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Mapping Overlapping Commuting-to-Work Areas

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Abstract

This article focuses on mapping and delineating commuting areas of work travel (commuting-to-work area - CTWA). Traditional procedures for delimiting these areas assign each municipality to a single catchment area. Commuting distances and the complexity of commuter flows have increased steadily over the years. A classical method in transport planning is a mapping of flows where origin and destination are connected with a straight line resulting in a visualisation of the overlaps. However, the proposed new commuting-to-work area delineation describes a 2-dimensional catchment area of each urban core naturally overlapping with other catchments. Four different degrees of generalisation of CTWAs, from a morphological to a circular area, are discussed and compared to alternative mappings.

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1. Introduction

The traditional conceptualisation of travel-to-work trips is a commute from the relevant residence to a proximal urban centre where jobs and other economic activities are concentrated. In the last 40 years, this pattern of commuting flows has changed substantially in Switzerland (Moser, 2007; Schuler et al., 2007). Fewer and fewer people still work and live in the same locale. Furthermore, work is not necessarily concentrated in the traditional cores anymore, and new suburban centres of work have emerged. A much more complex pattern of relationships between places has supplemented the simple pattern of radial commuting flows from adjacent regions into large centres. Long-distance commuting trips between the large urban centres of Bern, Zürich and Basel have become especially prominent over the years.

The motivation for this paper is to advance traditional methods of delineating commuting catchment areas to commuting-to-work areas with a technique that visualises and measures them, while allowing for overlaps. Areas are no longer self-contained; urban centres of the same or other hierarchical levels have strongly interacted over the years. Many, if not most, municipalities no longer belong to just one catchment area. Therefore, the overlapping areas become of central interest. The overlaps describe a blurring of administrative boundaries and prompt a rethinking of political and economical units. Furthermore, overlapping catchment areas are considered attractive business and residence locations, or indicate the presence of a polycentric urban structure.

Several studies have been undertaken recently on cartographic representations of complex and large commuting datasets (Nielsen and Hovgesen, 2008; Rae, 2009). However, only a few studies exist on visualisations of overlapping commuting-to-work regions (e.g. Botte, 2003; Schuermann, 2004; Tissandier and Rozenblat, 2007).

The approach of commuting-to-work areas (CTWA) has to be applied flexibly in space and time and also has to meet certain demands: The CTWA approach has to be applicable to point data to allow the analysis of individual and aggregated data (1). The workflow data is the only criteria to be considered. For this reason, the approach is applicable even if socio-demographic data is missing or scarce (2). The approach should have only one threshold value for the examined time period (3). Nine maps are presented here in three sections. The first section shows Swiss topography and the need for the visualisation of CTWAs (Maps 1-3). In the second section, different methodologies and the resulting degrees of generalisation are illustrated (Maps 4-7). The third section gives two examples of an analysis of overlaps in space and over time (Maps 8-9).

2. Commuting census data

The data used in this study comes from the journey-to-work flow datasets collected by the Swiss Census in the years 1970, 1980, 1990 and 2000. In this paper, aggregate in-commuting flows at municipality level are analysed; all years are standardised to the municipal boundaries of the year 2000 (Tschopp et al., 2003). The municipality is located as the centroid point of the main settlement of each municipality (Fröhlich, 2008). The dataset only provides information on flows inside Swiss territory because flows to neighbouring countries were omitted in the official data. This fact generates a bias in the results for municipalities near the Swiss border. The basic data of all visualisations is therefore a point dataset. In Figure 1, the number of in-commuters towards a centre is visualised by graduated point symbols. This simple approach is unsatisfactory because of the loss of visual information by point overlay. Therefore, a visualisation of all of Switzerland using this method is not productive for analysis.

Figure 1. Visualisation of inflows towards centres with graduated symbols.

Figure 2. The Swiss agglomerations of the year 2000 (Schuler et al., 2005).

