Erasmus University Rotterdam
Erasmus School of Economics
Department of Applied Economics
Master's Thesis Urban, Port and Transport Economics

Drawing the City: Delineating Functional Urban Regions

Lucas Rodriguez Gomez
346397
Supervisor: Giuliano Mingardo

Preface

While doing the research for my original topic about a transport gravitational model for the Veneto region in northern Italy, I found that finding the borders of the cities was a previous step that was definitive not just for the development of a gravitational model, but also for many other theoretical developments in regional economics, and public policy.

Governmental institutions already noticed the importance of it, and have been developing different models for determining it. Although many methods exists for delineating these cities, comparisons between different methods have been rarely done, and for very specific locations. That multitude of methods and procedures, and the lack of comparisons between them motivate me to write this Master's Thesis.

I would like to give special thanks to my friend Apostolis who gave me a roof during a great part of the writing process; my four women: my mother Polin, my girlfriend Johanna, my cousin Astrid and my best friend Monica; and my supervisor Giuliano. Without their support, advice, and stubbornness it would have been impossible to write this.

Finally, I would like to make an especial recognition to Luis Andres Colmenares, a student who was absurdly killed by, what it seems, his own fellows and friends.

Abstract

This paper evaluates different procedures commonly used in Europe for the delineation of Functional Urban Regions or Local Labor Areas. Procedures that analyze all flows despite its significance don't prove to be necessarily more efficient when delineating Functional Urban Regions, although they overall perform better than more polarized procedures. The existence of relatively small and open FURs is only well delineated by more polarized procedures, as these tend to observe polarity more than self-containment, providing important information for the delineation process. Also the lack of accuracy of the less polarized procedure, permits to conclude not only that none of the procedures is more efficient, but also that a comprehensive procedure must have both kinds of allocating sub-procedures.

Table of Contents

List of Figures and Tables

1 Introduction

To understand the real composition of a region, their real limits and the way it function, the borders of the real economic limits have to be understood. These limits rarely follow the political delimitations, reflecting more the historic nature than the real behavioral patterns of the people living their lives inside it. Moreover, and with the new technologies developed since the early 20th century, the sizes of the functional regions have been changing becoming bigger, and fuzzier.

The literature has produced several methods to delineate the Functional Urban Regions (FURs), especially in relation to labor FURs, denominating those as Travel-To-Works-Areas (TTWA), Local Labour Market [Areas] (LLM[A]) among others. For the porpoise of this paper they will be referred as Functional Urban Regions or FURs. This name, it is used basically for two reasons: first, TTWA, LLM, Mercado Locali di Laburo, and others refers explicitly to travels for work porpoises, while the analysis made in this paper relates both to an analysis of the commuting labor flows and the commuting to other reasons (students).

Although most European governments have made studies in order to identify these areas, and have this as a part of their scheduled statistics, there is still no consensus in the method used to delineate these areas. Several studies delimiting the regions along Europe, especially for The Netherlands and the Flanders region and Brussels in Belgium (van der Laan & Schalke, 2001; van Nuffel & Saey, 2005; van Nuffel, 2007), and the Travel-To-Work-Areas (TTWAs) of the British Department of Labor that has been used by the ISTAT and other public entities to delimit these areas. However very little has been done in Italy, where the delimitations of the Functional Urban Regions has been done by the Italian Statiscs Office, with a closed algorithm, which does not allow to evaluate the method used.

The purpose of this paper is to compare the different methodologies for delineating FURs using data from the Italian census of 2001 performed by the ISTAT for the Veneto region in Italy. For this matter, three different methodologies are compared both theoretically and in the field in order to develop which methodology is the most efficient. Not surprisingly appears that the procedures for delineating FURs are complementary more than substitutes as all of them add important information to the analysis of a region.

As it, the main research question is: Are the mainly used procedures in Europe a comprehensive procedure that is both effective and unbiased for delineating Functional Urban Regions? For responding this question, the paper is divided in six parts as follows: this introduction; second, a review of the methods used to delimitate LLMs and FURS; third, a description of the data; fourth a description of the Veneto region in Italy; fifth, the calculation of the FURs of the Veneto region using the different approaches available; and finally the conclusions along with policy recommendations and proposal for future research is done.

2 Theoretical background

In this chapter the general theoretical ground for the development of the paper is presented commencing with a literature review related to FUR delineation and followed by a detailed presentation of the procedures used for the analysis. Finally, the procedures are compared from a more theoretical view and the methods for evaluating regions and procedures empirically are presented.

The concept of a Local Labour Areas, or TTWA was developed by Smart (1974), for England. From this initial work, different procedures have been developed in Europe and United States in order to identify the new composition of regions, and especially in local labor markets.

According to van der Laan & Schalke (2001), the different procedures to delineate FURs can be divided into two big groups, depending on the background assumptions of the method, and the way it shapes the different FURs: heterogeneous and homogeneous.

Heterogeneous methods assume a labor market divided into various sub-markets, depending on the industry, specific skills, gender, etc. As policies and most studies relating FURs are based on a regional basis more than in a specific labor sub-market with some conditions, the evaluation of this type of division is beyond the reach of this paper.

On the other side, homogeneous methods assume an additive labor market, with an aggregated labor supply and demand, with only geographical boundaries. This type of delineation is the one used by most governmental agencies, and authors. As stated by Hunter & Reid (1968): “the essential points about a local labour market are the bulk of the area’s population habitually seeks employment there, and that local employers recruit the most of their labour from that area”. This principle can be amplified to a Functional Urban Region (FUR) by thinking of it as the area where most people live their daily lives. As such, the correct way to delineate FURs would be taking into account the flow for the whole population, and not subsets of it.

A FUR is an area on which most of the people that lives in that area develop their normal daily activities and functions around one or various centers – FURs can be divided in mono-nodal or multi-nodal depending on the number of centers that it has -. The main center around a FUR develops is the foci –in cases of poly-nodal regions the foci is the biggest center-, and serves as the name for the FUR.

Between homogeneous methods described before a new distinction can be made depending on the way the foci are selected. As such, methods which define the foci a priori and aggregate municipalities to the FUR of the foci are called deductive methods. On the other side there are the methods on which the identification of the foci is an integral part of the process; these methods are called inductive methods.

As noted by van Nuffel (2007), deductive as well can be divided into two groups according to the source of the data for the selection. If the data used to select the foci is different than the used for the delineation of the FURs, the procedure has the foci externally determined. If the data used for the selection of the foci is the same used for the delimitation process the foci are internally determined. As such, is clear that procedures with foci externally determined have an important bias as the basic elements of the FURs are being selected from a different source. The methods with foci internally determined have the important issue of setting the number of FURs, as well as their foci only by an early analysis that leaves important part of the data out.

Again inductive methods can be divided. This division is made according to the number of flow the procedure analyzes. As such, the methods that analyze the biggest flow are one group, the ones that analyze the two main flows are a second group, and the ones that analyze all flows are the last group.

Hypothesis 1: In delineating FUR none of the inductive procedures is efficient both effective an unbiased.

Effectiveness relate to the capacity of the procedure to delineate FURs that are in fact Functional Urban Regions in the sense that they have a self-containment ration reasonably high –although a long discussion has been along the threshold value to consider an area a FUR (Casado-Díaz, 2000; Nielsen & Hovgesen, 2007; van Nuffel & Saey,, 2005), here we compare the different delineation given by the different procedures-. On the other side, a procedure is unbiased in the sense that municipalities with strong commuting links are allocated in the same cluster generating unbiased FURs.

In order to compare the different analysis one procedure of each kind of method is used over the same data. For the single link methods, Primary Linkage Analysis was chosen; this method was developed by

Nystuen and Dacey (1968), and it was used by van Nuffel and Saey (2005) for Flanders region. For dual link procedure developed by van der Laan and Schalke (2001) for The Netherlands; this method has been used also in the Flanders region and Brussels by van Nuffel and Saey (2005); and for the all links analysis the methodology by Coombes, et al. (1986) for the 1984 Travel-To-Work Areas Revision in Britain; variations of this methodology has been used in Italy for the definitions of the Sistema locale de laburo, and in Valencia by Casado-Díaz (2000).

3 Methodologies

In this chapter the procedures and methodologies to delineate and evaluate FURs and potential FURs are presented. First the presentation of the methodologies to evaluate the number of significant links, and self-containment ratio, important tools in analyzing municipalities and different areas. Second, the procedures evaluated are presented.

