# Urban Sprawl beyond Growth: from a Growth to a Decline Perspective on the Cost of Sprawl

## Introduction

Previous research on the cost of urban sprawl is dominated by a growth perspective. The majority of available cost-of-sprawl studies intend to show that substantial infrastructure cost savings can be achieved by increasing urban densities and locating new development near existing built-up areas. However, many European regions are already facing population decline and a quasi surplus of urban land. Moreover, the phenomenon of regional and urban shrinkage can even be found in booming economies in North America and Eastern Asia.

From this point of view, we ask whether the problem of sprawl comes to rest with the end of urban growth. Our research is based on the argument that urban sprawl, its main physical features, and its negative outcomes on the efficiency of urban systems are not merely a by-product of urban growth. Building on earlier studies that differentiate between types of urban sprawl, we identify sprawl-like development paths in cities facing demographic change. We aim to assess these development patterns with respect to asset management and public services. Recent experience in Germany demonstrates that the decrease of population densities is strongly linked with additional costs due to infrastructure underutilization. In general, fewer residents have to pay more for oversized facilities. Moreover, additional costs can result from enforced investments to keep up system efficiency or to demolish and downsize non-efficient facilities.

This paper is organized in three main sections. We begin with a brief review of the international cost-of-sprawl debate and a discussion of cost relevant urban form variables. A second section reflects on recent changes in Germany's urban development due to demographic change. We characterize this special form of development pattern as "excessive sprawl" and "shrinkage sprawl" and talk about its outcomes on the costs of providing urban services. The final part of this paper empirically characterizes the processes of shrinkage sprawl in certain parts of Germany. The indicators we calculate for this task are based on area statistics on population, land use, and building activities. The results are then visualised in a GIS environment, showing where and to what extent excessive and shrinkage sprawl occur in Germany.

## Cost of Sprawl – a brief review

There is general agreement that urban land use patterns and the costs for providing neighbourhood and community services such as roads, water supply, sewer disposal and schools are closely interlinked. Urban sprawl characterized by low density developments, large outward expansions, and leapfrog growth patterns are likely to produce much higher infrastructure expenditures compared to compact urban forms.

A broad literature review revealed the most significant attributes of urban form that are associated with infrastructure service costs. Since they are only valid for a specific scale, they are standardised as per-capita or per-unit costs (see Burchell et al. 2005):

- At the neighbourhood level, the residential density is directly linked with the expenditure on neighbourhood infrastructure: the higher the density, the lower the per capita length of collector roads, water distribution lines or sewer collection lines. Below a density of 35 to 40 units per hectare net urban land, or a floor-space ratio of 0.5, network related per-capita costs increase exponentially (Schiller 2002). Given the same number of dwelling units, capital costs can vary enormously (Doubek, Zanetti 1999; Ecoplan 2000; Real Estate Research Corporation 1974).

- At the sub-regional level, the spatial pattern of urbanised areas, especially the degree of centralization and contiguousness of built-up areas is of particular importance. In compact, contiguous patterns, infrastructure costs are significantly lower than in spread-out patterns (Carruthers, Ulfarsson 2003; Speir, Stephenson 2002). In highly dispersed service areas, the length of inter-neighbourhood service components that connect separated service areas is higher than average (Burchell et al. 1998, p. 46 f.; Gassner, Thünker 1992). Therefore, infrastructure costs in such areas can be more than four times higher than in more compact urban areas (Braumann 1988; Doubek, Zanetti 1999; Ecoplan 2000).
- On the regional level, the spatial distribution of urban areas and its associated service areas affect per-capita costs. Urban systems with a higher concentration of built-up areas in central cities are more likely to benefit from efficiency gains offered by economies of scale (e.g. the use of larger treatment plants). Generally, fixed costs are carried by a larger number of people in larger cities, so that the per capita costs are lower than in small towns or spread-out subdivisions.

While the general influence of urban form variables on infrastructure costs is undisputed, the magnitude of cost savings to be gained through urban development policies remains controversial. This is most likely due to inconsistent methods used in empirical studies, differences in the sample of development patterns, and the way attributes of urban form are measured. Roughly estimated, cost savings of up to 30% are realistic when typical sprawl patterns (low density, spread out pattern) are used as a benchmark. Based on empirical evidence (see above), the "density influence" seems to be more important than the "pattern influence".

