Road Network Analysis as a Means of Socio-spatial Investigation – the CoMStaR[1] Project

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1. Introduction

Urban development strategies aimed at improving sustainability such as densification, polycentrality and mixed-use planning are largely driven by economic and ecological considerations. The social dimension of such concepts is largely unknown. It is difficult to predict the effects of spatial restructuring measures on the social structure of cities. A key question is to examine how sustainable urban and regional planning strategies can be evaluated taking into account the interrelationship between spatial and social structures.

In this context, our aim is to investigate road networks and urban infrastructure using graph-based analysis methods to gain insight into the interdependency of social patterns and the structure of the environment. We will describe methods for determining the meaningful characteristics of a network, which can serve as significant parameters for correlating social data with the urban infrastructure.

1.1 The Data Basis of the Socio-spatial Investigation

For our investigation, we elected to study an area of the urban space of Dresden in Germany. Dresden town planning office provided us with the necessary spatial data such as the entire road network, buildings, administrative zones and maps of the built structure.

In addition, we also purchased population data for Dresden from Microm (www.microm-online.de). The Microm data set consists of a point cloud with approximately 54,000 points. Each data point corresponds to an aggregation of on average 5 households. The data is classified according to milieu providing data about both the socio-economic conditions and the degree and kind of modern lifestyle (Figure 1). Each data point is assigned to one of the ten milieu classes shown in Figure 1.

The different milieus have particular preferences with regard to residential location. Using a graph-based analysis of the infrastructural conditions, the intention was to identify, verify and understand these preferences and with them the typical social patterns in urban areas.

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[1] "CoMStaR": Computer-based methods for socially sustainable urban and regional planning

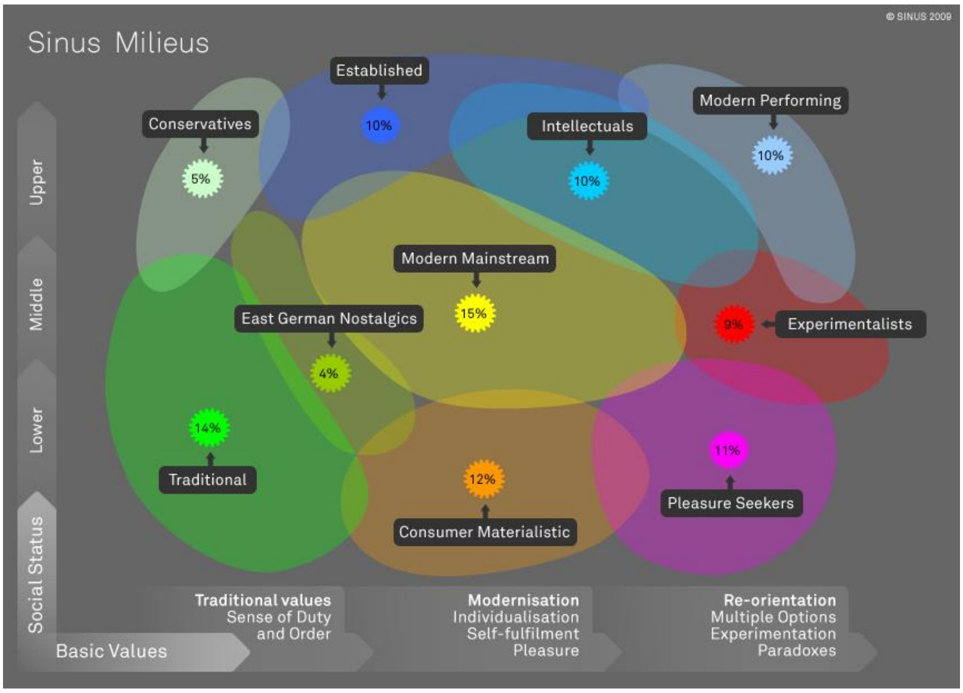

Figure 1. Sinus Milieus: the horizontal segmentation corresponds to different ways of life, the vertical segmentation to socio economic conditions
(source: SINUS SOCIOVISION GMBH).

1.2 Infrastructure and Milieus

The intention of the research project is best illustrated by way of example. Figure 2 shows the infrastructure and built structure of two separate urban districts in Dresden: “Gorbitz” and “Löbtau”.

