Using flow maps to explore functional regions in Slovenia

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ABSTRACT
This article presents the methodology and the graphical support for the analysis of local labour markets and delimitation of functional regions based on daily labour commuting data. For delimitation of functional regions of Slovenia, which has been chosen as a study case in our research, the commuting aggregation approach has been used considering only one spatial phenomenon, which is the daily labour commuting between municipalities. In comparison with other methodologies the commuting aggregation approach delimitates the functional regions without predefined centres and on two different levels. For this purpose we analysed commuter flows between Slovenian municipalities using JFlowMap software, a graphical tool which provides various techniques for producing and analysing flow maps visualizations.

Key Words*: local labour market, functional region, commuting, mobility, flow map.*

1 INTRODUCTION

A functional region is a territorial unit resulting from the organisation of social and economic relations that is characterised by high frequency of intra-regional interactions, such as intra-regional trade in goods and services, labour commuting, and household shopping (Karlsson and Olsson, 2006). It is characterised by its agglomeration of activities, and by its intra-regional transport infrastructure, facilitating a large mobility of people, products, and inputs within its borders. This uniform territorial unit often presents an important platform for development strategies of the country or region. For their delineation one may consider different methods and different directly or indirectly geo-referenced data, such as population flows, trade in goods and services, communications, traffic flows, service connections, newspaper circulation, financial flows, etc. (Vanhove and Klaassen, 1987). From the mentioned interactions, the daily interaction in the labour market can be considered as a good approximation for the functional region, and as such is used in most European countries (OECD, 2002).

Regionalization into functional regions consists of two separated problems that can be regarded as modifiable areal unit problems (MAUP) (Unwin, 1996). First, there is a scale problem, which refers to the choice of the appropriate number of regions; second, there is an aggregation problem, which basically refers to the choice of an appropriate regionalization (Cörvers, Hensen and Bongaerts, 2009). In practise, two different concepts to delimit functional regions are used: (a) delineation around a pre-defined centre, and (b) delineation using algorithms or cluster analysis based on a combination of distance, closeness, commuting thresholds, travel times, etc. In our previous research (Drobne, Konjar and Lisec 2009; Konjar, Lisec and Drobne 2010) we analysed and discussed different methods to delimitate functional regions. Furthermore, we have

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developed a new methodology that refers to the second approach and does not need predefined input data on functional centres. This methodology has been already proposed and discussed (Drobne, Konjar and Lisec, 2010), but never really implemented due to complex aggregation of spatial units based on commuting data. The methodology consists of two levels of aggregation. On each of these two levels different methodology for the aggregation of municipalities has been used. The analysis for the Slovenian case that we present in this article consists of visualization of the commuter flows between all municipalities in the country and of the commuter flows in the directions of the centre municipalities on both levels. This way we can compare the quality of the delimitation of functional regions with the new methodology. The main goals of this paper are: First, to discuss the commuting aggregation approach delimitating of functional regions without predefined central municipalities by aggregating municipalities one by one, using only the commuters' data. Second, to compare flow map representations of the results of applying this two level approach with the flow maps of the actual commuter flows. For this purpose we used JFlowMap, a graphical tool developed at the University of Fribourg, Switzerland, which provides techniques and powerful tool for the analysis and presentation of spatial interactions.

2 METHODOLOGY

Different factors determine where persons with a fixed place of residence choose to work. In theory it is supposed that workers have good information about jobs, wages and travel costs, that all jobs are concentrated in two centres i and j, and that all wages are the same in i and j, but in general a bit higher in j ($w_j > w_i$). Another assumption is that all the jobs are equal in terms of skills demand, and that all workers have the same skills. In a theoretical model, all workers live on a linear strip between i and j. Travelling from any point between i and j is associated with travel costs, c_i and c_j, that increase with the distance to i and j, respectively. In this conditions, it is now assumed that the objective of every workers is to maximise the real wage (w) net of the generalised travel cost (c). This net wage we refer to as ω. The net wage at any location between the two centres is max $\{\omega_i, \omega_j\}$. The two functional regions consist of the locations (x), which satisfy either $FR_i\{x: \omega_i(x) > \omega_j(x)\}$ or $FR_j\{x: \omega_j(x) > \omega_i(x)\}$ (Karlsson and Olsson, 2006).