Of course, some of these "anti-sprawl" claims are heavily disputed. Some scholars argue that leapfrog development is just a temporary phenomenon. Given an unregulated land market, open spaces left between existing built-up areas and new development are soon filled with further development. Therefore, sprawled areas could be transformed into a more compact urban form associated with more efficient infrastructures (see Peiser 1989). In this sense, urban sprawl is regarded as a temporary transformation phase in a long-term process which would finally result in an efficient spatial arrangement of urban land uses regarding the costs of infrastructures.

However, current development trends in industrialised countries raise doubts about this interpretation. In the US as well as in European countries, a large amount of further development takes place in exurban areas far beyond the inner and outer suburban belts (Nelson, Sanchez 1997; Siedentop et al. 2003). Even if urban agglomerations will be able to attract further growth, there is no guarantee that growth-induced development will take place on infill parcels in dispersed settlements, leading to higher overall densities and a more compact urban form. Moreover, an area-wide contiguous urbanised landscape could come into conflict with ecological considerations such as the protection of recreation areas or the adherence of air quality standards.

**Urban sprawl beyond growth**

The mid- and long-term demographic projections for industrialized countries differ dramatically. Countries like the US or Great Britain are expected to experience ongoing population growth, associated with increasing demands for urban land, housing, and urban infrastructure. In contrast, various other European countries will increasingly have to adapt their regional and urban development strategies to the impacts of demographic change. The German Federal Office for Building and Regional Planning (Gatzweiler et al. 2006) estimates that in 2005 25 % of all Europeans lived in cities or metropolitan areas with shrinking populations. This share is expected to increase. In Germany, population has declined since 2003, due to a decreasing migration surplus and a negative natural population development. Even the most optimistic scenarios are based on the assumption that population figures will stagnate over the next 20 years. The latest forecast issued by the Federal Statistical Office predicts a population loss of between 8 and 13 million people for 2050 (Statistisches Bundesamt 2006).

In the 1990s, urban and regional development trends in Germany were dominated by contrasting trends between the states of former West Germany (“Western states”) and the states of former East Germany (“Eastern states”). The Western states had an area-wide population growth, whereas the Eastern states lost population (mostly to the West). At the same time, the Western states experienced an interregional and intraregional deconcentration of population and employment. Remote rural areas and inner ring suburbs gained most of this population. In contrast, Eastern states experienced an interregional concentration of population and employment, accompanied by small scale suburbanisation in metropolitan areas. The population gains mostly came from peripheral rural areas.

Until recently, population losses in Germany have been regarded as a problem specific to the Eastern states. However, there is growing evidence that areas in the Western states are facing demographic decline as well. This contains old industrialised areas (e.g. the Ruhr-Area and the Saarland) as well as a broad belt along the former inner German border (Figure 1).

Deindustrialisation and population decline leave many cities with large amounts of underutilised or vacant industrial and residential land. These are major driving forces for a new type of urban sprawl, for which we use the term “shrinkage sprawl” (see also Nuissl, Rink 2005). One could assume that urban shrinkage should discourage urban sprawl because fewer residents require fewer housing units, less urbanised land and less infrastructure. However, in Germany three major factors work against this logic:

- the ongoing demographic trend towards smaller households, counterbalancing the negative effect of population decline on housing demand,
- the fiscal competition between communities to attract new inhabitants and companies, fuelled by tax regulations and public subsidies for the provision of newly urbanised land for housing as well as for industrial and commercial land uses,

- "planning routines" of local land use planners that favour greenfield development over brownfield projects, where brownfield development is perceived as more complicated and riskful, and
- a strong preference for low density housing especially in suburban and rural regions with low land prices.

