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The Expansion of Densely Inhabited Districts in a Megacity - Case of Tokyo

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Abstract: Understanding the patterns of human concentrations within megacities is of fundamental importance to our understanding of megacity dynamics, and for megacity management and policy making. This study presents an updated investigation of the historical expansion of densely inhabited districts (DIDs) in the world's largest megacity, Tokyo. Long-term DID data (1960-2010) at 5-year intervals were analyzed in a geographic information systems framework. Results show that Tokyo completed rapid growth phase and is now in a maturity phase with minimal growth. Extension was the main form of expansion, although fragmented growth in the form of patches was also noted. The rate of DID expansion was strongly related to economic trends. However the direction and shape of expansion was influenced much by geographic and policy related factors. West and southern directions had earlier and greater expansion, likely related to the historical Tōkaidō corridor. Over 95% of all DIDs are located within 4km distance from a railway line. The coastline and distance from the CBD had some modifying influence. During the course of expansion, there was substantial decrease of population density in the inner wards. Future trends in Tokyo's DIDs will be greatly influenced by aging demographic trends. This study therefore shows that megacity spatial expansion is a dynamic process influenced by various processes whose roles vary over time.

1. INTRODUCTION

Extensive global urbanization and land use intensification have led to uneven spatial development and the proliferation of megacities (Brenner & Schmid, 2015; Wenzel, Bendimerad, & Sinha, 2007). There are presently more than twenty-five megacities housing over 10 million inhabitants each, and by 2030 the figure is expected to be over forty (United Nations, 2014). Large urban agglomerations are increasing not only in their numbers around the world, but also in their absolute sizes (Jedwab & Vollrath, 2015; Pacione, 2009). Administrators of megacities face mega-challenges associated with high urban densities, traffic congestion, environmental and health hazards (Bloom & Khanna, 2007). As cities get larger, spatial information is becoming an indispensable resource for monitoring growth and delivery of services.

1.1 Issues in megacity spatial expansion studies

A large body of literature has emerged to investigate the spatial growth of megacities. This has been supported by advances in remote sensing and geographic information systems (Dewan & Corner, 2014; Doytsher et al., 2010; Sharma et al., 2016). By analyzing recurrent observations on a megacity-scale, it is possible to determine explicit patterns of land cover change (Schneider & Woodcock, 2008). An important land cover feature that is commonly used in megacity expansion studies is built-up area. Using this parameter it is possible to estimate the urban spatial extent (Peng et al., 2015), and over time determine rates and types of urban expansion. For instance it has been shown that Asian and African megacities are expanding spatially at unprecedented rates (Muzzini & Aparicio, 2013; United Nations, 2014). Some key forms of urban expansion reported in literature are: edge expansion, leap-frog, and in-filling expansion (Angel, Sheppard, & Civco, 2005). While valuable knowledge about megacity growth has been obtained using built-up area observations, there is increasing awareness of the need to understand the dynamics of human concentrations within megacities.

Zhong et al. (2016) point out that to discover patterns in the changes of human concentrations within megacities is of fundamental importance to our understanding of megacity dynamics, and is essential to transport planning, urban management and policymaking (Zhong et al., 2016). However a challenge for any initiative to study the spatial dynamics of human concentrations across megacities is the lack of fine resolution data of populations. Census data for most megacities is usually available summed up for relatively large administrative areas/blocks that limit detailed spatial analysis of megacity-wide population dynamics. How can the spatial expansion of large populations be quantified for effective land-use administration? Doytsher et al. (2010) showed that many megacities lack strategic frameworks to guide and create their own spatial data infrastructures (SDI) and the authors suggest that new tools and policies are needed to baseline and monitor growth and change across megacities and to forecast areas of risk (Doytsher et al., 2010).

A further concern in megacity spatial expansion studies pertains to modelling long term trajectories. This is related to factors that influence the volume and forms of megacity expansion (Angel, Sheppard, & Civco, 2005). Some of the factors identified in literature include: physical geographic factors, demographic changes, socio-economic changes, transportation systems, consumer preferences for proximity, and governance (Angel, Sheppard, & Civco, 2005; Dewan & Corner, 2014; Li, Sato, & Zhu, 2003). The prediction of future land change in empirical models is often based on the interpretation and input of several of these factors to create a probability map which indicates the suitability of a location for a certain land use relative to the suitability of other locations (Poelmans & Van Rompaey, 2010). However megacities represent the accumulation of successive layers of collective activity and desires, and this involves macro-economic transformations and policy changes (Portugali et al., 2012). Moreover the underlying driving factors of long term growth are not constant over time and they cannot be fully captured by fixed mathematical relations. Dynamic models are therefore necessary for any attempt to represent the long term spatial growth of megacities (Portugali et al., 2012). Unfortunately creating such models is a complex task, particularly when considering cities in regions affected by numerous unpredictable events, such as dramatic economic crises, changes in planning policies, natural disasters, wars, terrorism, and other issues that may profoundly modify the evolution of urban areas (Barredo & Demicheli, 2003).

The study of urbanization process and land use change is different from other disciplines because it does not allow experimentation on the ground (Alsharif & Pradhan, 2014). When developing long-term urban growth scenarios and policies, urban planners have to rely on either simulation models or historical case studies (White et al., 2000). Historical case studies provide descriptions and explanations about unique urban patterns or changes within real-life contexts, aimed at providing positive examples on successful urban policies with the hope that the experiences reveal some important learning points for future policies. Considering the limited studies on population dynamics in megacities, and the high uncertainty inherent in most models of long-term megacity trajectories, we suggest that it could be useful to make case-studies inquiries of the historical growth of megacities from various regions, thereby contributing to an evolutionary theory of megacities growth.

