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An application of the node place model to explore the spatial development dynamics of station areas in Tokyo

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Abstract: The high level of integration between railway and real estate development in Tokyo makes the city an interesting example for other metropolitan areas looking for ways to promote transit-oriented development. To successfully promote such a development pattern, an understanding of development dynamics in station areas is crucial. In this paper, a node place model is used to determine which transport and land use factors are responsible for structuring station area redevelopments in Tokyo, and to what extent. The interaction between specific transport and land use features—most importantly, proximity by train to the central business district and the number of train connections versus workforce concentration—is a powerful force structuring developments in Tokyo. However, other factors—most notably government policies—should also be taken into account.

Keywords: Transport; land use; node-place model; Tokyo

1 Introduction: Transit-oriented development in Tokyo

In many metropolitan areas around the world, planners are attempting to give railways a central role in urban development. In Tokyo, this is already the case; millions of people depend on the Tokyo rail system for commuting to and from work and for making use of all sorts of facilities. Besides being a dominant mode of transportation with a market share of over 50 percent within the Tokyo metropolis, the railways also play a decisive role in shaping the region's urban structure. During the period of enormous economic growth after World War II, it was largely the railways that facilitated the development of Tokyo. As a result, large areas of land have been developed around the railway lines that radiate outwards from the city center. The integrated development of railways and their surroundings was stimulated by the fact that private railway developers owned not only the railway infrastructure but also large parts of the areas surrounding it. This allowed them to develop residences, offices, department stores, and recreational facilities in conjunction with the railway network. Private railway operators in Japan consider themselves to be "lifestyle supporters" with a vested interest in maintaining and increasing the vitality of communities along their railway lines. They believe that this goal can be realized through fully exploiting synergies between transportation, real estate, and retail-related services. In this way, the operators of private railways hope to maintain their services as the natural choice of travelers pursuing their daily activities.

The structure of the private railway network in Tokyo has proven to support the formation of subcenters. The network consists of several radial lines running from the suburbs to the center of Tokyo. With the exception of the Chuo line, all these lines terminate on the Yamanote loop, a circular line that connects most of Tokyo's urban centers (Figure 1). The government did not allow private railway operators to extend their lines inside the Yamanote loop. The reason for this was that the government did not want the competition from the private railway operators as both the Yamanote loop and the streetcar network within the loop were government-owned. Therefore, private railway operators had to establish their terminals along the Yamanote loop and the millions of commuters that needed to go to the city center had to switch trains there. This structure created natural growth points at the intersections of the main radials and the loop (Sorensen 2001), and these growth points became the seeds of urban subcenters. At present, the most famous subcenters are Shinjuku, Ikebukuro and Shibuya, each of which attract millions of visitors every day.

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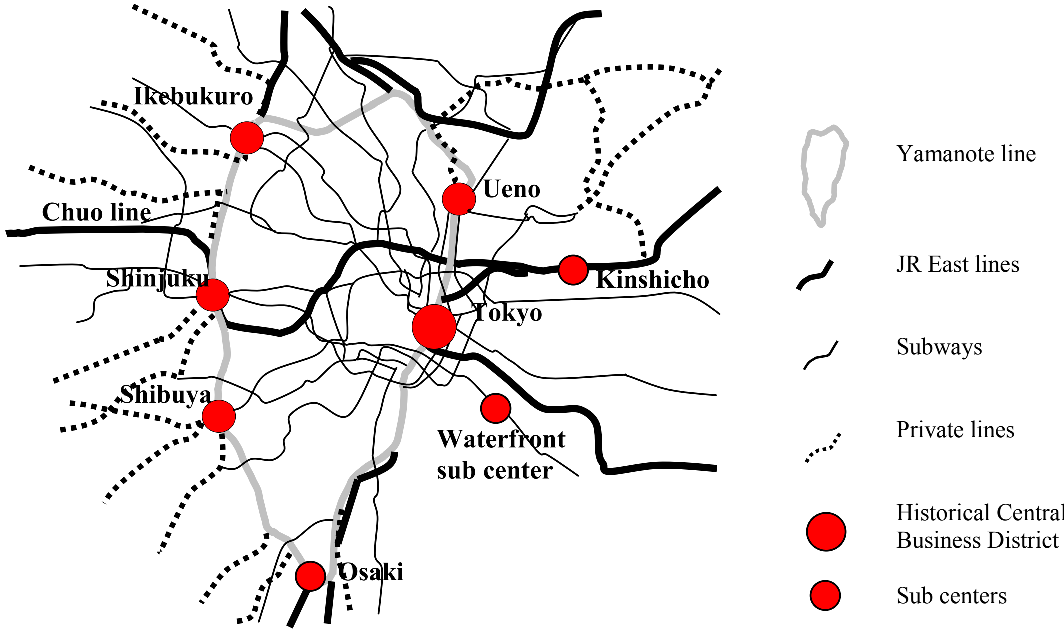

Figure 1: Structure of Tokyo's Railway Network.

Besides private railway operators, the government has also played a direct role in supporting transit-oriented development. Much of the success of the government's efforts can be attributed to the flexible planning style used by government planning agencies. The "loose" character of government planning efforts is perhaps best illustrated by the way the land use zoning system is used in combination with volume controls. The land use zoning system in Japan specifies 12 basic zone types, which can be roughly divided into three categories: residential, commercial, and industrial. Although the names "residential" and "industrial" might seem to indicate a rigid separation of uses, neither zone type is limited to only residential or industrial usages. For example, even in the most strictly zoned residential area it is possible for residents to dedicate a part of the house to small-scale commercial activities such as a store. Commercial zones have the fewest use restrictions. Virtually every kind of land use is allowed here and controls on building activities are the weakest. In Tokyo, a commercial zoning designation is traditional in the areas around stations, along major roads, and in the central business district.

The government has used the instrument of Floor Area Ratio (FAR) to further encourage the growth of the subcenters and regional centers in Tokyo by assigning these areas higher FAR values than their surroundings. The central business district, the central core in figure 1, has traditionally been assigned the highest FAR values, followed by the subcenters around the Yamanote loop. The regional centers also have higher values than their suburban surroundings, but their values are considerably lower than those of similar areas in the city center, as they are seen as having less potential for development. In Japan, FAR values are designated by law but not fixed. Several instruments exist that allow for a relaxation of existing FAR values. In general, exemptions to existing FAR values are granted when a private developer meets certain conditions such as investing in public infrastructure and/or open space. Developers who do so are rewarded with authorization for additional building volume, also referred to as the "FAR bonus." The size of the bonus depends on the proportion a developer invests. In the end, this practice benefits both the government and the private sector; the government receives public infrastructure for which it does not have to pay, while the private sector receives an additional building volume which enables them to make a greater profit. Such planning incentives have greatly influenced development around rail stations.

