A MICROSCOPIC VIEW ON
SOCIAL COSTS OF RESIDENTIAL URBAN SPRAWL
Literature Review and Calculation approach with regard to the sponsorship as a tool for fiscal and land use policy

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Abstract

The long-run costs of different forms of urban development are seen as one of the major problems in the field of land use and transport. Based on international literature this paper derives criteria and requirements for a framework to estimate Social Living Costs as a base to calculate Residential Urban Sprawl Costs on a microscopic scale. Therefore especially questions of cost-by-cause principle and sponsorship of Social capital costs are treated, since economic and fiscal problems occur actually, when costs are not paid by those who are causing them. Another important point is the careful and well considered choice of both the investigation areas and the included cost items. Aspects of local urban policy, such as Land Readjustment and Urban Redevelopment, as well of land use attributes including locational aspects (such as centrality and Transit Oriented Development) are supposed to have a major influence on the costs remaining for the society.

1. Introduction

Urban development in urban agglomerations is still characterized by deconcentration of population and employment as well as separation of functions and sprawling land use patterns. In terms of residential locations, next to the impact of the land price mechanism, one of the main reasons appears to be the decline in environmental quality of the densely built city centre, among others due to traffic congestion and pollution. Although currently many local efforts are undertaken to re-vitalize and enhance the quality of the local environment in city centers and re-urbanizing residential development, the predominant trend of suburbanization supports fundamental changes of transport systems, which mainly lead to an increase of private car use the private households’ ecological footprint.

One important aspect of these land use – transport interactions, however, is the question of the long-run costs of different forms of urban development. The topicality of this question can be understood by considering declining tax revenues and locally higher expenses which results in increasing debts of local governments. The declining and ageing society as well as the gravity of metropolis to migration flows leads – for instance in Japan – to an indifferent development trend: shrinking and growing areas at the same time. In both cases it becomes more and more difficult to shoulder the costs for investment, maintenance and service of the growing demand, respectively local underutilization of network infrastructure and social infrastructure, also indicated as Social Capital. Especially the extent of locally used infrastructure and its servicing depend on the land use pattern, such as local access roads, public transport infrastructure and service, energy and water supply, sewage and waste disposal, telecommunication networks, educational and health facilities, safety and security institutions and local cultural facilities (Public Costs). Moreover, rising transport demand and
ongoing chance of land use from green fields in built-up areas supports the decline of scarce natural resources as well as local pollution and global climate change. These impacts of the residential suburbanization can be economically regarded as Environmental Costs. The interrelations are shown in Fig. 1. in a simplified way.

Population decline leads additionally to local under-utilization of infrastructure, which boosts the maintenance costs not only per capita, but also from a technical point of view. Nevertheless, its finançability does not only depend on the amount of infrastructure, but first of all on the sponsorship: Social Costs are partly repaid by the causers, respectively beneficiary. Many fiscal and land use instruments have direct relation to housing and transportation: one-time or regular charges, fees, taxes, and Value Capture due to Urban Development Contracts (often combined with voluntary Land Readjustment Projects). On the other hand there are also indirect and direct subsidies, e.g. by tax breaks, or for social housing, depending on households’ individual situation.

However, there is little knowledge about the effect of these instruments on the guidance of urban development towards socially efficient locations. The following paper focuses on findings in international literature on urban sprawl costs in order to develop an integrated calculation model of social costs of residential urban sprawl including the aspect of sponsorship. It represents a part of an ongoing doctoral dissertation, and includes its aim and approaches and the derivation of the calculation model, applied to Nagoya Metropolitan Area.

2. Studies on Residential Costs of Sprawl

2.1 Social and Public Costs Studies

One of the seminal works on Urban Sprawl Costs, the 1974 study by the American Real Estate Research Corporation - the first of its kind - looked broadly at development patterns in different metropolitan areas across the United States and focused primarily on density, comparing the effects of two stereotype development types (RERC, 1974). An recent major Sprawl Cost Study by the Transportation Research Board of the American National Research Council estimated for the entire USA, that a disperse land use development will lead to extra costs in the dimension of a triple-digit billions of dollars within 25 years (TCRP, 2002). Therefore, the estimation is based on analyses of two growth scenarios, which are different in terms of the spatial distribution of households and employment at the level of counties due to data availability and consistency (“BAU”, “Compact Development”). Based on several models by Rutgers University, cost estimation is divided in the impact on resources and personal costs (individual travel costs based on regression-based travel modeling, quality of life, and the livability of cities).