Figure 2. Infrastructure and built structure of the urban districts “Gorbitz” (left) and “Löbtau” in Dresden (right).

Gorbitz is characterised by large-scale, industrially-prefabricated residential housing built in the 1980s and situated on an attractive valley incline. The net income per household in Gorbitz is significant lower than the average wage. Nevertheless, the social structure is comparatively mixed. Löbtau, by contrast, is arranged around main access routes and is characterised by older buildings with a cemetery in its centre. Although Löbtau is becoming increasingly attractive it is still considered to be a ‘common’ residential area. Due to the proximity of the university and the old buildings, Löbtau has become especially popular with students.

By examining the formation of milieu clusters – contiguous areas where one or two milieus predominate – structural separations became apparent which are very similar to those observed by visually examining the infrastructure alone. The point clouds of the milieu clusters correlate clearly with the boundaries of the infrastructure, although here only the milieu classification of the points were input into the cluster algorithm. Figure 3 shows the extent of the milieu clusters for Gorbitz and Löbtau as well as the respective milieu distribution within the clusters. A comparison with Figure 2 shows clearly that both the spatial extension of the milieu clusters and the infrastructure boundaries correspond well with one another.

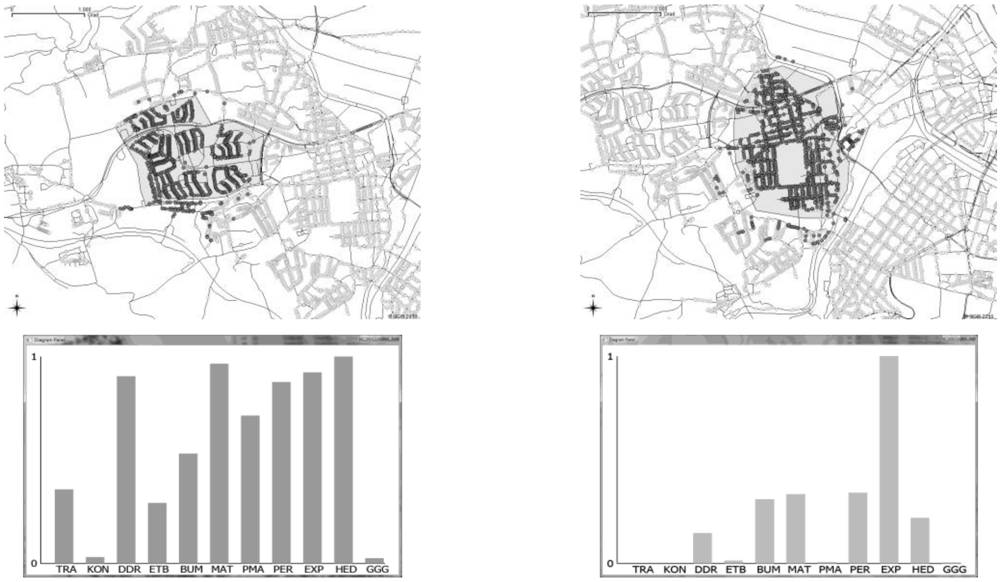

Figure 3. Milieu clusters for the districts Gorbitz and Löbtau (top) and the milieu distribution within the clusters (bottom). The abbreviations used in the diagram correspond to those ones defined in Figure 4.

The intention of the research project is to develop algorithms for detecting relevant parameters in the street distribution in order to cluster the road network into segments and investigate the milieu distribution within those clusters with a view to revealing the infrastructural preferences of the respective milieu classes. Graph analysis is the most important means for undertaking the project (Diestel 2005).

2. Graph Analysis

2.1 Identification of Characteristic Subgraphs

The algorithms and methods used to identify subgraphs by their characteristic properties are still being explored. In order to be able to cluster the road network graph and to analyse subgraphs, we first clustered the existing milieu data points using the WEKA software (Hall 2009). The milieu classification of the points and their locations were fed as input into the cluster algorithm. Based of these various point clusters we identified subgraphs of the road network by combining all the paths between these cluster points.

2.2 Subgraph Analysis

We subsequently determined various characteristics of the subgraphs using parameters such as those from the Space Syntax method (Rose et al. 2008) or as described, for example, in Cardillo et al. (2006). For each subgraph we calculated some 20 descriptive features, for example:

- total length of the road network,
- total area covered by the subgraph,
- average node degree,
- depth and breadth of the tree, calculated from the deepest point (Tukey 1975) as the root,
- average degree of the neighbourhood graph,
- variance in the directions of the edges,
- average number of edges per polygon,
- proportion of grid-like structures in the total area,
- integration and choice (as described in space syntax).