This paper attempts to understand which transport and land use factors are responsible for structuring station area redevelopments in Tokyo, and to what extent. For this the node-place model developed by Bertolini (1999) is used. First, with the help of this model, the transport and land use factors shaping the development of station areas are identified. Second, the outcomes of the model are compared with the actual investments taking place in and around station areas to find out if stations develop according to the expectations of the model. Third, explanations are sought for the matches and mismatches between the identified development potential and its actual realization, in order to illuminate the broader complex of factors that comes into play. Eventually, a better understanding of the development dynamics in station areas in Tokyo might help those cities that are looking for ways to promote the integration of public transport and urban development, or "transit oriented development" (Cervero 2004; Dittmar and Ohland 2004; Dunphy *et al.* 2004).

2 Exploring the relation between transport and land use in station areas

It is generally recognized that land use patterns and transportation patterns are closely related to each other. It is easily understood that the spatial separation of human activities creates a need for personal travel and goods transport, and thus influences the mobility behaviour of actors such as households and firms. Less widely appreciated is the converse impact of transport on land use (Banister 1995; Giuliano 2004; Wegener and Fuerst 1999). It is obvious that the availability of infrastructure makes certain locations accessible, but exactly how developments in the transport system influence the locational behaviour of landlords, investors, firms, and households is less clearly understood. The idea of the "land use transport feedback cycle" (Giuliano 2004; Meyer and Miller 2001; Wegener and Fuerst 1999) is often used to illustrate the complex relationship between land use and transport. In this cycle, land use and transport patterns both influence each other. Land use patterns partly determine the location of human activities such as living, working, shopping, education, and leisure. The distribution of human activities requires use of the transport system to overcome the distance between the locations where these activities take place. These activities create new travel demand and, consequently, a need for transportation services, whether in the form of new infrastructure or more efficient operation of existing facilities. The resulting increase in accessibility co-determines the location decisions of landlords, investors, households and firms and so results in changes of the land use, starting the cycle again. This process continues until a (provisional) equilibrium is reached or until some external factor intervenes (Meyer and Miller 2001).

The node-place model of Bertolini (1999) follows the reasoning of the transport land use feedback cycle and aims at further exploring the underlying relationships, with a focus on station areas. The basic idea is that improving the transport provision (or the node value) of a location will, by improving accessibility, create conditions favourable to the further development of the location. In turn, the development of a location (or an increase in its place value) will, because of a growing demand for transport, create conditions favourable to the further development of the transport system. The node-place model's emphasis on "conditions" is important, as it indicates a development potential that may or may not be realized, as other factors may also affect the outcome.

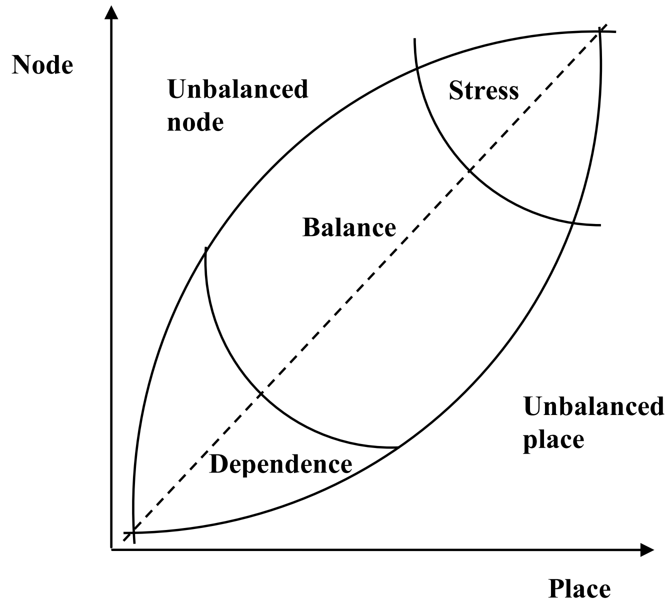

Figure 2: The Node-Place Model (after Bertolini 1999).

The node-place model distinguishes five ideal-typical situations for a station area (Figure 2). Each situation reflects a particular relative position of a station area on the node and place scale, or, in other words, its position in the node or place hierarchy of an urban region. The "balanced" areas are found along the middle line; their relative positions on both the node and place scales are roughly equal. It is expected that, due to transport and land used interactions, these relative positions will be comparable in most cases. At the top of the line are the "stressed" areas: locations where both the node and the place have been used to the fullest. "Stressed"station areas have a relatively strong position on both the node and place scales. Further development in these areas can become problematic as multiple claims on the limited amount of space can easily cause conflicts. At the bottom of the line are the "dependent" areas where the struggle for space is minimal. Both the node and the place values are relatively so weak that factors other than internal node-place dynamics (e.g. subsidization) must intervene in order for the area to sustain itself. Furthermore, two unbalanced situations exist. Above the middle line are the "unbalanced nodes," locations where the transport systems are relatively more developed than the urban activities. Below the middle line are the "unbalanced places" where the opposite is true. An "unbalanced" station area thus has significantly stronger relative position in either the node or the place scale.

According to the reasoning of the land use feedback cycle, both of the unbalanced location types are expected to move towards a more balanced state over time (or, at least, to tend to move in that direction). For example, an unbalanced node may, in principle, either see its place value go up in the long term (e.g. by attracting property development) or see its node value go down (e.g. by a relative reduction in transportation services). Conversely, an unbalanced place may experience either an improvement in connectivity that increases its node value, or development at a relatively lower density that decreases its place value. The unbalanced locations are the most interesting because they have, according to the model, the highest development potential (in terms of either land use or transport). However, the realization of this potential is not a certainty, but may be affected by other factors. The next section explores the development dynamics of a range of stations within the Tokyo metropolitan area using the node place model.

3 The node place model applied to Tokyo

The number of stations in the Tokyo Metropolitan Area is considerable. The average distance between stations is 1.2 kilometers, and it is common to find more than 20 stations on a single suburban commuter line. More than 60 passenger train lines serve approximately 1200 stations in the Tokyo metropolitan area. Most of the stations, however, fulfill a local role in the network and function as local centers for the surrounding residential community. They handle fairly small numbers of passengers (by Japanese standards), and this is reflected in the relatively low intensity and diversity of activities in and around these stations. For the application of the node-place model, stations that fulfill a regional role in the network were selected. This regional role is illustrated by having at least one transfer option to another railway or subway line. Eventually, 99[1] stations matched this criterion. The stations were selected within a radius of 30 kilometers from Tokyo Station using GIS (Geographic Information Systems). Tokyo Station is considered to be the official center of Tokyo; therefore, in railway statistics, the direction of a trip is always plotted relative to Tokyo Station.