These and other previous and ongoing case studies for Europe and America focus specifically on the impacts of urban sprawl, which is generally defined as land development with unlimited outward extension, low-density residential and commercial settlements and leapfrog development (Downs, 1998). Most of them suggest a correlation between the costs for infrastructure and density (cf. Fig. 2 as one result of a study for the German Federal Office for Building and Regional Planning (Siedentop et al, 2007).

1 In case of sewage and heat energy for example, German estimations expect additional maintenance measures in case of overcapacity of 20-30%. In case of sewage this is mainly accounted for the increased frequency of cleaning of the pipes (Schiller/Siedentop, p.88).
...for Japanese middle sized cities: c.f. JSBRI, 2005, p.149). On the other hand they show the lack of transparency and often less cause orientation of funding systems of infrastructure.

However, without giving a specific definition of urban sprawl, but focusing only on infrastructure costs, recent European research was caused by the rising problem of shrinking regions due to ageing society and out-migration (especially in many regions of Eastern Germany). The major aim is to conduct a cost-benefit-analysis for local public budget (fiscal impact analysis), a part of the social costs, following the example of TCRP (2002: p. 261 ff). Firstly, Gutsche (2004) showed in his doctoral dissertation the relation between housing policy and municipal budget, and moreover – in order to show the environmental effect – he modeled the housing development induced trip generation in Hamburg Metropolitan Region. The main finding is that the current German fiscal system supports housing development at locations with high transport demand.

Indeed only part of previous studies allocated the sprawl costs (fragmentary) to the beneficiaries: A study from Switzerland pointed out that from a fiscal as well as an economic point of view high costs are not problematic inherently, but only if they are not included in the market-mechanism (ARE, 2000). It consequently considered this problem of sponsorship in detail and concluded for Switzerland that the question of affordability rather affects the private sector than the society (p.18). Moreover, externalities of private road transport (e.g. environmental load, traffic disturbance) are included in this study.

All in all, the reviewed studies suggest quite different potentials to reduce costs by influencing the land use structure. The wide range of cost reduction potential of selected infrastructure sectors, depending on how detailed and for what time horizon the study is applied, can be seen from Fig.3.

2.2 Requirements for a Microscopic Social Cost Model

Table 1 summarizes the main characteristics and findings of important studies that introduced a new aspect to calculate social costs of sprawl (highlighted in bold-italic). It also shows their weak points, as pointed out by subsequent studies, or as a result of our own evaluations. Already the first major Sprawl Costs Study in 1974 had been criticized for the failure to disentangle the density from other factors, especially local conditions had been found as very important in subsequent studies and can partly overlay the relationship between density/centrality and infrastructure costs (cf. ARE, 2000, p. 26f, Biermann, 2002, EPA, 1993, Seitz, 2002, p. 19). For example the local supply-demand-situation (capacity utilization) of each type of infrastructure has huge influence on the marginal costs. One of the main problems of the most comprehensive TCRP study is the large scale scope of investigation, which inevitably leads to leveling effects. Therefore, the cost estimation should be rather done on a microscopic/neighborhood scale.

Moreover, although partly very detailed in terms of revenues and costs related to housing (e.g. Gutsche, 2004), it can be stated that none of the reviewed studies considered the influence of specific local policies with economical effect, such as municipal housing or the application of certain urban development policies.

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2 Each point stands for empirical investigated values in 8 different building structure types in three municipality types, differed by their compactness. The investigation has been done for the region Havelland-Fläming in the west of the federal state of Brandenburg (6800 km², 730.000 inh.) and can be regarded as representative for Germany.
In order to understand and model the land use pattern realistically, the investigation should be done based on the smallest available statistical unit.

The aim of the most important recent German infrastructure study (Siedentop et al, 2006) was to develop a generally applicable cost estimation model. However, by doing the pre-selection of cost sectors, only those sectors had been selected that are not subject to local political decisions (so that waste collection, for example, had been excluded, p.39). Even though this argument is traceable, this approach does not allow a total estimation of social costs. The TCRP-study however has a wider, more comprehensive scope, but the choice of considered cost sectors is not justified and seems to be indiscriminately. Among the network infrastructure, for example, only local roads, water supply and sewage are considered (cf. chapters VII, VIII).

Moreover, when choosing an appropriate small unit, the allocation of the real triggered costs becomes more difficult. Though it is quite easy to do this for new technical network infrastructure (lifelines), such as water distribution pipes, sidewalks, streetlights, sewer collector pipes, and local streets, it is harder for technical or social point infrastructure, such as kindergartens, schools, police, fire, recreation centers, libraries, and general government. However, the first question should be which cost sectors are potentially sensitive to the land use structure:

The choice of cost sectors should be done as a result of a local pre-analysis in order to find out all items sensitive to urban form and location.