1.2 Rationale for a historical study of the expansion of Tokyo's DIDs

In this study we investigate the historical expansion of Tokyo. Tokyo has been the world's largest megacity since the 1970s, and is projected to remain as the world's largest city in 2030 with 37 million inhabitants (United Nations, 2014). Tokyo presents an interesting study area because despite its immense proportions and dynamism, many observers are surprised at how well the megacity functions efficiently, productively, and sustainably (Hein, 2010; Okata & Murayama, 2011). Presently there is a notable rise in the number of poor mega-cities around the world (Glaeser, 2014; Jedwab & Vollrath, 2015). Yet as Jedwab and Vollrath (2015) note, on the other end of the scale we have the currently rich mega-cities that were able to grow sustainably avoiding problems of congestion. How did these cities such as Tokyo become so large while avoiding the issues of poor mega-cities?

Tokyo is also interesting because it is one of the few megacities in the world with epochal historical experiences that include destruction by war, economic shocks, natural disasters, and major demographic transitions. The growth of cities is strongly influenced by economic, physical, and institutional constraints and is a result of human activities. These complex interactions have spatial features because they take place on the two dimensional surface of the earth. Therefore we seek to understand how the spatial patterns of human concentrations in Tokyo have evolved as the nation passed through various phases of growth.

Japan has a long tradition of high quality mapping, and there have been numerous spatial studies particularly in the Japanese language documenting the trajectories of the nation's urban areas. A landmark spatial study that is available both in Japanese and English languages was carried out by Himiyama et al. (1995), who read into machine readable form the land-use maps of Japan, and collated them into a 2-km grid that was published as an atlas (Himiyama et al., 1995). Fuse and Shimizu (2004) performed rubber-sheeting of important maps produced in the Edo (1603 and 1868) and Meiji (1868 and 1912) periods to conventional map coordinate systems (Fuse & Shimizu, 2004). They carried out various applications, e.g., quantitative analyses of land use, and bird's eye-view visualization of landscapes of the Edo period. Zheng (1991) presented a density function analysis of the Tokyo metropolitan area, showing substantial suburbanization during the period 1975-85, and he also estimated the directional density functions of three railway-line regions (Zheng, 1991). Nakabayashi did an analysis of the nature of buildings in post-war Japan. Siebert (2000a) performed a detailed spatial and temporal analysis of the urbanization transition types and zones in Tokyo and Kanagawa prefectures, and revealed the sequential transformation of individual administrative units from village to town to city and to ward, from 1900 (Siebert, 2000a). The same author also visualized the historical spatio-temporal changes of shoreline, rivers, administrative boundaries, population and rail networks. More recently, Bagan and Yamagata (2012) investigated changes in land-use and land-cover across Tokyo metropolitan area during 1972–2011 (Bagan & Yamagata, 2012), and they demonstrated the usefulness of the grid-based method in linking disparate data-sets. The valuable knowledge from these past studies has thus contributed to showing the unique characteristics of Tokyo, with the aim of assisting in city wide planning and development, as well as demonstrating the application of some state-of-the-art techniques of geo-spatial analytics. Overall most spatial expansion literature of Tokyo focused on land-cover changes with particular focus on built up area. Though a few of these studies have referred to Tokyo's population concentrations (Bagan & Yamagata, 2012; Zheng, 1991), we find limited updated literature in the English language, inquiring into Tokyo's long term growth with particular reference to human concentrations, at a megacity-wide scale.

1.3 The aims of this study

The purpose of this study is to investigate the long-term expansion patterns of densely inhabited districts of Tokyo. Specifically we 1) determine the spatial extent and rates DID expansion, 2) describe the forms of expansion, and 3) identify some economic, geographic and policy factors associated with Tokyo's growth. By using DIDs and population density as main indicators, this study thereby presents a longer and finer temporal resolution analysis of Tokyo's spatial expansion than studies that used mainly built-up area measurements. Moreover by taking a megacity-wide scale, we capture major trends that emerge from the cumulative patterns of small census units thereby providing new information that may not have been revealed in past prefectural level and small scale studies of parts of the megacity. We hope to provide a requisite of materials from which emerging megacities can learn from Tokyo's experiences.

2. METHODOLOGY

2.1 Study area

Tokyo began as a castle called 'Edo' which was constructed by the Shogun Tokugawa Ieyasu after 1600, and it grew to be one of the largest metropolises in the world by the early 1700s (Ito, Nagashima, & Hons, 1980). After the imperial restoration in 1860s, Edo was selected as the national capital city (renamed to Tokyo), and was remodeled into a modern city by the introduction of railway, tram and trunk road network, modern water supply and modern parks. In the twentieth century Tokyo has experienced a rapid growth with various issues associated with urban form and urban environment (Nakai, 1988). The rapid urbanization of the nation's population since Meiji times, and particularly during the post-WW II period has been quite unprecedented (Ito, Nagashima, & Hons, 1980). In this study we focus only the Tokyo metropolitan region as defined to cover four prefectures; Tokyo-to, Kanagawa, Chiba, and Saitama. The total land area of the four prefectures is approximately 13149 km^2, though the densely inhabited districts cover only a fraction of this. Most of the study area has altitude less than 70m above sea level, except for the western mountain area and the south-eastern and north-eastern parts that also have high altitude.