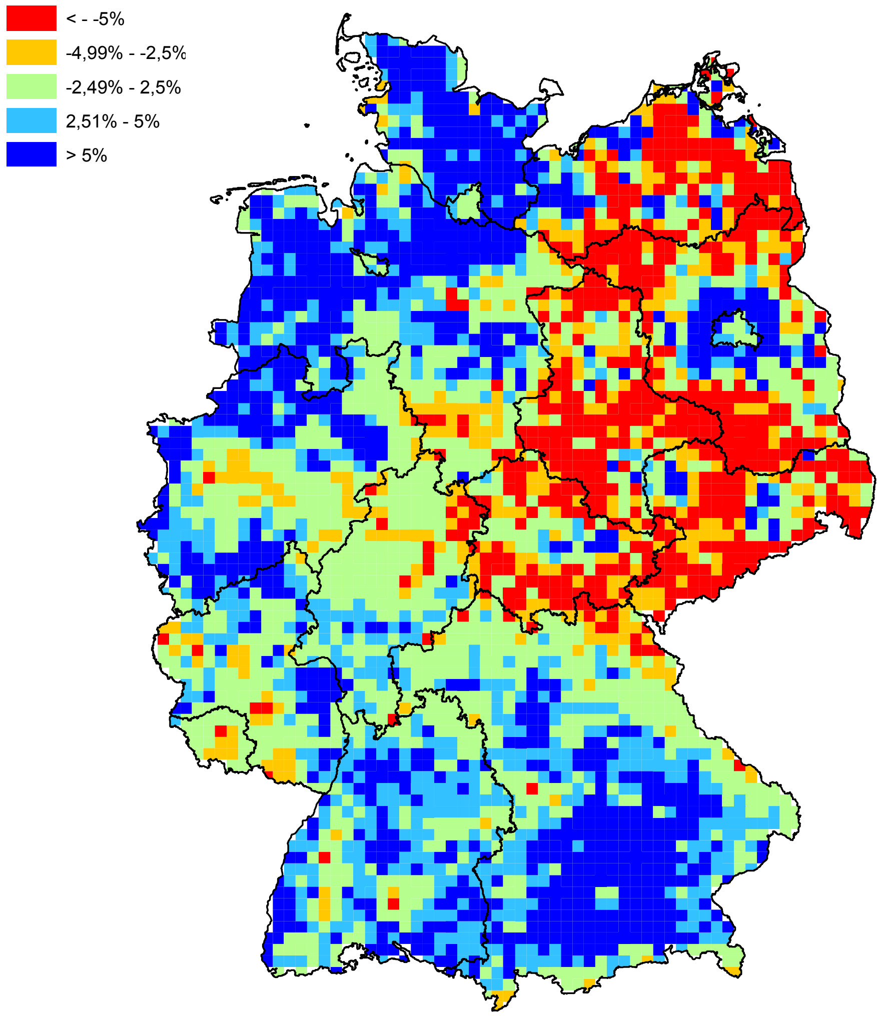


**Figure 1: Population Development in Germany from 1996 to 2006 (in %)**

Based on recent German data on population and land use we observe a genesis of urban land use with a characteristic sequence of three stages (see Figure 2a). In stage one, called "growth sprawl", annual growth rates of population and urbanised areas are positive with urban growth outpacing population growth. Stage 2, termed "excessive sprawl", is characterized by a growing imbalance of urban and population growth. While the annual population growth drops, the growth of urbanised areas remains high. Stage 3, called "shrinkage sprawl", shows a negative population development accompanied by a fall in urban growth rates. We expect a fourth stage with a negative growth of urbanised areas in regions that are faced with a severe decline in population figures.

