TECHNICAL REPORT

ESPON

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Functional Urban Areas (FUA) and European harmonization

A feasibility study from the comparison of two approaches: commuting flows and accessibility isochrones

CONTENT

- Stakes: Significant progress has been achieved recently about the construction of FUA defined from commuting flows. However, several questions remain about the comparability of such urban objects, due to the strong heterogeneity of LAU2 size and of settlement contexts.
- Methodology: This report aims at assessing the feasibility of another method based on accessibility isochrones (including speed parameters) and to question the complementarity between both methods used for defining FUA.
- Results: For a set of about 10 large cities, urban isochrones perimeters are constructed from different congestion models focusing on road trips. They raise new questions when compared to FUA constructed from commuting flows.

35 pages

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MULTI DIMENSIONAL DATABASE DESIGN & DEVELOPMENT

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Introduction

The issue of international harmonization is fundamental for each European database. But this issue is particularly sensitive and complex for the construction of functional objects such as Functional Urban Areas (FUAs). More than for other urban objects, there is no real consensus about the methodology and the choice of parameters. Furthermore, the construction of FUAs relies on less easily accessible data about jobs concentration and commuting flows. The FUAs that have been constructed until now (FUAs from ESPON 1.1.1, FUAs from ESPON 1.4.3., FUAS from IGEAT, New LUZ from the consortium OECD-European Commission) do not answer completely this harmonisation issue, even if some authors suggest interesting solutions. The latest version of the New LUZ (2012) shows considerable progress in that domain, so that New LUZ can be considered as the first official harmonised database for an important set of large European functional areas. However, several questions still remain about the comparability of such urban objects, in particular as regards to the strong heterogeneity of sources (LAU2 sizes) and to the heterogeneity of settlement contexts (monocentric/polycentric urban structures).

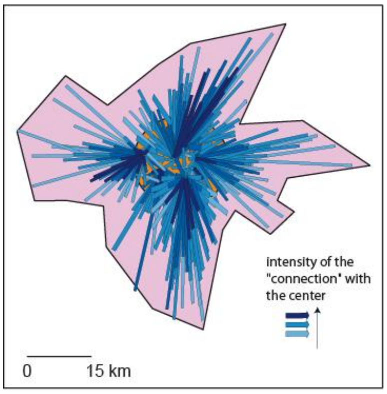
This report aims at better understanding the issues linked to the harmonisation of FUAs throughout Europe. We will first shed light on the dominant model used until now by European projects for constructing FUAs. This model considers FUAs as an area polarized by commuting flows around a pole that concentrates jobs or inhabitants. However, other projects explore a different approach, based on accessibility isochrones, that defines jobs polarisation from a theoretical model of access to work and not from empirical data[1]. Our premise is that we will learn a lot from the comparison of these two approaches. The aim of this technical report is thus not to propose an operational solution, a new methodology that would allow the construction of a new FUAs database. It is rather to expertise these two different approaches and find out what processes could be the most relevant for ensuring international harmonization. In other words, one of the most important questions that needs to be answered is: *Is it possible and coherent to implement the same methodology and parameters in each country, taking into account the variability of data, the heterogeneity of the settlement contexts and the differences in the resolution of LAU2?*

In order to provide elements to answer this question, we propose to build and compare two types of functional areas (**Figure 1**) in several sample zones, including about 10 cities (for a complete description of this sample, see Annex 1), that reflect different case studies in terms of monocentric/polycentric pattern, regional settlements, or sprawl dynamics. These two approaches integrate inputs (commuting flows, transportation networks…) and parameters (levels of attractivity for commuting, transportation time…) that may take into account the variability of data, settlement contexts or administrative units resolutions between countries.

[1] Federal Institute for Research on Building, Urban Affairs and Spatial Development (2010), Metropolitan Areas in Europe. Abstract of a new BBSR study. *BBSR-Berichte Kompakt* 7/2010. Bretagnolle A., Giraud T., Mathian H. (2008), Measuring urbanization in United States, from the first trading post to the *Metropolitan Areas* (1790-2000). *Cybergeo*, 427, http://cybergeo.revues.org/index19683.html

Figure 1: A comparison between two approaches of FUA

Connection : Flows



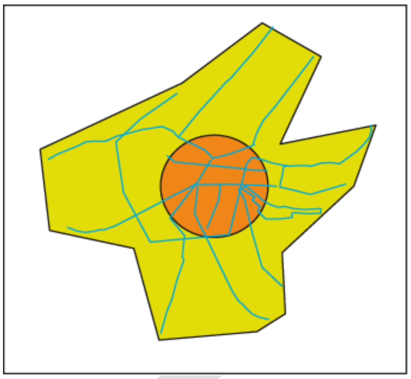
Modelisation of the travel to work area

Parameter(s) of the model: k

-Is k depending on country ?