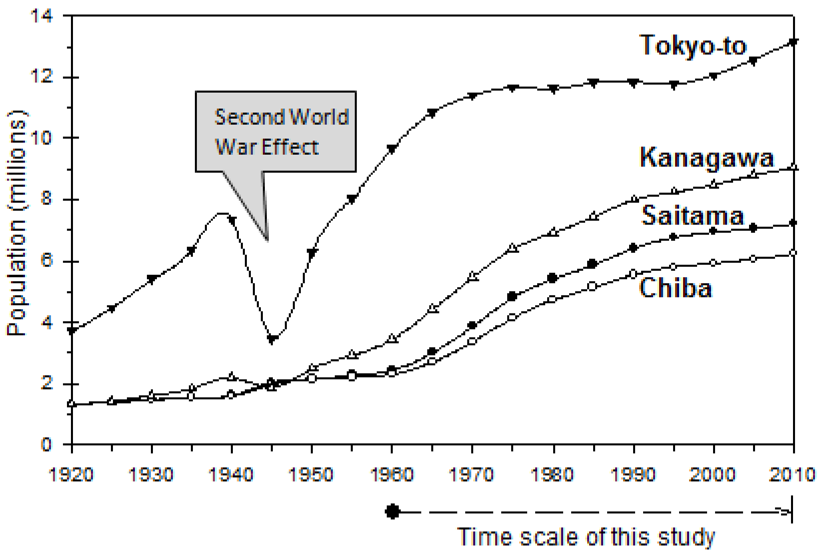

Figure 1. Long term population trends of four prefectures covering Tokyo Metropolitan area

2.2 Data Description

In this study we are concerned with the densely inhabited districts as they represent areas of concentrated human populations in the megacity. Japan is a highly dense society, and even as early as 1975, 57% of the population lived in Densely Inhabited Districts (DIDs) which covered only 2% of the land area of the country (Ito, Nagashima, & Hons, 1980). The DID is an innovative spatial information concept that was developed by the Japanese to identify the actual population situation in urban areas, thereby supporting the operation of land administration functions. The Japanese Statistics Bureau defines a DID as a district containing basic unit blocks with a population density of 4,000 or more per square kilometer, such districts being adjacent to each other in a municipality and forming an urban area with a total population greater than 5,000 (Japan Statistics Bureau, 2016). DIDs have been widely used for urban planning, transport planning, environmental measures, disaster prevention, and other administrative measures. We recognize that the concept of DIDs is Boolean in nature, hence we also examine actual population density data within the DIDs, and even the ages of the populations within the prefectures, in order to get a more holistic understanding of the long-term dynamics of Tokyo's population.

Vector data for DIDs were sourced from the Japan National Land Numerical Information download service. DIDs have been designated in each survey since the 1960 Population Census of Japan, and so we used the complete available set; 5-year DID data from 1960 to 2010, though we note that by 1960 Tokyo was already experiencing rapid population growth

(Figure 1). From the same source we also obtained vector data for rail and subway stations, highway sections, and airports showing the years when each of the services were established. Land-use mesh/grid data for the years 1975, 1995, and 2005, were also acquired from the Japan National Land Numerical Information download service. In order to reduce the number of classes, we reclassified the land use maps into the following categories; agriculture, forest, wasteland, buildings, transportation, other land, rivers and lakes. Economic data such as Gross National Income (US$) were obtained from the World Bank data-bank (The World Bank, 2016).

2.3 Methods

As this is a case study, we have used mainly descriptive statistics in a geographic information systems framework. Firstly vector and grid data for the selected regions were converted to raster data and resampled based on a similar resolution. We used a resolution of 30 meters in order to maintain a high degree of precision for the geostatistical computations. All computations were performed using IDRISI software. Some maps for the final output were created in ArcGIS software. Graphs to summarize the statistical outputs were produced using Sigma-plot software.

3. RESULTS

3.1 Rates of expansion

The extracted area (km^2) trends of Tokyo's densely inhabited districts (DIDs) are presented in Figure 2. The total area of new DIDs between 1960 and 2010 is approximately 2323.2 km^2, which reflects a 3.3 fold increase in size. Most of the DIDs are connected to form a single contiguous group. When comparing the main contiguous DID group and patches that are distributed across the metropolitan area, we find that the main contiguous DID expanded by 2002 km^2 which is approximately 3.7 fold, while the total area of patches expanded by 321 km^2 or approximately 2.2 times in fifty years. Expansion curves, particularly of the main contiguous DID group follow a sigmoid pattern that has an initial exponential phase, followed by slowing growth, and finally a maturity phase with minimal growth.

The rate of expansion of Tokyo's DIDs varied greatly during the course of the 50 years (Figure 3). Peak rates of expansion reached over 100 km^2 per annum between 1970 and 1975 for the main contiguous DID, and between 1965 and 1970 for patches. These peak growth rate levels have not been retested since then, although there was a short-lived spike in 1985-1990. Thereafter, near zero growth rates were seen. Based on these results we identify the years 1975 and 1995 as working estimates for key turning points in Tokyo's long-term growth. The growth rate plots of DIDs have a similar pattern to those for economic parameters. Both Gross Domestic Product (GDP) rate and Gross National Income (GNI) rate peaked in 1970-75, followed by a decline, and both experienced a short-lived spike in 1985-90. Hence there is a strong association between economic output and megacity expansion.