3.1 Statistics to measure the procedures

Before and after the delineation of the FURs the areas must be evaluated in terms of two main indicators: the number of significant links, and the self-containment ratios. The number of significant links indicates how many of the outgoing flows of the area represent a significant percentage of commuters. The self-containment ratios measure which percentage of the commuting of the region is inside the region. Although a FUR not necessarily must have high self-containment ratios, the importance of these ratios in evaluating regions as a whole remains in the mean self-containment ratios of the areas on which the region is divided.

Multiple Linkage Analysis

This method measures the number of significant flows of different areas, comparing the set of outgoing flows of an area with a series of simulated sets. As this, the test provides information about the procedure that best suits a zone.

For a given municipality all the outgoing flows are ordered from the largest to the smallest. As this the biggest outgoing flow has F_1 commuters, the second F_2, and the nth F_n, conforming the original set of flows.

Equation 1

$$Original\ set: (F_1, F_2, F_3, \dots, F_N)$$

$$Set\ 1: (\hat{F}_1, \hat{F}_2, \hat{F}_3, \dots \hat{F}_N)_1 = \left(\sum_{i=1}^{N} F_i, 0{,}0, \dots, 0\right)$$

$$Set\ 2: (\hat{F}_1, \hat{F}_2, \hat{F}_3, \dots \hat{F}_N)_2 = \left(\frac{\sum_{i=1}^{N} F_i}{2}, \frac{\sum_{i=1}^{N} F_i}{2}, 0, \dots, 0\right)$$

$$Set\ 3: (\hat{F}_1, \hat{F}_2, \hat{F}_3, \dots \hat{F}_N)_3 = \left(\frac{\sum_{i=1}^{N} F_i}{3}, \frac{\sum_{i=1}^{N} F_i}{3}, \frac{\sum_{i=1}^{N} F_i}{3}, \dots, 0\right)$$

…

$$Set\ N: (\hat{F}_1, \hat{F}_2, \hat{F}_3, \dots \hat{F}_N)_N = \left(\frac{\sum_{i=1}^{N} F_i}{N}, \frac{\sum_{i=1}^{N} F_i}{N}, \frac{\sum_{i=1}^{N} F_i}{N}, \dots, \frac{\sum_{i=1}^{N} F_i}{N}\right)$$

Where:
$\hat{F}_i$: simulated biggest i-th flow.
N: Number of outgoing flows.

Equation 1 presents the algorithm to generate the set of simulated flows for the different significant flows. As it, the first element of the set of simulated flows for one significant flow is equal to the sum of all outgoing flows, with all other elements equal to zero; the first two elements of the simulated set for two significant flows are equal to the sum of all outgoing flow divided by two, and all other elements are equal to zero. In the set for Nth significant flows all the elements are equal to the average number of commuters per flow.

In order to find the number of significant flows, each of the simulated flows is used as the explanatory variable to predict the real set of flows. The simulated set that produces the highest coefficient of determination R^2 is chosen, and the number of flows different from zero in the set is the number of significant flows.

Criticism to this method refers to the existence of problematic areas, on which there is more than one maximum, or not a clear maximum for a number of significant flows[1].

[1] Nuffel 2007.

Skew

Skew is an instrument from statistics where is commonly used. As it, centered distributions have a skew near to zero, while distributions with more concurrence in the highest [lowest] limit have a higher [lower] skew. Here, skew relates to the set of outgoing flows from an area, measuring the intensity of the main flows as part of the whole set of flows for the area.

Equation 2

$$Skew_i = \frac{\left(\sum_{\forall j} F_{ij} - \overline{F_i}\right)^3}{N\sigma^3}$$

Where:
i,j: Municipalities, or areas.
F_{ij}: Number of commuters from area i to area j.
$\overline{F_i}$: Average number of outgoing commuters per flow in the area.

As this, a lower skew reflects a higher number of significant flows, reflecting a better quality of the zone.

Self-containment ratios

As a FUR is defined as the region where most people live their daily lives, self-containment ratios are one of the best ways to measure it. Coombes, et al., (1986), van der Laan, et al. (2001), van Nuffel (2007), Casado-Díaz (2000), Bruijsten (2010) use the procedure to verify quality of the zones, optimize the FUR, or measure openness and nodality of FURs for a whole set of different data.

There are two different self-containment ratios, both measuring to the inner commuting (F_{ii}): household self-containment measures the inner commuting as a percentage of the total outgoing commuters, while labor self-containment measures the inner commuting as a percentage of the total ingoing commuters. As it, both measure the level of self-containment of the FUR, both on the household or the labor side.

Equation 3

$$HSC = \frac{F_{ii}}{\sum_{\forall j} F_{ij}} \qquad LSC = \frac{F_{ii}}{\sum_{\forall j} F_{ji}}$$

Where:
i,j: Areas, municipalities, FUR.
HSC: Household Self-Containment Ratio.
LSC: Labor Self-Containment Ratio.
F_{ij}: Commuters from area i to area j.

By definition a bigger area should have bigger self-containment ratios. However, these ratios are not related necessarily, as relatively small regions can have high self-containment ratios. As FURs are defined as the regions where most people live their lives, these ratios are a key part in the definition of a FUR, an important difference with the Travel-To-Work Areas, as here size of the FUR would not be such a key issue.

3.2 Principal Linkage Analysis

This procedure was developed by Nystuen and Dacey (1968), and works by analyzing the largest flow that comes out from each municipality in order to cluster municipalities into Functional Urban Regions.

As described by Nystuen the municipalities are ordered according to the total ingoing commuters and ranked by it. All the municipalities that send their biggest outgoing flow to a municipality with a lower rank are the foci. All the municipalities that send their biggest outgoing flow to a higher ranked municipality are subordinates. As such a municipality *A* is subordinated to a municipality *B* if it sends its biggest outgoing flow to *B,* and the total ingoing commuters of *A* is smaller than the total ingoing commuters of *B* (if the total number of ingoing commuters of *A* is bigger than in *B*, *A* would be a foci).

All municipalities are directly or indirectly linked to one and just one foci, as the ranking prevents for ambiguity , and no reflexivity in the relation is assumed (two municipalities are reflexive if the principal links of each one are directed to the other one). As it, all municipalities subordinate to a foci form the FUR of the respective foci.

Criticisms to this technique are based on the fact that it assumes a hierarchized region, on which each region has only one node. Additionally, the analysis of only the biggest flow leaves out of the analysis all the other flows, independently of its significance, something that can lead to an incorrect delineation, especially in the limit areas of the FURs where the belonging to one or another region is not so clear.

3.3 van der Laan - Schalke Procedure

The van de Laan - Schalke procedure was presented in a paper by the same authors in 2001. This paper makes a comprehensive analysis of the commuting flows in The Netherlands in order to delimit the different FURs proposing a nine step procedure. The procedure can be divided into two big parts, a first part that is objective, with a clear set of rules to cluster the different cities, and the second procedure which follows methods that are discretional to the author and the region. In this section the general procedure is described.

The first step of the procedure links a municipality to a foci if its biggest flow (F_1) is directed to that foci; F_1 represents more than 25% of the total outgoing commuters of the municipality; and the difference between F_1 and F_2 is bigger than the 60% of F_2 (F_1-F_2>0.6*F_2). The second step links a municipality to a FUR if the foci of that FUR belongs to other FUR (that is if F_1 of the foci fills the conditions set on the first step). The third step links the foci of the FUR to their own FURs.

In the fourth step, all remaining municipalities all inked to a FUR if F_1 is directed to the FUR foci; and F_2 is directed to a municipality in the same FUR. The fifth step repeats the fourth step, with F_1 directed to any municipality in the FUR, and F_2 directed to the foci. Step six links a municipality to a FUR if both F_1 and F_2 are directed to municipalities in that FUR.

In the seventh step, similar FURs are integrated. As such, a FUR (i) is integrated with other FUR (j) if three conditions are met: 1) F_1 of i's foci is directed to j's foci; 2) F_2 of i's foci is directed to a municipality in j, or i; 3) F_2 of other municipalities in i are directed to j.

The steps 8 and 9 are relatively discretional . *"Step 8 adds remaining municipalities to a cluster if a commuting relation exists and also considers whether small clusters of only three or four municipalities* *can be taken together"*[2], while *"Step 9 links the 18 remaining municipalities to an existing cluster because of their geographical position"*. As these steps depend in the characteristics of the data, the discussion of those steps is on the next chapter.