As already denoted, the commuting aggregation approach is one of the approaches to define functional regions that are not based on predefined centres of the regions. The starting points are the small spatial units (the municipalities) by itself, and the functional connections between them, which in our case are defined by data on commuting flows of working population. This methodology is partly based on the local labour market approach and commuting zone approach both already described in our previous work (Drobne, Konjar and Lisec 2009; Konjar, Lisec and Drobne 2010). The first step of this approach is to calculate the share of people commuting from the municipality i to any other municipality. The maximum share (commuting flow) is then used to aggregate the municipality i to the municipality j, which is the provider of working places for the maximum flow of commuters from i. By formation of new relatively small local labour systems, it is possible to identify some of the centres by the number of municipalities that were aggregated to the central municipality (the municipality with the pre-defined centre of the functional region). The importance of using first the maximum share of commuters is in the fact, that we get rid of the smallest municipalities from which the majority of people go to work to only one municipality that usually offers the higher number of working places in the region. The formation of local labour systems goes from small labour market sub-systems of several centres to the complex systems with limited number of centres. In the first step defined local labour market (sub-) systems are then included into the second step, where mutual dependence between the local labour (sub-) systems is calculated:

$$(C_{ab} + C_{ba})/min\{P_a, P_b\}, \quad (1)$$

In (1), C_{ab} (C_{ba}) represents the number of commuters from the local labour system a (b) to the local labour system b (a), and P_a (P_b) is the number of working population in the local labour system a (b). Mutual dependence can be used for the second aggregation and formation of new functional regions at a higher level. In this way, delineated functional regions include all spatial units (municipalities) that are connected by maximum flows of daily commuters (workers), and all municipalities that are strongly dependent. The importance of using the mutually dependence between municipalities as a criteria for the second aggregation is in the fact that local (sub-) systems already include a various number of municipalities that can be connected in different directions. By calculating the mutual dependence we take into consideration commuter flows to and from the local labour market (sub-) systems, which allows us to get a better overview of the importance of connections between these systems.

3 INTRODUCING JFLOWMAP

For the purpose of our research we used JFlowMap (http://code.google.com/p/jflowmap/), a graphical tool developed at the University of Fribourg, Switzerland, which offers various visualization techniques for producing and analysing flow maps, one of the most often used visualizations of mobility flows. Flow maps represent entities flowing between geographical locations (movement of goods and people, airline or network traffic, etc.) with lines connecting the flow sources and the destinations. They are one of the most widely used representations of migrations and mobility of people. Flow maps usually do not accurately show the exact paths of the movement, instead they are aimed to answer questions such as:

- Where on the map are the major sources and destinations of the flows?
- What is happening within a specific location?
- In which direction do the entities move?
- Where are the largest and the smallest flows?

The source and destination of each flow are depicted on a geographical map and connected by a line, which can be straight or routed to avoid intersections with other flows or the underlying areas of the map. The line widths are often used as a natural way to represent the flow quantities (e.g. the number of commuters).

In the basic view of JFlowMap the flows are represented by straight lines and their directions are indicated by colour markers. The markers are proportional to the flow lengths so that by looking at one side of a flow it is apparent whether the other side is close or far away. This is similar to the line shortening technique described in (Becker, Eick and Wilks, 1995). The direction markers show the flow directions (red - "outgoing", green - "incoming) and at the same time help to reduce the perceived occlusion, because the opacity of the flow lines can be set to a much lower value than the opacity of the markers (the user can change the opacities of the flow lines and direction markers). Therefore despite the occlusion the underlying flows can still be seen by the user without the need of using a filter, as the flow lines are transparent. The flow lines are sorted by the flow quantities before drawing and the larger flows are drawn above the smaller ones as they are usually more important and therefore should be more apparent to the user. The quantities of the flows are mapped to two visual variables: the widths and the colour saturations of the flow lines. The user can select the maximum width of a flow line which corresponds to the flow of the largest quantity.

JFlowMap is able to produce views which support interactive exploration: e.g. flow and node highlighting, selection, and dynamic queries for filtering out flows by their quantities or their lengths (Shneiderman, 1994). With the filter support it is easy to find the largest or the smallest flows, the longest or the shortest ones, or flows with quantities or lengths in a specific interval. Besides, the prototype has a zoomable user interface, which allows the users to zoom smoothly and continuously into any sub region of the map and explore it in detail (Bederson, Grosjean and Meyer, 2004). The widths of the flows stay the same even when zooming. This makes it possible to explore small regions, which could be fully or partially covered by scaled-up edges otherwise.

The users of JFlowMap can cluster nodes with different clustering algorithms. The nodes of each cluster can then be merged so that only the aggregated flows between the cluster centroids are displayed. Reducing the number of displayed flows, and thus reducing the line intersections and the occlusion of the flows, can often make the visualization more comprehensible (Herman, Melcon and Marshall, 2000).

However, it comes at the price of reducing the amount of visible details to the user at one time. In JFlowMap the user can change the maximum size of the clusters and see the updated clustering results. This way it is possible to see a summarized overview of the data and dynamically adjust the level of detail. The views which JFlowMap provides and the techniques which it supports make it an appropriate and powerful tool for the analysis of spatial interactions. Therefore we chose it to produce visualizations for our exploration of the Slovenian commuter dataset.