3.1 The node value

To determine the node value or the transport provision of a location, four criteria were analyzed, based on previous applications of the model and expert interviews in Tokyo: the number of train connections departing from a station; the type of train connections present at a station; the proximity to the central business district by rail; and the number of bus connections departing from a station. Bertolini (1999) used seven criteria and Reusser *et al.* (2008) used 10 criteria to determine node values. For practical reasons, only four criteria were used in this application.

1. Number of train connections Ridership and the number of train connections are closely related. In general, a station that offers multiple connections will attract more passengers than a station that only offers one connection. In addition, a station that offers multiple connections will also have a larger development potential then a station that does not. This criterion excludes the local stations, which are less valuable in terms of development potential, as is clearly illustrated by their weakly developed station areas. For the 99 stations with more than one transfer option, the number of train connections was calculated based on 2005 data. Subways and Shinkansen (high speed railway) lines are included in the calculation. Not included are transfers from a local express to a rapid express, as both trains run on the same line.

2. Type of train connections In Tokyo, private railways operate several types of train service on their lines. These range from train services that stop at every station to services that only stop at a certain number of stations. It is obvious that the latter type of service, in Japan called rapid express service, reduces travel time to the subcenter. This reduction is reflected in the land and real estate prices, as stations with a rapid express stop are more expensive in terms of land prices and rents than stations that only have a local express stop. The number of rapid express services that halt at a station was calculated on the basis of the number of train connections that each station had in 2005 (criterion 1).

3. Proximity to CBD by rail Tokyo station is situated in the heart of the historic central business district. More than 4000 companies, including the head offices of many national and international firms, are located in the surrounding area, contributing to approximately 20 percent of Japan"s gross domestic product. Approximately 240,000 people work in the area and another 700,000 people visit the area every day (Okada 2006). The CBD is the site of the highest concentration of jobs and workers within the Tokyo metropolitan area (Kawabata 2003). Therefore, proximity to the CBD by rail is an important factor in determining the development potential of a

[1] Initially 131 stations were selected but due to a lack of available data the list was reduced to 99 stations.

station area. Proximity to the CBD by rail is calculated by using a Japanese train route finder website.

4. Number of bus lines departing from a station Buses in the Tokyo metropolitan area serve a secondary role, carrying passengers to and from train stations. Most large private railway companies operate several bus lines that are complementary to their railway systems and serve the surrounding residential areas. Each company has its own exclusive territory corresponding to the area where they operate railway lines. For example, the Tokyo metropolitan government mainly operates buses within the 23 wards while private railway operators go far beyond that. However, like private railways, private buses are not allowed to cross the Yamanote line that encircles central Tokyo. To determine the number of bus lines that depart from the selected stations, online maps of 20 different bus operators in 2005 were analyzed. Only those bus lines that included a stop in front of the rail station were included in this calculation; therefore, some stations have a score of "0" as they do not have a bus stop near the station.

Together, these four factors determine the value of a node. In contrast to the original application of the node place model in the Netherlands (Bertolini 1999) the number of car parking facilities and the number of bicycle parking facilities were not analyzed in this study, as most of the selected stations lack these facilities. The majority (60.6%) of people who travel to a station in the Tokyo metropolitan area do so on foot (Institute for Transport Policy Studies 2005). This is possible due to a combination of high densities typically found around stations and short distances between stations. The fact that all housing agencies feature walking distance to the nearest station in their advertisements underscores how important it is that stations can be reached on foot.

3.2 The place value

To determine the place value (the quantity and diversity of human activities) of a station area, six criteria were analyzed: the size of the population around the station; the characteristics of the nearby workforce; and the degree of multifunctionality. These match the criteria used in the original application by Bertolini (1999).

1. Population around the station

In Tokyo, the construction of private railway lines went hand in hand with the development of the surrounding areas. Before constructing the railway line, a private railway operator bought large tracts of land along its planned route. These lands were developed for commercial and residential purposes. By the time a station was completed, the first inhabitation in the surrounding areas had started (Cervero 1998; Mizutani 1994). The aim of the private railway developer was to create a so-called "railway-oriented lifestyle" in which people greatly depend on the railways for conducting their daily activities. That means living in the suburbs and using the train to travel back and forth to the center or subcenter for shopping and working. That this worked out quite well is illustrated by the high share, over 50%, the railways have in urban transport within the Tokyo metropolitan area.

The residential population around a station was measured from the center of a chome or neighbourhood district. The station that is the nearest to the center of a chome is assigned the area's total population. The maximum distance from a center to a station is set at 700 meters following Bertolini (1999) and Reusser *et al.* (2008). A Japanese GIS website[2] was used for making the calculations. At the time this analysis was carried, out the most recent data available were from 2001.

The same Japanese GIS website was used to calculate the number of workers within 700 meters of a station. At the time this analysis was carried out, the most recent data available were from 2001.

2. Economic cluster 1: Services and administration

The GIS data available for Tokyo were the number of workers in offices, branch offices, and offices in houses.

3. Economic cluster 2: Retail, hotel and catering

The GIS data available for Tokyo were the number of workers in stores and restaurants.

4. Economic cluster 3: Industry and distribution

The GIS data available for Tokyo were the number of workers in transport distribution centers and warehouses, private warehouses, gas stations, factories, and crafts.

5. Economic cluster 4: Education, health and culture

The GIS data available for Tokyo were the number of workers in schools, hospitals, temples, inns, and bathhouses.

The residents and the workforce together represent the potential users of transportation services. In Tokyo, however, it is safe to say that the majority of residents and workers are also actual users of the train, because most people do not have another alternative. Private automobile use is expensive because

[2] http://gisplaza.stat.go.jp (in Japanese only).

drivers must pay multiple tolls, commuting allowances are rare, average travel speeds during peak periods are 14 km/hr, and parking in Tokyo is exorbitantly priced. The train, on the other hand, is punctual, has a high frequency (every 2-3 minutes during rush hour and every 5 minutes during off-peak hours) and the travel costs are, in some cases, fully covered by the company.