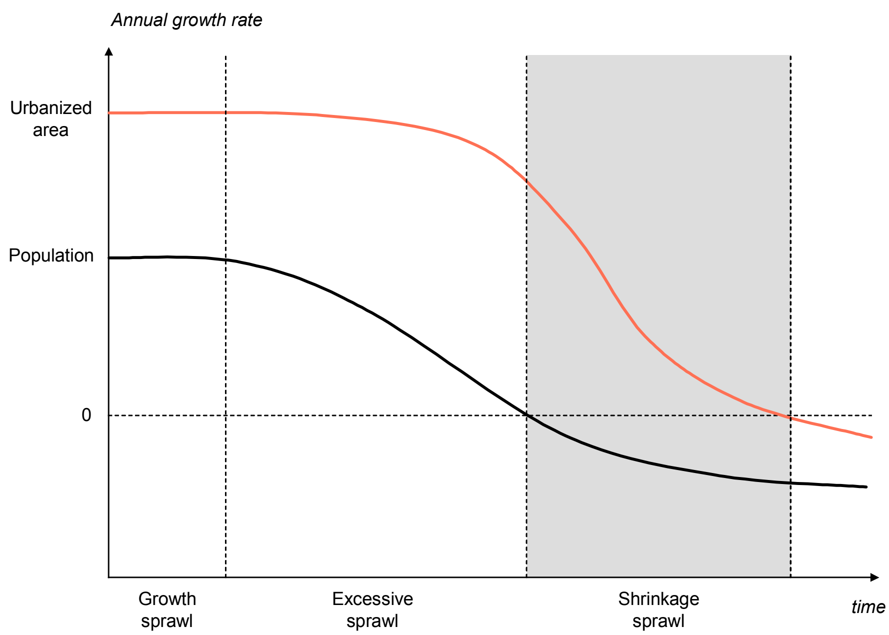


**Figure 2a: Sprawl genesis – from “growth sprawl” to “shrinkage sprawl”**

One outcome of this temporal sprawl pattern is a dynamic decrease in urban density with the largest density decline in stage 2. With respect to the change of urban form, a “perforation” process within the urbanised area becomes visible (Figure 2b). In the Eastern states, in 2002 15 % of the total housing stock was vacant. For the whole country it is estimated that about three million units are vacant. At the same time, the amount of brownfield land is increasing significantly.

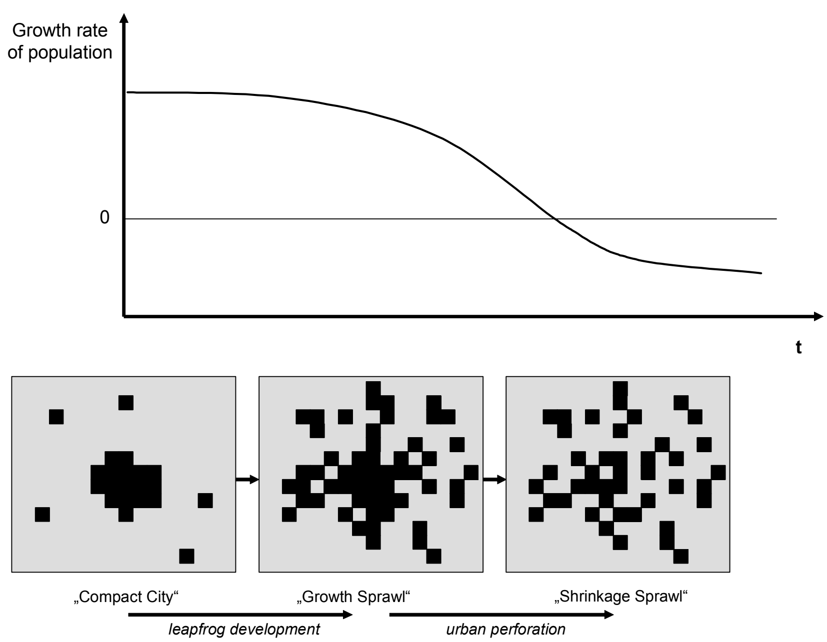


**Figure 2b: Pattern dimension of “shrinkage sprawl”**

What are the effects of the processes described above on infrastructure costs? The few studies that exist in this domain have reported that per-capita costs for providing and maintaining technical infrastructures increases in line with the decrease in urban density (Koziol 2004; Siedentop et al. 2006). Compared to social infrastructures like schools or public health services, the technical supply economy is less capable of adapting its cost structures to shrinking population figures. As a result, per-capita costs rise due to efficiency losses. For example, increasing (overhead) costs are incurred by the necessity to keep up an ubiquitous provision with decreasing population figures ("duty to supply"), by the immobility and indivisibility of facilities (for example the necessary minimum size of water treatment plants), as well as the share of standing expenses (70 – 80% with technical infrastructure networks). Consequently, areas in decline will have to accept higher costs if the existing infrastructure provisions are to be kept and maintained. Alternatively, a development path where infrastructure services adapt with a time lag to the decreasing demands is described as "cost remanence"[i] in the German discussion (figure 3).

