Demographic Change and Infrastructural Cost – A Calculation Tool for Regional Planning

Georg Schiller[1], Dipl. Ing.

[1] Leibniz Institute of Ecological and Regional Development (IOER). Department of Housing and Building Ecology. Weberplatz 1. D-01217 Dresden. Germany. Phone: +49/351/4679-248. Fax: +49/351/4679-212. E-mail: g.schiller@ioer.de, s.siedentop@ioer.de

Paper proposed for SUE-MoT Conference 2007, Glasgow
"Economics of Urban Sustainability"

ABSTRACT

Urban densities largely determine the requirements and costs of infrastructures and their operation. The higher the density, the more cost-efficient the infrastructure. Traditional approaches to cost calculations of such structures generally assume that they are used at full capacity. However this assumption does not hold true under conditions of shrinkage. Instead one finds the under-use of infrastructure and utilities, with resulting increases in per capita costs. Reducing costs by simply reducing capacities is made difficult by the high share of capital cost going toward investment and ever longer life expectancies. The tool presented here examines the interplay between small-scale differences in the development paths of population and settlements. The resulting effects on costs helps point the way to ensuring more efficient structures over the long-term. One example region is taken to show that even with a development trend favouring increasing costs, application of a consistent settlement policy based on the current urban stock can avoid higher future costs for infrastructure in the medium-term. With zero population growth, costs for infrastructure can increasingly become a limiting factor in future policies on urban settlement.

Keywords: urban infrastructure, cost, urban structures, regional development

1. Introduction

Previous research on the effects of urban forms on the public costs of investment, operation and maintenance of network-related technical infrastructure (water, energy and gas supply, sewage disposal) has generally assumed a paradigm of growth. Most current studies are intended to show that substantial costs savings can be achieved by increasing urban densities and locating new development near existing built-up areas. In most “Cost-of-Sprawl-Studies” cost estimates assume constant population densities and consumption levels over time. However, this postulate seems inapplicable to the many cities and regions throughout the world facing population decline and economic stagnation. Decreasing population densities in residential areas is strongly linked to rising additional costs from network underutilization. As lower system utilization increases the per capita costs in operating and maintaining roads, sewer or drinking water networks, one can summarise by saying that fewer residents must pay more for oversized infrastructure facilities. Moreover, additional costs can arise from enforced investments to maintain system efficiency or to demolish and downsize non-efficient facilities.

A team of scientists at the Leibniz Institute of Ecological and Regional Development (IOER) has developed an innovative tool to calculate the costs to infrastructure (social and technical infrastructure) from shrinking development. The proposed paper will give an overview on the methodological frame of the tool and the team’s central findings. Furthermore the paper will indicate basic strategies to meet cost-efficient structures in shrinking regions.

2. Influence of urban density on infrastructure costs

In scientific discourse it is widely agreed that costs for the provision, operation and maintenance of infrastructure facilities and systems are highly dependent on the characteristics of urban form. At the neighbourhood level, residential density is directly linked to expenditures 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 40 dwellings per hectare net urban land[1] network-related per capita costs increase exponentially (Schiller 2002; Gassner et al. 1986) (see also Figure 1). The construction costs can vary enormously for the same number of housing units (Ecoplan 2000; Doubek and Zanetti 1999; American Farmland Trust 1986; Real Estate Research Corporation 1974).

[1] This corresponds approximately to a floor space ratio of 0.5 m² (floorspace per m² net urban land) or a gross population density of 70 (inhabitants per hectare gross residential area).

