INFRASTRUCTURE COSTS AND URBAN SPRAWL – AN INTERNATIONAL CASE STUDY

Stefan Klug, Fraunhofer Institute for Systems and Innovation Research (FhG-ISI), S.Klug@isi.fhg.de

Yoshitsugu Hayashi, International Research Center for Sustainable Transport and Cities (SUSTRAC), Graduate School of Environmental Studies, Nagoya University, yhayashi@genv.nagoya-u.ac.jp

ABSTRACT

Urban dispersion processes in metropolitan areas have led to patterns of suburbanisation and urban sprawl. German agglomerations, which are conventionally characterised by a rather polycentric and dense urban structure, are now facing the challenges of urban scattering towards agricultural areas at the urban fringe. In contrast, Japanese urbanisation has been characterised by a mix of agricultural and urban activities since the 1960s. These processes are inseparably connected with the shift of private mobility from green transport modes to cars. Urbanisation is always accompanied by the development of physical infrastructure, which requires huge investments, determines the structure of a city over long periods of time and cannot be readily adjusted to changing demand patterns. Thus, the impacts of urban sprawl on providing and funding local urban infrastructure represent complex and important issues to be considered in this context. This comparative study, conducted for the metropolitan regions of Nagoya in Japan and Munich in Germany, confirmed the impacts of density and other parameters of urban sprawl on public costs. The saving potential, which was calculated as the cost difference between the most infrastructure efficient and most intensive municipalities, is 85% on average for Munich and 57% for the Nagoya region for sewage, primary schools and local roads.

Keywords: Urban sprawl, financial impact, local infrastructure, public costs, infrastructure efficiency, Nagoya, Munich

INTRODUCTION

Urban dispersion in metropolitan areas has led to dispersed land use patterns. Suburbanisation and urban sprawl have many causes and effects, which are often interrelated and thus difficult to distinguish. These are closely linked with the shift in private mobility from green transport modes to cars (urbanisation-motorisation nexus). In terms of financial sustainability, a sprawling land use pattern triggers various economic effects on different levels and for the different economic agents concerned. A major share of the costs involved has to be borne by the public sector, which has to provide and fund most of the local urban infrastructure. Infrastructure assets require huge investments, determine the structure of a city over long periods of time and cannot be readily adjusted to changing patterns of demand.

Moreover, the public sector is subject to declining tax revenues and a growing financial burden due to a shrinking and ageing population. Several studies have shown that the main problem of the increasing public cost of sprawl concerns the costs for additional infrastructure. Development in existing urban areas can generally be serviced by the existing infrastructure and utilities, provided there is sufficient excess capacity, whereas greenfield development usually involves substantial extensions of these systems (Burton 2001, p. 225). Additional transport infrastructure, utilities and facilities for certain age groups are necessary when new residential areas are developed. These costs generally arise if urban development takes place in a dispersed manner towards the municipal borders.

German agglomerations, which are conventionally characterised by a polycentric and dense urban structure, have been facing the challenges of urban scattering towards agricultural areas at the urban fringe for several decades now. This is different to Japan, where urbanisation has always been characterised by a mix of agricultural and urban activities. However, both countries are experiencing the phenomenon of population decline with the consequence of decreasing public budgets, which focuses public interest on the financial sustainability of urban infrastructure.

These processes can best be described by the terms 'suburbanisation' and 'urban sprawl', depending on the spatial scale considered: Suburbanisation is the *regional* process of both population and employment migrating towards the urban fringe. This process is often accompanied by a specific local pattern of dispersed urban development – 'urban sprawl'. This is a '*physical pattern of low density expansion of large urban areas under market conditions mainly into surrounding agricultural areas. Sprawling is the leading edge of urban growth and implies little planning control of land subdivision*' (EEA 2006). This definition shows that sprawl is more complex than just a low level of urban density. In 'costs of sprawl' studies, sprawl is seen as "the occurrence of growth in places where it is difficult to provide public services, i.e. significant residential and non-residential development in rural, undeveloped and developing suburban areas" (TRB 2002: 43).

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AIMS AND APPROACH

Objective and Scope

Although several studies on the social or public costs of urban sprawl exist, there is little evidence of the effect of other sprawl parameters beyond density. Moreover, there is no international comparative study of entire metropolitan regions involving all the municipalities in each region. The hypotheses of this research are

1. Public infrastructure costs are influenced by certain parameters of urban sprawl and private mobility.
2. Sprawled municipalities have to bear higher specific public infrastructure costs per user – independent of national framework conditions.

Hence, the primary objective is to develop an appropriate methodology to evaluate the financial impacts of urban sprawl and mobility, and test this with empirical data in order to derive the underlying mechanisms of the local public costs of urban sprawl for two international case studies - the metropolitan regions of Munich in Germany and Nagoya in Japan.

Research Approach

The impact of certain parameters of urban sprawl and mobility on the public cost of local infrastructure is estimated. As an indicator for these costs the extension of local infrastructure networks is analysed. After understanding the relation between sprawl/ mobility and infrastructure costs, the saving effects are estimated for each region by comparing the most infrastructure efficient and intensive municipalities (interregional comparison). In addition, suggestions are made for shifting residential urban development towards more cost-efficient locations which involves the improvement and application of combined planning and fiscal measures.

Stepwise multivariate regression modelling has been applied in order to specify the financially relevant spatial effects. The parameters are derived from a literature review. Sprawl and private mobility are operationalised by eight distinct parameters, and the financial impact is tested using infrastructure complexity data as cost indicators. Data are taken from statistical sources and geographical databases.

BACKGROUND AND METHODOLOGY

Urban Development and Transport

The problems associated with urban development started in both countries after the 2nd World War. Suburbanisation, urban sprawl and motorisation were negative side-effects of economic growth, which was accompanied by production expansion, income growth, and urbanisation (cf. Hayashi 1996)[1]. This process occurred very intensively in the case of Japan: rapid economic growth went hand in hand with rapid urbanisation. As a result, almost half of Japan's population lived within a 50-kilometre radius of the major metropolitan areas of Tokyo, Osaka, and Nagoya by the end of the 1980s. Though living standards in Japan have risen rapidly, new problems have also arisen, including housing, and growing urban dispersion (Shibata 1987, p.9, 17).