Although it permits a less skewed regions than the PLA this procedure assumes a relatively high polarized region with at most two significant flows per municipality. As such, the same problem as with PLA as only takes a limited number of flows that, although it works for most municipalities clearly exists municipalities with a few significant flows it can lead to miss places in municipalities and FURs with higher number of significant flows.

3.4 Cluster Analysis (TTWAs)

The analysis done it's a variation from the methodology presented by Coombes, et al. (1986), and that it is used for the delineation of FURs by various governmental agencies. The exposition of this procedure is divided into two parts: on the first one, the procedure is presented; in the second, the equations that regulate the procedure, as well as the procedure are evaluated.

From this method is very important to highlight that has a double nature deductive-inductive. It has a deductive nature as the foci are chosen in a prior step to the general procedure; it has also an inductive nature as modify the FURs inside the procedure.

3.4.1 Procedure

The procedure is divided in six steps, that are divided into a set of sub steps.

1. The first step selects the foci for the possible FURs calculating both the Household Self-containment Ratio (Equation 3) and the Ingoing Outgoing Ratio (Equation 4).

[2] van der Laan, Schalke 2001.

Equation 4

$$IOR_i = \frac{\sum_{\forall j} F_{ji}}{\sum_{\forall j} F_{ij}}$$

Where:
i,j: Municipalities
F_{ij}: Commuters from area i to area j.
IOR: Ingoing – Outgoing Ratio

IOR is the ingoing-outgoing ratio, F_{ij} the number of commuters from municipality i to municipality j and HSC is the household self-containment ratio. Municipalities who are in the highest 20% (τ_1) are selected as possible foci for the FURs[3].

Equation 5

$$\sum_{\forall f} F_{fi} - F_{ii}$$

Where:
f: Foci.
i: Foci analyzed.
F_{fi}: Commuters from foci f to foci i.

2. In the second step the different foci are compared and the FURs amalgamated. This step is divided into 5 sub-steps:
   2.1. All the foci are ranked according to the expression in Equation 5; each foci i is analyzed separately beginning with the highest ranked;

Equation 6

$$min\left(\frac{F_{ii}}{\sum_{\forall f} F_{fi}}, \frac{F_{ii}}{\sum_{\forall f} F_{if}}\right) > \tau_2$$

Where:
$\tau_2 = 0.5$
f: Foci.
i: Foci analyzed.
F_{fi}: Commuters from foci f to foci i.

[3] It is worth to highlight that this 20% is a first threshold value in the procedure.

2.2. If minimum between the household and job self-containment ratios of the foci i is above 0.5 (Equation 6), the foci is not amalgamated, and the analysis starts with the i+1 ranked foci; if under, continues to 3;

Equation 7

$$\frac{F_{ji}}{\sum_{\forall f} F_{jf}} > \tau_3$$

Where:
$\tau_3 = 0.1$
f: Foci.
i,j: Foci analyzed.
F_{fi}: Commuters from foci f to foci i.

2.3. All the foci j which outgoing commuters to i represent more than 10% of their total outgoing commuters are selected (Equation 7). If there is no foci j that complies that condition i is not amalgamated, and jump to i+1 ranked foci; if under continues to 4;

Equation 8

$$\frac{F_{ij}}{\sum_{\forall f} F_{jf}} > \tau_4$$

Where:
$\tau_4 = 0.01$
f: Foci.
i,j: Foci analyzed.
F_{fi}: Commuters from foci f to foci i.

2.4. All the foci j which total incoming commuters from foci i represent less than 1% of the total outgoing commuters of i are excluded (Equation 8); if there is no foci j continues with i+1 foci, if any continue to 5;

2.5. All foci i are ranked according to Equation 9.

This is the link function on which all the FURs are ultimately formed. As this, the highest ranked foci j is amalgamated with i if the value of this function is higher than 0.002 (τ_5); if under the foci i is not amalgamated and the analysis continues with foci i+1.

Equation 9

$$\frac{F_{ji}^2}{\sum_{\forall f} F_{jf} * \sum_{\forall f} F_{fi}} + \frac{F_{ij}^2}{\sum_{\forall f} F_{if} * \sum_{\forall f} F_{fj}} > \tau_5$$

Where:
$\tau_5 = 0.002$
i,j: Municipalities analyzed.
f: Foci.
F_{fi}: Commuters from foci f to foci i.

Until this stage a first selection of the foci has been made, and close related foci have been amalgamated into new enlarged foci.

3. In stage 3 this foci are amplified to potential FURs by both linking unclassified municipalities to a foci or amalgamating some foci and FURs. As step 2, this step is divided into a series of sub-steps as follows:
   3.1. All foci i for which the value of Equation 10 is above 0.625 (τ_6), no further analysis is done in this stage. All foci with less than 0.625 are ranked from the highest to the lowest, order in which the analysis is done foci by foci.

Equation 10

$$min\left(1, \sum_{\forall f} F_{if}/\tau_7\right) * min\left(1, F_{ii}\Big/\left(max\left(\sum_{\forall f} F_{if}, \sum_{\forall f} F_{fi}\right) * \tau_8\right)\right) > \tau_6$$

$\tau_6 = 0.625$
$\tau_7 = 2000$
$\tau_8 = 0.75$
f: Foci.
i: Area analyzed.
F_{fi}: Commuters from foci f to foci i.

Is important to notice that this is the other equation that regulates the algorithm, as in it there are the two main threshold values: the minimum number of commuters living inside (τ_7, 2000) and the minimal self-containment ratio (τ_8, 0.75) of the FUR.

3.2. For the foci i, the step 2.3 is repeated, with the important difference that the possible fusions are not only with other foci, but with all municipalities and foci with a value for Equation 10 lower than 0.625;

3.3. For remaining municipalities the Equation 9 is calculated, and the municipality with the highest value is fusion with the foci or FUR i;

3.4. The new FUR is evaluated according to Equation 10. If complies the condition of sub step 1, continue with foci (FUR) i+1 if not the procedure is repeated.

Step 3 is repeated until the value of Equation 10 is over 0.625 for all FURs, or any FUR with a value under 0.625 doesn't have any municipality j that comply condition of sub step 2.

4. In step 4 the remaining municipalities are allocated in potential FURs:
   4.1. All the remaining municipalities i are ranked according to the total outgoing commuters;
   4.2. For municipality i all potential FURs j to which i has an outgoing flow are selected. If there is no foci j to which i has an outgoing flow, the municipality i is out in reserve;
   4.3. All selected foci j are evaluated using Equation 9. Municipality i is allocated to the FUR to which Equation 9 has the maximum value;
   4.4. The procedure continues with the i+1 highest ranked remaining municipality, until all remaining municipalities are evaluated;

This procedure is repeated for municipalities in the reserve until there are no more municipalities in the reserve, or none of the municipalities in it was possible to allocate.

5. In step 5 all FURs that fail to achieve the minimum for the threshold values are allocated into other FUR:
   5.1. All FURs are ranked from the lowest to the highest according to their value for Equation 10. If the value for the highest ranked FUR (the one with the lowest value for Equation 10) i is above 0.9267 (τ_9) the analysis stops;
   5.2. The FUR i is separated, and step 4 is repeated for all municipalities that were in that FUR.

Once all the FURs achieve the minimum value for self-containment, the procedure optimizes the sum for all the FURs of Equation 10 moving border municipalities between different FURs. This step is skipped due to two factors: this extra-step doesn't add any important optimization, and adds an extra complexity to the evaluation that surpasses the reach of this paper.

3.4.2 The equations and the threshold values

In PLA and van der Laan – Schalke procedures there is a clear distinction between the measurement of the direction of the flow and its intensity[4]. In cluster analysis both the intensity and the direction of the flow are measured by Equation 9. In order to understand better this function, we first rewrite as:

Equation 11

$$\underbrace{\frac{F_{ji}}{\sum_{\forall f} F_{jf}}}_{A} * \underbrace{\frac{F_{ji}}{\sum_{\forall f} F_{fi}}}_{B} + \underbrace{\frac{F_{ij}}{\sum_{\forall f} F_{fj}}}_{C} * \underbrace{\frac{F_{ij}}{\sum_{\forall f} F_{fi}}}_{D}$$

Where:
i,j: Municipalities analyzed.
f: Foci.
F_{fi}: Commuters from foci f to foci i.