6. Degree of multifunctionality

In Tokyo, stations are the true urban centers of the city as most shops, restaurants, offices and amusement facilities are concentrated around them. However, this does not mean that all stations have the same function. For example, the CBD of Tokyo is supported by several subcenters, each fulfilling a different role in the urban network, either as economic, entertainment, or cultural centers. Furthermore, stations also play different roles in the transportation network. They can either have a local, regional or national role, which in turn has consequences for the quantity and diversity of functions to be found in their areas. Determining the degree of multifunctionality can provide insight into this double role. To calculate the degree of multifunctionality, data on workers grouped into the four economic clusters described previously was processed according to the following formula:

$$x_1\text{=population}$$
$$x_2 \ldots x_5\text{=workers/economic clusters}$$
$$x_6 = 1 - \frac{(a-b/d)-(a-c/d)}{2} \text{ with } \left\{ \begin{array}{l} \text{a=max}(x_1,x_2,x_3,x_4,x_5) \\ \text{b=min}(x_1,x_2,x_3,x_4,x_5) \\ \text{c=}(x_1+x_2+x_3+x_4+x_5)/5 \\ \text{d=}(x_1+x_2+x_3+x_4+x_5) \end{array} \right\}$$

The node and place indicators described here are based upon the original application of (Bertolini 1999)and a later application in Switzerland by Reusser *et al.* (2008).

4 Results

The approach used by Reusser *et al.* (2008) for Switzerland served as the reference for plotting results of the node-place model in this research. The place criterion "workforce" and the node criteria "number of train connections" and "number of bus connections" were log-transformed to reduce the unevenness in their individual scores. For the other criteria, the original scores were used as the differences between them were very small. Furthermore, all criteria were rescaled to have a score between 0 and 1. The station with the highest score (e.g., the largest number of passengers), was assigned a score of 1, and the station with the lowest score (e.g., the lowest number of passengers) a score of 0. The two indices were Z-transformed to obtain comparable scaling. This means that the distances in the node-place diagram are in standard deviation units.

Correlation analysis was used to determine which transport and land use factors are responsible for structuring station area redevelopments. First, the node and place criteria were individually compared to explore what combination is most influential in structuring the development of station areas. Second, combinations of node and place criteria were compared to identify any pair combinations with a stronger influence than individual pairs. In this, we departed from previous applications of the model, in which only combinations of all node and place factors have been considered. This different interpretation stems from the different question we are asking: which transport and land use factors and interactions are more relevant? Fifty-four combinations of node and place criteria were explored to determine to what extent these combinations are related to each other. This resulted in fifty-four possible relations, or fifty-four possible node-place models (M). In the matrix below, only the individual comparisons between node and place values are illustrated, as well as two combinations of node criteria that appeared to have a stronger influence (and thus a greater potential for structuring urban redevelopment in station areas) than when compared individually. The combined node criteria were calculated by summing their individual values (see table 1 below). No combination of place criteria is shown, because no combination showed a stronger correlation than individual criteria.

Table 1 presents the relationships between transport factors (node criteria) and land use factors (place criteria). Population appears to be negatively related to node criteria, except for the number of bus connections (M4), where there is a slight positive correlation. This means that in Tokyo, the areas around stations with a high number of rapid trains, a high number of train connections, or a location relatively near the CBD have relatively small residential populations. Stations with a limited number of rapid trains, a limited number of train connections or locations further from the CBD have relatively large residential populations.

The size of the area workforce is positively related to the node criteria, which means that stations with a high number of (rapid) trains, a high number of train connections, a high number of bus connections, or a location relatively close to the CBD have relatively large workforces, and vice versa. This correlation is strongest in the case of the combination of number

Table 1: Overview correlation scores of node-place combinations

Node Criteria (N)	Place Criteria (P)		
	P1 Population	P2 Workforce	P3 Degree of multifunctionality
N1 Number of train connections	M1 −0.225**	M2 0.558*	M3 −0.08
N2 Number of bus connections	M4 0.017	M5 0.238**	M6 0.065
N3 Type of train connections	M7 −0.003**	M8 0.328*	M9 0.003
N4 Proximity to CBD	M10 −0.301*	M11 0.520*	M12 −0.028
N5 Proximity to CBD and number of train connections	M13 −0.325*	M14 0.666*	M15 −0.065
N6 Proximity to CBD and type and number of train connections	M16 −0.234*	M17 0.645*	M18 −0.044

of train connections and distance to the CBD (M14). These are already interesting insights, which depart from the focus on generic correlations between density and public transport provision (e.g. Wegener and Fuerst 1999), as they show a positive relationship between the network position of a station and workforce concentration, but a negative relationship when population concentration is considered. This finding implies that functions (i.e. residential or commercial), should be considered along with densities when exploring linkages between transport and urban form. As for the degree of multifunctionality, the picture is less clear. Models M6 and M9 seem to indicate that stations with either a large number of rapid trains or large number of bus connections are more multifunctional. Stations that are situated closer to the CBD or have a high number of train connections tend to become more monofunctional, as illustrated by the negative correlation of M12 and M3. Again, relationships more subtle than just density versus transport provision seem to be at play. However, neither correlation is particularly strong, pointing to the weak structuring role of this place criterion. It is interesting that only certain influences get stronger when transport supply factors are combined. Stations that are located near the CBD and time have a high number of train connections and/or service by a high number of rapid trains have larger workforces than stations that only match the first criterion (M14 and M17 versus M11). However, adding the type of train connections to the node criteria does not seem to have an added value, as the lower correlation score indicates. Altogether, model M14 seems to have the strongest structural influence on station area developments in Tokyo and therefore this model is used in the rest of this analysis which focuses on the second question, that is, to what extent these transport and land use factors structure development, as opposed to factors outside the node place model.

Figure 3 illustrates the relative position of each station area according to its node and place values in model M14. A large number of station areas are balanced as they have a relatively equal position on the node and the place scales. It is assumed that these relative positions are comparable due to transport land use interactions. Examples of balanced station areas are Ikebukuro, Ryogoku and Inadazutsumi. Ikebukuro Station is the core of one of the urban subcenters along the Yamanote

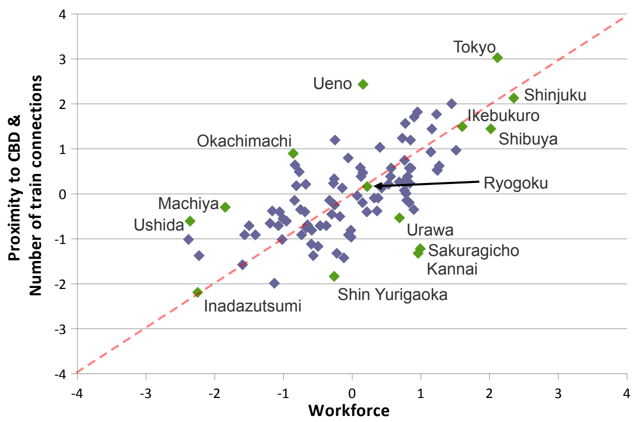

Figure 3: Node-place model 'Proximity to CBD and Number of Train Connections versus Workforce' ($p < 0.001$). Distances in standard deviation units.

line and as such has a relatively strong workforce. Ikebukuro is also a major transfer node for commuters coming from the suburbs in the northwestern metropolitan area. Ryogoku Station is situated next to the historical central business district and has intermediate node and place values. Inadazutsumi station is located in Tama New Town, a residential suburb west of Tokyo that is relatively far away from the CBD. It has relatively weak node and place values.

