessary demand of time for passengers who visit relatives and tourism.

4.1.8 The typical periods of time

The intensive periods of time which passengers usually choose is between 7-9am in the morning, and before 7pm at night. The ratio of other time periods chosen are more or less balanced.

4.1.9 Conclusion

The Beijing-Tianjin intercity high-speed railway for leisure travel is slightly higher than for business travel. For leisure travel the largest flow is for visits, while travel for business accounts for the largest shares in official business flow. The characteristics compared with other lines did not show obvious differences. This indicates that there is great potential for the Beijing-Tianjin intercity high-speed based on the effect of commuter flow and induced passenger flow.

Among the passengers taking the Beijing-Tianjin intercity high-speed railway, 54% of them are company employees or public institution clerks. This ratio is higher than for other railways. Passengers with an average monthly household income of $320 and above accounted for 84% of travelers. Those with incomes of more than $800 reached 32%. This expenditure is also significantly higher than for the other lines. The Beijing-Tianjin high-speed rail passengers' income level is relatively higher. Marketing measures can be made on account of its high quality service requirements and high consumption capacity.

The Beijing-Tianjin intercity high-speed railway passengers are mainly between 21 - 40 years old. They are active, energetic and are needed to participate in collective activity features such as the implementation of tcorresponding marketing measures.

The Beijing-Tianjin intercity high-speed railway passenger is often a passenger on a long term basis (above 70%). This part of passenger travel was focused mainly on Friday and the weekends. Corresponding marketing measures such as passenger credits and frequent membership may be considered for this kind of travel feature, so as to enhance their sense of belonging to railway high-speed products.

The Beijing-Tianjin intercity high-speed railway passenger on the rankings for the recognition of the high-speed railway considered speed, convenience, comfort, safety, punctuality and price. Among them the lowest priority is price. From the perspective of income structure, the proportion of low-income passengers between the Beijing and Tianjin high-speed railway stations is significantly lower than the other lines. Under the circumstances of enhancing transportation capacity in the future, additional discount coupons or discount ticket forms can be considered to narrative flow-income passengers, so as to expand the base of commuters.

Based on the date and time of travel, the passenger flow from Friday to Monday, 7am-9am, 4pm-7pm reaches maximum. Train operation plans can make some adjustments according to this data. To improve the efficiency of CRH (China Railway High-speed, usually refers to the emu trains which operate after the sixth railway acceleration in China on April 18, 2007), train number distribution averages can be managed, off-peak period measures such as the 5th point, which is proposed, can be considered and discount coupons or discount tickets can be used to attain a more balanced distribution of passenger flow.

4.2 Analysis of characteristics of Jing-Zheng transport corridor

Jing-Zheng transport line is a section of the Beijing-Guangzhou transport channel, starting from Beijing, traveling through Haoding, Shijiazhuang, Kandan, Xinxiang to the city of Zhengzhou. This is one of the busiest sections of China's north-south transportation. Jing-Zheng channel includes national highway, express highway, railway, civil aviation and other modes of transportation. In 2003, the quantity of railway flow accounted for 26.4% of all traffic of the channel, and passenger turnover accounted for 33.7% of the total turnover. At the same time, the corresponding highway capacity accounted for 73.6% and 66.3%, respectively. Thus, highways and railways were undertaking most of the traffic pressure. Following the development of China’s society and economy, trip modes of the channel are in continuous developement and stages of improvement. The transportation structure is also changing.

We selected seven areas along this line as samples: Zhengzhou, Xinxiang, Anyang, Handan, Shijiazhuang, Baoding and Beijing. The samples are selected in order to comprehensively and objectively reflect the status of travel. The research method was adopted following a questionnaire and fixed spot study of maximum car flow. Within the comparatively busy lines or sections of the channel, the researchers selected the main long-distance bus station, passenger train and long-distance bus and airport hubs for sampling. The trip direction and the transportation flow has no implications according to the passengers of the investigation, nor does trip distance above 200 km (passenger travel in districts is excluded).

The survey content includes: basic situation of passenger by differing trip mode; the travel purposes, demands and the option of trip modes of passengers; passengers for any mode of transport's satisfaction with the service properties, and the ideal sort; the level of satisfaction and the ideal rank of the trip modes.

Table 5. Most unsatisfactory service attribute rank (%)

Index	Single mode of transportation	Expensive	Uncomfortable	Inconvenient	Unsafe	Slow	Unpunctual	Total
Railway	11.65	23.07	16.10	11.93	6.54	21.38	9.33	100
Road	5.23	38.69	40.52	3.79	3.41	7.56	0.80	100
Flight	9.82	78.04	2.80	7.68	0.97	0.52	0.17	100

4.2.1 **Passengers' occupation distribution**

Passengers' occupation distribution is mainly composed of different trip modes and the proportion of all kinds of travelers. Business administrators take the largest proportion of the travel flow of Jing-Zheng channel, accounting for 24.1%, followed by scientific research personnel, individual business personnel, workers and peasants.