The first thing to notice in Equation 11 is that while parts A and B of the equation measures the flow from j to i, parts C and D measures the counter flow, giving the same weight in the index to both. Part A and B [C and D] of the equation measures the importance of the flow from j [i] to i [j] both in terms of the importance as an outgoing flow to j [i] in part A [D], and as an ingoing flow for i [j] in part B [C].

Equation 10 multiplies the condition of size with the condition for self-containment. Rewriting Equation 10, the components of it can be clearly in Equation 12.

[4] In PLA the intensity of the flow is established in the fact that the analysis is done only over the largest outgoing flow. In VLaan the intensity is measured both in step 1 (the conditions for the foci), and the fact that only the two largest commuting flows are measured.

Equation 12

$$min\left(1,\sum_{\forall f} F_{if}/\tau_7\right) * min\left(1, min\left(\frac{F_{ii}}{\sum_{\forall f} F_{if}}, \frac{F_{ii}}{\sum_{\forall f} F_{fi}}\right)/\tau_8\right)$$

τ_7: Size condition
τ_8: Self-Containment condition
f: Foci.
i: Area analyzed.
F_{fi}: Commuters from foci f to foci i.

The first part of Equation 12 is the size of the outgoing flows, the number of inhabitants of FUR i, while the second part is the self-containment condition. As a FUR grows, the first part of Equation 12 grows, as more municipalities mean more outgoing commuters, independently of the size of the flows between those municipalities.

On the other side, the second part will have a behavior that changes when the linkages between the municipalities change. For understanding this behavior we assume that municipality j is added to FUR i, creating the FUR i+j. Like this, the new flow would be as stated on Equation 13

Equation 13

$$F_{(i+j)(i+j)} = F_{ii} + F_{jj} + F_{ij} + F_{ji}$$
$$\sum_{\forall f} F_{(i+j)f} = \sum_{\forall f} F_{if} + \sum_{\forall f} F_{jf}$$
$$\sum_{\forall f} F_{f(i+j)} = \sum_{\forall f} F_{fi} + \sum_{\forall f} F_{fj}$$

Where:
j: Municipality added.
i: Original FUR
i+j: New FUR
F_{ab}: Commuters from a to b.

Equation 14

$$HSC_{(i+j)} = \frac{F_{ii}+F_{jj}+F_{ij}+F_{ji}}{\sum_{\forall f} F_{if}+\sum_{\forall f} F_{jf}}, LSC_{(i+j)} = \frac{F_{ii}+F_{jj}+F_{ij}+F_{ji}}{\sum_{\forall f} F_{jf}+\sum_{\forall f} F_{if}}$$

Where:
j: Municipality added.
i: Original FUR
i+j: New FUR
F_{ab}: Commuters from a to b.

Using the flows from Equation 13, the self-containment ratios for (i+j) would are as in Equation 14. As this picking the municipality j with the maximum value for Equation 9 guarantees the maximum possible increase in Equation 10, thus the self-containment of the FUR.

This procedure establishes various threshold values along the way in order delineate the FURs. This threshold values has been marked in the procedure as τ_i, and are located in steps 1 (τ_1), 2.2 (τ_2), 2.3 (τ_3), 2.4 (τ_4), 2.5 (τ_5), 3.1 (τ_6, τ_7 and τ_8) and 5.1 (τ_9), and their related to Equation 9 or 10, or two define the percentage of municipalities that will be considered a cluster for a next step. As this, threshold values can be divided in three groups. The first group is the one of those τs related to Equation 9 formed by τ_3, τ_4 and τ_3; the second by those related to Equation 9, τ_2, τ_6, τ_7, τ_8 and τ_9; and the third group is conformed only by τ_1 that determines the percentage of the municipalities that are considered to be foci.

As it τ_3 guarantees that F_{ji} is a significant link of j; τ_4 and τ_5 guarantee that adding municipality j to FUR i will increase the self-containment ratios of i. In Equation 6, τ_2 guarantees that potential FURs with already high self-containment ratios don't absorb other potential FUR spuriously; τ_6, guarantees that most foci have at least 1,250 inhabitants or a minimum self-containment ratio of 47% for step 3 while τ_9 guarantees the same for final FURs setting minimum values for inhabitants and self-containment in 1,854 and 70% respectively, while τ_7 and τ_8 set the main threshold values of 2,000 inhabitants and 75% self-containment ratio (notice that even when τ_6 and τ_9 set lower threshold values this are a percentage of the main values τ_7 and τ_8).

4 The Veneto region

The Veneto region is located in the north-east of Italy. It has 4,912,438 inhabitants[5] in 581 municipalities and seven provinces with a GDP per capita of €30,700. Economy of the region is divided in manufacturing; commerce, communication and transport; and financial activities with shares between 20 and 25%, while the rest is shared by other sectors.

Table 1: Factsheet Veneto Region

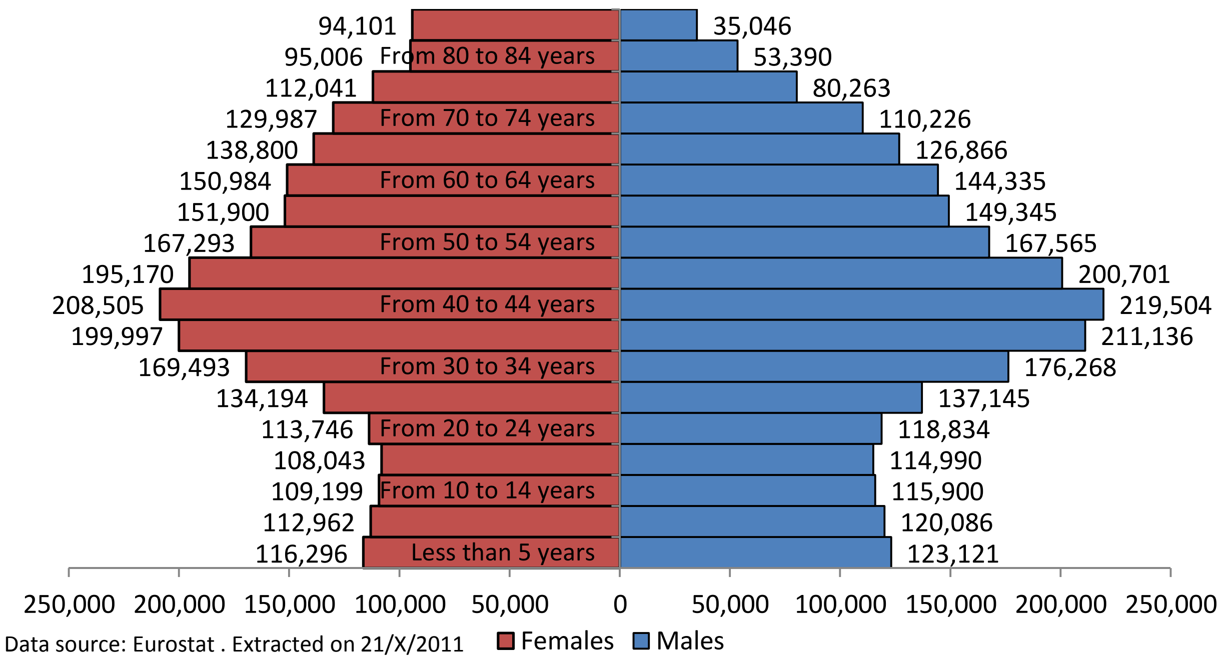
Province	Capital	GDP/Pop (€)*	Population	Area (km^2)	Density (Pop/km^2)	Ingoing Commuters	Outgoing Commuters
Padova	Padova	30,900	909,775	2,102	433	453,570	443,126
Verona	Verona	31,000	896,316	2,895	310	432,900	435,240
Treviso	Treviso	30,000	869,534	2,411	361	416,974	420,410
Vicenza	Vicenza	31,600	852,242	2,682	318	439,426	433,588
Venezia	Venezia	30,900	844,606	2,173	389	388,511	399,607
Rovigo	Rovigo	27,900	246,255	1,709	144	110,152	118,818
Belluno	Belluno	31,300	213,612	3,591	59	101,663	101,722
Veneto	**Venezia**	**30,700**	**4,832,340**	**17,563**	**275**	**2,343,196**	**2,352,511**

Source: Eurostat. Extracted on: 21/X/2011

From the total population 51% are females, and 19% have less than 20 years. As seen on Figure 1, the current highest population in the Veneto is for the ones between 20 and 60 years old, with a maximum for the population between 40 and 45 years old and minimum for the range between 15 and 19 years old. As it, 55.4% of the population is on working ages (ages between 20 to 59 years),

[5] Data for 2010. Source: Eurostat.