3. Results: Correlations between Milieu Data & Road Network

As described above it is hard to define milieu clusters with only one or two dominant milieus. This means that we cannot assign the typical characteristics of a special subgraph to only one milieu and it is, therefore, hard to draw conclusions regarding a particular milieu's preferred infrastructure.

To obtain at least a first impression we assigned the characteristics of a subgraph to a milieu on the basis of its percentage proportional representation. The summation and normalization of all clusters results in the correlation shown in Figure 4.

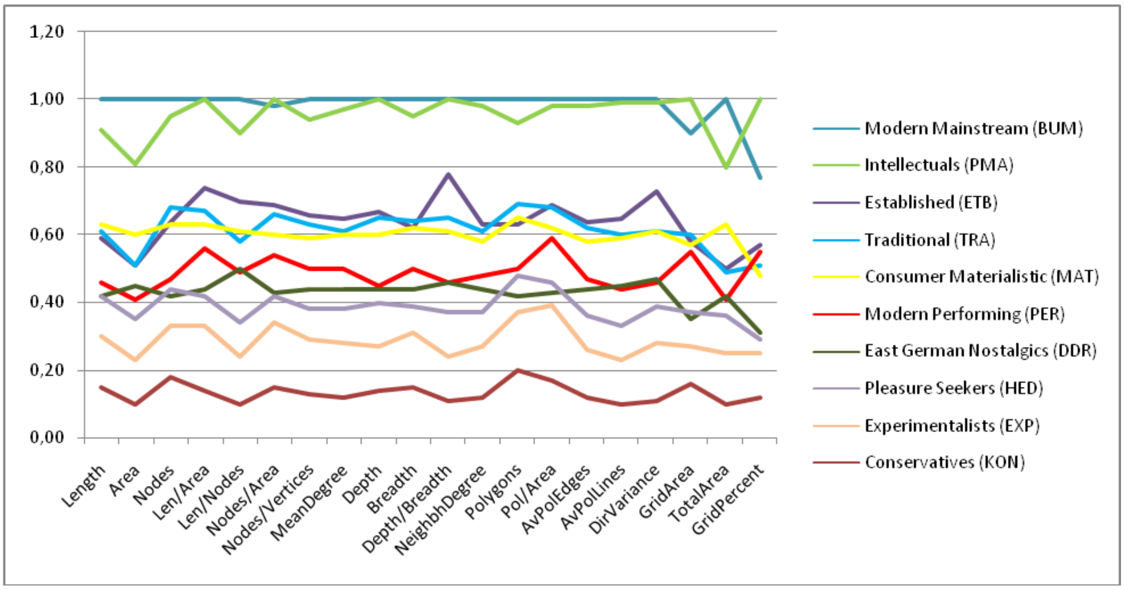

Figure 4. Correlation of the milieus with the characteristics of the road network.

In the light of this evaluation, we can draw two conclusions concerning the infrastructural preferences of various milieus.

1. Some diverging tendencies can be recognized, e.g. “ETB”, “PMA” and “DDR” tend to live in areas with a deep tree structure, meaning that the infrastructure branches often without cross connections (this corresponds to the D-type

described below). By way of contrast, the milieu “BUM”, “MAT” and “DDR” are commonly found in regions with less grid-like structure.

2. The curves in the graph for some milieus exhibit an insignificant curve shape, which may be attributed to the lower density. On the other hand one could argue that those milieus do not tend to segregate and tend to prefer special infrastructure structures respectively.

Another interpretation of the data was undertaken using Marshall types (Marshall 2005). Marshall classified various arrangements of road networks into 4 types: A = old town, B = bilateral type (grid structure), C = characteristic (mixed) and D = distributive (tree-like). We undertook a supervised classification of all single subgraphs using the calculated characteristics mentioned above so that we could label the corresponding milieu points as A, B, C or D-type (Figure 5).

