ONE M² INFRASTRUCTURE FOR ONE M² FLOOR SPACE?!

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Summary

The resource consumption for urban infrastructure should not be omitted when looking for sustainable urban development. The expenditure for infrastructure is a clear function of urban density. But even within specific types of urban residential areas – which are linked to characteristic density – the margin of variants can be very large. The research project presented used GIS tools to analyse urban settlements based on the urban structural type (UST) approach. An UST is a built up area of homogeneous character (open space/buildings) along which the urban area can be differentiated and most physical aspects can be described (material flow, land take, ecological indicators). Examples are: linear developments of the 20ies and 50ies, detached single family home areas, heavy built up blocks of turn of century.

As GIS-analyses is considered of high importance for urban land use monitoring, the possibilities to analyse density and related infrastructure efforts were tested in a case study. The presentation will discuss difficulties found during GIS-analyses.

Keywords: Infrastructure, urban density, residential area, Urban structural Type, GIS-Analyses

1 Introduction

Starting point of the investigation was a digital block-map of the city of Dresden. More than 3650 polygons of residential area – about 2-5 acre each - within the municipality needed to be attributed along seven defined UST. Theses polygons assemble 400 Statistic blocks / neighbourhoods of Dresden. Beside the digital block-map aerial photography and cadastral maps 1:10 000 were used to select the areas. The floor space density for these polygons was then calculated by division of gross floor space – given by statistic of these blocks – and the net residential area. The findings were compared with empirical on-site investigation of areas identified as representative for the specific Urban Structural Types. These representative areas were investigated in detail and planimetered on base of cadastral maps 1:1000. Characteristic values for these areas were calculated and compared with the GIS-calculation-results.

2 Specific density values for defined UST

The comparison proved on one hand, that the **average value** of a specific UST calculated by GIS and the empiric value of the representative did mach quite well (+/- 15 %), but on the other hand the **deviation from the average** of a UST could reach factor 2-10. Deviations in medium to high density areas were up to a maximum of factor 4. Densities found in single home residential areas were up to factor 10 and densities could exceed levels of heavy build up blocks with 1.7 FSI (**Tab. 1**).

Some of these deviations were easy to explain, as polygons didn't in all cases contain exceptionally just one type of building associated with the UST. For example some multifamily residential buildings (MURB'S) could easily be part of a polygon which was identified by aerial photography and cadastral map as single family residential area. The investigation focused on low-density areas (single family homes), because of this high deviation and the fact, that infrastructure material- and land-take per square meter floor area grows exponentially below densities of FSI 0.5 (gross floor space in m² per net residential land in m² = FSI floor space index), (Schiller 2002; Gassner et al. 1986).

Tab. 1 Floor space index of characteristic urban residential areas (UST in Germany) by on-site and GIS-analyses

Abbreviation	UST-Title	On-site empire (Representative)	GIS-empire average	Value range without outliers
SFH-1	Free standing single family homes	0.15	0.26	0.10-0.94
SFH-2	Semidetached or Terraced	0.37	0.38	0.20-0.91
MURB-1	Heavy build up blocks	1.19	0.91	0.51-1.65
MURB-2/3	Linear Development (20ies- 50ies)	0.85	0.86	0.48-1.50
MURB-4	Prefabricated housing estates	1.19	1.09	0.52-2.00
MURB-5	Open Block detached tenements	0.72	0.77	0.50-1.43
MURB-6	Open blocks, Villas	0.39	0.53	0.10-0.94

3 Low density area – GIS-analyses

The further investigation concentrated on the uncertainties of GIS-analyses. A second indicator to differentiate areas was introduced for better understanding of the density related issue: the surface area of roads and sidewalks per gross floor space (RSI = Road space index). The indicator is in a similar way as the FSI a direct function of urban physical density (Buchert, M. et al. 2004). Out of the 3650 polygons about 260 were of single family home areas. These were analysed in a graphic synthesis of these two indicators (**Fig. 1**).