A similar process can be observed for urban areas in Europe. From the mid 1950s, European cities have expanded on average by 78%, whereas the population has grown by 33%. The data also clearly shows that this trend has accelerated since the end of the 1990s: the rapid increase of urban areas and infrastructures has consumed more than 8000 km^2, about the size of Luxembourg (EEA 2006, 2009). According to EEA (2006), suburbanisation and urban sprawl have particularly affected:

- countries or regions with high population density and economic activity (Belgium, Netherlands, Southern and Western Germany, Northern Italy, the Paris region),
- regions, cities that experienced rapid economic growth and/ or high population density (Ireland, Portugal, Eastern Germany, and Madrid region), and
- smaller towns along new transportation corridors or/and along coasts connected with river valleys.

The ESPON (2010) FOCI Project identified two main processes leading to urban sprawl: the first is the aggregation of existing small scattered settlements around a main urban agglomeration; the second is the creation of new built-up areas spread over agricultural land in the vicinity of an urban centre.[2]

The Japanese 'urban transition' process, however, is similar to that of the whole Asian region, and is characterised by an intense mix of agricultural and non-agricultural activities i urban sprawl is often found in the perimeter regions of giant cities and sometimes in the form of corridor development adjacent to main roads and railways that link reasonably close, large cities (McGee 1989, p. 94).[3] Consequently, the sprawled zone is directly connected to the urbanised, often densely inhabited core zones, whereas in Europe (and North America) suburbs tend to form first, and urban sprawl then arises in-between or beyond this suburban development.

Both suburbanisation and urban sprawl interact closely with private mobility. Due to the increasing separation of functions, the complexity of daily activity patterns increases. This is fostered by the trend of out-migration. Families migrating from the core to peripheral areas often still have social or employment links to their former residential areas. Motorisation and urban sprawl are potentially influenced by the same causal factors. Wegener (2005:2) stated for Germany:

> "It is generally believed that the private automobile has been the primary cause of the expansion of cities. However suburbanisation and urban

[1] The complex effects of economic development, motorisation, suburbanisation and the environment were illustrated in Fig. 3 of HAYASHI 1996: 7.

[2] For more details about the phenomenon of urban sprawl across Europe, see Braun *et al* (2010).

[3] At the beginning of the 1990s, this pattern was called 'kotadesa' or 'desakota' by the geographer Terry McGee and other theorists. He formed this word by combining kota and desa, which mean town and village, respectively, in Bahasa Indonesia. Other suggested terms include 'extended metropolis' or 'dispersed metropolis', but the need for a unique English-language term remains (Ginsburg 1991, p. xvii).

> sprawl is not caused by the car but has been the consequence of the same changes in the socio-economic context of urban life that were also responsible for the growth in car ownership: increase in income, more working women, shorter work hours and a consequential change in life styles and housing preferences."

In Europe and Japan, cities have begun to sprawl only recently because the urbanisation pattern has been strongly influenced by public transportation systems, mainly railways (Batty *et al.* 2003, p. 9; Hayashi *et al* 1994, p. 69). In Japan, the railway companies only started seeing serious competition from private automobiles in the late 1970s, whereas in the US, the average working family commonly already owned a car in the 1930s (Sorensen 2002, p.142). However, widespread car ownership took off in the second half of the 1980s in Japan and, nowadays, motorisation trends are very similar in Germany and Japan when comparing the national average ownership rates of 440 (Japan) and 550 (Germany) passenger cars per 1000 inhabitants (MIC 2006: 107, UBA 2007). Thus, increasing dispersion of land-use patterns goes hand in hand with the increasing role of cars for private mobility in Germany and Japan.

Parameters and Financial Impacts of Urban Sprawl and Mobility

For a systematic analysis of the effects of urban sprawl and mobility, a definition of sprawl is necessary which is based on measurable indicators. A study by Galster *et al* (2001) defines sprawl as a condition of land use that is represented by low values on one or more distinct dimensions. Most of them are taken into account when modelling the financial impact of different aspects of urban sprawl on local infrastructure configuration.

Parameters

One core parameter of urban sprawl is *density*. However, many studies accentuate the danger of focusing on an administrative district, such as the municipality, as a nominator for density. Kasanko *et al* (2006, p. 114) stated that one must be cautious when comparing overall population densities in various municipalities, since the administrative areas vary so considerably. Moreover, the boundary of the municipality does not always coincide well with that of the urban area, so that gross density measures reveal little about the density of the built-up parts of a city (Burton 2001, p. 229-30). This is also true for the case study municipalities, so that the urban area will be taken as the nominator for density within this study. Next to the urban form and land use, the utilisation of the available residential living space is also an important indicator considering its potential impact on specific infrastructure costs. Two indicators are taken to account for the different dimensions:

- Urban Density (UD, = sum of population and employed population divided by urban area).
- Housing Density (HD, = number of persons divided by residential floor space).

According to the comprehensive sprawl definition by Galster *et al* (2001), the following measurable indicators of urban fabric play an additional role:

- Centrality (cen = size of densely inhabited areas[4] in total urban area),
- Concentration (conc = size of the largest 'independent settlement'[5] in relation to total urban area),
- Nuclearity (nuc = number of 'independent settlements' within the municipality), and
- Continuity (cont = average size of 'independent settlements' within the municipality).