There are also, however, examples of station areas in more extreme positions. In the upper right corner are the so-called "stressed" station areas. This situation is represented by the stations of Shibuya and especially Shinjuku. Both stations are major transfer nodes in the urban transportation network of Tokyo and are used by millions of travellers each day. At the same time, these stations are important urban subcenters in the Tokyo metropolitan area, with large concentrations of commercial, amusement and business facilities. This explains their high node and place values.

Moving away from the middle line, one finds the examples of unbalanced station areas. To the left of the middle line are the so-called unbalanced nodes. These are areas that have a relatively stronger node value, meaning that the workforce around these stations is relatively small compared to its distance to the CBD and its number of train connections. Tokyo Station is an example of an unbalanced node. Situated in the very heart of the CBD, it has the highest number of workers after Shinjuku Station, and the highest node value of all 99 analyzed stations. This is because Tokyo Station is not only an important transfer node in the urban network like Shinjuku Station, but also an important transfer node in the national network as it is the terminus for all high-speed railway lines in Japan.

Ueno Station is also an example of an unbalanced node. Like Tokyo and Shinjuku, it is an important transfer node in the urban transportation network of Tokyo. Its surrounding area, however, is relatively underdeveloped in terms of workforce. Other examples of unbalanced stations are Okachimachi, Machiya and Ushida. The relatively small workforces in these station areas are at least in part explained by the local context. For example, a large part of the area surrounding Ueno Station is occupied by a park and some important national museums. Furthermore, Ueno Station is located in the historical downtown district of Tokyo. It is one of the few traditional residential areas left in Tokyo, characterized by low-rise, high density wooden houses. Generally, it is the area where the working class lives. The stations of Okachimachi, Machiya and Ushida are also situated in such traditional residential neighbourhoods, which partly explains why their station areas contain relatively small workforces.

To the right of the middle line are the so-called unbalanced places. These are the station areas that have a relatively stronger place value than node value, meaning that the workforce in these stations is relatively large compared to the distance to the CBD and the number of train connections.

The stations of Kannai, Sakuragicho Urawa and Shin Yurigaoka are examples of unbalanced places. Kannai Station is regarded as the political and economic core of Yokohama and houses many governmental offices, such as the city hall, as well as corporate headquarters. Sakuragicho station is located near the Minato Mirai district, one of the main business areas in the city of Yokohama.

Around Urawa Station, many of the prefecture's governmental agencies and cultural facilities are concentrated, including the prefectural office, the city hall, the prefectural library and court, and the prefecture's convention center. The relatively strong concentration of public functions—which are less subject to market forces, including accessibility—might explain why these stations have relatively large workforces. Shin Yurigaoka station is a regional center on the Odakyu line, which extends outwards from Shinjuku to the southwestern part of the metropolitan area. Many department stores can be found around the station, as well as the public library and the ward office.

As Figure 3 illustrates, there are no "dependent" areas among the selected stations. This can be explained by the fact that only stations which fulfill a regional role in the railway network were selected for this study. A regional role implies having at least one transfer option to another railway or subway line. This does not mean that these types are not present in the Tokyo metropolis. Their number is, however, likely limited by high population densities (ranging from 4000 to 13000 persons per square kilometre), an extensive integrated railway network and market forces that determine developments. These are all circumstances that favour a transit oriented mode of development in Tokyo.

5 Model versus reality

Now that the development potential has been determined for each of the selected station areas, the question arises of whether this development potential is actually realized or not. If the station areas indeed follow the development path assumed by the node-place model, why is this so? And if not, why does the model differ from the reality? Here, not only transport and land use factors, but also other external factors come into play.

Potential answers to these questions have already been mentioned in the discussion of "unbalanced station areas" in the previous section, and may be further explored through a more dynamic examination of recent developments in three station areas, each representing one of the most extreme ideal-typical situations the node-place model distinguishes: Shinjuku Station illustrates the stressed station area; Urawa Station serves as an example of an unbalanced place; and Ueno Station represents the unbalanced node. The dependent station area is not described, as this type was not present in the station areas selected for study. Several interviews were held with officials involved and documents available on the Internet have been analyzed for this purpose. The aim of this analysis, in line with the rest of the paper, is not to predict or advise a particular development path for station areas in Tokyo, but rather to gain a better understanding of the forces that shape their development.

5.1 A stressed station area: The case of Shinjuku Station

Shinjuku is the busiest station in the world in terms of number of passengers served. Daily the station is used by an average of three million people. Shinjuku Station is an important terminal where millions of commuters coming from the western suburbs have to switch trains in order to reach the city center. Stimulated by its important strategic position in Tokyo's railway network, Shinjuku Station has evolved into one of the main urban subcenters within the Tokyo metropolitan area.

Shinjuku is identified by the node-place model as a stressed station area. This means that both the node and place functions have been used to the fullest. Improving the transport provision and/or the further development of the station area could easily cause conflicts due to the limited amount of space available.

The infrastructure investments since 2004, the year most data for the model were collected, seem to illustrate that Shinjuku will maintain and even further improve its status as an important hub in the transportation network (see figure 4). Since June 2008, a new subway line has entered service between the subcenters of Ikebukuro, Shinjuku, and Shibuya on the western section of the Yamanote line. This line, built to relieve congestion on the Yamanote line, will form an integral part of a larger regional network offering through services to the northern and southern parts of the Tokyo metropolitan area. In the new network, five railway operators use each other's tracks and share rolling stock. Out of the 13 subway lines in Tokyo, 11 offer this kind of regional through service. Another planned investment is the earlier mentioned JR Keiyo line that will be extended to Shinjuku station and eventually end at Mitaka station. The extension should be under construction by 2015. Both investments will increase the number of railway connections to Shinjuku Station, which means that at least in absolute terms the station's node value will rise farther.