The problem becomes more serious by the general reduction of consumption levels which affect the operation of water supply and sewage disposal. In extreme cases this can lead to the malfunctioning of systems. In many Eastern German towns, as little as about 30 to 40 % of the original rated capacity value of the water supply network is being used. Sewage and district heating networks are similarly affected. Besides the problem of income losses because of lost fees, which in the beginning is the most important problem for the providers, additional mid- and long-term costs emerge because of necessary operation-related measures. For example, costs arise if the time increases in which the water remains in the drinking water networks, so that additional flushing of the pipes is necessary in order to prevent the water from contamination by germs. The same is the case for sewage pipes. Here, additional flushing is necessary against offensive smells and depositions in the pipes.

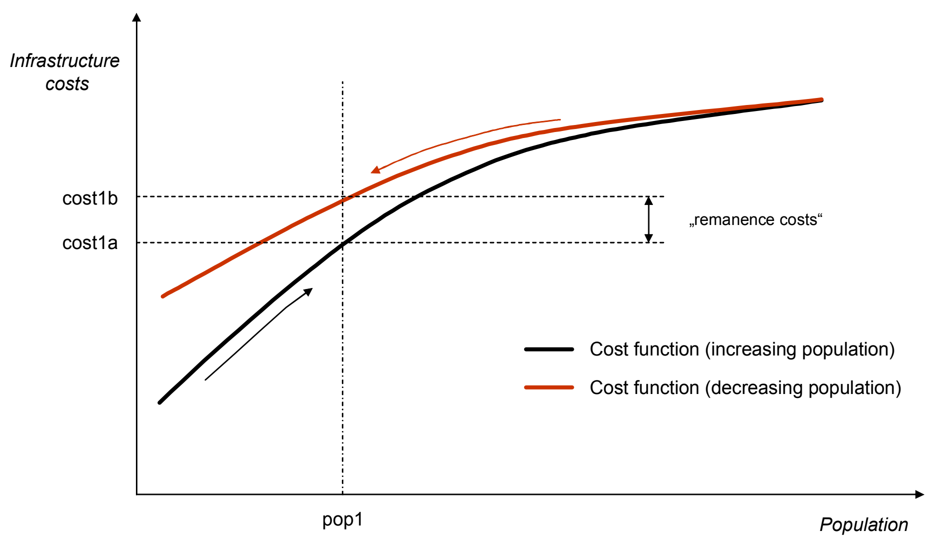


**Figure 3: "Cost remanence" in case of decreasing demand on infrastructure services (adapted from Junkernheinrich, Micosatt 2005)**

The tolerance and affordability for operational and building underutilization differs with the media. With respect to sewage treatment and district heating, it is estimated that an under-utilization of 20 to 30 % compared to the original rated network capacity already requires operational measures. The drinking water and electricity supply are much more robust. Measures like those mentioned above are only necessary when the underutilization reaches 60 – 70 %. Moreover, if underutilization figures fall short of 50 to 60 % (sewage, district heating, gas) and 70 to 80 % (drinking water, electricity), additional building measures might be necessary (Freudenberg, Koziol 2003).

**Indicators**

The empirical part of this paper introduces a number of indicators, focusing on the novel concept of "shrinkage sprawl", the third phase of the timeline for sprawl genesis we introduced above. The resulting maps show where shrinkage sprawl is most likely to become an issue in Germany, with varying degrees of predictable results. Due to the nature of this type sprawl, the indicators that we can present are mostly drawn from density-related information sets. These are valuable in showing where changes in density suggest that shrinkage has or will become problematic, and also add some more detailed information in terms of building activities and new area consumption. However, we are not able at this point to empirically demonstrate that urban patterns are changing as a result of shrinkage. This is for two reasons: firstly, one can not expect that urban patterns adapt to shrinking populations in the form of observable, vacant areas immediately (at least not without considerable time lag). And secondly, data on infrastructure effects that we would expect have not been available for this analysis, at least not the spatially disaggregated format that we would require. Further studies will have to take a closer look at these likely effects, for example infrastructure and fiscal impacts like decreasing levels of traffic, public services, energy and water consumption, or tax revenues.