Private transport is very closely linked with urban sprawl. Previous findings show that car use is significantly lower in higher density city areas at all levels of wealth (cf. Newman and Kenworthy, 1989, Hayashi *et al* 1994). However, in this study, the focus of interest is on the effects of certain driving forces of urban sprawl. These also include *private mobility* based on the following indicators:

- Motorisation (CO = number of cars per 1000 inhabitants in each municipality), and
- Modal split (MS = private trips made by rail in relation to total trips originated in each municipality),

Financial Impact

The financial impact of urban sprawl is estimated by analysing the complexity of important infrastructure stock items on a municipal basis. These represent the level of infrastructure supply (e.g. specific length of the sewage system) and act as a cost indicator in the analysis. The data are entered in terms of length and covered area of networks in relation to the number of users. The most important infrastructures for the municipal budgets are:

- local roads (*data sources: MiC 2008c, MiC 2008d, RPV 2002*),
- water supply network, (*data sources: Aichi-ken 2004, Gifu-ken 2005, Mie-ken 2005*)[6],
- sewage network (*data sources: Aichi-ken 2004, Gifu-ken 2005, LStAD 2008a*),
- kindergartens (*data sources: Aichi-ken 2004, Gifu-ken 2005, Mie-ken 2005, LStAD 2005a*), and
- primary schools (*data sources: Aichi-ken 2004, Gifu-ken 2005, Mie-ken 2005, LStAD 2005a*).

[4] For the Japanese case study the DID-area is taken (MiC 2008a), whereas in Germany the 'higher' and 'high density' areas are used according to the geographical database of the Munich Region (RPV 2002).
[5] 'Independent settlements" are characterised by a contiguous built-up area according to GIS areal picture interpretation from 1999/2000 (RPV 2002) and GIS Land Use Survey data of 1997 (MLIT 2007).
[6] No data were available for Munich so that this infrastructure item is only integrated in the Japanese models.

Whereas the network infrastructures (sewage, roads) are divided by the total number of users (inhabitants plus employees), the schools are only used by the inhabitants, so they are divided by the resident population.

Interregional Comparison

One outcome of the analysis of fiscal impacts is the option to rank the municipalities according to their infrastructure efficiency, considering only those infrastructure items which influence could be proved for one or more parameters of urban sprawl or mobility. The 'Top5' and 'Bottom5' in each region are taken as samples for the interregional comparison, which allows deeper analysis in terms of the differences in each parameter of urban sprawl and public cost. For this purpose the sample size had to be adjusted for the Nagoya region. Since many municipalities here have recently merged and merging often leads to inefficiencies in the first years of the newly created community, the real cost values are regarded as not being representative. Moreover it seems appropriate to exclude municipalities for the deeper analysis that already existed in 2005 but do so no longer due to recent amalgamation. Thus they were also excluded before ranking. For the remaining limited number of municipalities, more specific cost data have been evaluated in order to determine the real spending associated with sprawl-relevant infrastructure over the previous 10 years. If these data are known, the saving potential of changing sprawl and mobility parameters can be estimated for each country. Fig. 1 shows a summary of the indicators used for the comparative quantitative analysis.

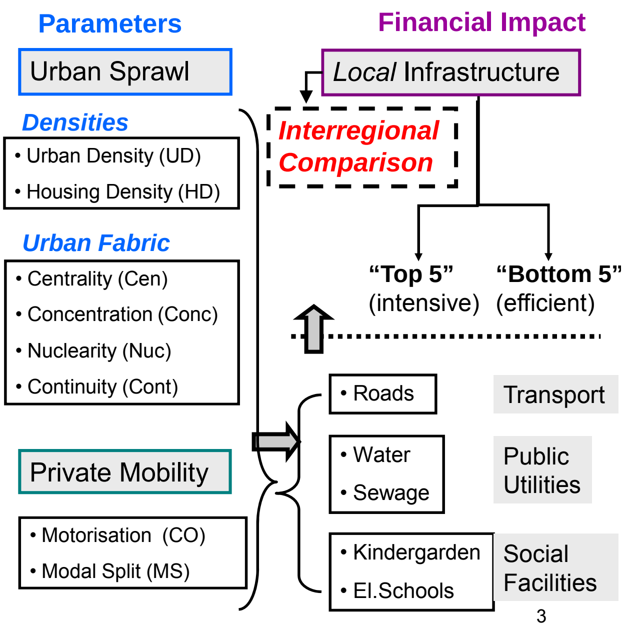

Figure 1 – Analytical Approach

SPATIAL PLANNING AND INFRASTRUCTURE FUNDING IN JAPAN AND GERMANY

As pointed out above, urban sprawl is the result of several diving forces and it influences local infrastructure costs. However, when comparing the situation in two countries, qualitative aspects also need to be considered. First of all, spatial planning systems differ so that urban planning and planning control also has a different role in preventing sprawl in both regions. Secondly, the provision, standards and funding of public utilities and social facilities differ in each country, which influences the financial impact of sprawl.

Regional and Urban Planning

In the early stage of urbanisation, several measures were undertaken in Europe to control urban growth - for example, the introduction of 'garden cities' and the delineation of green belts. When the urban problem became more serious in Japan in the latter half of the 20th century, politicians were able to learn from the successful strategies in Europe and tried to implement those measures. Many 'New Towns' were planned in the 1960s to relieve the agglomerations and the Green Belt around Tōkyō was also part of the official Development Plan.

These early responses to the rising problem of urban sprawl are now considered to be rather short-sighted, since they were based on the simplistic assumption that growth could be halted. The European green belts and urban cordons served to preserve open land, but not halt growth which simply leapfrogged over them (Batty *et al* 2003, p.11). Thus, at the beginning of the 21st century, sprawl is perhaps the biggest problem facing urban planning in both countries. It encapsulates the key problem of urban transportation which revolves around the car as the dominant means of travel. It focuses attention on the problem of preserving and conversing the already established infrastructure, such as transit oriented developments and historical road links. It also includes the problem of declining environmental quality as the countryside is 'paved over'.