As far as the place dimension is concerned, currently the south side of Shinjuku Station is being redeveloped. An artificial ground has been created above the railway tracks on which a multi- storey structure will be built. This building is to function as an integrated traffic junction and will include a highway bus facility, a taxi depot, a public parking lot, and station facilities. Furthermore, JR East is planning to construct a new building on the south side of the station, an investment that will increase the size of the workforce in the surroundings area somewhat in absolute terms.

The increase of the already high node value can be explained by the huge number of people that pass through Shinjuku Station every day. As mentioned previously, the new subway line is intended to relieve congestion on the Yamanote Line. Many private railway operators in the Tokyo metropolitan area are dealing with congestion rates of well over 180 percent on their lines. To relieve congestion, tracks are quadrupled or new lines are built. An increase in frequency of service is no longer possible without additional investments, as trains currently depart along the main commuter lines every three minutes during peak periods. The policy goal of the Tokyo Metropolitan Government is to reduce the congestion rate to 150 percent (Council for Transport Policy 2000). For this goal to be reached, additional investments are required.

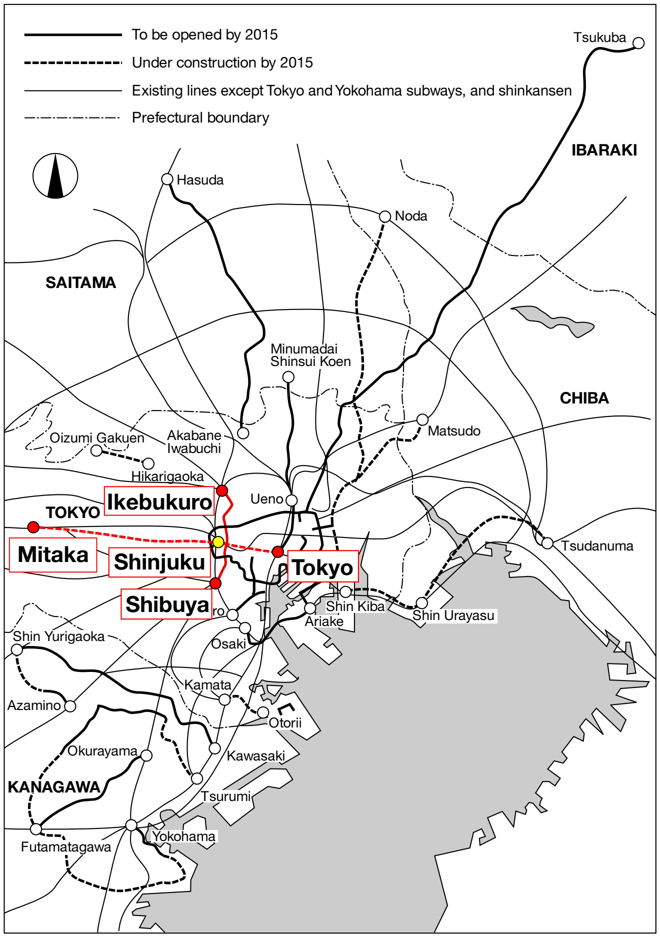

Figure 4: Shinjuku Station: Position in the railway network and investments targeted at station area. Adapted from Japan Railway & Transport Review (2000).

That the place value further increases can be explained by the fact that Shinjuku is one of the designated subcenters and as such has higher permissible FAR values. In addition, the national government has designated the area around Shinjuku Station as one of the areas where urban redevelopment is urgently needed. In these so-called "priority development areas for urban renaissance," various incentives are provided to encourage private sector investment. Last but not least, the local situation around the south exit of Shinjuku Station (traffic congestion, lack of pedestrian space, and inconvenient transfer from trains to highway buses) requires some action.

Taken together, these developments suggest that, in absolute terms, the node and place values will increase. The development direction of both node and place value seems thus to be contradictory to the expectation of the node-place model. Both developments should, however, be assessed with respect to trends in other station areas, as the model is concerned with relative rather than absolute changes. Some of these other trends are discussed below.

5.2 An unbalanced node: The case of Ueno Station

Ueno Station is an example of an unbalanced node. Following the reasoning of the land use transport feedback cycle, it should either decrease its transportation services (in relative terms) or attract more property developments. In addition also a combination of the two is possible (Reusser *et al.* 2008). Ueno station is, like Shinjuku station, one of the subcenters located around the Yamanote loop line. It distinguishes itself from the other subcenters by having a large concentration of cultural facilities in its station area, including the Ueno Zoo, the Tokyo National Museum, The National Museum of Western Art, and Tokyo National University of Fine Arts and Music. Therefore, Ueno is considered an important cultural center in Tokyo. In addition, Ueno station is also an important hub for commuters and it was formerly the terminus for the high speed Shinkansen trains connecting Tokyo with the north of Japan. With the extension of the Shinkansen network to Tokyo station in 1991, this role has diminished. Investments since 2004 show that the role of Ueno Station as an important node in the metropolitan railway network is about to change. In 2010, a new through route was established between Ueno and Tokyo Station (see figure 5), reducing travel time between the northern areas and the center of Tokyo. Passengers from three commuter lines no longer have to transfer at Ueno in order to reach central Tokyo. This may cause the position of Ueno station as an important transfer hub to further diminish in the future.

As for the place dimension, no spatial developments have occurred in the area surrounding Ueno Station since 2004. Two years earlier, however, the station itself was rearranged. Obsolete station facilities were removed and approximately 6000 square meters of additional commercial space was created. This was done in order to attract more passengers to the station; according to the station owner, Japan Railways East (JR East), the effort was successful. As no other investments are currently planned in the station area, the area's workforce is expected to remain at its current size.

Ueno Station thus appears to follow the development path suggested by the node-place model. The railway investments indicate that the station's node value will decrease, at least in absolute terms. The explanation for this is that JR East faces intensifying competition from subway companies and other railway operators who are developing their networks and services. In response, JR East is currently increasing its services, reducing its transfers, and eliminating a number of transfers.

