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DFG-SNF-Projekt: Räumliche Erreichbarkeiten und die Dynamik der Pendlerverflechtungen in Deutschland und der Schweiz 1970-2005

Author(s):
Killer, Veronika; Axhausen, Kay W.

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DFG-SNF-Projekt: Räumliche Erreichbarkeiten und die Dynamik der Pendlerverflechtungen in Deutschland und der Schweiz 1970-2005

Mapping overlapping commuting areas

Veronika Killer
Kay W. Axhausen
Abstract

This article focuses on mapping and delineation of commuting areas. Commuting distances and the complexity of commuter flows have increased steadily over the years. A reasonable generalisation for the representation of the commuting areas for different purpose is needed. Different cartographic representations, linear and 2-dimensional, overlapping and non-overlapping, are discussed. A commuting area describes a 2-dimensional “sphere of influence” of an urban core. Traditional procedures for delimiting these areas assign each municipality to a single catchment area. One possibility for defining functional areas is the intramax algorithm (FLOWMAP 7.2). This algorithm ignores the overlaps and the differentiation between incoming and outgoing flows. A classical method of transport planners is mapping of interaction where origin and destination is connected with a straight line. Alternatively, methods are generating measurable overlapping commuting areas of inflows. Four different stages of, from a morphological to a circular shaped area, are discussed. Additionally, various overlaps between the catchment areas of centres of equal and unequal rank can be determined.

Keywords

Commuting areas; Overlaps; Cartography; Generalisation; ETH Zurich; Institute for Transport Planning and Systems (IVT)

Preferred citation style

1 Introduction

Traditionally, workers had been commuting daily from their home location to their workplace close-by or to the next urban core where jobs and economic activity were concentrated. In the last 40 years, this pattern of commuting flows changed substantially (Moser, 2007; Schuler et al., 2007). Less and less people still work and live at the same place. This has been caused by the improvement of traffic infrastructure and increasing speeds of commuting. In Switzerland, mean distance of individual transport nearly doubled between 1970 and 2000 from 6.60 km to 11.50 km. Distance travelled in public transport increased only slightly. However, travel times are almost unchanged (Fröhlich, 2008). Furthermore, work is not necessarily concentrated in the traditional cores anymore, but new suburban workplaces emerged. The simple pattern of mainly radial commuting flows from adjacent regions into the large centres has been replaced by a much more complex linkage of relations. Especially, most municipalities do not belong to just one catchment area anymore. The overlaps are now of central interest.

The overall idea of the project, of which this paper is part of, is to find appropriate measures that indicates spatial effects and strength of interaction of commuting flows. Furthermore, commuting effects should not be allocated to a (predefined) centre, so strength of interaction or decoupling of different centres can be measured. Methods, introduced in this article, intend to test different visualisation techniques and to find appropriate delimitations of overlapping commuting areas. In future work their growth over time, and strength or extent of the overlaps, will be analysed.

The presented map is a sequence in three sections. The first section explains the Swiss topography and the need for visualisation overlapping commuting areas. Several studies have been undertaken recently for cartographic representations of complex und large commuting data-sets (Nielsen and Hovgesen, 2008; Chiricota et al., 2008; Rae, 2009). But for visualisation of overlapping regions only a few studies exist (e.g. Botte, 2003; Schuermann, 2004; Rozenblat and Tissandier, 2008). In the second section of the map different methodologies and resulting degrees of generalisation are illustrated. The third section gives an outlook on additional information which will be deduced from the proposed visualisations and analysed in detail in following work.
2 Commuting census data

The data used in this study comes from the journey to work flow datasets collected by the Swiss Census. The commuter matrices of the years 1970, 1980, 1990 and 2000 have been validated by Fröhlich (2008). Census participants, all persons resident in Switzerland, were asked about their workplaces. The dataset provides only flow inside Swiss territory, neighbouring countries are missing. This fact generates a bias of results in regions near the Swiss border. In Swiss census also modes and socio-demographic characteristics are collected. Here only the total commuting flows for the year 2000 are analysed. The point dataset has a spatial resolution of each community’s centroid (Fröhlich, 2008).