3. Classical methodology of mapping travel-to-work areas

The classical methods to delimitate catchment areas or travel-to-work areas are based mainly on functional commute-to-work criteria. These catchment areas of contiguous localities define an area where at least some share of population live and work in the core or in the agglomeration. The flows within the region are maximised, and those between different regions are minimized. Thus, approximate self-contained regions are obtained (e.g. Coombes and Openshaw, 1982). These regions are statistical units and normally have a political relevance. Because of the limited scope of this paper, an extended literature review has to be omitted. The paper concentrates on the existing officially adopted Swiss methodology.

In Switzerland, a regionalisation of agglomerations, metropolitan areas and labour market regions exists (Thierstein et al., 2003; Avenir Suisse, 2005; Schuler et al., 2005). The method of limiting agglomerations (see Figure 2) includes, in addition to the commuting flows, demographical aspects and morphological coherency of the built-up urban

area. This approach has been used since 1980 with slightly varying methodologies and threshold values. Figure 3 visualises the Swiss labour market regions, a spatial categorisation based on smaller functional and homogenous administrative regions called MS regions. This method allocates each municipality to just one of catchment areas based on sixteen predetermined workplace centres, even if the interaction is small.

Figure 3. The Swiss labour market regions (Schuler et al., 2005).

4. Section 1: Mapping of commuting-to-work areas

Visualisation of commuting-to-work areas with the INTRAMAX algorithm

The first step visualises the regionalisation based on the functional criteria of commuting to work alone. However, this approach is predicated on the municipality level and does not allow overlaps.

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 without predefining centres using a stepwise hierarchical algorithm. Its objective is to maximise intrazonal interactions. The resulting areas tend to consist of an urban area and its adjoining suburban or rural areas (e.g. [Feldman et al., 2005](#); [Nielsen and Hovgesen, 2008](#)). The number of regions is sensitive to the number of iteration steps (see Figure 4). It is attempted to delimitate sixteen regions imitating the official Swiss labour market regions (see Map 2). Unlike the official labour market regions (see Figure 3), the INTRAMAX algorithm (see Map 2) combines a number of regions (e.g. Lugano and Bellinzona). Moreover, the mountain regions (coloured grey) remain autonomous and are disconnected from medium or larger urban centres. They are not centred on a specific urban centre (see Map 2). The other regions are associated to one of the sixteen large- or medium-sized urban centres.

Figure 4. Regionalisation by the INTRAMAX algorithm for the year 2000. (a) 2880 (b) 2860 (c) 2800 and (d) 2000 iteration steps.

Visualisation of commuting-to-work areas by linear flow mapping

A classical method of mapping spatial interaction and linkage data is flow mapping, a simple technique that shows patterns of origin-destination flows with a single line or arrow. Today, several software products facilitate the mapping of very large origin-destination matrices (e.g. FLOWMAP 7.2, several ArcGIS extensions). This simple linear visualisation technique (see Map 2) is taken as a starting point in several contemporary studies exploring information in complex spatial interaction data (Nielsen and Hovgesen, 2008; Rae, 2009). The flows in Map 3 highlight strong inter-linkages amongst selected urban centres in lowland Switzerland.

5. Section 2: Methodologies of different degrees of generalisation for overlapping commuting-to-work areas

The classical methods to delimitate urban catchment areas, as discussed above, try to obtain these areas mostly for administrative or statistical use. However, a place or a district can be linked to several centres. Therefore, different methods of overlapping commuting-to-work areas are developed here. The following four stages of generalisation show the spatial evolution from the most detailed, taking into account that the Swiss landscape is shaped by lakes and mountains, to an abstract urban model. It is focused on the shape of the resulting CTWAs rather than on their size. Therefore, each threshold value selected is arbitrary to a certain degree, but the resulting areas are of similar size to those in the official classification.

The concepts and methods of the four different generalisations are as follows.

1st degree of generalisation: A morphological CTWA (by means of the kernel density method)

Kernel density estimation transforms point pattern into a continuous representation of density (see [Fotheringham et al., 2000](#)). It is essentially an interpolation or smoothing technique that generalises points to an area. The interpolation leads to a value of density for each raster cell of Switzerland. In this example, the values are fixed at 4 km for the radius and 1 km for the raster size (values are chosen to obtain a smooth density surface). Figure 5 shows a density map for all inflows to the sixteen centres included in the calculation. However, kernel densities are calculated separately with the inflows to each centre in order to obtain spatially well-defined commuting areas for each centre (see Map 4). Contour lines are generated from the density surface and a threshold value of 2×10^{-6} is selected for the density. These commuting-to-work areas reflect the landscape morphology (see Map 4). Lakes and valleys limit areas and furthermore, areas are not contiguous.