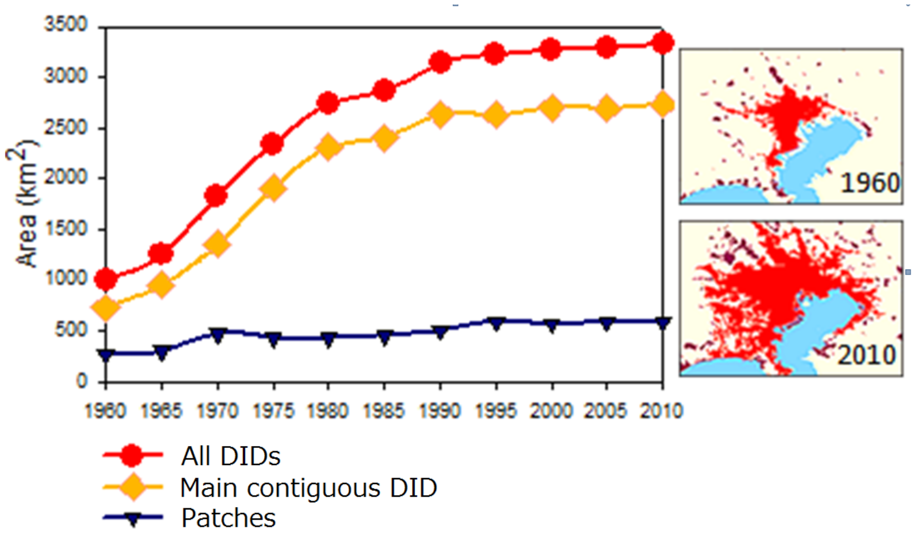

Figure 2. Growth curves of Tokyo's DIDs (left). Maps of Tokyo's DIDs in 1960 and 2010 (right).

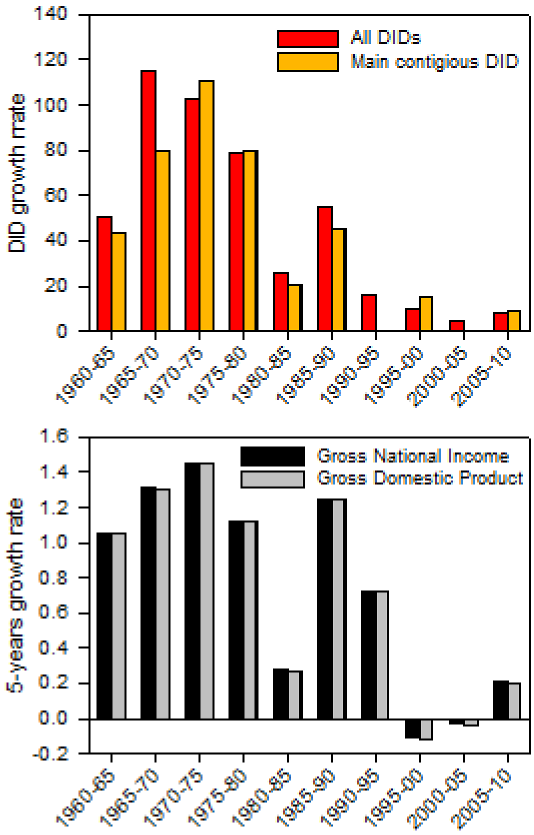

Figure 3. (a) Growth rates of Tokyo's DIDs computed at 5-year time steps. (b) Gross National Income and Gross Domestic Product growth rates of Tokyo's four prefectures.

3.2 Direction of expansion

The expansion of DID in the 50 year period was greatest towards the southern and western prefectures (Kanagawa and Tokyo-to), and least in the east direction that encompasses Chiba prefecture (Figure 4). Important variations in the direction of concentrated growth are seen upon examining the three time phases (Table 1). During the early phase (1960-75), Kanagawa prefecture dominated DID expansion. During the second phase (1975-95), Tokyo-to experienced reduced growth rate while Kanagawa and Chiba expanded much. The eastern prefecture of Chiba had high DID growth rate in the second and third phases (1995-2010), though the actual magnitude of growth in square kilometres was comparatively low particularly in the maturity phase.

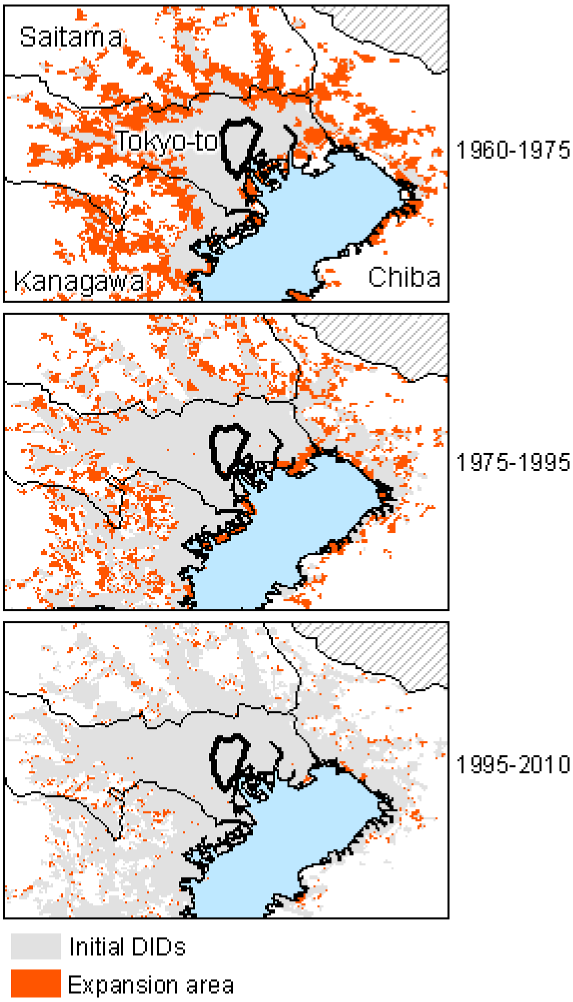

Figure 4. Maps showing DID expansion for the exponential phase (top), slowing growth phase (middle), and maturity phase (bottom).