For the empirical results of this study, we build on density and building activity-related measures as indicators for shrinkage sprawl, focusing on observations on the level of local municipalities ("Gemeinde") and available area statistics. The selected indicators are:

1. *Urban density*, measured in people per hectare urbanised area (including urban land used for transport and recreational purposes), provides the basic information on population densities in Germany's urban areas. It is a static measure that does not reflect on the process of shrinkage sprawl as such, but serves as the base configuration that process indicators can be analysed against.
2. The *change in urban density* is the main indicator for the process of shrinking or growing population numbers in urban areas. It is measured in percent over a period of time, with positive values indicating growth, and negative numbers showing shrinkage.
3. New urban area consumption in hectares. This measure shows to what extent the local planning regime is providing land area for development.
4. The *number of new dwellings in newly developed urban area* serves as an indicator for the level of building activities in new developments. It is largely a market-driven measure. Higher values can be expected where demand for living space is high and land resources are scarce. Lower values will be evident in areas where new urban area is used by either low-density developments, or capacity is simply not reached due to the lack of demand. In relation to shrinkage sprawl we use this indictor to identify mismatches between the capacity

provisions of local authorities (= new urban area) and associated uptake rates (= building activities).

As mentioned above, the indicators used for this study were implemented on a GIS platform. The underlying datasets were sourced from municipal area statistics and linked to the 2003 shapes of local municipalities ("Gemeinde")[ii]. Due to the federal structure of statistics data management in Germany, these area statistics are often inconsistent, especially when dealing with multi-temporal data from the early years after the reunification of former Eastern German states. A number of statistical routines for data integration had to be developed to ensure the comparability of datasets, with a few data gaps remaining.

The advantage of the GIS approach is that the relationships between and among the different indicators become apparent in a spatial sense, although the underlying information has been sourced from area statistics. Since municipalities in Germany vary enormously in size, we scaled the indicator results to a 10x10 km grid, where each cell of the grid contains the indicator value of the municipality it covers. If one cell intersects multiple municipalities, an area weighted average is calculated. In general, the 10x10 km cell size is a good compromise between minimising generalisation effects through disaggregation on one hand, and the requirement to provide sufficient levels of detail for the interpretation of results on the other[iii].

Figure 4 (left) shows the mapped results for the urban density indicator for the year 2004. The main urban agglomerations can be identified by densities above 20 people per hectare (dark grey). Most of the core cities have densities above 40 ha (black). In terms of the overall distribution, the map reveals a north – south increase in population densities, overlain by a horseshoe-like structure (densities from 11 people per hectare, reaching from the Stuttgart Region to the "Saxony triangle" Dresden – Halle – Leipzig), and higher population densities in the very South.

The colours in figure 4 (right) illustrate how urban densities in Germany have changed in the time period from 1996 to 2004. Red, orange and green colours show decreasing urban densities, shades of blue show increases. On the first glance one can see the significant difference between the former Eastern German and the Western states: orange and red colours (over 10% decrease, for red colours over 25%) dominate in Mecklenburg-Vorpommern, Sachsen-Anhalt, and Brandenburg. Saxony and some parts of Thuringia also largely display values in the -10 to -25% range. The reasons (and magnitude) of these population losses is a well-studied subject in recent German demography studies. Initially, the political turmoil after the reunification in 1990 triggered migration patterns flowing from East to West in the early nineties. What can be seen in the observed time period (1996 to 2004), though, are largely flow-on effects, caused by push- (ongoing economic disparities, structural problems in the former Eastern German states) and pull-factors (opportunities in employment, education, lifestyle in former Western German states). On top of this, demographic change with low birth rates and an ageing population is showing its effects in terms of an overall population decline. For the former Western German states, this map also illustrates a more subtle message with regards to urban densities in rural and metropolitan regions: the dominance of the "green" category (0 to -10% loss in urban density) suggests that there are large areas where urban densities decrease slightly, but consistently. On the contrary, the distributions of blue colours (increases in urban densities) are indicative for an ongoing centralisation process. They are mostly located in or around the main metropolitan regions, i.e. urban densities around the centres are increasing.