Figure 1: Population by age and sex in the Veneto



4.1 The data

Each ten year ISTAT collects a census of commuting patterns for Italy. This census contains information about origin, destination, number of commuters, gender of the commuters and transport mode among others. For the purpose of this paper we use the 2001 data and the variables province of origin, city of origin, province of destination, city of destination and number of commuters.

For 2001 there is a census for ingoing commuters and another for outgoing commuters. These datasets (incoming, out coming) are merged into one dataset, obtaining all the flows, their intensity (number of commuters) and the direction (origin and destination) in the Veneto. The complete dataset used have the form shown in Table 2, where Code Origin and Code Destination are the ISTAT codes of the municipalities of origin and destination respectively[6].

[6] The first two digits of the ISTAT code is the code for the province of the municipality, therefore this data base also contains the information for the provinces.

Table 2: Format of the Complete Dataset

Code Origin	Origin	Code Destination	Destination	Commuters
23001	Affi	23001	Affi	430
23001	Affi	23091	Verona	117
23001	Affi	23023	Cavaion Veronese	115
23001	Affi	23018	Caprino Veronese	76
23001	Affi	23006	Bardolino	58
23001	Affi	23062	Rivoli Veronese	56
23001	Affi	23036	Garda	38
23001	Affi	23030	Costermano	37

Source: ISTAT.

As such, each observation in the database represents a flow from one municipality to another or to itself, and commuters is the intensity of that flow (the number of commuters). The complete database consists of 50,528 observations for 581 municipalities in the Veneto region with a total of 2,376,519 commuters.

5 Results

This chapter is divided in two big parts. First, an analysis of the municipalities in the region is developed in order to understand the commuting behavior of the region. Second, the results of the different procedures as well as a comparison between them are presented. As it, the highlights of the procedure are showed when necessary, followed by the presentation and evaluation of the results. Then, when considered pertinent, small modifications to the procedures are presented in order to improve the quality of the results. Finally, the results of the different procedures are compared.

5.1 Flow analysis in The Veneto region

In this section a generalized flow analysis at municipality level is done. First, self-containment ratios and size are evaluated then a MLA is performed in order to know the general shape of the region.

Table 3: Municipalities in the Veneto - Descriptive statistics

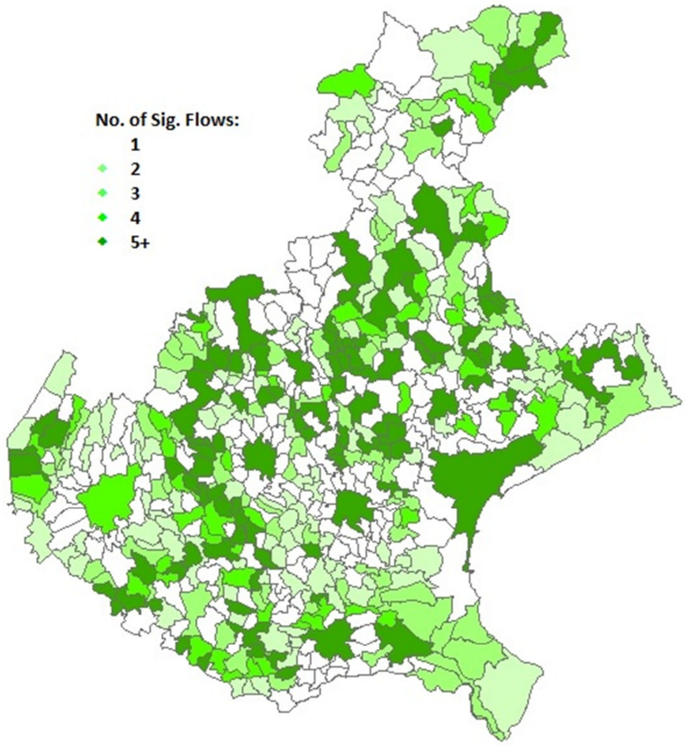
Statistic	Out[1]	Inc[2]	ii[3]	HSC[4]	LSC[5]	SC[6]
Mean	3,992	3,992	2,208	45%	58%	43%
Max	125,716	169,538	108,538	95%	93%	84%
2nd. Max.	125,536	166,947	107,251	90%	91%	82%
Min	35	9	3	8%	18%	8%
Std. Dev.	9,285	12,907	7,540	13%	13%	11%

[1] Outgoing commuters. [2] Incoming commuters. [3] Inner commuting. [4]Household Self-Containment Ratio. [5]Labor Self-Containment Ratio. [6]Self-Containment Ratio.
Source: Own elaboration.

The medium municipality in the Veneto has almost 4,000 commuters, with an average self-containment ratio around 50%. This shows a highly open region, with most municipalities having half of the population commuting every day to a different municipality.

Figure 2 shows the results of the MLA at municipality level. The big centers of labor, or possible foci, are the municipalities with a high number of significant flows surrounded by municipalities with just one significant flow that goes to the foci.

Figure 2: Significant Links per municipality



*ArcMap Output. Source: Own elaboration

5.1.1 Relation between significant flows (MLA) and skew

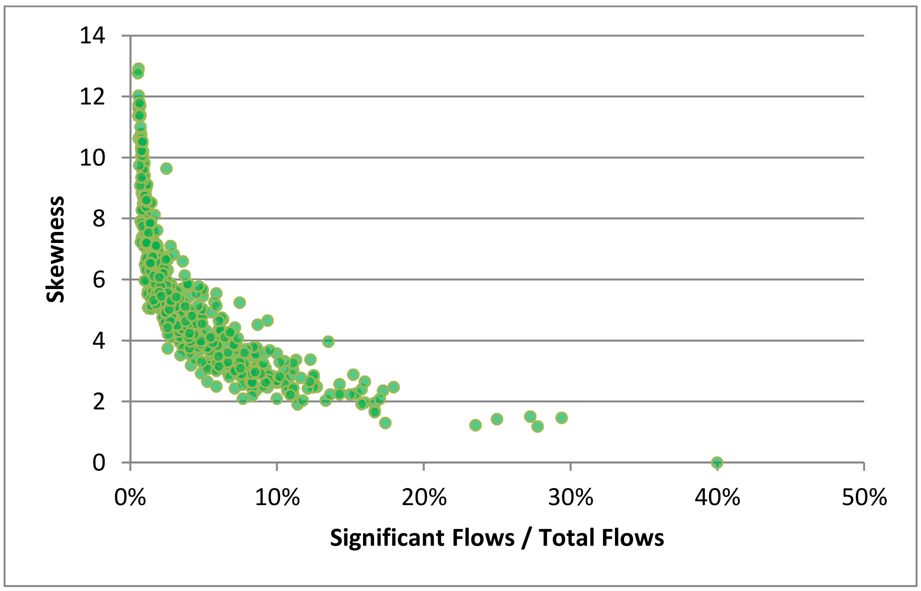
It exist a non-linear relation between the skew and the percentage of significant flows over the total number of flows, as seen in Figure 3. This kind of relation is of the kind defined by:

Equation 15

$$Skew_i = \left(\frac{MLA_i}{N_i}\right)^{\beta}$$

Where:
$\beta \in (-\infty, \infty)$
i: Municipality analyzed.
Skew: Skew of the municipality as defined in Equation 2.
MLA: Multiple Linkage Analysis as defined in Equation 1.
N: Number of outgoing flows in the municipality.

Figure 3: Relation between MLA and skew



*Source: Own elaboration.

As the main question to be answered by these tests is the number of significant flows that a municipality actually has, the percentage of significant flows is put as a function of the skew, by linearizing with logarithm and managing Equation 11 is obtained.

Equation 16

$$ln(\%Flows_i) = \alpha * Skew_i \qquad \%Flows_i = \frac{MLA_i}{N_i}$$

Where:
i: Municipality analyzed.
Skew: Skew of the municipality as defined in Equation 2.
MLA: Multiple Linkage Analysis as defined in Equation 1.
N: Number of outgoing flows in the municipality.