![Figure 1: The Swiss agglomerations of the year 2000 (Schuler et al., 2005).](image)
3 Methodology of mapping commuting areas

Traditionally, geographers and planners have used three classificatory viewpoints in defining regions. The delimitation of an area is generally based on homogeneity, functional criteria, or on fixed administrative boundaries. The classical method to delimitate catchment areas, found in a large number of countries, is to define catchment areas as the contiguous localities where at least some share of population work in the core or in the agglomerating areas (see figure 1). Figure 1 shows the agglomerations for the Swiss core cities. Besides commuting flows generally further demographical and morphological aspects are included into this approach (Schuler et al., 2005).

The usual methods for the determination of catchment areas allocate each municipality to just one of an arbitrary number of catchments, even if the interaction is small. Figure 2 visualises the Swiss labour market regions, a spatial categorisation including all communities of Switzerland (Schuler et al., 2005).

3.1 Visualisation of commuting areas by linear flow mapping

A classical method of mapping spatial interaction data is flow mapping, a simple technique that shows patterns of origin and destination linked flows with a single line or arrow. In transport engineering and transport planning, the mapping of dynamic flows has been developed. Today several software products map very large origin and destinations matrices (e.g. FLOWMAP 7.2, several ArcGIS extensions). This simple linear visualisation technique (map, Figure 2) is the starting point of other contemporary studies to explore information in complex spatial interaction data (Nielson and Hovgesen, 2008; Rae, 2009; Chiricota et al., 2008).

The flows in Figure 2 (see map) point out the strong linkages in lowland Switzerland. Inflows are highly overlapping, even though only flows of more than ten commuters are visualised. The degree of interaction or overlaps is difficult to identify in this map.
3.2 Visualisation of commuting areas with the intramax algorithm

A functional area is described by the interaction within a region. The intramax algorithm, implemented in the software FLOWMAP (7.2) developed by the University of Utrecht (Van der Zwan et al., 2005) delimits functional areas to produce a regionalisation based on an interaction matrix. The intramax algorithm analyses size of the interaction between different locations. It is a stepwise hierarchical algorithm. In each step two areas are grouped together and the interaction between these two areas becomes an intrazonal interaction of the new grouped area. Maximising the intrazonal interactions is the objective. The process is repeated until all areas are grouped together and all interaction becomes intrazonal (Van der Zwan et al., 2005).

The procedure has been tested in several studies. It shows a strong tendency of resulting areas, which consist of an urban area and their adjoining suburban or rural areas (e.g. Feldman et al., 2005; Nielsen and Hovgesen, 2005). The results are sensitive to the realised number of steps. In Switzerland, there are 2896 administrative community in the year 2000. After 2877 steps the resulting regions are clearly identified (see map, Fig. 3), but not centred on a specific centre. Still, the associated centre is obvious. The map tries to delimitate 16 regions imitating the official Swiss labour market regions. Unlike the official regions (Fig. 2) some regions of the
intramax algorithm (see map, Fig. 3) are combined (e.g. Lugano and Bellinzona). Moreover, mountain regions are disconnected from medium or larger urban centres. This analysis helps to get a general idea about the real existing commuting areas with a spatial resolution on municipal level. No interactions and linkage of the flows between the centres are visualised, however.

**Figure 3:** Regionalisation by the intramax algorithm by number of steps for the year 2000.
4 Methodology of different degree of generalisation of overlapping commuting areas

The classical methods to delimitate urban catchment areas, as discussed above, try to gain definable areas mostly for administrative or statistical use. But, they do not represent the real complexity of commuting behaviour. Often a place or a district is linked to different centres. Generating overlapping areas makes it possible to analyse impact and interaction of the daily commute. The basic data of all visualisations of this paper is a point dataset. In figure 4 the inflows are visualised by graduated point symbols. This approach is unsatisfactory, because of loss of information by overlay. A visualisation of all of Switzerland with this method is not productive for analysis. The following four stages of generalisation show the spatial trend from the most detailed, taking into account the Swiss landscape shaped by lakes and mountains, to an abstract urban model.