Urban development and design differ greatly between the two countries. In contrast to the Japanese style of 'growth control', urban planning in Germany is broadly defined as the consciously goal-oriented and normative thinking and designing of urban areas within a specific historical, cultural, social, economic and location-sensitive context (Hohn 2000, p. 17). Germany has a long tradition of urban planning, with land-use zoning being applied since the end of the 19th century when it was first introduced by several cities (e.g. *Staffelbauordnung* in Munich). Urban planning is split across different hierarchical public bodies based on the 'counter flow principle' (*Gegenstromprinzip*). This describes the mutual interaction of local and trans-local, and regional and trans-regional planning. Accordingly, the organisation of smaller spatial units should be adjusted to those of the total area. On the other hand, the organisation of the total area also needs to consider the situation and requirements of smaller units (RPV 2005). In order to enable similar living conditions throughout the state, the federal government is eligible to issue planning regulations. The most important local planning instruments are the 'land utilisation plan' (*Flächennutzungsplan, F-Plan*) and the 'legally binding land-use plan' *(Bebauungsplan, B-Plan*) based on the Federal Building Code (*Baugesetzbuch*) (see ARL 1995).

Japanese urban patterns appear quite 'chaotic' from a Western point of view. Impressive scenery is often interspersed with built-up areas and facilities of all kinds and traditional localities are often 'compromised' by multi-storey apartment blocks. Thus, the question arises as to whether any important elements of spatial planning actually exist, such as the strict distinction between developable and non-developable areas (Schwarzenbach *et al.* 1991). Indeed, Japan has constantly borrowed from Western ideas and techniques, transformed, and combined these with other local traditions which has resulted in a planning system that is different both in conception and in execution to that in any other developed country (Sorensen 2002: p.5).

The Japanese planning system is generally described as a method of 'urban growth control' and its legal basis is the City Planning Act enacted in 1919, and revised in 1968. After the revision, urban growth boundaries were implemented by stipulating that every municipality should define a City Planning Area and divide it into an *Urbanisation Promotion Area (UPA)* and an *Urbanisation Control Area (UCA).*[7] This aims to prevent disorderly urbanisation and promote appropriate urban development by securing a certain quality of public facilities (Nagoya city 2002, p.65). UPA areas have been defined as land where urban development generally exists and where planned urbanisation is volitional within the next 10 years; within these areas, land has been subjected to use-specific zoning (*yôto-chîki-seido*) in accordance with the Building Standards Act. UCA, on the other hand, are characterised by contiguous tracts of farmland totalling 20 ha, and woodland areas of 100 ha and more. Only developments or "transactions of land that fulfil approved purposes" are allowed here (Jacobs 2002, p.186). This is supposed to guide and phase prefectural and municipal growth more efficiently. Moreover, a development permit system was instituted to ensure greater concurrency between infrastructure capacity and new land development. The prefectures became involved with the establishment of prefectural City Planning Councils, which order the municipalities to designate UPA and UCA within the delineated City Planning Areas (Jacobs 2002, p.186). Other important laws are the Agricultural Promotion Areas Act and the Nature Conversation Act (Barett and Therive 1991: 63).

Although the planning instruments in both countries appear similar, there are noteworthy differences in their impacts on planning practise. In Germany, the B-Plan has to be developed from the framework conditions of the F-Plan, and urban development generally requires the existence of a B-Plan or a B-Plan-like instrument with very few exceptions. In Japan, land-use zoning is also regularly applied for the defined UPA, whereas the UCA is supposed to be mainly used for agricultural land. For this reason, the UCA sites do not have public sewers and partly do not have access to water mains. However, as a result of differences in land prices in UCA and UPA, municipalities and other public authorities have often exploited the UCA as a reservoir of relatively cheap land for schools, hospitals and industrial centres (Hebbert 1994, p. 83). Thus, many Japanese suburban municipalities show a common structure: While the built-up area is expanding rapidly into the neighbouring farmland, their internal structure remains loose-knit, with large areas of undeveloped land also within UPA. Landowners in UPA follow a rational strategy of portfolio management when they put just a small proportion of their plot onto the market and leave the rest undeveloped as long as possible (Hebbert 1994, p. 77).

Urban planning aims to influence the urban form and the way land is used. According to Hohn (2004), it is indisputable that urban and regional development requires political control rather than being subject to market forces, which are usually blind to social and ecological matters. Japanese planning practice does not apply restrictive building regulations, the individual wishes of building owners are often prior-ranking (Kaltenbrunner 2001). Japan *does* have a comprehensive and extensive system of planning instruments, but their practical application is another issue and often a problem. Moreover this system is only a long-term policy tool, because the absolute rate of land-use change is slow in relation to other options

[7] According to the City Planning Act of 1968, municipalities have to be demarcated in already built-up areas, or those expected to become so within a decade (UPA) and 'Urbanisation Control Areas' (UCA, *shigaika-chōsei-kuiki*) where, in the words of the Act, 'no development is allowed in principle, so as to control the disorderly expansion of the urban area' (Hebbert 1994, p. 7, for the newest development: Hohn 2000p. 614).

as pointed out by McLaren (1992, p.273) for the UK. However, there are significant international differences in terms of the renewal rate of the built environment. The White Paper on Land Use, Infrastructure and Transport in Japan found that the average lifetime of buildings is only 26 years compared to 44 and 75 years in the USA and UK, respectively (MLIT 1996).[8] The latter value can be regarded as the European standard and therefore also applied to Germany by analogy. This age difference also has a strong influence on the infrastructure: Its renewal rate is much higher in Japan, provoking higher investment, but with lower maintenance costs than is the case in Germany.[9]

Local Infrastructure Funding

In economic theory, infrastructure is defined as part of the real capital stock, which enables productivity in the economy. Developing infrastructure often requires large initial investment, since it forms the basic physical systems of a country's or community's population. These are all the facilities, equipment and materials necessary for energy supply, transport, telecommunications, and the protection of natural resources. In addition, it comprises educational, scientific, health-related, and social facilities. Infrastructure has the character of a public good, meaning that market mechanisms are not appropriate for its allocation. Often, the price for using infrastructure can only partly cover the costs of its provision and maintenance, which would otherwise become too high for users. The remaining costs are usually covered by general tax revenues (Jochimsen and Gustafson 1970).

Local (physical) infrastructure is the sum of point and network infrastructure and utilities including public and semi-public facilities: roads, bridges, public mass transportation systems, water, electricity, and other public utilities, postal services, and sewage, among others. Social facilities are also included, e.g. hospitals and medical institutions, educational institutions, judicial and police systems, public administrative services, and financial and monetary institutions. As far as their services and benefits are limited to the community, these items make up the local public infrastructure.