Table 1. Proportion of new DID area in each prefecture

	Kanagawa	Tokyo-to	Saitama	Chiba
1960-1975	32%	26%	23%	19%
1975-1995	31%	14%	26%	29%
1995-2010	30%	14%	24%	32%

3.3 Types of expansion

3.3.1 Extension

The most abundant type of expansion was extension, which is the formation of new DIDs adjacent to prior existing DIDs. This type of expansion was most intensive during the exponential phase of growth. Visual inspection of the maps shows that the extension was spatially uneven. Selective extension favored the formation of elongated DID corridors stretching from the main contiguous DID. Extension also resulted in the absorption of some existing patches by the main contiguous DID.

3.3.2 Fragmented growth

Fragmented expansion was observed in the form of new patches of DIDs. The total number of DID patches in 1960 was 100. The figure increased to 157 by the year 1975, then it was 209 by 1995, and by 2010 it was 278. The number of patches increased despite the amalgamation of many patches into the main contiguous DID. While the total number of patches was highest in the latter phase of growth, the total area of patches was lowest in that phase. It seems therefore that fragmented growth was more rampant in the phase of slow growth compared to the rapid growth phase.

3.3.3 In-filling

Infilling was observed in the main contiguous DID. In-filling is a kind of extension that occurs in the confines of captured open spaces. The majority of the captured open spaces were observed in Kanagawa prefecture, though small captured open spaces are also seen in other prefectures (Figure 5). The total size of captured open spaces was approximately 96 km^2 in 1975, 154.4 km^2 in 1995, and 216.3 km^2 in 2010. The total area size of in-filling was 7.4km^2, 58.3km^2, and 42,3km^2, in 1960-1975, 1975-1995, 1995-2010 respectively. Infilling was greater in the phases of slow growth and maturity. However the rate of infilling was less than the rate at which open space was captured, and consequently the net size of captured open space increased.

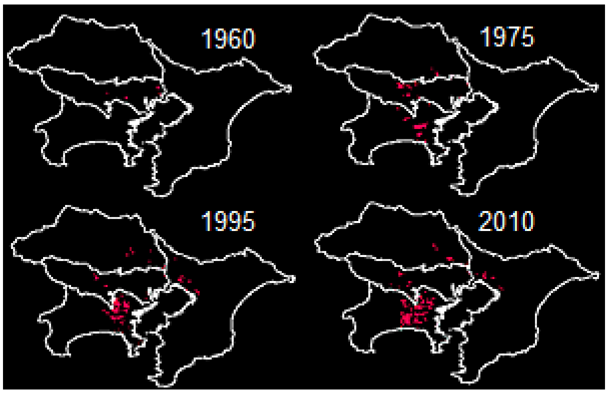

Figure 5 (a) Maps showing the captured non-DID areas. (b) Comparison of the total captured non-DID area and total in-filling

3.4 Association between DIDs and some physical and transportation factors

Figure 6 shows relationships between DIDs and some physical and transportation factors. It can be observed that there is a strong association between railway lines and DID location. Over 95% of all DIDs are located within 4km distance from a railway line. Most of these railway lines were established before 1975 so we can infer that railway lines influenced the location of establishment of DIDs. Moreover each of the outward corridors of DIDs follows a major railway line.