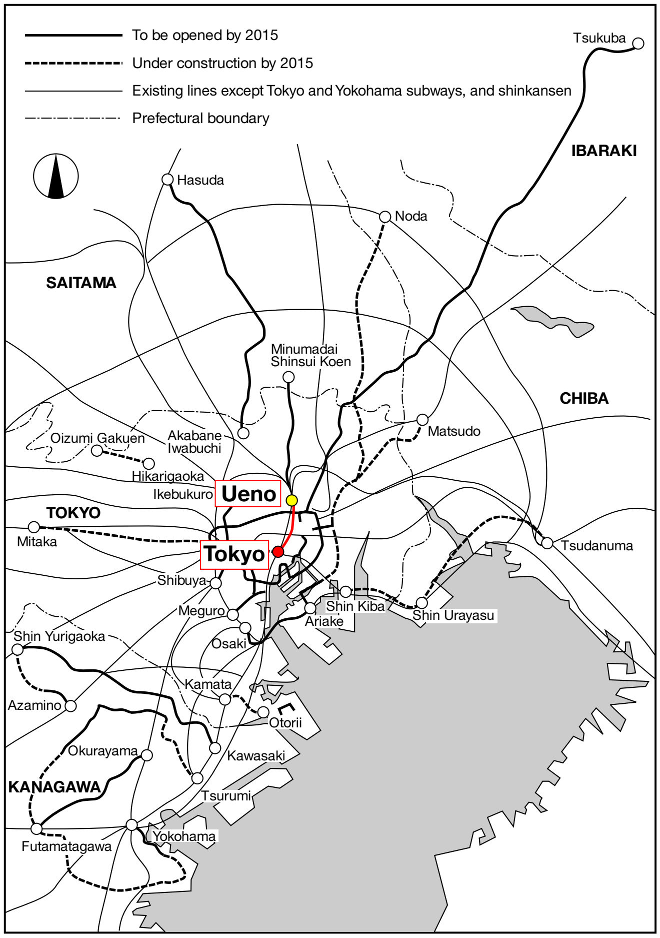

Figure 5: Ueno Station: Position in the railway network and investments targeted at station area. Adapted from Japan Railway & Transport Review (2000).

The investments carried out at Ueno Station are an example of the latter measure. JR East regards Ueno Station as just one of the stations in their network and the reduced importance of this station is compensated for by an increase in the position of another station elsewhere in their network—in this case, Tokyo Station. In the end, the number of passengers using the JR East stations will not decrease.

Considering the station's decreasing node value, the fact that the station's place value (represented by the size of the area workforce) will remain roughly the same is in line with the expectations of the node-place model. The fact that JR East generally owns little land around its stations and thus has little means to attract a significant number of new workers into the area might have also contributed to this situation. JR East was established in 1987 when the Japan National Railways was privatized. In order to pay off (part) of the enormous debt Japan National Railways had incurred during the years a large part of its land holdings were sold. As a result, there was hardly any land left to be transferred to JR East. Therefore, JR East mainly focuses its investments on the efficient utilization of the station building itself and of its railway tracks. The latter is done by using either the space above or underneath the railway tracks. Furthermore, the government seems not to regard the Ueno area as a priority; unlike many other subcenters, no special policies have been developed for the area.

5.3 An unbalanced place: The case of Urawa Station

Urawa is an example of an unbalanced place. This station should, following the reasoning of the land use transport feedback cycle, either increase its level of train services or develop in a lower- density fashion (in relative terms). In addition, also a combination of the two is possible (Reusser *et al.* 2008). The area around Urawa Station is an important government center, with many of the prefecture's governmental offices such as the city hall and the prefectural office and court, concentrated nearby, as well as the prefectural library.

Currently, Urawa Station and the railway tracks within 1.3 kilometers of the station are being elevated. The elimination of at-grade crossings will alleviate chronic automobile and pedestrian congestion. Along with the elevated railway tracks, a new passenger platform will be built for the Tohoku passenger and freight trains that currently pass through the station. Also, the Shonan Shinjuku line running between Omiya in northwestern Tokyo and Ofuna in the southwestern part of the city will be able to stop at Urawa in the future. Previously this was not possible, as the line ran on tracks originally laid only for freight trains and lacked passenger platforms. The elevation of the railway tracks will make it possible to increase the number of trains, especially during rush hour. Furthermore, it will improve the access for passengers wanting to travel towards Ikebukuro and Shinjuku as the Shonan Shinjuku line will directly serve both stations from Urawa in the future.

In the comprehensive development plan for Saitama City, Urawa Station is regarded as an urban centers. The area around the station is being redeveloped in conjunction with the railway elevation project. In the vicinity of the station area, four redevelopment projects are underway or have been completed. One project, completed in 2006, involved the construction of a residential high-rise building of 31 stories and another of nine stories. This is a typical example of the many urban redevelopments that have been carried out in recent years around station areas. An explanation for this is that the areas along railways are usually the oldest parts of the city. There are still many low-rise, high-density areas dominated by wooden buildings near railways, which are inefficiently used and at the same time vulnerable to damage from earthquakes.

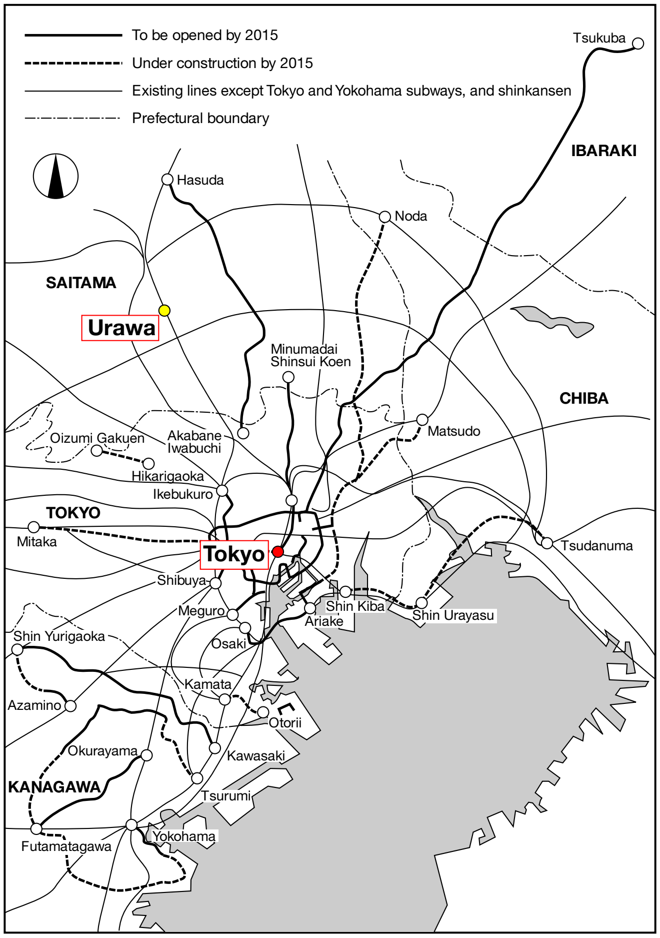

Figure 6: Position of Urawa Station in the railway network. Adapted from Japan Railway & Transport Review (2000).