2nd degree of generalisation: A radiating CTWA (by means of the line density method)

Figure 6 displays the pattern of all inflow lines (see Map 5) of the Swiss centres as a line density surface. [Rae \(2009\)](#) has applied this visualisation technique in the UK. The line density is calculated for a raster cell size of 1 km and a radius of 2 km (values are chosen arbitrarily to obtain a smooth surface density). As in the first generalisation, a threshold value is selected (density 0.1) after generating the contour lines. This method produces roughly radial shaped commuting areas (see Map 5). The strong interrelationship of two cities is visualised by their connection.

3rd degree of generalisation: An elliptical CTWA (by means of a confidence ellipse)

A two-dimensional confidence ellipse or standard deviational ellipse is an explorative method to investigate the relationship between two variables. The confidence ellipse represents the smallest possible area within which the true value of the commuting population should be found with a certain probability around the geographical mean of the flow vectors. After a detailed investigation of the possible values, a value of a 70% probability is adopted to generate stable and reasonable CTWAs. Schönfelder and Axhausen (2004) and Rai et al. (2007) have applied similar methods in their characterisation of human activity spaces. This method has the advantage that attributes besides the size of the catchment area can be measured and quantitatively compared, such as shape, shift, or angle with regard to the next centre (see Map 6).

4th degree of generalisation: A circular CTWA (by means of the standard distance)

The circular delimitation of CTWAs 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 as the first standard deviation (68.3%) (see Map 7).

6. Section 3: Analyses of the overlaps in space and time

For analytical use, it is important to develop measures that can be applied to every municipality or area of a region or country. A relatively simple and quantitatively comparable measure is necessary to show the impact of commuting for every community in space and time and allow a comparison. Therefore, the third degree of generalisation will be chosen for analysing spatial patterns of commuting in future work. Several measures can be derived from this elliptical commuting-to-work area approach: e.g. each community can be described by a measure of complexity with the number of overlaps (see Map 8). Map 9 describes the increasing size of commuting areas associated with the sixteen largest Swiss urban centres.

Figure 5. Inflows to the most important centres as a kernel density raster.

7. Discussion and Conclusions

Basic cartographic representations (points, lines and areas) produce visualisations with different properties. Point representations are, because of the large dataset involved and the required scale, not applicable within this context. Lines demonstrate the complexity of the commuting linkages. The polygonal visualisation allows a measurable simplification of travel-to-work interaction. The degrees of generalisations can be adapted to different purposes and scales:

Generalisation 1 (see Map 4): this visualisation is reasonable for case studies of single urban areas based on individual data and practical spatial planning projects.

Generalisation 2 (see Map 5): this visualisation emphasises the functional connection and not the real spatial impact, and is therefore suitable for conceptual analyses in spatial planning.

Generalisation 3 (see Map 6): in addition to the generalised spatial extent, the main axis of commuting impacts is visualised, approximating the morphological shape.

Figure 6. Inflows to the most important centres as a line density raster.

This generalisation is reasonable for use in statistical modelling on individual or aggregated data at the municipal level.

Generalisation 4 (see Map 7): this visualisation gives a simple idea of the spatial extent of an urban boundary (e.g. for research in urban economics).

The CTWAs identified by this research indicate that they are strongly influenced by the physical geography of Switzerland. The size of the CTWAs differs by the population size of the city concerned. However, the size of the CTWAs and their overlaps are substantially affected by parameters set by generating the contour lines and has to be examined in further studies.

Software

Several software packages were used for 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 implements the INTRAMAX analysis (courtesy of the Faculty of Geographical Sciences of Rijksuniversiteit, Utrecht). The confidence ellipse was implemented in R (<http://www.r-project.org>) to allow flexible control over the threshold values in further research.

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