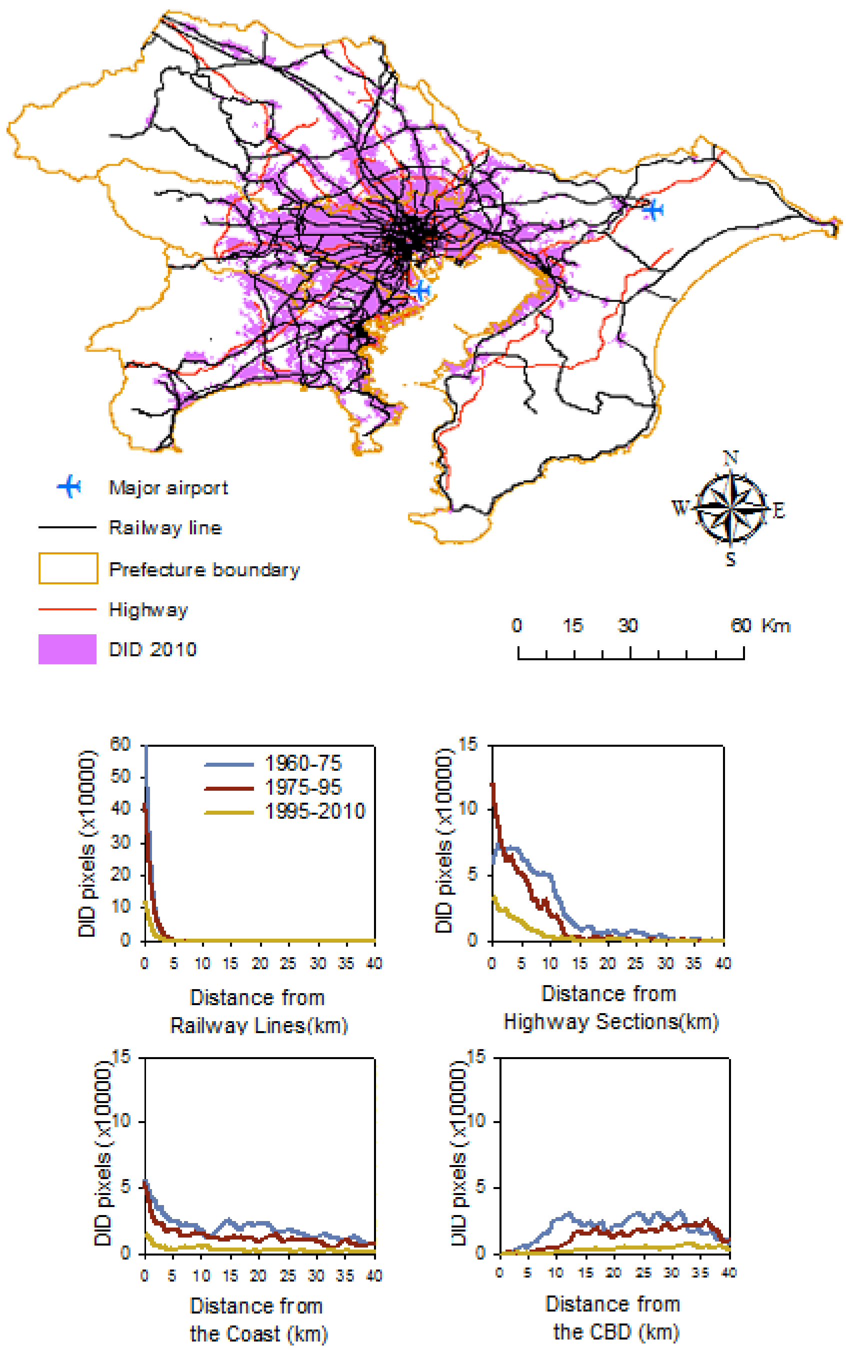

Figure 6. The location of new DIDs with respect to distance from railway lines, highway sections, the coastline, and the central business district (CBD)

There is some association between DID location and the distance from highways, though some DID pixels are also seen over 10 kilometers from highway sections. The association between highways and DID location may have been indirectly influenced by railway lines. The majority of highways are located almost parallel to key railway lines. Moreover most of the highways were completed after 1975, which is also the reason for the surge in the initial 1975-95 plot for distance from highways.

The bay of Tokyo is historically known to have been one of the key factors for the site selection of the original castle town. Hence a large proportion of the coast was already occupied by DIDs at the beginning of this time series. In our study period we find that distance from the coast had a lesser influence on DID location compared to transportation related factors. Nevertheless it is noted that the first three kilometers from the coast were favored for DID location in all three growth phases of this study.

Distance from the CBD is another factor traditionally associated with urban population densities. As much of the areas near the CBD were already densely inhabited by 1960, most of the new DIDs after 1960 were established from 5 to over 40 kilometers from the CBD.

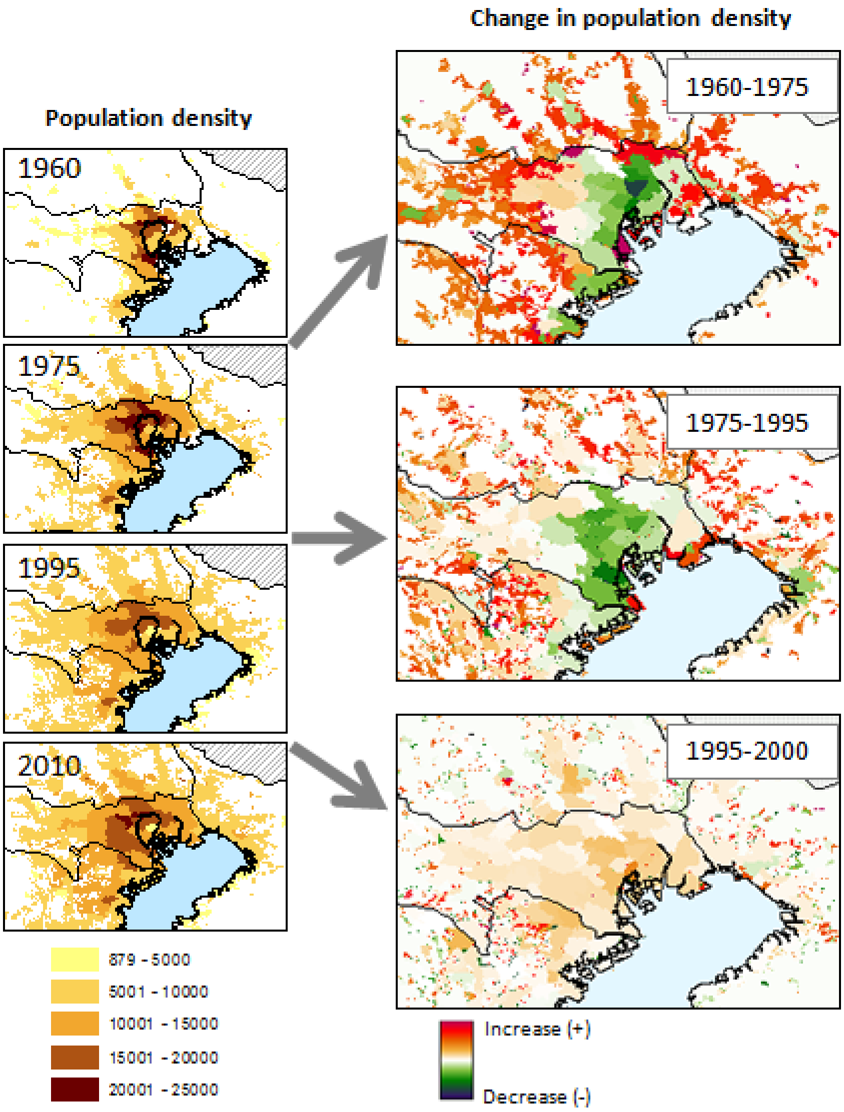

Figure 7. Changes in population density in DIDs.

3.5 Population densities

Having assessed DID expansion, it is also important to investigate trends in actual population densities within the DIDs. Figure 7 shows maps of Tokyo's population densities. The Yamanote loop line has been inserted for reference to the central business districts. The highest population densities have been located in the western parts of the Yamanote line since the early years. It is however important to note that the inner districts experienced a reduction in population densities from 1960 to 1995. At the same time the population in outer wards was rising.