In Germany, the construction, connection and allocation of all the necessary local infrastructure for new urban development (*Erschließung*) is basically a municipal task (§ 123 BauGB). The legal definition comprises the provision of necessary sites for transport, green areas, water supply, waste and sewage treatment and disposal and the construction of these facilities. Thus, it includes *public utilities* and t*ransport infrastructure*, but not the secondary infrastructure or *social facilities* (‘Folgeeinrichtungen’) (Gassner and Thünker 1992, p. 2). However, the size and distribution of social facilities are also partly influenced by the degree of urban sprawl and mobility, so that they are part of the analysis.

Infrastructure is a basic charge for local governments in both countries. Municipalities are, in principle, responsible for all matters directly affecting everyday life. These include activities in the areas of social affairs, education, leisure (sport facilities, swimming baths) and technical issues such as waste disposal (refuse and sewers), water supply. This is valid for Germany (BBR 2000, p. 10) and Japan (Ozaki 2005, p. 23). The revenue and expense structure of municipalities is similar in both countries – municipalities require about half of their revenues

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[8] This issue has been evaluated by kato *et al* (2003, p. 25). The authors investigated the social capitalisation and urban space quality for Nagoya in their study
[9] This was proven by comparing the respective sectors of the municipal budgets in both case study regions.

from local taxes and spend the biggest share on civil works, social welfare and education. In both cases, social facilities are funded by general tax and transfer revenues. However, the investment and maintenance of local roads and utilities is funded differently. In Germany, it is partly recovered by the beneficiary due to specific charges. In Japan, only the privately operated utilities rely exclusively on private charges. Other local infrastructure is mainly financed by general revenues or transfers from other governmental bodies, earmarked for specific purposes.

THE CASE STUDY REGIONS NAGOYA AND MUNICH

The choice of example regions in Japan and Germany is based on the following considerations. Both countries contain prospering monocentric conurbations with a forecasted population growth – at least in short to medium term. Consequently, it is necessary to prevent further urban sprawl as the result of the ongoing urbanisation dynamics. Clear evidence of the saving potential in infrastructure costs can aid in applying planning and financial instruments appropriately. The metropolitan areas were defined according to the 'functional urban region' in both cases. Thus, the result of the analysis can act as the basis for a feasible and effective urban policy concept.

Both cities are characterised by their historical importance and current high level of development. Moreover, both cities are facing certain driving forces of suburbanisation and urban sprawl: In the past 20 to 25 years, "Nagoya suffered from extremely high land prices, cramped housing, and a scarcity of open space." (Jacobs 2002, p. 180) Also Munich's biggest problems are related to housing. The extent of the housing shortage, especially for lower income groups, is regarded as an extreme particular case in Germany, since the city and region are relatively attractive as a place to live and work (Munich city 2008).

Central Japanese Region Nagoya

The Japanese study example is the Chukyo Region with *Nagoya* in its centre. Japan's third biggest region is the only monocentric major metropolitan region and is less complex spatially than either the Tōkyō or Ōsaka regions. By carrying out several Urban Regeneration Projects, the city government of Nagoya aims to strengthen the city and break away from its image as a modern functionally-planned industrial city (Fukushima 2003: 1). Nagoya city is a little more than 300 km^2 in size - about the same as Munich city. Nagoya is located within the core area of Japan - the Tōkaidō Megalopolis - named for the almost continuous stretch of urbanisation that extends along the old Tōkaidō highway between Tōkyō and Kyoto. Nagoya was founded in 1609 as a planned, fully-fledged fortified city, and became the chief administrative and commercial centre of a major feudal domain when Japan was ruled by the Tokugawa clan. The heart of the city was destroyed by Allied air raids at the end of 1945 (Eyre 1982, p. 13). The inner city area was redesigned in large-scale land readjustment projects and in general agreement with the landowners. Nagoya has been accorded special status in Japan since 1956 when it became a *Government Ordinance Designated City.* Nagoya was granted development planning responsibilities and powers similar to those afforded to prefectures in other areas (e.g. development permission for bigger projects) (Jacobs 2002: 183).

With regard to the study objective, it is also necessary to consider both the functional relations of the surrounding municipalities to the core city as well as the exclusion of municipalities with a rural character.[10] One popular definition of the region regularly applied by the Population Census Committee is the 'Chūkyō Major Metropolitan Region' (*Chūkyō Daitoshiken*) that includes all the surrounding municipalities if at least 1.5% of their adult population commutes to the core city of Nagoya for work or education. This region comprises almost 100 municipalities in an approximately 50 kilometre range from the Nagoya City Hall according to the latest survey (MIC 2005). However, to ensure international comparability, the same 'urbanisation indicator' has to be applied as in Munich, focusing on the share of urbanised area in total area. Taking the average of the prefectures Aichi, Gifu and Mie (usually referred to as the Chubu Region) as a reference value, eight municipalities located at the urban fringe are excluded from this investigation.[11]

Munich Region in Bavaria

It is thought that *Munich* was founded in the year 1158 and gained its historical significance in the 16th century when it became capital of the reunited Bavaria in 1506. The city was then the capital of the new 'Kingdom of Bavaria', with the state's parliament (the *Landtag*) and the new archdiocese of Munich and Freising located there. Many of the city's finest buildings belong to this period and were built under the first three Bavarian kings. The city later became a Nazi stronghold when the National Socialists rose to power in Germany in 1933. Just like Nagoya, the city was very heavily damaged by Allied bombing during World War II. After American occupation in 1945, Munich was completely rebuilt following a meticulous and - in comparison to other war-ravaged West German cities - rather conservative plan which preserved its pre-war street grid (Munich 2008). One reason for this was economic, being able to use the existing underground sewers.