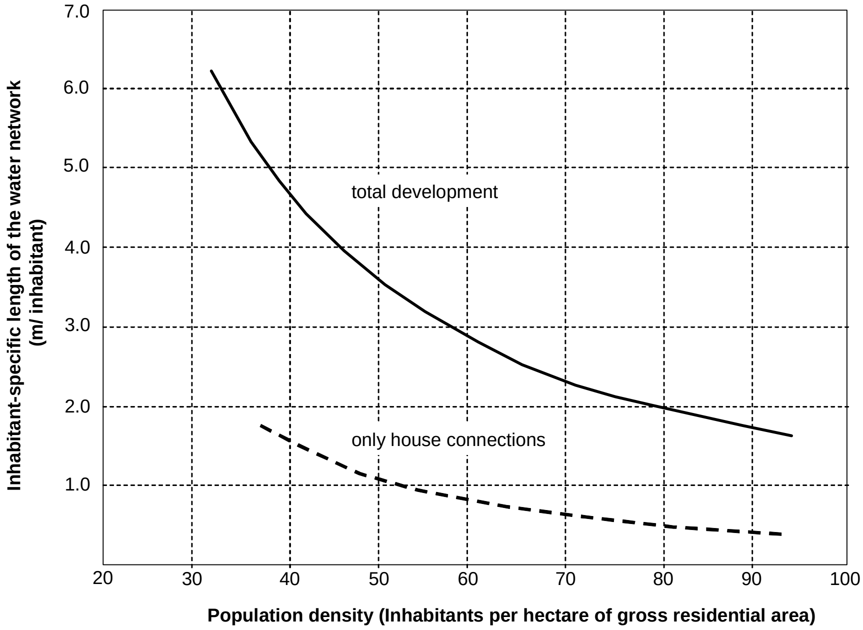


Figure 1 *Network length of water provision in relation to urban density, illustrated by the example of Erfurt, Germany. Source: Schmidt 2000 (modified)*

However, infrastructure costs are also be influenced by factors other than urban form characteristics. Local factors, such as topography, the building plot and reserve capacities in local infrastructures all play considerable roles (Biermann 2002; Schwarz 2001). The quality of urban design also has a major influence. In this paper, however, the focus is primarily on the effect of general settlement structure on infrastructure costs. This is independent of the diverse local factors.

3. Infrastructure costs under conditions of shrinkage

Shrinking processes over long periods of time inevitably uncouple the developmental paths of residential density (housing units per hectare) and population density (inhabitants per hectare). Figure 2 tries to show this effect based on a model calculation. For technical infrastructures this means a situation characterised by widespread under-utilization.

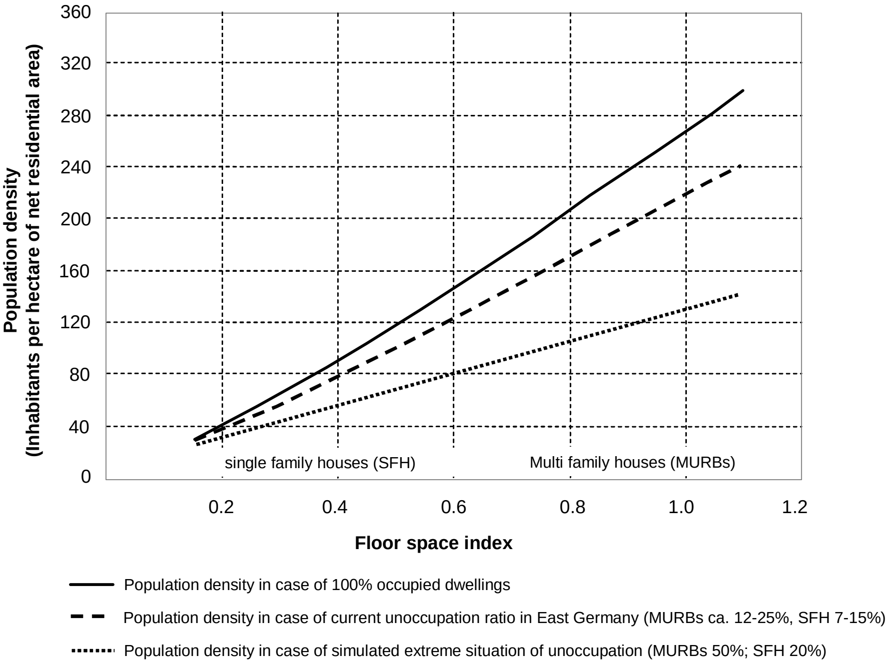


Figure 2: Building density and population density while assuming different levels of unoccupied housing (own calculations based on empirical data in the region of Havelland-Fläming - Brandenburg/Germany).

Social infrastructures such as schools or public health services can attempt to reduce costs in line with fewer users. In comparison the technical supply economy is less capable of adapting to shrinking populations. The requirement of maintaining a ubiquitous provision even in the face of a decreasing population (duty to supply), the immobility and the indivisibility of facilities (dictated, for example, by the minimum size of water treatment plants) as well as the share of standing expenses of 70% – 80% results in substantial cost persistence for technical infrastructure networks (Figure 3).