The concepts and methods of the different generalisations are:

1. **A morphological commuting area (by means of the kernel density method)**

   The basic idea of kernel density estimation is a transformation of a point pattern into a continuous representation of density (see Fotheringham, Brunsdon and Charlton, 2000). It is simplified an interpolation or smoothing technique which generalises points to an area. The interpolation leads to a value of density for each raster cell of Switzerland, according to quantitative threshold values. In this example, the values are fixed at 4 km of search radius and at raster size of 1 km. Figure 5 shows a density map for all inflows to the 16 centres included in the calculation. However, kernel density is calculated separately with the inflows to each centre to obtain spatially well-defined commuting areas for each centre. Contour lines are generated from the density surface and a reasonable threshold value is selected (a density of 0.000002).

   This method produces commuting areas reflecting the landscape morphology (see map, figure 4). Areas are limited by lakes or valleys. Furthermore, areas do not have to be connected, but can be split. Particularly, large urban centres belong to nearly every other commuting area.
2. A radiating commuting area (by means of the line density method)

Figure 6 displays the pattern of all inflow lines (map, figure 2) of the Swiss centres as a line density surface. This technique has been introduced in UK by Rea (2009). The line density is calculated with a raster size of 1 km and a research radius of 2 km. As the procedure above, after generating the contour lines an appropriate threshold value is selected (density 0.1). This method produces radial shaped commuting areas (see map, figure 5). The strong influence from one urban core to another is visualised by one spout connecting these two centres.

3. A elliptical commuting area (by means of the confidence ellipse)

A two-dimensional confidence ellipse or standard deviational ellipse is an explorative method to investigate the relationship between two variables. Confidence ellipses defined as the smallest possible area in which the true value of the population should be found with a certain probability (in this study 70 %) around the geographical mean of the flow vectors. Similar methodological techniques have already been used by Schönfelder and Axhausen (2003) and Rai et al. (2007) for the characterisation of human activity spaces. This method has the advantage that attributes besides size of the catchment area can be measured and quantitatively compared, such as the shape, shift, or angle with regard to the next centre (see map, figure 6).

4. A circular commuting area (by means of the standard distance)

The circular delimitation is a well-established urban model assuming a plain and uniform hinterland. Standard distance measures the degree to which features are concentrated or dispersed around the mean. The area is calculated with the first standard deviations (68.3 %) (see map, figure 7).
Figure 4: Visualisation of inflows in centres with graduated symbols.

Figure 5: Inflows of the most important centres as a kernel density raster.
5 Discussion and Conclusions

Cartographic primitives, as point, line and area, produce visualisations of different properties. Point representations are, because of the large dataset and the required scale, not advisable for this study. Lines demonstrate the complexity of the commuting linkage. Methods of social network studies could be applied to get concrete measures out of linear interactions (e.g. Palla et al., 2005; Chiricota et al., 2008). The 2-dimensional polygonal visualisation allows a strong simplification of the complexity. The generation of overlapping 2-dimensional areas highlights the strength and complexity of spatial impacts of commuting, of one, two, or even for every Swiss community (see map, figure 8). Each community gets a measure of complexity by number of overlaps. Additionally, impacts can be linked to a specific centre that is not possible for a density surface. This method can be employed in national or communal spatial planning projects to detect regions with urban sprawl or attractive living situations. Apparently, the results are strongly influenced by chosen parameters of the geometries. Identifying this effect will be important in further studies.

The different degrees of generalisations can be used for different propose and scale, depending on the specific research question. For our study, it is important to develop measures which can be applied to every Swiss community. A relatively simple and quantitatively comparable measure is necessary to show the impacts of commuting for every community in space and time. Figure 9 on the map describes the increasing size of commuting area the 16 largest urban centres. Besides the size of the catchment area, the shape, shift, or angle with regard to the next centre can be identified. Information about strength of interaction of two centres, about polycentricism, or main commuting flow of every community, can be obtained.
6 Software

A bundle of software packages was used for this analysis and cartographic representation. Generally, figures are visualised with ESRI’s ArcGIS 9.2. Several GIS-Tools and Extensions are used for analysis: Line Density Tool, Kernel Density Tool, Standard Distance Tool, ET Geowizard Extension and Point to Lines Extension. The software FLOWMAP 7.2 calculates the intramax analysis. This software has been developed at the Faculty of Geographical Sciences of Rijksuniversiteit Utrecht. The confidence ellipse was implemented in R (A Language and Environment for Statistical Computing) to allow flexible control over the threshold values in further research.

![Figure 6: Inflows of the most important centres as a line density raster.](image)
References