A further research gap in almost all of the relevant studies can be stated in a missing straight “society oriented approach”, which allocates the costs to the beneficiary by individual repayment by burden charges, taxes etc and regards the costs not paid according to causer-pays-principle as external from the market (cf. chapter 4). Most studies did not consider the costs under the viewpoint of external effects. The TCRP investigation is distinguished costs of resources, which include a part of the fiscal impact of public services and external costs of land use and building construction, and personal costs, which comprises both monetary private costs and non-monetary costs, to be paid by individuals independent from the beneficiaries.

Yet often is the impact on municipal budgets the motivation for European studies. As mentioned above, only the Swiss study considers the problems of sponsorship, causer allocation and cross-subsidization – in fact in two steps (ARE, 2000, p.133):

- 1st step: sponsorship of the costs by the beneficiaries as a whole (burden charge level, cost coverage),
- 2nd step: Cost allocation according to the causer pay principle (burden structure).

A detailed analysis of cost sponsorship is important in order to find out, to what extent costs are externalized.

Although the importance to consider the sponsorship of costs, excluded from the market system has been emphasized in the Swiss study, the estimation of the external costs (in terms of the pricing system) in the transport sector could be done only roughly on the base of aggregate data for two types of communities in agglomerations (ARE, 2000, p.A-18). Following the example of Gutsche (2004), a more detailed approach to estimate these indirect costs seems to be necessary, first of all considering the specific conditions of each neighborhood and its influence to the transport demand in person-km of each transport mode, e.g. by taking empirical data from person trip surveys. Therefore, Transit Oriented Development (TOD) deserves special consideration, since Public Transport seems to be strongly influenced, both in terms of efficiency and competitiveness, by the structural organization of an urban area (Camagni et al, 2002, p.214). On the other hand – integrating the aspect of Quality of Life in the Social Cost concept – also the traffic problems as a result of scale diseconomies (cf. Camagni et al, 2002, p.202) on the residents of central/ dense areas need to be included in these calculations. Furthermore, negative externalities as a result of residential land use, such as loss of biodiversity and other natural damage costs, have not been considered in any of the reviewed studies. Empirical
analyses on the environmental costs of different typologies of urban development are very rare (Camagni et al., 2002, p.200).

- The external costs of both residential land use and the generating and destinating private transport activities need to be included when calculating social living costs.

The same study showed that it is not enough to focus on existing settlements, but also on enlargements or redevelopment of settlements. For this case a marginal cost approach, focusing on additional physical development, seems most appropriate to determine the additional costs occurred by an additional beneficiary of a certain public service. A difference in the cost estimation occurs especially, if infrastructures have over-capacity. Yet these costs need be calculated in the long run, in order to include maintenance, repair and replacement, so that the problem of ageing of technical infrastructure, often problematic in bigger cities, can be easily included in the estimations. The TCRP-study, however, capitalizes on water, sewer and local road infrastructure, buy excluded the repair and upkeep costs in case of roads (TCRP, 2002, p.11).

- Only a marginal annual cost approach ensures that social costs are fully to be taken into account.

Also the alleged static character of many studies had been object of criticism. In case of leapfrog development for instance, it would not be considered that the cost difference can be leveled in future when "urban infill" between the central and the sprawled development occurs, so that in the end they could turn to compact developments (urban sprawl regarded as limited transformation phase). However, the forces of sprawl were historical mainly centrifugal (Schiller/ Siedentop, 2005, p.85). In regard to the ongoing population decline such a development is rather unlikely, so that this drift cannot be followed.

3. Aims and Approach

The previous chapter showed that the American Cost of Sprawl studies, which were based on a continuous population growth, had been recently completed by studies focusing on the problem of declining regions and cities, which is seen as the major future problem in Japan, Germany and many other countries. The aim of all these studies was, or is, a more or less comprehensive estimation of costs as a tool and justification for (mainly local) politicians to support a more sustainable urban development policy. However, since the problem is both fiscal and economic, it should include the aspects of sponsorship from the viewpoint of social costs as negative external effects. The calculation result should be suitable as a base to develop a land use and fiscal strategy, aiming to reach the cost-by-cause principle and can evolve its power to control land use.