4.2.2 **Passenger income**

Survey results show that passengers with an income of less than $160 and $160-$320 accounted for the largest proportion, 29.4% and 32.1%, respectively. Comparing income level of different models, it can be found that, for passengers with less than $160 monthly income, proportion of highway has the largest proportion; for monthly income between $160-$320, railway has the largest proportion; for monthly income of over $320, flight selection has the largest proportion.

4.2.3 Passenger travel purpose

The purposes of personal affairs, business and visiting relatives, accounted 39%, 16% and 15% respectively, totalling more than 70%. Official affairs accounted for 39%, for the purpose of business travel, 26%, and non-official business accounted for 33%.

4.2.4 **Trip distance**

Highway passenger transport is flexible, convenient and suitable for short distance travel. Within the travel distance of less than 300km, highway occupies the biggest proportion of trips; for the distance of more than 300km, railway transportation has a greater market share.

The questionnaire asked passengers to rank the order of the service properties for all the travel modes, assuming that airline, high-speed and high-speed railway, and highway are all available. The most important service properties for different modes of transportation are listed as shown in *Table 6*.

Table 6. Most important service choice proportion

Index	Most Important Service (%)				
	Safety	Fee	Comfort	Speed	Non-stop
Railway	54.78	13.75	12.06	13.09	6.32
Road	59.64	6.83	9.07	17.77	6.69
Flight	54.64	4.13	8.56	26.69	5.98

Passengers who are mostly concerned about safety, account for about 56%; speed and cost are the second concern, with non-stop service rarely being chosen as the most important factor; with the increasing income of passengers, the cost will no longer be the controlling factor. Passengers are not satisfied mostly with railway transportation being highly priced and low speed, with 23.1% and 21.4% respectively. Compared with *Table 2*, in which passengers value safety the most, Passenger's satisfaction in *Table 3* is higher for the existing transportation security than for speed, so in comparison, meeting the passenger's demand about speed and price is more urgent.

4.2.5 **Passenger's choice of travel mode**

The proportion of passengers who are willing to choose the CRV is the largest, about 42.4%. It is followed by highway, which is about 16.7%. This suggests that the demand of passengers is more about speed and comfort. These demands should determine the direction of future transportation development. However at the same time, there are 14.4% of passengers choosing the present railway, showing that there are still some consumers considering cost as the key factor of their decision.

4.2.6 **Travel frequency**

Table 7. The number of passenger travels

railway	average	most
0 ~ 10 times	7.2	4
0 ~ 20 times	14.5	5
airplane	average	most
0 ~ 5 times	4.2	2

Research data shows that most of the passengers travel by railway 0 - 10 times per year, with an average of 7.2 times, and with four times at most. Passengers by highway are mainly concentrated in the range of 0 - 20 times, with an average of 14.5 times, and with five times at most. The frequency by airplane mainly concentrated in the range of 0 - 5 times, with an average of 4.2 times, and two times at most. The travel frequency distribution curve is as shown in *Table 7.*

The number of passengers traveling by highway is significantly larger than by train (about once). This suggests that the railway service is not sufficient, neither is transport supply and the development of the regional railway is further needed.

4.2.7 **Conclusion**

By analyzing the social and economic features, travel purpose, trip distance and the trip mode choice behavior for Jing-Zheng transport channel, this paper can predict the demand structure change for future rail lines, so as to guide the coordinated development of transportation.

In the future transportation market, safety, speed and comfort will be the main factors that are considered by the majority of passengers. Construction of high-speed railway, direct expressway and a complete network of express highway and civil aviation is the best choice for the complex and diverse demands of the future passenger.

It should be pointed out that further study is needed to analyze the different psychological factors of behavior and the natural environment of different passengers.

5. SUMMARY

Through an analysis of the intercity transportation characteristics of Beijing-Tianjin and Jing-Zheng urban agglomerations, we can conclude three characteristics for intercity transportation:

1) Intercity transportation is still primarily for business purposes; the future trend has turned to meet the mutual demands of commuter and business.

2) The intercity rail has become the most popular trip mode for business purposes for its speed, convenience and safety. As cost is still the main influencing factor of the intercity rail, the users are still mainly high income people. Therefore, further action of reducing cost is needed to satisfy the travel demand of the majority of passengers.

3) Thanks to the speed, many long-distance intercity commutes can take place during the daytime. The intercity rail shows a peak in the morning and evening. It also provides support and assurance for commuter travel.

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