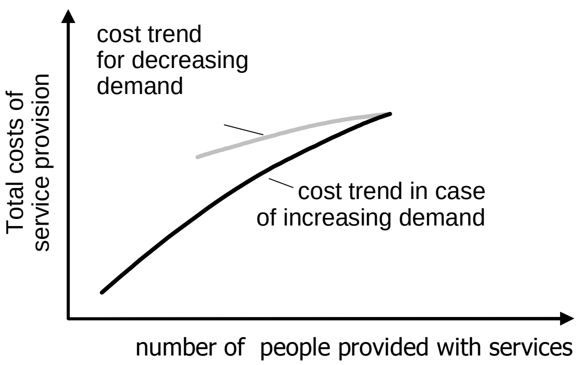
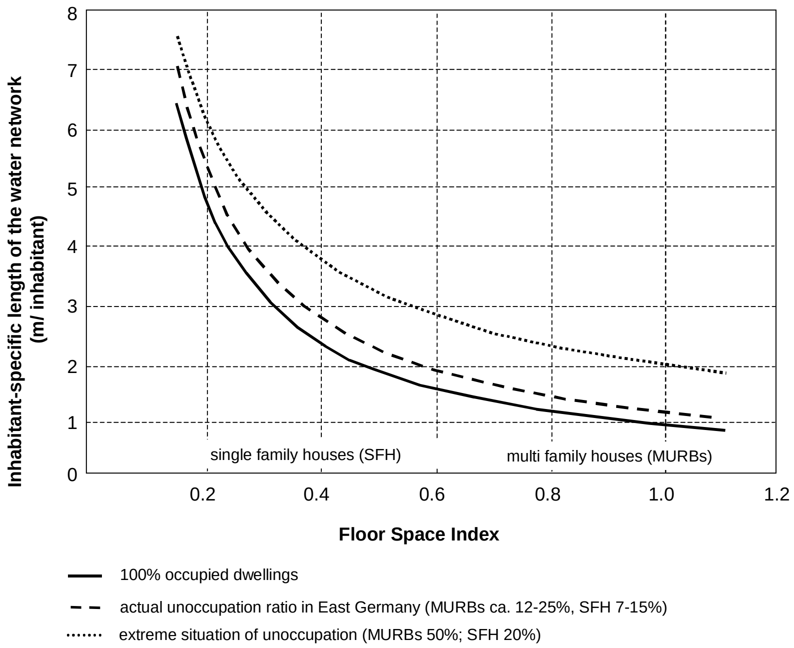


Figure 3: Persistence effect on costs for infrastructure services even while demand is decreasing. Source: Junkernheinrich/Micosatt 2005 (modified)

If the infrastructure provision in areas with decreasing density is to be maintained, then considerable losses in efficiency must be accepted as the consequence. Figure 4 provides illustration using the example of the specific costs for a sewage disposal network. If the network in multi-storied blocks of flats with huge vacancy is not adopted, then efficiency (meter sewage pipe per inhabitant) drops to that of a dense settlement with detached and semi-



detached houses.

Figure 4: *Specific length of sewage pipes in relation to building density and unoccupied housing (own calculations in the region Havelland-Fläming (Brandenburg/Germany) using parameters for the specific infrastructure provision for development according to Buchert et al. 2004).*

The problem is exacerbated when the general reduction of consumption levels affects the operation of water supply and sewage disposal. In extreme cases this can lead to the malfunctioning of systems. In many eastern German towns the active capacity of the water supply network is only about 30% to 40% of the original value (Marschke 2004:79). Sewage and district heating networks are similarly affected. In addition to the problem of lower income from lost fees, the most pressing initial problem for providers, further mid-term and long-term is to cover costs for necessary operation-related measures. For example, if water remains stagnant in the drinking water networks for some time, then costs arise from the additional pipe flushing necessary to protect the water from contamination by germs. This is also true for sewage pipes. Here additional flushing is necessary to reduce offensive smells and deposits forming in pipes. Currently the costs for operational measures are only a fraction of total costs; however the share will rise considerable if no countermeasures are adopted in the mid-term and long-term. For example, the operational costs for sewage treatment in Frankfurt/Oder (Germany) have risen by a factor of six within ten years (Koziol 2004:71).
The degree to which under-utilization necessitates operational and building measures varies with the utility. It has already been estimated that operational measures are required when the utilization of sewage treatment and district heating networks drops by 20% to 30% from the original rated capacity. The supply networks for drinking water and electricity are much more

robust, so that measures such as mentioned above are only necessary when under-utilization reaches 60% – 70%. Moreover, if under-utilization figures are as high as 50% to 60% (sewage, district heating, gas) and 70% to 80 % (drinking water, electricity) then additional building measures may be necessary (Herz, quoted in Freudenberg and Koziol 2003:64).