A social cost calculation model needs to be applied on the level of neighborhoods and breaking down the costs, caused by each private household. Beyond the term of urban sprawl, which exact definition is controversial and varies with the time, this research focuses on the effects of residential developments of different location and urban structure within a different land use policy framework on the costs, remaining for the society, other than the beneficiary. Therefore the estimation needs to focus on both, the spatial and instrumental dimension, in order to include the applied local land use policy and its internalization effect. By doing so, a reliable foundation can be gained to develop an adequate instrumental strategy.

When analyzing the current urban policy in Nagoya region, various urban planning strategies and development methods towards decentral concentration are applied in the residential sector. Current research on Nagoya suggests that this strategy is successful to reduce infrastructure maintenance costs (Mine, 2006). Taking other studies on infrastructure costs into account, it can be expected that
this strategy contributes to maximize the locational benefits and reduce the imbalance between benefit receivers and cost burdeners by

- Financially involve the private sector within Land Readjustment Projects,
- Concentrate on locations with access to railway systems (= TOD), and
- Redevelop and renovate built-up areas at centers or sub-centers with structural problems ("Social Capitalization" of abandoned, underused, or sites with development needs)

Based on this, projects involving various strategies and development methods need to be investigated in order to evaluate the cost efficiency of current land use policy. For suggesting the right urban policy the following hypotheses need to be verified:

- Social Residential Location Costs depend on location and urban form ("land use attributes") and rise with growing distance from central places and with declining density (population + building);
- Redevelopment of urban centers and Land Readjustment Projects are effective strategies to reduce the Social Residential Urban Sprawl Costs and to mobilize underutilized land at efficient locations;
- Transit Oriented Development is a essential element within a strategy to reduce Social Living Costs

In order to specify the dependence of Social Living Costs on land use attributes on the one hand, and policy parameters (contributions by fiscal instruments, respectively development method) on the other hand, the aim of this paper is to develop an Estimation Model of Social Costs of residential land use on a microscopic scale. In order to consider the effect of local conditions and policy of each investigated neighborhood in detail, a multiple case study approach is chosen. The comparison of the calculation results give insight in both Social Residential Urban Sprawl Costs and socially efficient locations and should be a reliable base for an appropriate regional strategy of land use and fiscal instruments for new and redeveloped residential built-up areas.

4. The Cost Model

4.1 Applied Theory and Basic Framework

The basic framework includes all cost effects in relation to residential land use including private transportation demand in order to finally estimate Social Residential Urban Sprawl Costs by comparison of the microscopic Social Living Costs. Therefore a well considered definition of Social Living Costs is necessary, different from common understanding: The classic economic definitions regard social costs as all costs associated with an economic activity, and therefore includes both costs borne by the economic agent and also all costs borne by society at large. However, in order to establish a clear border between social and private costs, this paper defines Social Living Costs as the remaining net costs for the society triggered by residential land use including the demand of private transport. The society comprises the collectivity of affected people in current and future generations, who are paying directly or indirectly, but have no benefit from the occurrence of these costs.

A strategy based on the costs-by-cause principle can only be applied, if the full range of relevant social costs are known or can be estimated. Therefore the main criteria for choosing the cost items should be a possible sensitivity to certain microscopic locations and land use parameters, especially those which are characterize sprawling development.

The social costs problem can be regarded as a problem of the existence of external effects according to the Theory of external effects. In economics, an externality is a cost or benefit from an economic transaction that parties "external" to the transaction receive. Every decision made by an economic
agent will also have an impact on the other members of the society: those enjoy the benefit of the land use and transport system impose costs or dis-benefits on society, but do not themselves pay for them (spillover effects). The basic framework of the social costs model is constructed upon the viewpoint that all costs not paid by the causer-pays-principle are externalities, in other words: Social Costs. With focus on residential land use it includes the costs of both housing and private transportation demand; by comparing the values for different locations, the Social Residential Urban Sprawl Costs can be estimated as a final result.

As shown in Fig.4, Public Costs of housing and private transport, which are closely related with residential land use development, can be grasped as the sum of the direct life cycle costs of local infrastructure (e.g. roads, sewage system) and local services (e.g. waste collection), in order to consider not only money flows, but the real costs according to an economic cost calculation. These Public Costs of infrastructure and service also include social subsidies. As for the Environmental Costs, it is basically necessary to consider the environmental load of both the production and disposal as well as the use of infrastructure and vehicles (mobility). The second point comprises both the effects by the transport originated by the residents living in the case study area and the effects of transport ending there, in other terms, costs externalized on the inhabitants. The counterpart in the housing field is the land use change in case of newly developed residential areas on green fields. The natural effects comprise mainly the loss of biodiversity, damaging of soil and effects on microclimate (heat island effect) due to sealing.