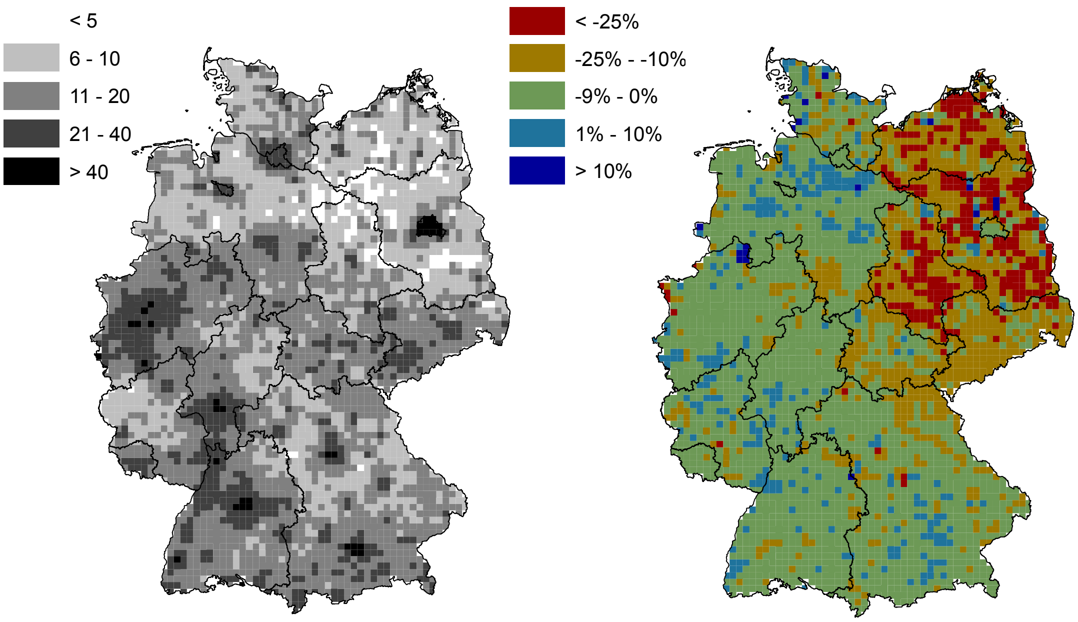


**Figure 4: Urban density in people per hectare 2004 and change in urban densities 1996-2004 (in %); cartography by IREUS; data source: German Federal Office for Statistics, State Offices for Statistics**

In contrast to the well-researched effects of demographic change and migration patterns, the effects on urban infrastructure and public services are subject to a variety of uncertainties with regards to costs, future population changes, and the financial standing of local authorities. The indicator in figure 5 – new urban area developed in 1996 to 2005 - demonstrates that strategies to combat population decline often rely on initiatives to increase the attractiveness of an area, using development strategies that are designed for growth, not decline. Bearing the distribution of urban density changes from figure 4 in mind, the indicator clearly shows that there is a mismatch between the size and amount of new developments and the local population dynamics. Although new area consumption occurs all over Germany, the states of Brandenburg and Sachsen-Anhalt, but also Mecklenburg-Vorpommern, Saxony, and Schleswig-Holstein exhibit particularly high values. Much of these developments are politically supported as a means of economic development for these states. At the same time, the conflict with the government's own sustainable development goals in terms of urban area consumption targets, and the underlying population dynamics question the viability of these developments.

The data visualised in figure 6 provides some more empirical evidence on what this conflict entails. The map shows how many new dwellings have been built in new urban area from 1996 to 2004[iv]. As described above, this serves as an indicator for the dynamics between capacity provisions on the one hand, and market forces (expressed as uptake rates) on the other. Areas where more than 50 dwellings are built on each hectare  new urban area (black) are likely to experience high demand for real estate, driven by population dynamics and a general shortage of living space (Rhine-Ruhr area, Rhine-Main area, Stuttgart Region, Munich, Berlin, Hamburg). On the other end of the spectrum, less than 5 dwellings per hectare support the notion that there are severe discrepancies between the amount of new urban area developed and the amount used – at least for residential purposes.

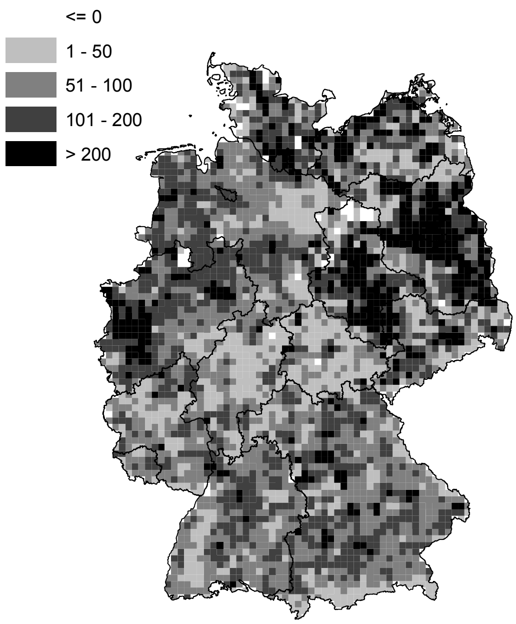


Figure 5: New urban area 1996 – 2004 (in hectares); cartography by IREUS; data source: German Federal Office for Statistics, State Offices for Statistics