This equation is estimated using robust estimation in order to prevent heteroscedasticity. Obviously, this estimation is not completely correct in statistic terms as it ignores the fact that the percentage of significant flows is a result obtained from a previous regression process, and the mathematical problems that it generates. However, it is a good enough indicator for the actual number of significant flows.

Table 4: % of significant flows as a function of the skew

No. of Observations: 581
R^2: 0.8042

	alpha	Std. Er.	t	P-value
Skew	-0.45603	0.002859	-159.53	0

Source: Own elaboration.

As seen Table 4 regression statistics are very good, having a high R^2, and a very low standard error for the coefficient of the skew. The number of significant flow are estimated again using the results of the regression analysis, in order to compare the two results the number of estimated significant flows by the two methods are compared in Table 5.

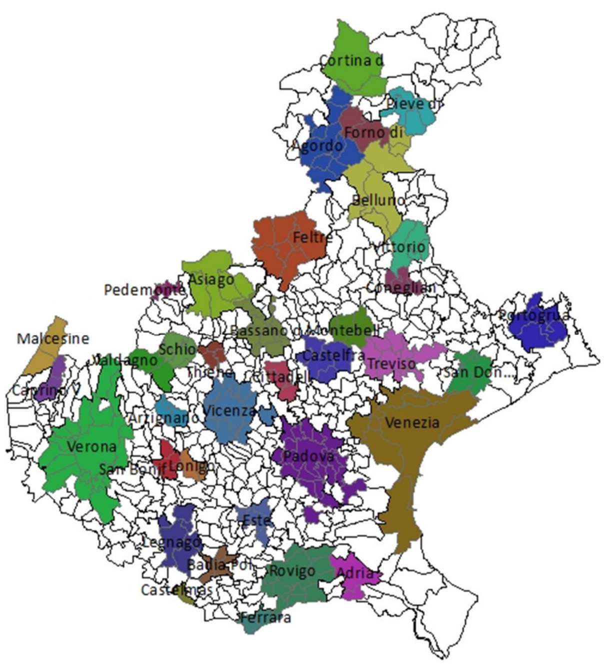
Municipalities with only one significant flow both from the MLA procedure and the skew procedure are considered to be close related, and with high polarity, to the municipality to which their primary flow is directed. The enlarged municipalities can be seen on Figure 4. On this map is important to notice that not just the big centralities in the region emerge as enlarged municipalities, but also the emergence of small centralities among the region.

Table 5: Significant Flows Skew Estimation and MLA

		Estimated Significant Flows				
		1	**2**	**3**	**4**	**5+**
Significant Flows MLA	**1**	164	56	2	0	0
	2	5	82	35	2	0
	3	2	18	45	13	2
	4	0	6	21	19	5
	5+	0	4	22	33	45

Source: Own elaboration.

Figure 4: Enlarged municipalities



*ArcMap Output. Source: Own elaboration.

As such Padova, Verona, Vicenza, Rovigo, Agordo and Venezia emerge as the main centralities in the region. However, the emergence of smaller centralities all along the region, and in zones relatively far from the foci of the FURs, reveals a very complex region, with polarized sub-regions in an intermediate layer between the municipalities and the FURs.

5.2 Sistema locale di lavoro: Functional Urban Regions in the Veneto

ISTAT has designed the *Sistema locale di lavoro* (SLL), following a procedure similar to the one presented in section 3.4. As this, municipalities in the Veneto are divided among 41 SLLs, of which 34 are mainly localized in the region. As this is the official division for the FURs in Italy, it is taken as the reference frame for comparisons and the general description of the Veneto.

On the seven SLLs that are localized mainly outside the Veneto are 17 municipalities, of which 11 are in Rovigo and belong to the SLLs Poggio Rusco (Bergantino, Calto, Castelmassa, Castelnovo Bariano, Ceneselli and Melara), and Ferrara (Canaro, Fiesso Umbertiano, Occhiobello, Pincara and Stienta). Of tThe other six municipalities one belong to Venezia province (San Michele al Tagliamento, belongs to Latisana), two belong to Treviso (Gaiarine and Portobuffolè, both belong to Pordenone), one to Belluno (Livinallongo del Col di Lana, belongs to Badia), and two to Verona (Peschiera del Garda and Brentino Belluno that belong to Castiglione Delle Stiviere and Ala respectively).

Figure 5: *Sistema Locale di Lavoro*

*In white municipalities that belong to SLL outside the region
**ArcMap Output. Source: Own elaboration.

In Figure 5 appear the 34 SLLs in the Veneto area. As seen on Table 6, although self-containment ratios are relatively high, exists a high variability, and reveals a zone highly polarized region. The main concern is that the self-containment ratio (the minimum between the household self-containment ratio and the labor self-containment ratio), is under 75% for seven SLLs.

Table 6: Self-containment ratios SSLs - Descriptive Statistics

	HSC[1]	LSC[2]	SC[3]	Skew	SF[4]	%SF[5]
Mean	80%	85%	79%	4.090	2.47	5.1%
Maximum	94%	94%	90%	5.969	8.00	11.4%
Minimum	61%	72%	61%	2.754	1.00	1.6%
Std. Dev.	8.0%	4.2%	7.0%	0.861	1.83	2.8%

[1]Household Self-Containment Ratio. [2]Labor Self-Containment Ratio. [3] Self-Containment Ratio [4]Significant flows. [5]Percentage of significant flows over total flows.

Source: Own elaboration.

Table 7 shows the SLLs that have under 75% self-containment ratio. Of those, Badia Polesine and Montagnana have both a high number of significant flows and a low skew, showing a behavior of a FUR with a relatively high degree of openness. The case of Este and Adria are similar, as both have two significant flows to the same SLL for both the first and the second flow; in the case of Adria (18,932 ingoing commuters)the SLL have a strong polarization to Verona (299,111 ingoing commuters) and Rovigo (299,111 ingoing commuters); Este (49,871 ingoing commuters), behaves more as a local labor center as reveals its higher ingoing commuters, and the high labor self-containment ratio, although it has a possible subordinate relationship with Padova. This is also the case for San Giovanni Ilarione (5,945 incommers), which is a subordinate of San Bonifacio (60,128 incommers), Bovolone (28,907) and Grezzana (7,421 inc.) last two subordinates of Verona.

Table 7: Self-containment ratios SSLs: Values under 75%

SLL[1]	HSC[2]	LSC[3]	SC[4]	Skew	SF[5]	%SF[6]	1st Flow[7]	2nd Flow[8]
San Giovanni Ilarione	61%	88%	61%	4.018	1	4%	San Bonifacio	Arzignano
Grezzana	65%	87%	65%	3.854	1	4%	Verona	San Bonifacio
Adria	67%	72%	67%	4.034	2	4%	Padova	Rovigo
Bovolone	70%	82%	70%	4.159	2	3%	Verona	Legnago
Este	70%	82%	70%	4.408	2	3%	Padova	Rovigo
Montagnana	71%	82%	71%	2.856	3	5%	Vicenza	Este
Badia Polesine	71%	83%	71%	3.103	6	11%	Rovigo	Ferrara

[1]Sistema locale di lavoro.[2]Household Self-Containment Ratio. [3]Labor Self-Containment Ratio. [4]Self-Containment Ratio. [5]Significant flows. [6]Percentage of significant flows over total flows. [7]Biggest outgoing flow. [8]Second biggest outgoing flow.

Source: Own elaboration.

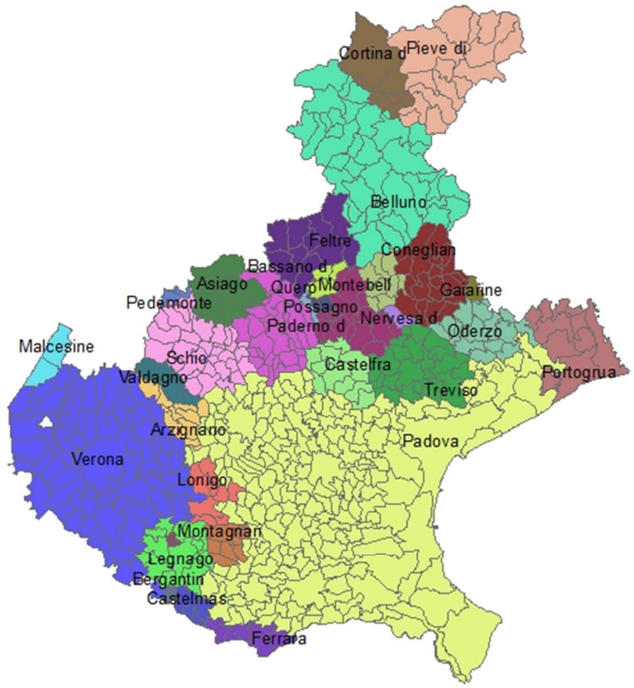
5.3 Primary Linkage Analysis (PLA)

The PLA for the Veneto gave a total of 31 FURs. As seen on Table 8, Padova is by far the largest FUR, with a total of 209 municipalities linked to it. Verona is the far second, with a total of 80 municipalities. However the case of Padova is illustrative about the method. As Venezia is a very large municipality not only in inhabitants, but also in area (414.6 Km^2), a very important number of its flows are inside flows. As such the incoming flows of Venezia, counting its inner flows, are the highest in the region, but without these flows, it's second. As such, the procedure counts Venezia as a subordinate of Padova, resulting in a map as shown in Figure 6.