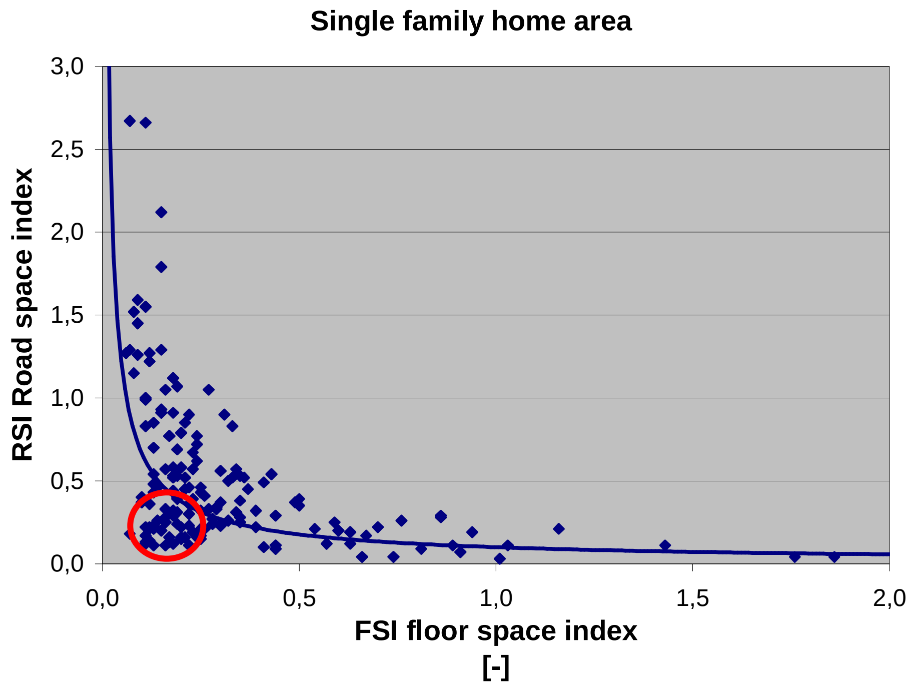

Fig. 1 Relation Road-Space-Index to Floor Space Index

The correlation between RSI and FSI is illustrated well by the diagram. Each dot stands for a polygon of single family home area. But the illustration brings some queerness to the attention. There are densities higher 1.0 and areas with very low density but at the same time with very low RSI smaller 0.3. This could lead to the presumption, that these areas are of high efficiency in terms of required road-surface per house or floor space. A closer look at these areas presented the same specific peculiarities for all of them. They were housing areas situated in merely rural areas in the outskirts of the municipality. The road-surface allocated to them was very few, because the GIS automated algorithm does allocate amounts of public roads surface relational to the spatial extension of adjacent polygons. In this case large polygons of agricultural area took the burden of road surface, while the comparatively small housing areas took a far too small proportion. At the same time it could be observed, that the polygons drawn around housing areas in the outskirts were often too narrow and therefore too small in area. This problem was solved by the decision to allocate roads and sidewalks predominantly to residential areas (transit roads from one settlement to the next were anyway excluded from the investigation). The query types queued into the exponential curve. Having done this a second problem occurred (**Fig. 2**).

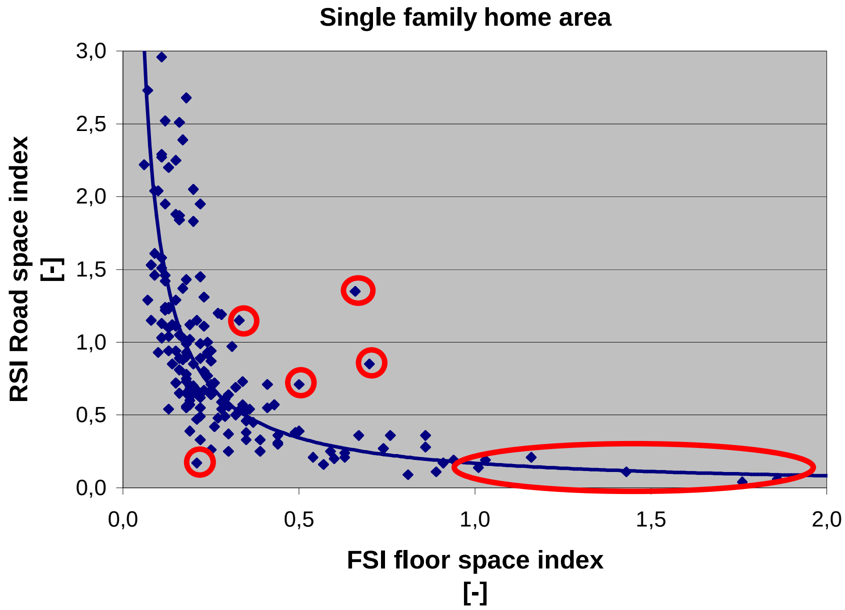

Fig. 2 Relation: Road-Space-Index to Floor-Space-index – rural area corrected

Checking some strange outliers it was found, that some of digital maps used as base for the survey – the Dresden digital block-map – did not comply with the statistical blocks, or by attributation “industrial area” or “agricultural area”, some polygons “disappeared” from the housing area, but statistics still mentioned housing floor space. Secondly, as mentioned above, the attributation to one of the seven UST was not always that unequivocal. Single family homes, large villa (single family) and open MURB were not that easy to distinguish by aerial photography and cadastral maps. By looking at these outliers in a hot spot analyses, some of the misinterpretations could be corrected (**Fig. 3**).