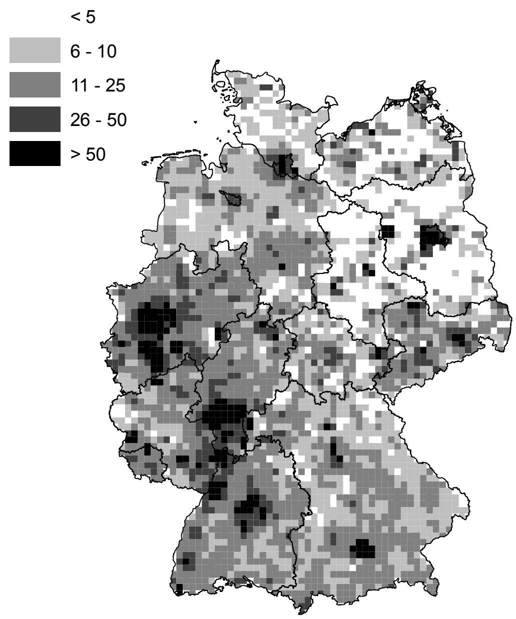


Figure 6: Number of new dwellings in newly developed urban area (1996-2004); cartography by IREUS; data source: German Federal Office for Statistics, State Offices for Statistics

This is the case in much of Sachsen-Anhalt and Brandenburg, also in Mecklenburg-Vorpommern, Schleswig-Holstein, and some smaller areas of Lower Saxony, Thuringia, and Bavaria. When checked against the amounts of new urban area provided (see figure 5), the under-utilisation of new urban area in these areas experiences further significance. It is evidently here where most new urban area is developed and least is being used.

**Conclusions**

Cost-of-sprawl studies claim that significant cost savings regarding infrastructure supply could be realized if a better planned and more compact urban development is achieved (Sierra Club Foundation 2000; Sierra Club of Canada 2003). In contrast, in countries like Germany the infrastructure debate with regards to urban development is fundamentally different due to the effects of population decline. Large amounts of vacant urban land, vacant housing, and underutilized supply networks and facilities raise the question if cost-effective urban infrastructures could be sustained under conditions of urban shrinkage (Koziol 2004).

This paper aimed to identify areas where a new type of urban sprawl called “shrinkage sprawl” is evident. We introduced a number of widely accepted (urban density, new area consumption) and new indicators (number of new dwellings in newly developed urban area) to show the distribution of shrinkage sprawl in Germany. As an effect, we expect an ongoing perforation process of urbanised areas leading to a dispersed and fragmented urban form. We discussed the potential outcome of these processes with respect to infrastructure costs. All else being equal, the lower the urban density, the higher are per-capital infrastructure costs. Our point is that “growth sprawl” and “shrinkage sprawl” – although totally different in their causative factors – are quite similar in their negative effects on infrastructure efficiency. A dispersed and fragmented pattern of urban land use can be found in areas with an intensive growth pressure as well as in areas with a severe decline of population and employment. Urban land use policies have to develop effective strategies to cope with this source of sprawl beyond growth.

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[i] The translation of this term ("Kostenremanenz") has become an accepted term in the German literature over the last few years. Not being aware of an appropriate translation in the English literature, we suggest that "cost remanence" be adopted for the phenomenon described.

[ii] Federal Bureau of Statistics (= Statistisches Bundesamt): municipality shapes; State Offices for Statistics (= Statistische Landesämter): area statistics (population, urban area, building activities, residential area)

[iii] The average size of the municipality polygons we used for Germany is 28 km2, the size of a cell is 10 km2.

[iv] Please note that the new urban area used here is comprised of building and open space areas only, whereas the new urban area shown in figure 5 also includes areas for industry and transportation.