4 EXPLORING LOCAL LABOUR MARKETS IN SLOVENIA

4.1 Commuters flows in Slovenia

Figure 1 shows commuter flows between municipalities in Slovenia. Because of the high density of many small flows and a great number of municipalities in Slovenia, in order to get a better overview, only flows bigger than 50 commuters are given. The data on inter-municipal commuting to work were acquired from the Census 2002 (SORS, 2009). This dataset is the only one which has a distinction between the daily and weekly commuters. According to this dataset, there were a total of 287,272 inter-municipality commuters between 192 municipalities. Most of them (more than 74%) commuted by cars, either as drivers or passengers. Only 9% of the working population commuted to work by bus and less than 1.5% by train (Bole, 2004). We analysed 7171 flows of commuters between 192 municipalities. Among these flows there are 803 flows of 50 or more commuters. We produced a flow map representing these 803 flows which shows the high importance of Ljubljana in the labour market system of Slovenia. It is also apparent that there are a lot of connections in the east of Slovenia and much less in the west. In particular, there are not many flows going from the north to the south (in west as well as east Slovenia).

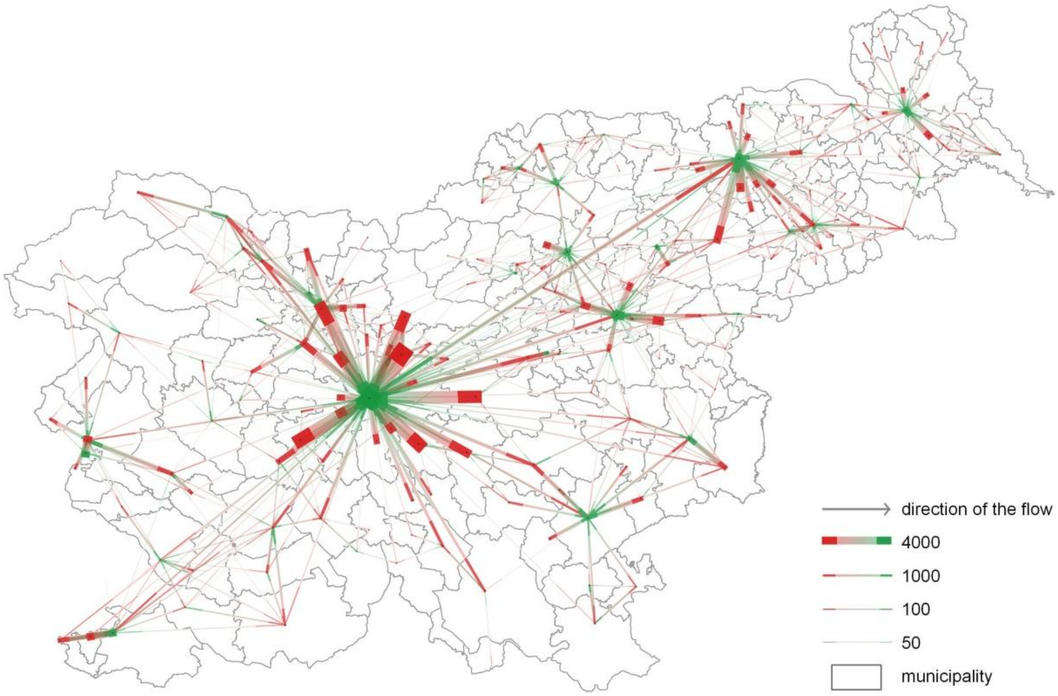

Figure 1: Commuters flows with more than 50 commuters between 192 municipalities in Slovenia

4.2 Functional regions in Slovenia

The idea of the commuting aggregation approach originates from the question, how to use data on commuting at a lower level where regional centres are not predefined. Having used maximal commuters flows, we first formed small local labour markets at the lowest scale that consisted, for example, also only of two municipalities. The result of this first step was delineation of Slovenia into 31 local labour markets that were reutilised, and again aggregated using the idea of mutual dependences between so defined labour market areas as typical for the commuting zone approach. Here, some final modifications of the method were used. In some border municipalities we rechecked the directions of some highest dependencies and corrected the appurtenance to a labour market, when it was necessary.

In Figure 2 we can see the 31 functional regions delimitated after the first aggregation with the appurtenant recalculated commuter flows between so formed local labour markets. In Figure 3 we show 10 functional regions after the second aggregation and how the functional regions formed this way on a higher level include all the main flows of commuters between the municipalities in Slovenia. Only flows of more than 100 commuters are shown in these two flow maps. By comparing the two figures one can see that the second aggregation connected mainly all the local labour market (sub-) systems which have high commuter flows between them in Figure 1.