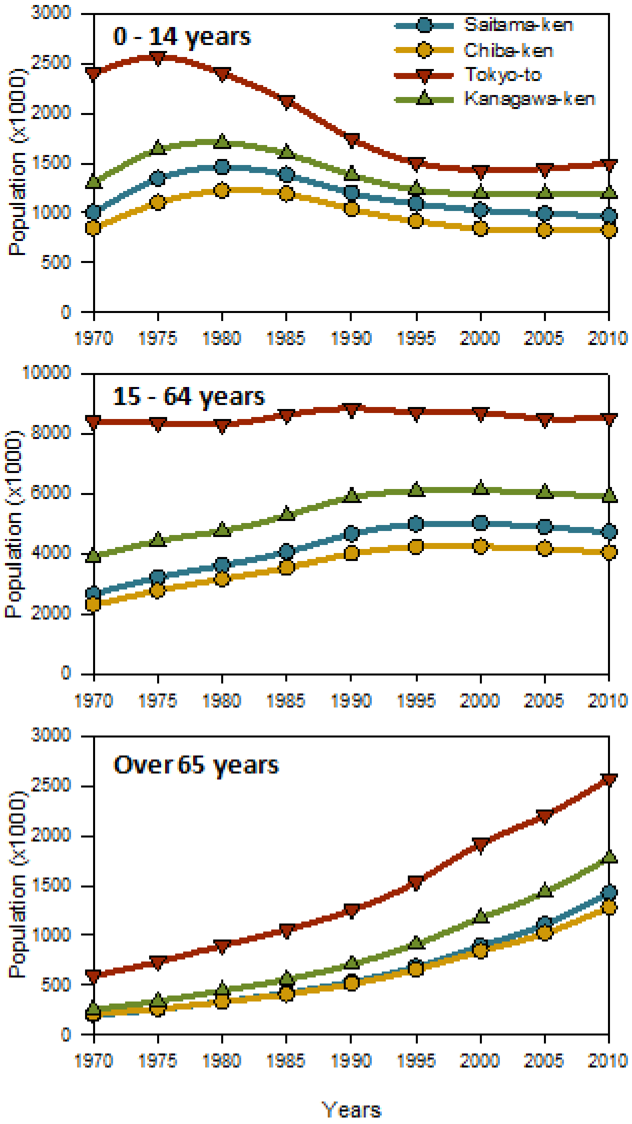

Figure 8. Age trends by prefecture.

3.6 Population ages

Figure 8 shows the trends in population by age for each prefecture. Since the mid-70s there was a decreasing trend in the age group of 0-14 year olds in all prefectures. This decreasing trend seems to have stabilized after 1995. While the population of 15-64 year olds was increasing gradually from 1970 to the mid-90s in Kanagawa, Saitama and Chiba prefectures, Tokyo-to did not change much. The age group of over 65 year olds has seen an increasing trend in all prefectures. These age trends will likely have a big influence on future DID trajectories.

4. DISCUSSION AND CONCLUDING REMARKS

This study has analyzed the expansion of Tokyo's densely inhabited districts (DIDs). Tokyo's historical growth was complex passing through various stages and forms of growth. By using 5-year intervals and a long time-frame (50 years), this study could reveal temporal details about key turning points in the historic growth. Tokyo passed through an initial exponential phase, followed by slowing growth and is now in a maturity phase. Though our study starts in 1960, literature shows that rapid growth actually began soon after the Second World War. The final phase we describe as maturity phase is characterized by minimal growth, and does not seem to be decline yet. However it is apparent that without a major rejuvenation of growth, the megacity could encounter decline as some older megacities have done in the western world (Turok & Mykhnenko, 2007). It is to be seen if the 2020 Tokyo Olympics and the on-going Abenomics will provide the necessary rejuvenation for Tokyo's growth.

4.1 Rates of expansion

The rate of DID expansion shows strong association with economic trends, in particular rates of Gross National Income (GNI) and Gross Domestic Product (GDP). The initial phase of rapid DID expansion (1960-1975) corresponds with the post-war period when the country experienced rapid economic growth, rising to be the world's second largest economy. This concurs with Ito (1991) who notes that Japan's hyper-rapid economic growth began in 1944 and ended in 1973. The time series of this study starts from 1960, which coincides with Prime Minister Hayato Ikeda's taking office and announcing his goal of "doubling average personal income within ten years", but this was achieved within 7 years. In this decade of accelerated economic growth, the country attained large trade surpluses supported by the yen fixed at 360 yen per dollar under the Bretton-Woods system. Detailed information about the state of the economy in this period is available in literature.

From 1975 there was a declining trend of DID growth rates, with no return to the historical peaks. There were several critical economic changes in the 1970s. For example, in 1972 Prime Minister Tanaka's government increased money supply and lowered the interest rate and this created inflationary pressure. Then there was the First Oil Shock after OPEC countries announced the oil embargo in October 1973 which resulted in "Wild Inflation" (Kyo-ran Bukka) for Japan, reaching levels of up to 30% by 1974. The oil shock had profound and long lasting impacts on the fabric of the Japan's economy. It had the effect of forcing the country into economic recession (Mihut & Daniel, 2012), with negative consequences for corporate profit and the labor market. The effective rate of available jobs, which remained constant over the period 1967-1974, dropped nearly to half at the end of 1975, and the net profit rate reached the lowest level after the Second World War, dropping below 1% in the manufacturing sector (at 0.76%) in the first half of the fiscal year 1975 (Mihut & Daniel, 2012; Yoshitomi, 1976). Concomitant to that were the decrease in investments and slowdown in technological progress (Mihut & Daniel, 2012).