4. Infrastructure costs of future development paths at the regional level

As indicated above, the capacity of the infrastructure stock is of central importance when evaluating the efficiency of infrastructures under conditions of shrinkage. A cost-saving urban and infrastructure development has to preserve a minimum degree of utilisation of plants and facilities. Under-utilizations of systems must be considered, as they can lead to sudden cost increases similar to situations of excess capacity. To analyse such effects it is necessary that the demand for infrastructure services be examined in a spatially differentiated way.
Taking these issues into account, Siedentop et al. (2006) have developed an infrastructure–calculation tool capable of addressing the interaction of different dynamics of population and urban development. The approach of estimating the costs of various settlement and population development paths has four main components (Figure 5):

- the “quantity structure“ that describes the parameters of physical infrastructure provision derived from legal or engineering standards
- the costs-model that describes infrastructure elements using monetary units
- scenarios to define development paths of population and urban form
- the cost accounting to calculate cost effects along defined calculation rules.

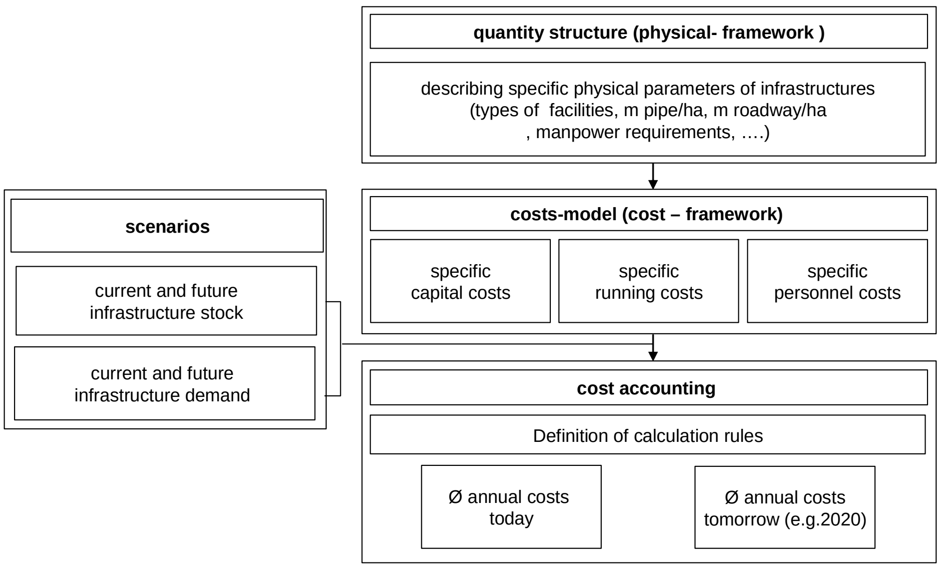


Figure 5: Structure of the infrastructure cost calculation tool

The model uses an Urban Structure Type approach in order to be able to show the interaction of different dynamics of population and urban development. Urban structure types (UST) are basic spatial units on a neighbourhood scale, marked by typical formations of buildings (e.g. neighbourhoods dominated by single-detached family homes). Each UST is characterised by typical urban density values. This is used to describe small-scale parameters for infrastructure-

equipment (e.g. length and profile of pipes) as well as population density parameters – both based on empirical and statistical data.
The tool allows both the calculation of costs at a regional level and costs at the level of city type (high/low density cities, cities with shrinking/growing population). Costs also can be differentiated between type (capital, operating, maintenance) and cost sponsors (public, private).
Figure 6 shows total annual costs in 2001 and 2020 for two development scenarios, calculated for the region Havelland Fläming (located south-west of Berlin). Details of the scenarios are shown in table 1.

Table 1: Basic scenario assumptions

Scenario Trend "Increase of Land Use"	Scenario Sustainability "Focus on SUBS[2]"
- concentration of population in the suburban belt - ongoing green field development - dominance of single detached family homes - disperse allocation of deconstruction of unoccupied buildings	- more regionally balanced population development - fewer new single family houses - more infill development - deconstruction of unoccupied buildings along the infrastructure networks

Following the trend path, the annual cost of providing technical infrastructure facilities in the case study region rises from approx. € 300 million per year to more than € 350 million, an increase of 17%. This would not be a serious problem if the population increased in line with this, but in fact the number of inhabitants (in both scenarios) remains stable at the 2001 level. In this case the total increase of costs can be attributed to the increase of per capita costs. In the alternative scenario, total costs and per capita costs both remain at the current level.