Altogether, 80 municipalities covering 2.14 million persons and 2270 km^2 are included. There were no changes to boundaries or area size within the investigation period because the last major merging period in Germany took place from 1971 to 1978 (*Gebietsreform*). As a result of this, the number of self-governed municipalities was reduced from 7100 (1952) to 2051 (1990) in Bavaria, aiming to create municipalities with at least 5000 inhabitants (Krapf 2008). The municipalities of the case study area are located in 7 different counties[12] (*Landkreise*) surrounding the core city, which vary in population size from 130,000 to 300,000 inhabitants.

RESULTS

Impacts on local urban infrastructure

Five major infrastructure items were used as predictor variables for another series of stepwise multiple regression models.

[10] Because the applied indicators of urban sprawl mainly measure centrality, density and the scatter of built-up areas within municipalities; predominately rural ones would be shown to have a high degree of sprawl. Test calculations with the predefined Chūkyo Region led to irritating results.
[11] These are the cities Ena and Motosu, and the towns Tarui, Sekigahara, Kawabe, Yaotsu, Nukata and Otowa.
[12] These are the counties Dachau, Ebersberg, Erding, Freising, Fürstenfeldbruck, München and Starnberg.

Roads and Public Utilities

The following table I shows the modelling results for roads and public utilities:

Table I – Regression results: Financial impact of urban sprawl and mobility (roads and public utilities)

	UD (person)	**HD** (person)	**Cen** (%)	**Conc** (%)	**Nuc** (areas)	**Cont** (ha)	**CO** (cars)	**MS** (%)	const.	$\bar{R}^2$
Nagoya										
Road (m)	–	-13.1	–	-4.60×10^{-2}	–	–	–	–	43.7	0.605
(t-value)	(–)	(–8.25)	(–)	(–3.08)	(–)	(–)	(–)	(–)	(11.0)	
Wat (m)	–	-6.03	–	–	–	–	–	–	20.34	0.151
(t-value)	(–)	(-3.44)	(–)	(–)	(–)	(–)	(–)	(–)	(4.30)	
Sew (m)	-7.75×10^{-2}	-11.1	–	–	–	–	–	–	48.2	0.427
(t-value)	(-5.74)	(-2.84)	(–)	(–)	(–)	(–)	(–)	(–)	(5.17)	
Munich										
Road (m)	-3.33×10^{-1}	–	–	-1.24×10^{-1}	–	1.30×10^{-1}	–	–	29.2	0.703
(t-value)	(-7.99)	(–)	(–)	(-5.20)	(–)	(2.83)	(–)	(–)	(18.1)	
Wat	no data									–
(t-value)										
Sew (m)	-8.17×10^{-2}	-3.58	–	–	1.15×10^{-1}	–	-	-6.38×10^{-3}	18.7	0.626
(t-value)	(-7.72)	(-4.23)	(–)	(–)	(3.97)	(–)	(–)	(-2.72)	(6.45)	

In terms of the specific length of local roads, the best fitting model for the Nagoya region assumes a linear relationship and can explain about 60% of the variance. The two municipal sprawl parameters concentration (Conc) and housing density (HD) have a negative impact on the specific road infrastructure stock. In Munich, a higher model fit ($\bar{R}^2$=0.74) could be found. Urban density (UD) and concentration (Conc) have significant influence on urban development.

In a next step, the extension of the drinking water supply network, because it was tested. was found to be sensitive in previous studies in terms of land use. But this could only be tested for the Nagoya region, because there were no data available for the Munich region. However, the coefficient of determination here was below 0.4, so these findings will not feature in the further analysis.

The way the public sewage network is quantified differs in each region due to data availability. For Nagoya, the area covered is considered, whereas, for Munich, network length data are used, which are weighted with the connection rate in order to allocate the network to the beneficiaries only. The sample size has been adjusted to communities equipped with a public sewage system or those where data were available. Among other factors, these excluded all municipalities from the Mie prefecture and the sample size in the Nagoya region was reduced to 60, compared to 58 for Munich.

Social Facilities

The results for the social (educational) facilities are shown below (Table II). Data on kindergartens were available for both regions and the adjusted number of facilities (kindergarten equivalents- ‘Kiga’) could be determined. However no significant correlation could be found in the case of Nagoya. In Munich, the significance was given on a level of adjusted R^2 = 0.15, which is regarded as too low for further considerations. Another important social facility are primary schools: the adjusted number of primary schools (school equivalents- ‘Scho’) was determined as an appropriate cost indicator. The equivalent represents the average size in order to balance the quantity-related costs. It was calculated according to the average number of children per school in each region. The units of ‘Kiga’ and ‘Scho’ in table II are their equivalents.

Table II – Regression results: Infrastructure impact of urban sprawl and mobility (social facilities)

	UD (person)	**HD** (person)	**Cen** (%)	**Conc** (%)	**Nuc** (areas)	**Cont** (ha)	**CO** (cars)	**MS** (%)	const	$\bar{R}^2$
Nagoya										
Kiga	–	–	–	–	–	–	–	–	–	–
(t-value)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	
Scho	–	-1,61		-4.42 $\times10^{-3}$	–	–	–	–	6.01	0.489
(t-value)	(–)	(-6.92)	(–)	(-2.01)	(–)	(–)	(–)	(–)	(10.3)	
Munich										
Kiga	–	-1.34	4.60 $\times10^{-2}$	–	–	–	–	–	8.81	0.152
(t-value)	(–)	(-2.02)	(-2.64)	(–)	(–)	(–)	(–)	(–)	(5.66)	
Scho	-2.00 $\times10^{-2}$	–	–	–	–	–	–	–	2.67	0.092
(t-value)	(-3.01)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(10.9)	

The coefficients obtained for Nagoya are based on a linear model involving the parameters housing density (HD) and concentration (Conc). Both are negatively correlated to the number of schools, indicating that denser inhabitation and construction of a city leads to higher efficiency in terms of school-related costs. The best fitting logarithmic model for the Munich area is based only on ‘urban density’; however, it can explain only 11% of the variation between the sample and the estimated regression line. Therefore it is not suitable to explain the impact of sprawl on school costs; obviously many other factors are involved when deciding on the construction of new primary schools. One factor could be the average size of municipalities, which is lower in Munich: Also, small communities tend to serve their population by providing at least one school, quite independently of land use efficiency.