As expected all of the municipalities are placed on the correct enlarged municipality, as the enlarged municipalities are a connection for the principal flow. Comparing the FURs from the PLA against the SLLs, 485 of the municipalities are located in the same FUR and SLL or the FUR contains the SLL to which the municipality belongs.

As shown in Figure 6 Padova as the largest FUR, absorbing the SLLs of Adria, Badia Polesine, Este, Porto Viro, Rovigo, San Dona' di Piave, Venezia and Vincenza; is followed by Vicenza that absorbs Bovolone, most of San Bonifacio, Grezzana and San Giovani Ilarione; Belluno absorbs Agordo and Schio absorbs Thiene.

Figure 6: FURs in the Veneto – PLA procedure



*ArcMap Output. Source: Own elaboration.

Of the 96 municipalities located in different FUR, 17 municipalities belong to SLL outside the Veneto, 15 belongs to Castelfranco Veneto, 14 to Montagnana, 7 to Portogruaro, 6 to San Bonifacio, 5 for both Arzignano and Feltre, and 4 for Conegliano, Treviso and Montebelluna. The rest of the municipalities are reparted among various SLLs.

Of the 79 municipalities that have different FUR than SLL in the Veneto, are 8 foci of FURs. Of those 8 FURs, 5 of them have self-containment ratios under 65% and hold a total of 9 municipalities (2 of them are FURs constituted only by its foci) which constitutes a clear failure of the procedure in locating those municipalities. On the other side, are the FURs of Oderzo, Valdagno and Lonigo. Oderzo has a total of 43,326 ingoing commuters and a self-containment ratio of 78%, which constitutes a FUR by itself, grouping a total of 8 municipalities of 3 different SLLs that with the this new FUR keep the same levels of self-containment; Valdagno is an inside division of Arzignano, with a self-containtment ratio of 72% (76% for Arzingamo FUR and 85% for Arzingamo SLL) showing that, although self-containment ratio is low by comparison, Valdagno is a local foci even when it does not attract enough commuters to be considered a FUR by itself; Lonigo have a relatively low self-containment ratio (68%), but confines two municipalities with one significant flow pointing to other municipalities in the FUR, showing again some polarity between different SLL. These FURs (Oderzo, Valdagno and Lonigo) concentrate a total of 25 municipalities, explaining more than 25% of the differences between PLA procedure and the SLLs.

Table 8 FURs (Terminals) by number of municipalities

Terminal	Municipalities by number of links to the Terminal[1]					
	Total[1]	1[2]	2	3	4	5
Padova	**209**	58	108	35	6	1
Verona	**80**	56	21	2	0	0
Belluno	**37**	14	20	1	1	0
Schio	**30**	11	15	3	0	0
Bassano del Grappa	**27**	20	6	0	0	0
Treviso	**21**	20	0	0	0	0
Conegliano	**19**	11	7	0	0	0
Pieve di Cadore	**16**	6	3	1	5	0
Montebelluna	**16**	10	5	0	0	0
Oderzo	**15**	7	7	0	0	0
Legnago	**13**	10	2	0	0	0
Arzignano	**11**	5	5	0	0	0
Castelfranco Veneto	**10**	8	1	0	0	0

[1] Total: Total number of municipalities in the FUR. [2] 1, 2, 3, 4, 5: number of municipalities linked to the FUR in repetition 1, 2, 3, 4 or 5.
Source: Own elaboration.

Of the municipalities with different results for PLA and SLL 6 have only one significant flow both according to both MLA and skew. This means that these municipalities are subordinated to other municipality, showing a possible misplacing in the SLL, or a hierarchical order in these SLLs. In Castelfranco Veneto are two of those six municipalities. These two municipalities (Fontaniva and San Giorgio in Bosco), along with five other (Tombolo, Galliera Veneta, Villa del Conte, Carmignano di Brenta and Grantorto) have their principal link with Cittadella which is connected with a first link to Padova, although Cittadella has more than five significant flows. This fact reveals that Citadella it's in fact a center in the region and could be considered a potential FUR. The rest of the differences in the delineation by the two procedures are in municipalities with more than two significant links, on which PLA has a clear deficiency.

As seen in Table 9, the FURs produced by the procedure have a huge variability in both size, and self-containment ratio. This phenomenon is explained by the fact that the procedure never takes into account neither the self-containment ratio nor the size of the potential FURs in the delineation procedure.

Table 9 : PLA – Descriptive Statistics

	Inc.[1]	Out.[2]	HSC[3]	LSC[4]	SC[5]	Skew	SF[6]	%SF[7]
Mean	75,800	75,934	75%	77%	73%	5.07	2.23	5.59%
Maximum	1,073,360	1,065,641	95%	95%	95%	10.64	9.00	15.00%
Minimum	252	413	34%	33%	33%	2.01	1.00	0.75%
Std. Dev.	195,644	194,316	15.93%	15.39%	16.48%	2.43	1.75	4.28%

[1]Ingoing commuters. [2]Outgoing commuters. [3]Household Self-Containment Ratio. [4]Labor Self-Containment Ratio. [5]Self-Containment Ratio. [6]Significant flows. [7]Percentage of significant flows over total flows.
Source: Own elaboration.

The fact that the procedure does not take into account any measures of self-containment or size of the municipalities and potential FURs (except in the terminal definition), and assumes highly polarized municipalities (implicitly is assuming that all municipalities have only one significant flow), makes this procedure inefficient as a FUR delineation procedure. However, the information that provides among the regions is extremely useful, specially measuring the biases of a region.

5.4 Van der Laan – Schalke Procedure

As told before, the van der Laan & Schalke procedure (VLAAN) has a first seven steps which are completely objective. As seen on 2.2 after seven steps there still 136 municipalities to allocate on a potential FUR which represent the 24% of the region; it is also important to notice the high number of potential FURs compared to other procedures. Table 11 shows how the high number of potential FURs has attempted against self-containment, with only the mean of the LSC in 75%, while the other two ratios are under it.

Table 10: Steps in the van der Laan – Schalke Procedure

Step	FUR[1]	MFUR[2]	Rem.[3]	%FUR[4]
1	59	310	271	53%
2	50	310	271	53%
3	50	357	224	61%
4 to 6	50	445	136	76%
7	46	445	136	76%

[1] Number of potential FURs. [2]Municipalities in a potential FUR. [3]Remaining municipalities. [4]Percentage of municipalities in a potential FUR.
Source: Own elaboration.

Table 11: van der Laan - Schalke after step 7– Descriptive Statistics

	Inc.[1]	Out.[2]	HSC[3]	LSC[4]	SC[5]	Skew	SF[6]	%SF[7]
Mean	43,048	42,137	73%	75%	71%	5.396	3.438	5.08%
Maximum	342,795	320,651	94%	94%	92%	12.886	15	31.25%
Minimum	252	413	38%	44%	38%	1.043	1	0.34%
Std. Dev.	77,110	74,271	12.68%	11.83%	13.01%	2.505	3.09	5.13%

[1]Ingoing commuters. [2]Outgoing commuters. [3]Household Self-Containment Ratio. [4]Labor Self-Containment Ratio. [5] Self-Containment Ratio. [6]Significant flows. [7]Percentage of significant flows over total flows.
Source: Own elaboration.

As mentioned earlier, the 8th and 9th steps of the VLAAN doesn't have a clear procedure, but instead they propose the integration of small clusters and remaining municipalities to the existence of commuting relationships (step 8), and geographic proximity (step 9). This presents a lack in objectivity on the procedure, leaving space for mistakes in the delineation of the actual FUR.