Between 1985 and 1995 there was a temporary spike of DID growth rate and a corresponding temporary spike in Gross National Income. This likely reflects the economic bubble period (1986-1991) wherein real estate prices and stock market prices were substantially inflated. After the bubble burst however, there was low DID expansion of below 10 km^2/annum. Economic literature refers to this period of economic stagnation as the "lost decade".

4.2 Direction and shape of expansion

The direction of Tokyo's expansion was greater towards the west and south, particularly in the early years. Prefectures in this direction are Tokyo-to and Kanagawa. That this direction was favored for DID expansion is greatly related to the Tōkaidō corridor which connects Tokyo to Japan's other megacities Nagoya and Osaka. The significance of the Tōkaidō in the history of Japan is outlined well in the literature. Historically the Tōkaidō was travelled by foot and wheeled carts, and the Tōkaidō railway line was established in 1889 (Traganou, 1997, 2004), so this encouraged settlements in that direction. Furthermore Kanagawa and Tokyo prefectures are attractive locations as they are both coastal prefectures, bounded by Tokyo Bay on the east and Sagami Bay in the south separated by Miura peninsula (Siebert, 2000a). These two prefectures were connected by rail as early as 1872, and this was Japan's first rail line (Siebert, 2000b). Siebert who examined the physical geography of Tokyo also notes that mountains in the west-end of Tokyo-to and Kanagawa limited further urban expansion in that direction (Siebert, 2000a, 2001), hence in later years expansion increased towards Saitama and Chiba direction.

The lagging of DID growth in Chiba prefecture is particularly interesting because it occurred despite policy effort and much financial investments to create Chiba New Town and the advantage of the establishment of Narita Airport. A major reason cited in literature for the failure of Chiba New Town to attract targeted population numbers is transportation limitations. The Hokuso line took long to construct, and the train fare is regarded as expensive. On the contrary, the successful Tama New Town in Tokyo-to and Kohoku New Town in Kanagawa already had railway infrastructure and were well connected to Tokyo.

4.3 Proximity factors associated with DID expansion

Among the proximity factors associated with DID expansion that were examined, transportation policy was the most dominant. With over 95% of all DIDs located within 4km distance from a railway line, it is clear that railway transportation is an integral feature supporting Tokyo's DIDs. Most of the lines were established before 1975 therefore it could be inferred that DIDs tended to grow near existing railway lines. These findings concur with literature emphasizing that Japanese railway companies intentionally foster DID growth near stations as part of their business strategy (Calimente, 2012; Zacharias, Zhang, & Nakajima, 2011)). Beginning in the 1920s, private railway companies purchased huge areas of land in the suburbs of Tokyo and developed housing estates and department stores next to stations as a business strategy (Okata & Murayama, 2011). This in turn created unprecedented demand for railway services (Zacharias, Zhang, & Nakajima, 2011). Transit-oriented development (TOD) in Japan is a fundamental characteristic of all central city urban development, and is almost exclusively rail-based (Dittmar & Ohland, 2003; Zacharias, Zhang, & Nakajima, 2011). Urban sprawl was limited by Urbanization Promotion Areas (UPA) which were demarcated to create systematic urbanization around train stations. Urbanization Control Areas (UCA) were also created to limit urbanization beyond the UPA. Contrastingly, informal sprawl is rife in many emerging megacities, (Benítez et al., 2012; Hill et al., 2014; Hove, Ngwerume, & Muchemwa, 2013). Tokyo provides an example case showing that a possible way of effectively controlling the extent of expansion is through long term investments into public transportation coupled with public policy support.

While discussing the association between Tokyo's railway network and DIDs, it is important to highlight that the trains of Japan are ranked among the most punctual in the world (Brebbia et al., 2014). Hence the movement of human capital and goods through the megacity is voluminous yet efficient. Transportation infrastructure contributes significantly to a city's prosperity by facilitating workers' access to employers, consumers' access to shopping and leisure activities, and firms' access to capital, labor and potential customers (Winston, 2014). In contrast many emerging megacities are lagging in public transportation infrastructure, and without the construction of new public transportation infrastructure the majority of people will have very limited mobility making their participation to the formal economy almost impossible (Vermeiren et al., 2012). A policy recommendation for upcoming megacities is investments in transport infrastructure such as railways that can be used for long periods and can be upgraded when required to match with new technologies.

4.4 Population density trends in DIDs

The study has also shown important trends in the actual population densities of the DIDs. The inner districts had decreasing population densities from the 1960s through to the 90s. Concurrently outer districts increased in population densities. This suburbanization occurred as undeveloped land in the outer districts was being developed, and this was supported by public policy to reduce congestion in the city center. For example many "New Towns" were created in outer districts to provide affordable housing to the large working class. Examples of such "New Towns" include Tama New Town in Tokyo-to, Kohoku New Town in Kanagawa just to mention a few. These trends were supported by policies to curb urban sprawl, such as the Urbanization Control Areas (UPA) and Urbanization Promotion Areas (UCA). The UPA and UCA became effective in most municipalities by 1975. Therefore in addition to economic factors, public policy also had a very strong influence in directing and controlling the extent of expansion.

4.5 Age composition and future trends

Tokyo's demographic composition has changed substantially over the past 50 years. The elderly population has been progressively increasing while the young population decreased substantially. These are critical changes in population structure, and all prefectures are affected. In contrast many emerging mega-cities face challenges of high urban fertility. For Tokyo, unless there will be substantial absolute population growth, the mega-city's DID face future decline. We have not mapped the age trends by DID, but this could be an interesting subject for future research. However it is apparent that appropriate policy measures are needed to better prepare for the future decline in DIDs caused by these demographic trajectories.

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