The Public Costs can be evaluated according to the classical method of Life Cycle Assessment\(^3\), whereas the second one is based on the individual transport behavior of individuals as a function of type, form and housing location. For both aspects the application of standard emission factors as a base for calculating the monetary value is necessary.

With special consideration of cost influencing factors, the Social Living Costs can be estimated as a result of the following calculation steps (cf. Fig.5):

- Determination and comparison of the locally relevant marginal Public Residential Land Use Costs consisting of infrastructure and service as a result of the land use attributes (location and urban form),
- Estimation of the Environmental Costs as a function of both land use attributes and the transport pattern of the residents,
- Consideration of the impact of (national and local) housing and transport related fiscal net contribution, such as property taxes, development charges, burden charges for the sewage system, waste fees, petrol taxes etc., reduced by subsidies (e.g. in case of municipal housing),
- Taking into account the development method, and the repayment of social costs by Value Capture (e.g. by land contribution within Land Readjustment Projects).

In order to verify the hypotheses and to reach the aim, a microscopic empirical approach is chosen: While taking the national framework into account, the case studies need to be chosen on a neighborhood scale. Although Social Living Costs are partly internalized by both fiscal and land use instruments, the net effect never results in full internalization of costs. The importance of the right amount and mix of these instruments can be seen – in Japan for example – in the spatial impact of

\(^3\) According to ISO 14040 Life Cycle Assessment is a systematic approach that provides a rational basis for estimating quantitatively and individually the environmental load of each life stage of construction of facilities and production of vehicles (material procurement and transport, construction and operating, renewal) on human kind and ecological system.
savings in inheritance and property taxes towards agriculture use even though it is much more efficient and part of the land use policy to convert it to residential use.

4.2 Determination of relevant Public Infrastructure and Service Costs

The following steps of narrowing down the Public Costs to identify those with spatial dimension will be undertaken, based on previous findings and the aim of this research:

a) qualitative pre-selection

The cost sectors are chosen according to the following criteria:

- **Cost Influence**: Influence on Public Costs by new housing developments?
- **Cost Allocation**: Causation by new residents allocatable?
- **Cost Relevance**: Is the circle of causer big enough?\(^4\)

The application of these criteria to every public cost sector leads firstly to the exclusion of those sectors which are not paid by the local government. Although also the regional and national governments provide municipal services, such as regional roads and education facilities, those services always serve major parts or the whole municipality, so that the inter-relation with small scale land use development is not given (cost allocation). Moreover, expenses of the semi public sector, such as public transport and utility companies are subject of the investigation, which are important in terms of sponsorship and cost coverage.

This methodology can be underlined by the choice criteria of the US American Chesapeake Bay Program’s study (USEPA, 1993), which made a classification of the Public Cost sectors based on capital intensity, form (network vs. point), spatial arrangement, and the size of service area. The study divides the capital cost sectors in **intra-neighborhood, inter-neighborhood and regional services** and concluded that those of intra-neighborhood services are most sensitive to net-density and lot size (USEPA, 1993, p.ES-8).

b) quantitative selection

Since in some cases the qualitative estimation might be difficult (e.g., the influence of a housing development on the construction or extension of a junior high school), other steps of narrowing down become necessary.

Firstly, the remaining public cost items from the qualitative pre-selection are displayed against the municipal population development (simple regression). Its sprawl relevance can be assumed, if the annual running costs, which can be filtered from municipal budget statistics, grow faster than population over time. A time span of at least ten years seems to be appropriate for this analysis.

Secondly, another regression analysis will show how each remaining cost item developed in relation to population density, respectively population distribution.

As a conclusion of the review of previous studies (USEPA, 1993, Gutsche, 2004, Siedentop et al, 2006), the following cost categories and items are expected to be included in the cost estimation:

- Utilities (Electricity, Natural Gas, Telecommunication, Water, Post Service)
- Disposal (Sewage, Waste Collection)
- Transport (Local Roads, Railway Transit, Bus Service)
- Health/Local Recreation (Public Green, Play Grounds)
- Education (Public Nurseries, Elementary Schools)
- Safety/Security (Fire Stations, Police Stations)