However, until this step, there is a good map of the polarities in the region, with a procedure that takes into account also the second flow. Actually, all municipalities that belong to the same expanded cities found in 4.1.1 are located in the same FUR, in VLAAN.

It is important to finish the delineation, as the purpose of all this procedures is in fact to allocate all (most) of the municipalities in a FUR. As it, the procedures continues with step 8, which is divided in 3 sub-steps, and following the same kind of procedure as suggested by van der Laan and Schalke (2001), municipalities are linked into a potential FUR and FURs are merged according to their commuting relation. First remaining municipalities are linked into a FUR if its main flow (F_1) goes to that FUR and their second flow (F_2) destination is another remaining municipality. After this, step 7 is repeated in order to merge small FURs, and step 6 is repeated again in order to link the municipalities with ties to the new FUR to it, resulting the map showed in Figure 7.

Figure 7: FURs van der Laan - Schalke

*ArcMap Output. Source: Own elaboration.

At this stage, there are still 81 municipalities to allocate in a FUR, the ones with many significant flows. At this point, van der Laan and Schalke (2001) propose to link the remaining municipalities to a link based on geographical proximity, defining the FUR of 14% of the municipalities by an external source.

However, VLAAN provides important information about polarities inside the FURs, and the FURs formed by the procedure are the similar to the ones produced by the SLLs, without a single FUR belonging to more than one SLL.

5.5 Cluster Analysis (TTWAs)

The cluster analysis as proposed by Coombes (1986), results in a total of 48 FURs, with a minimum self-containment ratio of 79%, the same as the SLLs. However, it exist an important difference: first, the number of FURs in the TTWA procedure is higher than the total number of SLLs. However, both the TTWAs and the procedure used by the ISTAT are variations over the same procedure.

Table 12: TTWAs – Descriptive Statistics

	Inc.[1]	Out.[2]	HSC[3]	LSC[4]	SC[5]	Skew	SF[6]	%SF[7]
Mean	49,670	49,590	80%	83%	79%	3.16	2.24	9.24%
Maximum	337,046	313,483	95%	94%	91%	5.44	6	33%
Minimum	2,373	2,397	72%	75%	72%	1.06	1	2.22%
Std. Dev.	72,285	68,393	6.35%	5.12%	5.38%	0.93	1.34	5.84%

[1]Ingoing commuters. [2]Outgoing commuters. [3]Household Self-Containment Ratio. [4]Labor Self-Containment Ratio. [5] Self-Containment Ratio. [6]Significant flows. [7]Percentage of significant flows over total flows.
Source: Own elaboration.

However the similarities, exists small differences in the borders of the FURs between the methods, as well as some important differences in the zone between Verona and Vicenza. This differences are mainly explained by the fact that, apparently, the algorithm used by ISTAT demands higher FURs in terms of inhabitants.

Comparing this procedure with PLA, appears the PLA of Lonigo, a part of the FUR (TTWA procedure) Noventa Vicentina, one of the troubled FURS in the TTWA procedure, and in part of the region where municipalities have links to opposite foci (Vicenza, Verona), and a wide range of significant links.

Figure 8: FURs in the Veneto – Cluster Analysis

*ArcMap Output. Source: Own elaboration.

6 Conclusions

After delineating the FURs in the Veneto region using three different methodologies, it is clear that those methodologies that use only the main flows to construct the FURs, performed less effectively than procedures that takes into account the whole set of flows.

There are two reasons for this. First, while the PLA assumes that all municipalities have only one significant flow and the Van der Laan-Schalke procedure one or two, the cluster analysis procedure takes into account all flows using a similarity function in order to evaluate the link between two municipalities. Second, due to its more complex nature cluster analysis procedure evaluates the intensity of the flows between the different potential FURs and municipalities each step, while the other procedures renounce to measure the intensity of the flows between two potential FURs, and just measure the existence of the link.

In terms of bias, procedures that evaluate the main links have 100% accuracy, while cluster analysis misses in 59 cases (89.8% accuracy). This reveals that while more effective in identifying FURs, the cluster analysis is biased. As it, the most effective procedure has a bias, proving Hypothesis 1.

Also, it has been clear from the analysis that procedures with fewer flows analyzed tend to reveal information about the region and the FURs that more complex procedures failed to reveal or discarded even when they were significant.

Is clear that none of the procedures have succeed in delineating FURs with high levels of self-containment, that links all municipalities to their objective FUR and that identify foci in the region. However, all the procedures analyzed proved to be useful in developing an objective procedure that allow identifying the FURs of an area.

6.1 Policy Recommendations

The current method for delineation of the different FURs among Europe suffers in general of one out of two diseases: uses unbiased procedures that are highly effective in polarized regions, but less effective constructing the FURs; or uses a procedure that is effective in non-polarized regions and in polarized relatively big regions, but misses small areas with a high polarity and self-containment, with a high risk of biased areas, that do not reflect the real world.

Due to both the origin of the FUR concept in the context of local labor economics, and the necessity of FURs large enough in terms of inhabitants, the cluster analysis procedures have been commonly used by governmental offices in detrimental of methods with more polarized focus. This has produced and inaccurate allocation of some border municipalities, as well as the overpass of some small FURs with small number of inhabitants.

The correct delineation of FURs is a matter of prime importance, as only identifying correctly this new level of city, the policies that pretend to act on a real local environment can be developed. Even when, as stated by van der Laan and Schalke (2001) is not good that borders change too often, the changes on the patterns in people’s movements must be recognized. Remember, studying the movement of matter, physics had led human kind to space; imagine where could lead us social sciences understanding the movement of human beings.

7 Bibliography

Black, W. R. (1995). Spatial Interaction modeling using artificial neural networks. *Journal of Transport Geography, 3*(3), 159-166.

Bruijsten, J. (2010). Polycentricity: In search of the 'pur-fect' region. *Master's Thesis Entrepreneurship, Organisation and Strategy Economics*. Rotterdam: Erasmus School of Economics - Erasmus University Rotterdam.

Casado-Díaz, J. (2000). Local Labour Market Areas in Spain: A Case Study. *Regional Studies, 34*(9), 846-856.

Coombes, M., Green, A., & Openshaw, S. (1986). An Efficient Algorithm to Generate Official Statistical Reporting Areas: The Case of the 1984 Travel-to-Work Areas Revision in Britain. *The Journal of the Operational Research Society, 37*(10), 943-953.

Horner, M. W. (2004, May). Spatial Dimensions of Urban Commuting: A Review of Major Issues and Their Implications for Future Geographic Research. *The Professional Geographer, 56*(2).

Hunter, L., & Reid, G. (1968). *Urban Worker Mobility.* Paris: OECD.

Nielsen, T. S., & Hovgesen, H. H. (2007). Exploratory Mapping of Commuter Flows in England and Wales. *Journal of Transport Geography*.

Nystuen, J., & Dacey, M. (1968). A Graph Theory Interpretation of Nodal Regions. In B. Berry, & D. Marble, *Spatial Analysis. A Reader in Statistical Geography.* Englewood Cliffs: Prentice-Hall.

Riguelle, F., Thomas, I., & Verhestel, A. (2007). Measuring Urban Polycentrism: a European Case Study and its Implications. *Journal of Economic Geography*, 193-215.

Smart, M. (1974). Labour Market Areas: Uses and Definitions. *Progress in Planning*, 239-353.

Sohn, J. (2005). Are Commuting Patterns a Good Indicator of Urban Spatial Structure? *Journal of Transport Geography*, 306-317.

Sultana, S., & Weber, J. (2007, May). Journey-to-Work Patterns in the Age of Sprawl: Evidence from Two Midsize Southern Metropolitan Areas. *The Professional Geographer, 59*(2), 197-208.

van der Laan, L., & Schalke, R. (2001). Reality versus Policy: The Delineation and Testing of Local Labour Market and Spatial Policy Areas. *European Planning Studies, 9*(2), 201-221.

van Nuffel, N. (2007, June). Determination of the Number of Significant Flows in Origin–Destination Specific Analysis: The Case of Commuting in Flanders. *Regional Studies*, 509-524.

van Nuffel, N., & Saey, P. (2005). Commuting, Hierarchy and Networking: The Case of Flanders. *Tijdschrift voor Economische en Sociale Geografie, 96(3)*, 313-327.