Summary

The infrastructure complexity-based cost parameters are significantly influenced by urban sprawl: Of the five tested infrastructure items, three were significant at a certain level. Each represents one major category of infrastructure: roads (transport infrastructure); sewage (public utilities); and primary schools (social facilities). However, there are some inter-regional differences: The Bavarian region shows higher model fits for road and sewage, whereas the number of school equivalents cannot be sufficiently explained by sprawl in the Munich region. Again, political reasons may play a role in these findings, for example for the lower connection rate to the public sewage system in the Nagoya region. Figures 2 and 3 show the influencing effects for each region:

Nagoya Munich

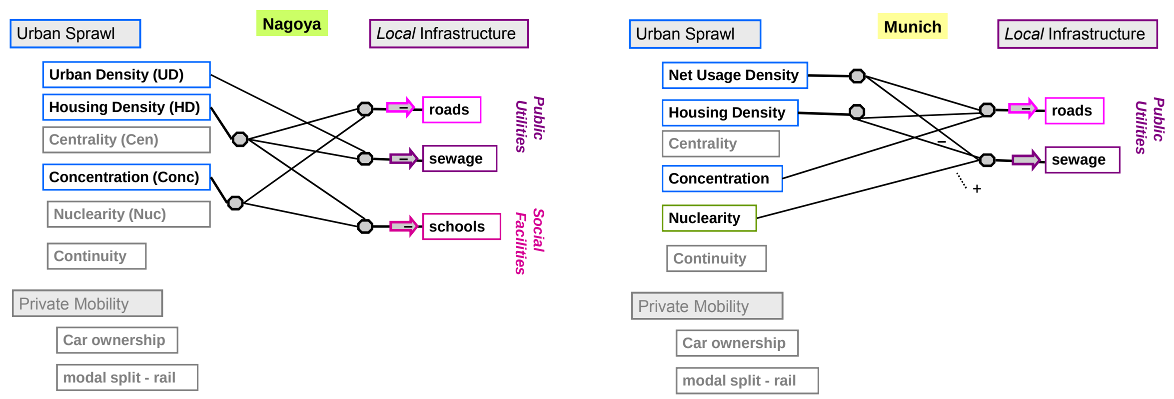

Figure 2 +3 – Financial impact of urban sprawl in Nagoya and Munich

Urban density, housing density and concentration influence the infrastructure-related costs in both regions. Additionally, nuclearity influences the sewage cost positively in the Munich region. All other influences are of a negative nature, indicating that growing values of sprawl parameters (= growing compactness) lead to a reduced need for roads, sewage pipes and schools. Whereas schools are not significantly influenced in Munich, they are influenced by two parameters (housing density and concentration) in the Nagoya region. The investigated parameters of mobility do not play a role in costs in either of the regions.

Quantifying the Saving Potential

In order to quantify the saving potentials, it is necessary to examine the monetary cost data. The best way to determine the real local expenses for certain infrastructure items is to analyse the municipal budget statistics. However, there was only sufficient data on the public spending on roads for a period of 10 years.

When comparing the average road-related expenses for the 'Top5' and 'Bottom5' municipalities according to infrastructure efficiency, the findings from the road infrastructure stock can be confirmed - namely that, in both regions, a considerable monetary saving potential is given, and that this is bigger for the Munich region: The costs range between 10,100 and 20,200 Yen per user per year for the 'Top5 and 'Bottom5' in the Munich region, whereas the same values for Nagoya are 13,700 and 18,700 Yen. Table III compares the saving potential in monetary and in infrastructure stock terms: The average saving potential related to the infrastructure stock is 85% in Munich and therefore much higher than in Nagoya (57%). These differences are confirmed by the monetary costs for roads (50% compared to 17% saving potential for Munich and Nagoya, respectively).

Table III – Saving potential from infrastructure stock and annual road-related expenses

	'Top5' and 'Bottom5'	**Sewage** length (m/user)	Elementary **Schools** (eq./1000 inh.)	**Road** length (m/user)	Ø	**Road expenses** (Y/user/year)
Nagoya	efficient	3.8	1.3	4.0	/	13670
	intensive	12.2	2.0	12.2		18650
	saving potential	69%	35%	67%	57%	17%
Munich	efficient	1.6	/	3.1	/	10120
	intensive	8.2		30.3		20205
	saving potential	80%		90%	85%	50% [7]

CONCLUSIONS AND RECOMMENDATIONS

The modelling results show that the financial impact can be explained by just a few parameters of urban sprawl in both regions: urban density (defined as population and employment in relation to the size of the urban area), housing density (population in relation to residential floor space) and concentration of urban development in the total urban area of each municipality. Specifically, local roads and sewage were found to be influencing factors, taking their extension as a cost indicator. In addition, for Nagoya, it was also possible to prove that the number of primary schools has an impact.

The study identified a common mechanism between spatial effects and the financial impacts of certain patterns of land use and motorisation for both case study regions. It found that urban density and housing density significantly influence the extent of specific local sewage and local road infrastructure. This implies that both the urbanised built-up area and the buildings themselves need to be used more efficiently.

However, in order to give appropriate recommendations, the mechanisms of each region need to be taken into account, with additional consideration of the qualitative framework conditions in each region. Figure 4 makes it clear that an increase in urban density has the potential to reduce specific sewage costs. Against the background that public sewage systems in Japanese urban areas are limited to UPA, it is recommended to increase the density within UPA, or, if the sewage system is not yet fully expanded, to redefine parts of the UPA.