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\(^4\) This criterion allows excluding public expenses for social welfare, which seems not to be relevant for this research question.
4.3 Calculation Method

a) Public Costs of Residential Land Use

For estimating the full long run costs, the evaluation of annuities of capital costs is necessary (1): the Public Costs of Residential Land Use $C_{pu}$ for facility $u$ in year $t$ consists of annualized development costs and running costs (maintenance, repair and service) for all relevant facilities $u$ in year $t$. The annualized development costs are determined by the marginal amount $\Delta f_u$ of facility $u$ multiplied with the basic cost unit $b$ for construction $c$ of facility $u$ multiplied with the annuity factor $ANF$ with target rate $r$ and useful life $n$ (2) (left part of the term in (1)). The maintenance costs are as well the product of the specific basic cost unit $b$ for running costs $r$ and the marginal infrastructure or service amount $\Delta f_u$. (The basic cost units depend on local standards and conditions and need to be investigated from the public sector case by case).

\[
C_{pu} = b_c \cdot x \Delta f_u \cdot ANF_{n,r} + b_r \cdot x \Delta f_u
\]

The annuity factor $ANF$ of capital investments can be calculated as follows:

\[
ANF_{n,r} = \frac{r \cdot (1 + r)^n}{(1 + r)^n - 1}
\]

Depending on the Land Use Attributes location (central – decentral) and the urban form (compact – disperse), the following influence on public costs can be expected for the considered urban development approaches (Fig. 6). Generally it can be assumed that the costs in case of redevelopment of existing urban areas are lower than in case of new development (Land Readjustment) and perform similar towards suburbia; this is also valid for the case that major parts of the technical infrastructure are renewed during the redevelopment process, taking into account the annuity of cost calculation. The cost curve for uncoordinated laissez-faire development is both higher and steeper due to the lack in timing and coordination with infrastructure development. The triangles visualize the cost effect when these developments are taken place in vicinity of railway stations (TOD). The costs become significantly higher due to the necessary investment in infrastructure and operating of railroads (or other forms of transit). These cost effect rises towards the disperse and decentral urban fringe, since the necessary transit investment per capita increases towards the suburban area.

b) Environmental Externalities

The extent of environmental externalities is determined by the resource efficiency of the settlement pattern. The literature refers mostly to two scarce natural resources: land resources for residential use and energy resources for mobility use (Camagni et al., 2002, 200). The pollutants, such as SO and NO, the climate gas CO$_2$ as well as the trafficnoise correlates with the energy use, so that this indicator can be taken to evaluate the environmental externalities from both, private transport generated and destined in the investigated area (aspect of quality of life). Referring to the specific literature on external costs of transport (e.g. IWW/ Infras, 2004), another important cost block are the external accident costs, however, the costs for transport infrastructure are already considered as public costs and congestions costs does not belong to this group, since they have no effect to the society as a whole, but they are rather limited to the transport sector (cf. IWW/ Infras, 2004, p. 9).

Consequently, the environmental costs $C_{env}$ basically consist of costs for space scarcity, resource + emission costs, and traffic accident costs. The space scarcity reflect the external residential land use...
costs and consist of the product of basic cost unit $b_{sw}$ and the size of the urbanized area $a$. The consumption of transport energy resources depends on the energy consumption factor $E$ for the transport modes bus (b), rail (r) and car (c) multiplied with the basic cost unit for environmental costs for energy resources $b_{res}$. Lastly the product of basic cost unit for accident costs $b_{acc}$ and the distance, originated in zone i (the traffic zone should be identical with the investigated area), depending on the transport mode, are belonging to these costs (3). The transport energy consumption factor $E_{t,i,j}$ for trips generated in zone I, respectively ending in zone j can be estimated according to equation (4) and (5).

### Additionally the effects of production and disposal of the relevant infrastructure need to be included, which are, for instance, very different between public transport systems and roads. These will be also indicated by the Life Cycle Energy Consumption $E_{infra}$ of the infrastructure itself.

$$C_{i,j}^{env} = b_{sw} \times a_{urb} + b_{res} \times x(E_{i}^{B,R,C,R} + E_{i}^{res} + E_{j}^{B,R,C,R}) + b_{acc} \times d_{i,j}^{B,R,C,R}$$

$$E_{i,j}^{B,R,C,R} = \frac{x}{100} \times E_{i,j}^{B} + \frac{x}{100} \times E_{i,j}^{C} + \frac{x}{100} \times E_{i,j}^{R}$$

$$bus : E_{i,j}^{B} = \frac{E_{c}^{B}(v_i) \times h_i}{n_{c}^{B}} \times d_{i,j}^{B} \quad (6) \quad car : E_{i,j}^{C} = \frac{E_{c}^{C}(v_i) \times h_i}{n_{c}^{C}} \times d_{i,j}^{C} \quad (7) \quad rail : E_{i,j}^{R} = \frac{G}{n_{R}^{R}} \times d_{i,j}^{R}$$