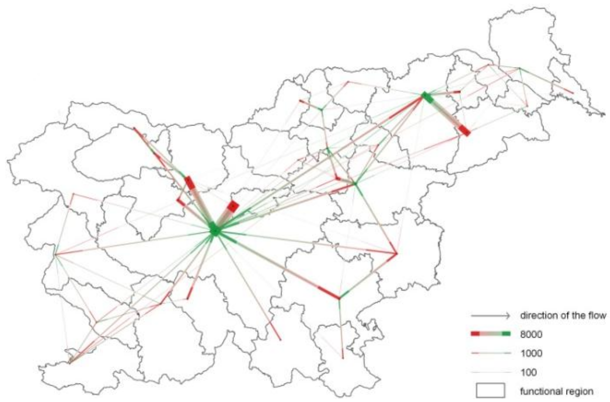

Figure 2: Functional regions after first aggregation with commuter flows between functional regions

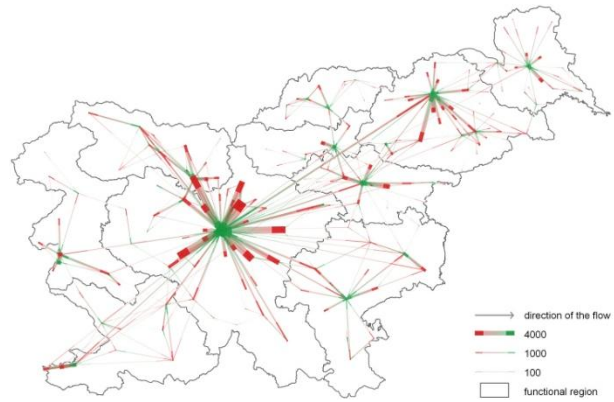

Figure 3: Functional regions after second aggregation with commuter flows between municipalities

The second type of visualization created with JFlowMap is shown in Figure 4 and Figure 5. Here the centre municipalities defined at each level are acting as magnets that attract commuters from other municipalities. In Figure 4 there are 31 central municipalities. In Figure 5, 10 central municipalities resulting from the second aggregation.

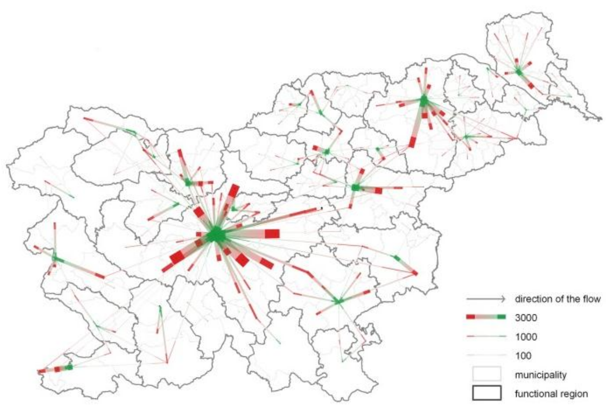

Figure 4: 31 centre municipalities with commuter flows

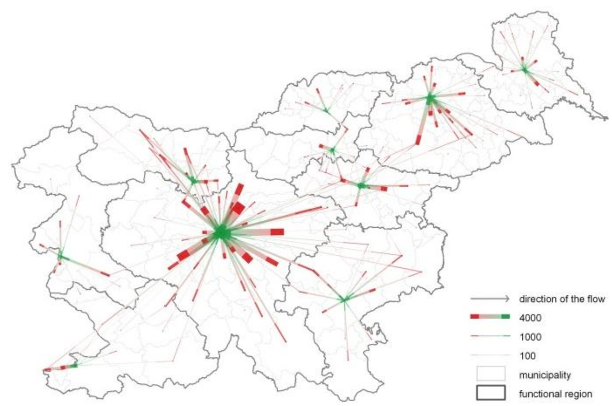

Figure 5: 10 centre municipalities with commuter flows

The regionalization of Slovenia into functional regions using commuting aggregation approach gave us a good approximation of functional regions which one by one include all the main commuter flows to their centre municipality. These regions are characterized by the highest number of significant flows of commuters which have them as destinations.

5 CONCLUSIONS AND FURTHER RESEARCH

Functional regions are considered as dynamic systems which are very complex and difficult to manage from the administrative point of view. As a consequence, a functional region is the most appropriate unit for economic analysis, and for interaction of political, social, and economic processes (Tomaney and Ward, 2000). In this paper we discussed the results of the application of JFlowMap, a spatial interactions data visualization tool, for the analysis of the Slovenian commuters' dataset and our methodology for the delimitation of functional regions. In the future, JFlowMap will be extended to support techniques and visualizations which would allow us to have a better overview of the dynamics and temporal changes in mobility flows, so that we could determine the possible directions of the development of the labour markets. This could greatly benefit the decision makers and spatial planners.

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