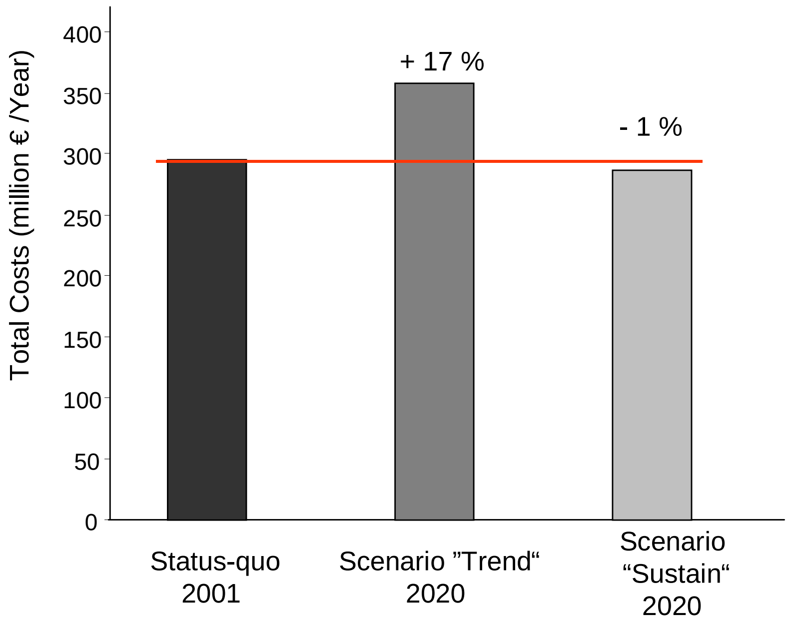


Figure 6: Results of cost calculation of alternative development paths – case study Havelland Fläming (Brandenburg / Germany)

[2] **S**ustainable **U**se of **B**uilding **S**tock

5. Conclusions

The phenomenon of shrinking cities confronts planners with an entirely new situation. Current provision of infrastructure is often pursued as a reactive engineering process, subordinate to urban and regional planning, while the importance of an active interdependence of urban and infrastructure planning is not yet commonly understood. However this is a basic pre-requirement of efficient urban forms, especially when population is declining. Model calculations show that costs can be stabilised under conditions of stagnation and shrinkage if the potentials of current stock are grasped in time. Of course this requires more thought and effort on the part of municipalities and regional planning associations.

The capacity of the infrastructure stock is of central importance when evaluating the efficiency of infrastructure systems under conditions of shrinkage. According to this, cost-saving urban development aims at a minimum degree of utilisation of plants and facilities. However an under-utilization of systems has to be considered, as this can lead to sudden cost increases, similar to situations when capacities are exceeded. The demand for infrastructure services has to be examined on the small-scale to analyse such effects. This requires new methodological approaches and tools to calculate future infrastructure costs.

There is no doubt that the tendencies mentioned above can also provide a chance for the urban development of towns suffering decreasing population. For core cities with high densities, downsizing and restructuring measures are opportunities to increase the value of surrounding areas and establish less dense urban structures. Under the slogan “More green, less Density,” restructuring policy turns from the goals of infill development to aim for an enrichment of high-grade ecological, functional and social elements in undevelopednon built-up spaces (Lütke Daldrup 2000). However, these approaches to shrinking cities have to be considered while preserving economically justifiable infrastructure facilities. It seems likely that the compact city previously legitimised by ecological, social and traffic-related considerations will experience a renaissance under conditions of shrinkage. Infrastructure costs are one limiting factor in urban development, and must be considered when dealing with urban and urban-regional settlement structures in the future.

6. Acknowledgements

This research originates primarily from the BBR (Federal Office for Building and Regional Planning) (Siedentop et al. 2006). Special thanks is given to all participants of the project partnering groups for the constructive collaboration and stimulating discussions, specifically Prof. Stefan Siedentop (Universität Stuttgart), Jens-Martin Gutsche (Gertz Gutsche Rümenapp Stadtentwicklung und Mobilität GBR, Hamburg), Prof. Matthias Koziol and Jörg Walther, both BTU Cotttbus.

References

American Farmland Trust (1986): Density-related Public Costs. Washington.