$E_{t,i,j}$ = Energy consumption for transport in generation zone i, respectively in destination zone j

$v$ = fuel consumption factor (cm$^3$/km)

$h$ = calorific power value (1: diesel oil = 9200 kcal/ cm$^3$, 2: petrol = 8400 kcal/ cm$^3$)

$n$ = average No. of passenger (can be estimated from Person Trip Survey)

$d_{i,j}$ = average travel distance (km/day), generated in zone i, respectively ending in zone j

(taken from Person Trip Survey)

$G$ = rail energy consumption factor (=5562 kcal/km)

$E_j$ = zone, $R$=rail, $B$= bus, $C$= car

(Basic values for $h$ and $G$ taken from Sugita et al. 2000, p.248)

Environmental Costs depends on the Urban Form and the Person Transport Pattern of the new located residents (cf. Fig.5). It can be generally assumed that the environmental transport costs and accident costs form the major part of these costs, which rises with the modal shift towards private car. Taking the full range of urban projects in the region, it can be imagined to sort them according to their development method, as well as their associated person trip pattern. The left part of Fig.7 shows the estimated distribution of certain ranges of modal split and its influence on environmental costs: Land Readjustment Projects will have a neutral effect to the modal split, since they are only partly realized at TOD locations, whereas Redevelopment Projects are often carried out in central, well served areas. Therefore its environmental costs are supposed to be lowest due to the modal shift towards public transport.

As shown in the right part of Fig.7, the cost function related to urban form is supposed to be converse depending on whether considering the environmental costs from the viewpoint of the residents as causer or as receiver. The environmental costs originated by the residents are increasing towards the urban fringe due to the higher share of car use, whereas the costs burdened on the residents are higher in the city centre due to the pollution and impact of local climate by the accumulated road traffic. In case of TOD those costs are going to be reduced for both considered aspects.

c) Repayment
Referring to Fig.5 again, the repayment \( R \) by fiscal net contribution \( FC \), as well as the effect of project related Value Captures \( VC \) need to be considered as the second part of cost evaluation (8). For the fiscal net contribution housing related charges and taxes \( Tax_{H} \) (e.g. property tax), transport related charges and taxes \( Tax_{T} \) and object related subsidies, mainly within social housing schemes \( Sub_{SH} \) need to be taken into account (9). The Value Capture consist of one or more of the following elements, the land contribution \( genbu \) in case of Land Readjustment Projects \( LR_{genbu} \), residential contribution within Urban Redevelopment Projects (URP) and private contribution within a Joint Building Ownership scheme \( JBO \) (10).

\[
\begin{align*}
R &= FC + VC \\
FC &= Tax_{H} + Tax_{T} - Sub_{SH} \\
VC &= LR_{genbu} + URP + JBO
\end{align*}
\]

### 5. Conclusion and Future Research

The introduced model enables a detailed estimation of the full range of triggered social costs of residential land use in monocentric agglomerations as base for a fiscal policy in consequent application of the polluter-pays-principle. Utilizing the economic behavior can have an important contribution to a more sustainable, cost saving future land use development.

In order to verify the hypotheses and to test the model, location specific data for new housing developments, located in dynamically growing areas are currently analyzed within the functional region of Nagoya in Central Japan (about 9 million inhabitants on 3900 km\(^2\)). Housing neighborhoods with different combinations of Land Use Attributes and applied urban policies are selected as case studies to be subject for a model cost calculation. Moreover the effects of railway orientation are object of this investigation.

An estimated distribution according of the applied Urban Policies to the entire urban area in relation to the Land Use Attributes within the region is displayed in Fig.8 (grey). The main focus of Land Readjustment Projects can be seen in the central area, where it has been well applied for urban reconstruction after the war, as well as in the suburban area. Redevelopment, on the other hand, mainly happens within the core city in central areas. Uncoordinated Development takes place in between, rather decentral, but with declining effect on the urban area as a whole towards the edge of the region.

The right y-axis (and the graphs in black), however show the effect on Social Living Costs: in case of applied development methods the Social Living costs are lower than the average, because of the effect of already existing infrastructure and facilities, respectively of Value Capture. But this effect decreases with lower centrality and density due to the higher public costs per capita. However, in case of uncoordinated development the cost are higher than the average and will rise with growing dispersity, but later on shallow down due to the declining standard of public infrastructure (e.g. sewage system, roads).