In order to make these areas more efficient in terms of land use and layout, the low-rises are being replaced by high-rises.

The area around the east exit of Urawa Station has been redeveloped as well. A public square and an underground parking area were completed in 2007, followed by a mid-rise building of ten stories in 2008 housing a department store, a cinema complex, and community facilities.

Taken all together, these developments suggest that (at least in absolute terms) Urawa's node value will increase while its place value will not increase in absolute terms (no significant growth in workforce) and possibly decrease in relative terms (as the workforce in other station areas grows). Both values seem to develop in line with the expectations of the node-place model. Because the redevelopment projects around Urawa Station mainly concern residences, they have little effect on workforce concentration and thus on the place value as defined in this application of the node-place model. However, this situation could change in the future. The prefectural government of Saitama regards Urawa as an important urban center and accordingly has assigned the station area higher FAR values than its surroundings. In this way, the government hopes to promote the further development of the area. Whether this will actually happen remains to be seen.

The railway investments indicate that, at least in absolute terms, Urawa's node value will increase in line with the expectations of the model. This can be explained by the chronic traffic congestion that made it almost impossible to cross the railway tracks, especially during peak travel periods. Removing this barrier was the only option to eliminate the traffic congestion. The elevation of the railway tracks made it possible, in turn, to build a new passenger platform that allows more trains to stop at Urawa Station. Subsidies provided by the national and local governments for grade separation projects and for the comprehensive improvement of railway stations may also have encouraged JR East to carry out this investment.

6 Discussion and conclusions

The node-place model has been used to gain insight into the development dynamics of 99 station areas in Tokyo. More specifically, it has been used here to identify the transport and land use factors responsible for structuring station area redevelopments, and to determine the extent of their influence. In addressing the first question, correlation analysis has revealed that the combination of proximity by rail to the CBD and number of train connections relative to workforce size (model M14) appears to have the strongest influence and is thus evidence of a powerful force shaping station area redevelopments in Tokyo.

In order to address the second question, three cases of station area redevelopments have been analyzed to find out whether or not the development path expected by this node-place model is unfolding, and why. The analysis has demonstrated that, at least in absolute terms, Ueno and Urawa seem to be developing in line with the expectations of the node-place model. In these cases, the development dynamics can be explained by following the reasoning of the land use transport feedback cycle defined in this paper. However, in the case of Shinjuku (and possibly Urawa in the future), factors that seem to play an important role fall outside the scope of the node-place model and the transport land use feedback cycle in general. Government policies have played an important role in triggering redevelopments around Shinjuku Station, as they may in the future at Urawa Station. Both stations were accorded special status by the government, and this has benefited them greatly in terms of permissible FAR values. Furthermore, local conditions such as chronic traffic congestion, (in the case of Shinjuku) a lack of pedestrian space, and an inconvenient transfer from train to highway buses have stimulated redevelopment. Finally, subsidies provided by the national and local government for comprehensive redevelopment and grade separation projects have encouraged redevelopment, especially in the case of Urawa Station.

As the three examples have illustrated, the node-place model cannot predict development, but can be used to gain a better understanding of development dynamics. Without the node-place model, we would not be able to determine the relative position of a station within the urban regional network. This would have made it more difficult to explain their actual development patterns. However, some critical remarks can be made about the node-place model. First, the balancing measures proposed in line with the thinking of the transport land use feedback cycle are not always realistic. Reducing transportation services is not likely a measure anyone will suggest under any market conditions, as this would entail a great loss of the value of previous investments in both transit and the built environment. It is equally unlikely that downsizing of developments will occur in metropolitan areas that are looking for ways to promote transit-oriented development. In Tokyo, for example, the scarcity of land (especially the central areas) precludes such an approach. In addition, many areas in Tokyo are characterized by inefficient land uses and an inefficient spatial layout. As discussed previously, many of these areas are situated along railways and have been or are currently being redeveloped and provided with much wider roads. The government is stimulating the redevelopment of these low-rise high-density areas by rewarding developers with higher permissible FAR values in exchange for carrying out particular investments such as providing public roads or parks in these areas.

Upgrading is therefore a more likely balancing measure than downgrading. The node-place model might, then, help in discovering locations suitable for development in the metropolitan area. For example, the application of the node-place model in Tokyo identifies a range of locations (the unbalanced nodes and places) that could serve as "natural" alternative development locations for the overcrowded Central Business District. An insight into these alternatives could help the government promote balanced growth throughout the Tokyo metropolitan area. More specifically, the node-place model could help the Tokyo Metropolitan Government realize its new city planning vision of the "Circular Megalopolis Structure." This structure focuses on the development of a framework of circular loops linking a number of core cities around central Tokyo. The core cities are the places where urban functions should be concentrated, while the urban axes should promote exchange between them. The government hopes that this new structure will lead to a greater functional and overall efficiency within the metropolitan area. Furthermore, it hopes that such a structure will contribute to creating a city where workplaces and homes lie in close proximity. In effect, it means that employment is to be promoted outside central Tokyo and residency is to be promoted in the city center. The node-place model could be useful in this context by pointing out the locations where opportunities for developing employment or transport services are greater, because there is enough transport provision to accommodate employment growth and vice versa.

On the land use side, the government could stimulate the development of these locations by assigning them higher FAR values than their surroundings and by providing road systems that make it possible to actually build such volumes. However, the latter measure can be especially time-consuming and expensive as large parts of the built-up area in Tokyo are still characterized by narrow roads. Widening the roads will arouse considerable community opposition, as it may disrupt entire neighbourhoods.

On the transport side, the position of stations in the network could be further improved by establishing new connections with other railway lines and by increasing the number of rapid services thereby reducing travel time and the number of transfers.

Last but not least, we recognize the limits of the specific application of the node-place model in this paper. Three cases cannot give sufficient insight into the development dynamics of station areas within a metropolitan area. For this, a more systematic analysis is needed in, ideally including analysis of development in all station areas that make up the metropolitan railway network. Also, showing how stations develop over time would make it possible to determine whether or not the development dynamics follow the expectations of the node-place model. Such an analysis has already been carried out for the Amsterdam region over the period of 1997-2005. The patterns identified there seemed to confirm the development patterns expected by the node-place model in general terms (Bertolini 2008). A systematic comparison of the Tokyo application of the node-place model with the Swiss application by Reusser *et al.* (2008) and the Dutch applications by Bertolini (1999, 2008) would be very interesting as well. The present applications, however, are too heterogeneous to allow this.

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