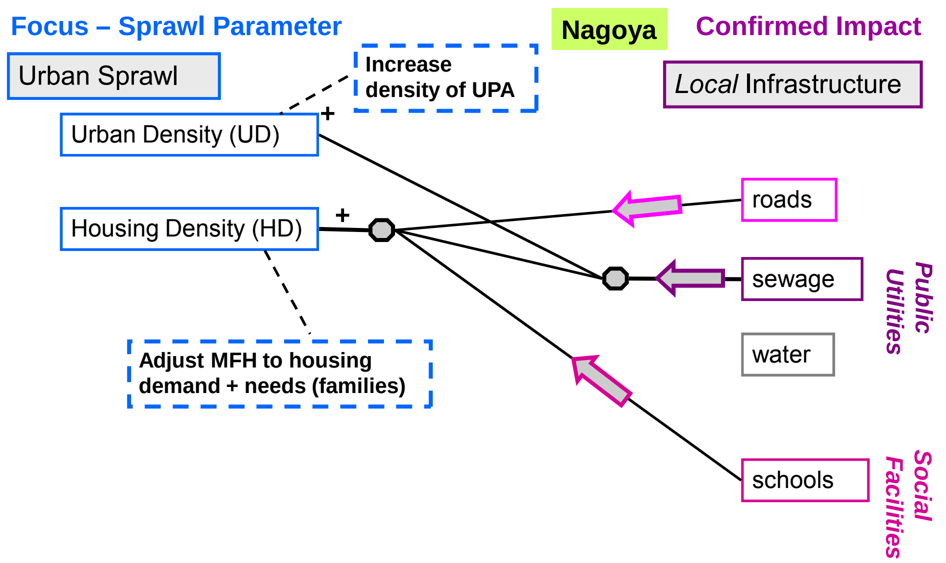

Figure 4 – Sprawl parameters - implications for the Nagoya region

Housing density is an important factor for all three kinds of infrastructure. Consequently, the efficient use of residential space needs to be encouraged. This is narrowly connected with the building form. The prevailing housing form of single-family houses tends to make the provision of necessary infrastructure more expensive. An important aspect is whether the needs of the residents match housing conditions. Therefore larger units should be encouraged, which better match the housing demands of families, and which is flexible enough to adjust the size and layout of flats in one building to changing demand situations over time due to ageing (such as children moving out). This could be done by giving incentives to developers to provide appropriate flats for families, especially in centres and sub-centres.

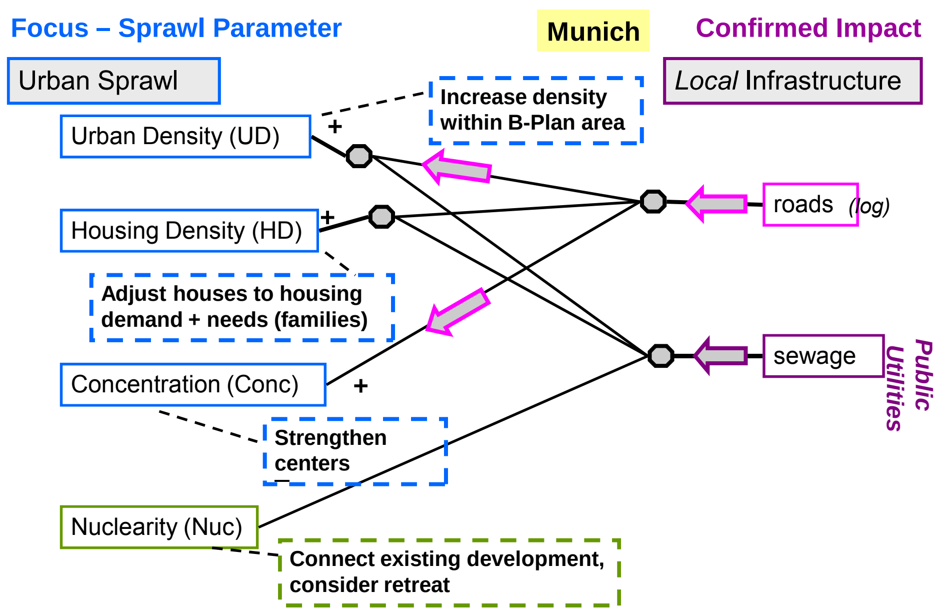

Figure 5 – Sprawl parameters - implications for the Munich region

In the Munich region, four instead of two sprawl parameters are correlated with financial impacts (Figure 5). The aspects of concentration and nuclearity need to be additionally tackled in order to reduce the cost of local infrastructure. Schools, however, do not belong to those infrastructures subject to sprawl.

Urban density needs to be increased in order to reduce the cost of road and sewage infrastructure. Housing density (HD) also influences the specific cost of both infrastructure items. As in Nagoya, the efficient use of existing buildings and the appropriate construction of new buildings need to be fostered, again to meet the demands of larger households with 3 or more members. Another sprawl parameter relevant for road infrastructure is the concentration of urban development, which is measured by the share of the major central urbanised area in the sum of total built-up areas in one municipality. Consequently, measures to strengthen city centres are recommended. On the other hand, the sewage network becomes more complex if the local urban structure is more polynuclear. Thus, existing developments should be connected in order to reduce the degree of polynuclearity. In the case of remote areas affected by depopulation processes, the retraction of urban area needs to be considered thoroughly. Mobility and continuity do not directly influence local infrastructure costs, so that these parameters are not part of the recommendations above.

In both regions, the largest saving potential could be found for sewage and road infrastructure – due to its huge stock amount (cf. Table III). The saving potential can reach up to 90% in the case of Munich, but maximum 69% in Nagoya when considering the stock parameters. When applying the real public expenses related to roads, the saving potential decreases to 17% in Nagoya and 50% in Munich. Assuming that the unit costs are similar, it can be concluded that the four parameters in Munich have a greater influence on cost than the two density aspects in Nagoya.

Finally, it is important to state that this study has delivered detailed insights but was not able to cover all the financial aspects of urban sprawl in the two case study regions. The financial impact was limited to the most important infrastructure funded by the public sector on the municipal level. Moreover, the differences in data availability also restricted the investigation: For the measurement of sprawl, a better geographical database would be needed to identify local sprawl patterns in more detail, and more detailed data on infrastructure (e.g. different diameters of sewage pipes) would be necessary to better capture the public cost. These also include data on the detailed location of the road and sewage networks within the municipalities. Given sufficient time and resources, it is suggested considering a larger number of urban sprawl parameters and infrastructure items in forthcoming studies.

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