With regard to residential land use and private transport, one strategy to control land use development, as well as influence the private transport choices to more sustainable modes is the promotion of TOD. In Germany there are several policies aiming to increase such a development – from enacting legally binding land use plans (Bebauungsplan) to governmental subsidies to the residents

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\(^5\) The diagram is simplified and doesn’t take into account other development methods, such as Comprehensive District Development, Excellent Building Arrangement Projects, Densely Built-Up Area Improvement Promotion Projects, cf. Nagoya City 2002
who decide to move inside of the catchment area of a railway-based public transport line. Also Land Readjustment and other private-public-partnership instruments, such as development agreements (Städtebaulicher Vertrag), as well as Urban Redevelopment are well applied methods to tackle the problem of rising municipal costs. All major land use instruments currently used in Germany have in common, that only certain cost elements can be legally binding privatized.

However, it could be shown that the Social Living Costs and therefore Sprawl Costs comprises much more than initial costs of constructing or maintaining the additional needed infrastructure. Therefore, after estimating the values for different characterized case study areas (including the marginal externalities), the existing instruments need to be further developed and applied, considering the specific regional and local conditions, i.e. taking into account differences of location, density and urban form. Nevertheless, this consequently requires a strong local policy, as well as deep insight and understanding of the rising social cost problem by the private sector, i.e. the private households living in high costly areas.

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Fig. 1: Driving Forces for Rising Social Residential Urban Sprawl Costs
Fig. 2 Relationship between network length and building density

Source: Siedentop et al. 2006, p.107-110
Fig. 3 Potential of Cost Reduction by Influencing the Land Use Structure (based on: Schiller/ Siedentop, 2005, p. 85)

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<th>Category</th>
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<th>20 %</th>
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</table>

Fig. 4 Composition of Local Public Expenses and External Costs related to land use pattern
Fig. 5 Estimation Flow for Social Living Costs
Fig. 6 Public Costs as a function of Land Use Attributes – Expected Results
Fig. 7 Environmental Costs as a function of Person Transport Pattern and Urban Form—Expected Results
Fig. 8: Total Urbanized Area and Social Living Costs by Urban Development Method
<table>
<thead>
<tr>
<th>Method</th>
<th>Cost Items</th>
<th>Main Results</th>
<th>Critical Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RERC 1974</strong></td>
<td>Infrastr. capital + operating costs, transp.+ travel costs, land + natural habitat preservation, quality of life</td>
<td>Urban density as fundamental variable of the overall costs sustained by the community</td>
<td>Density not disentangled from other factors, no consideration of sponsorship or causer allocation</td>
</tr>
<tr>
<td><strong>TCRP 2002</strong></td>
<td>Costs for resources (real estate development, water supply + sewage, road, public facilities), personal costs (private + external costs)</td>
<td>Savings by compact dev.: &gt; $100 billion/year</td>
<td>Comprehensive study, but too large scale scope choice of cost-items remains unclear</td>
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<tr>
<td><strong>USEPA (1993)</strong></td>
<td>Capital costs of intra-neighborhood/ inter-neighborhood and regional services</td>
<td>Intra-neighborhood services are “highly sensitive” to lot size and density</td>
<td>No env. externalities no consideration of sponsorship or causer allocation</td>
</tr>
<tr>
<td><strong>ARE (2000)</strong></td>
<td>technical: sewage, water supply, transport (incl. external follow up costs), waste, telecom, energy social: capital+running C (ARE)</td>
<td>ARE: savings by strongly compact dev.: 70% ÖROK: savings technical infrastructure 25-50%</td>
<td>Focused only on network infrastructure environment external effects included, but rough estimation of add. traffic (ARE)</td>
</tr>
<tr>
<td><strong>ÖROK (1999/2001)</strong></td>
<td>Social: educational, care and sport facility, technical: roads, water, sewage, heat</td>
<td>No savings social infrastructure but, techn. infrastructure 15% for compact vs. status quo development</td>
<td>No env. externalities only choice of relevant infrastructure</td>
</tr>
<tr>
<td><strong>Siedentop et al. (2006)</strong></td>
<td>all microscopic relevant lifeline and social infrastructure (result of pre-analysis of municipal development of population and public cost)</td>
<td>(no estimations yet)</td>
<td>/</td>
</tr>
</tbody>
</table>

Table 1 Studies on Social Costs of Urban Sprawl introducing *new* approaches