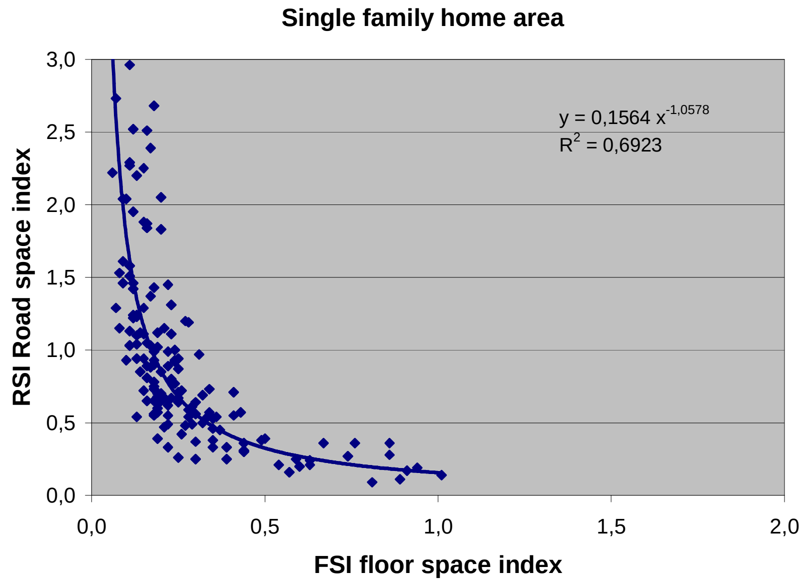

Fig. 3 Relation: Road-Space-Index to Floor-Space-Index – without outliers

The result of the analyses of single family home areas shows a scattered band, but a good regression coefficient of 0.7 with a clear exponential function between FSI and RSI. Last not Least, the GIS-analyses detected more than 36 % of analysed polygons to have more **than one square meter of road-surface per square meter of floor space.**

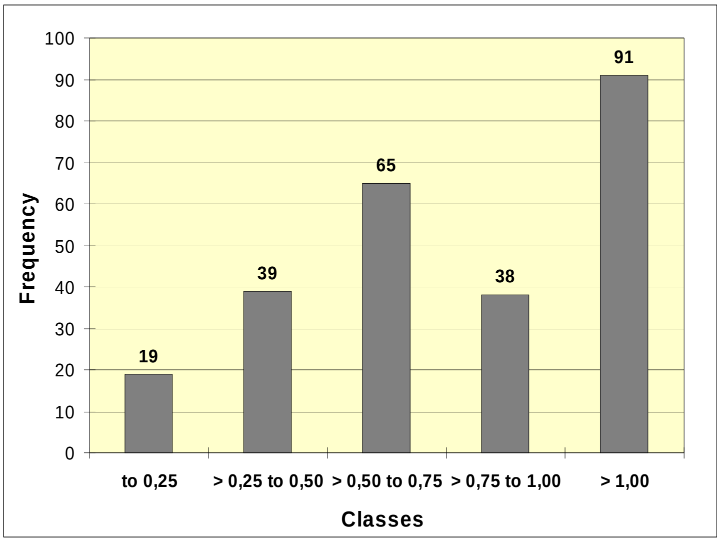

Fig. 4 Road-space-Index – Classes (m²R/m²Fl), Frequency (No. of SFH polygons)

One can link these findings to the sustainable development discussion. What is the specific resource consumption, the land take, the long term maintenance efforts and in result the costs for different urban settlement areas? Who will pay for these structural effects?

What does an urban structure situation of 1 m² road per m² floor space mean in resource terms? Bringing in research findings from Material Flow Analyses one can illustrate, that in this case 1.5-2.0 tons of buildings material will be embodied in roads and sidewalks and 2.5-3.5 tons materials in residential building. The investigation shows, that even material proportions of 1 ton to 1 ton can be found. The material and cost efficiency of urban settlements varies a lot. It is very much determined by urban density and type of access-grid. (Siedentop et al. 2006), (see paper by Schiller, Siedentop: "Preserving cost-efficient infrastructure supply in shrinking cities"). Sustainable urban design needs to pay far more attention to the infrastructure requirements.

4 Conclusions

The physical characteristic of urban areas can be analysed by patterns of urban residential areas (UST approach). The analyses bring up a whole sequence of characteristic features for the defined UST (German case).

Looking at infrastructure and urban density characteristics, the allocation of road surfaces to residential areas in outskirts of cities need to be well defined.

The GIS-analyses (digital aerial Photography, digital cadastral maps) interlinked with statistical data shows highly congruency to on-site empirical analyses results. This is particular true when looking at the average values.

An automated GIS-analyses will always need handmade correction, as some of the values suggest by great discrepancy wrong data entries. The corrections can by limited to some outliers and by that great time savings are possible on the way to achieve municipal wide area analyses.

GIS-analyses can deliver fast and extensive empirical data. The empirical data on physical urban form, on density characteristics, infrastructure efforts, Material flow, land take and costs of settlement structures allows plentiful monitoring options to support urban planning. The efficiency of settlement structure is of high importance. GIS-analyses using the UST-approach can guide the way for action towards a settlement structure with better environment and lower cost.

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