Biermann, S. (2002): Cost variation with density and distance and implications for sustainable urban form. Paper presented at the 5th Symposium of international Urban Planning and Environmental Association „Creating Urban Environments-Future Forms for City Living“ (UPE5). Oxford Brookes University, 23-26 September 2002. Oxford.

Buchert, M., Fritsche, U., Jenseit, W., Rausch, L., Deilmann, C., Schiller, G., Siedentop, S., Lipkow, A. (2004): Nachhaltiges Bauen und Wohnen in Deutschland. UBA-Texte 01/04. Berlin.

Doubek, C., Zanetti, G. (1999): Siedlungsstruktur und öffentliche Haushalte. Gutachten des Österreichischen Instituts für Raumplanung (ÖIR). Schriftenreihe Nr. 143. Wien: Österreichische Raumordnungskonferenz.

Ecoplan. Wirtschafts- und Umweltstudien (2000): Siedlungsentwicklung und Infrastrukturkosten. Gutachten im Auftrag des Bundesamtes für Raumentwicklung, des Staatssekretariats für Wirtschaft und des Amtes für Gemeinden und Raumordnung des Kantons Bern. Bern.

Freudenberg, D., Koziol, M. (2003): Anpassung der technischen Infrastruktur beim Stadtumbau – Arbeitshilfe. Fachbeiträge zu Stadtentwicklung und Wohnen im Land Brandenburg. Frankfurt/Oder: Institut für Stadtentwicklung und Wohnen.

Gassner, E., Heckenbücker, B., Thünker, H. (1986): Entwicklung des Erschließungsaufwandes nach Flächeninanspruchnahme, Bau- und Bodenkosten: Eine Untersuchung für Verhältnisse im Verdichtungsraum und im ländlichen Siedlungsraum. Forschungsbericht. Informationszentrum Raum und Bau, Fraunhofer-Gesellschaft, T 1845. Stuttgart.

Junkernheinrich, M., Micosatt, G. (2005): Kommunale Daseinsvorsorge im Ruhrgebiet bei rückläufiger Bevölkerung. Edited by Regionalverband Ruhr. Essen.

Koziol, M. (2004): The Consequences of Demographic Change for Municipal Infrastructure. In: German Journal of Urban Studies Vol. 44, No. 1.

Lütke Daldrup, E. (2000): Die „Neue Gründerzeit“ – Veränderte Rahmenbedingungen erfordern neue Strategien in der Stadtentwicklung. In: Raumplanung, Heft 91, S. 164-167.

Marschke, L. (2004): Stadttechnik im Umbauprozess: Probleme und Lösungsansätze. In: Herz, R. (Hrsg.): Stadtumbau und Anpassung der Wärmeversorgungssysteme. 5. Kolloquium Stadtbauwesen am 30.1.2004. TU Dresden, Lehrstuhl Stadtbauwesen, S. 79-86.

Müller, B., Siedentop, S. (2004): Growth and Shrinkage in Germany - Trends, Perspectives and Challenges for Spatial Planning and Development. In: German Journal of Urban Studies Vol. 44, No. 1

Real Estate Research Corporation (1974): The Costs of Sprawl: Detailed Cost Analysis. Prepared for the Council on Environmental Quality, the Office of Policy Development and Research, Department of Housing and Urban Development, the Office of Planning and Management, Environmental Protection Agency. Washington D.C.

Schiller, G. (2002): No Sustainable Building without Sustainable Infrastructure. In: Dyrstad Pettersen, T. : Sustainable Building 2002 - 3rd International Conference on Sustainable Building, 23 - 25 September 2002, Oslo, Norway. Summaries. Oslo : EcoBuild, 2002.

Schwarz, M. (2001): Aktuelle Probleme der Schaffung von Baurechten in Kleinstädten und Dörfern – Baulandbereitstellung unter erhöhtem Kostendruck. 420. Kurs des Instituts für Städtebau Berlin „Schaffung von Baurechten in der Praxis“. Vortragsmanuskript.

Siedentop, S., Schiller, G., Gutsche, J-.M., Koziol, M., Walther, J. (2006): Siedlungsentwicklung und Infrastrukturfolgekosten – Bilanzierung und Strategieentwicklung. Forschungsvorhaben im Auftrag des Bundesamtes für Bauwesen und Raumordnung sowie des Bundesministeriums für Verkehr, Bau- und Wohnungswesen. Final report. (BBR-Online-Publikation).