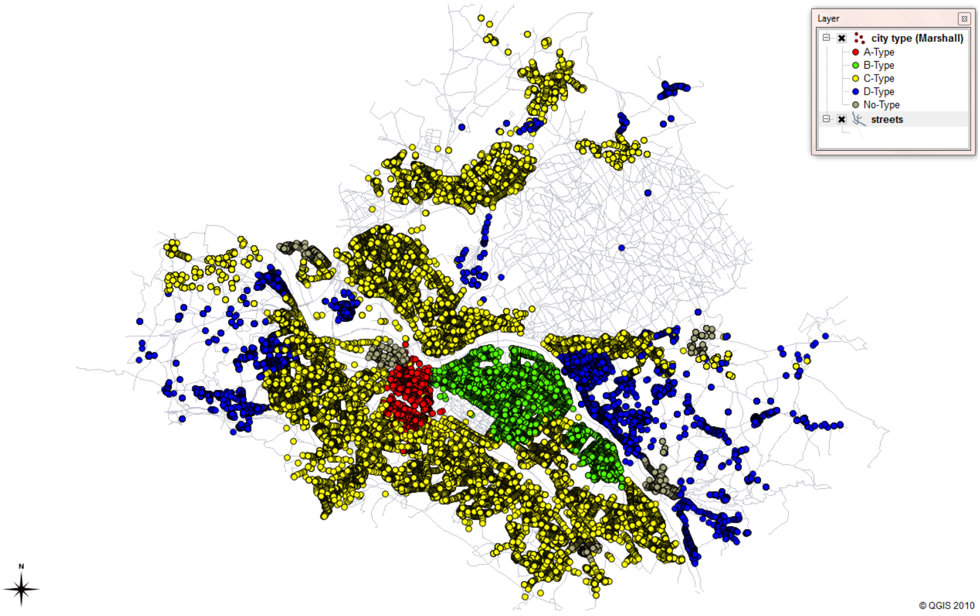

Figure 5. Classification of the milieu points into A, B, C and D-types (after Marshall 2005).

The resulting analysis of this classification is shown in Figure 6, for example “TRA” and “KON” are predominantly present in the old town whereas “PMA” is mostly found in type D.

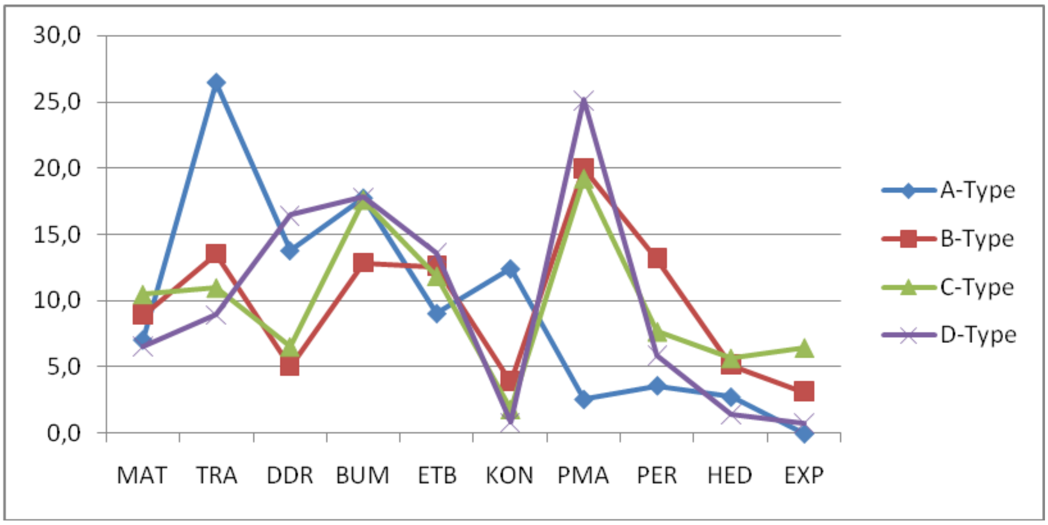

Figure 6. Distribution of the milieus according to A, B, C and D-type (in percent).

4. Conclusion

The study aims to highlight how urbanisation processes and structural changes impact on and affect social distribution. We use graph theory and the geometric analysis of vector data to examine correlations between infrastructure and social milieu. Furthermore we attempt to investigate the characteristics of graphs which can be used to describe the morphology and topology of a graph and allow us to extract subgraphs with specific properties. The long-term aim is to gain a better understanding of the interaction of people with their urban environments to support future decision-making processes in urban planning.

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