-Is k depending on city size ?

Accessibility : transport network



Modelisation of the one hour isochron

Parameter(s) of the model:

Different speeds according to

-Trafic data

-Frequency of transportation

In a first section, we focus on **observed FUA**, which are based on a system of relationships and are expressed here as the result of **polarisation by employment and commuter data**. The aim is to highlight the issues raised by harmonisation of sources and parameters.

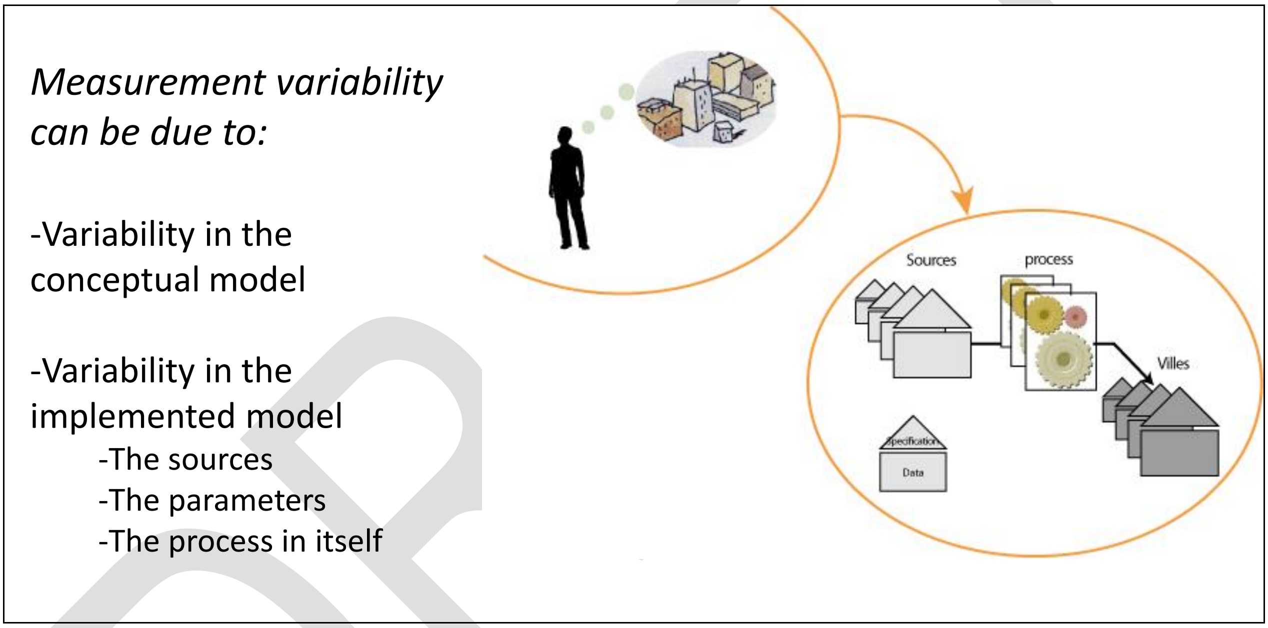
Then we shift to **potential FUA** and we propose an original methodology based on a theoretical model coupled with **local transportation networks and accessibility measures**, taking speed parameters into account.

To conclude with this feasibility study, we compare the results obtained through both approaches and will give some recommendations about the choice of parameters.

1 FUA based on commuter flows

The harmonisation of FUAs at an international scale depends on two main factors that can be a source of heterogeneity in the context of cities comparisons. First, each urban database reflects a specific way of appreciating the reality of cities, which can be identified as the ***conceptual model*** of cities (**Figure 2**). For instance, cities can be represented as political, morphological or functional objects. But even if the same conceptual model is considered, important issues can be raised by the way this concept is applied: what could be termed as the ***implemented model*** rests not only on the choice of the *sources* and of the *parameters,* but also on the setting of the *modelling process* in itself, which refers to the succession of operations to be carried out in order to build FUAs.

Figure 2: Urban databases and measurement variability



Mathian, 2012

For those reasons, it is essential to recall first the main assumptions underlying the conceptual model of FUAs, when FUAs are defined as areas polarised by a centre of jobs. Then we will see that if much progress has been made with the New LUZ by OECD/European Commission (2012)[2], different issues remain unsolved about the implementation of a common conceptual model. We will precise that point by presenting some results focusing on the sensitivity of FUA perimeters to the variation of data and parameters, for a sample of large cities.

[2] Djikstra L., Poelman H., 2012, *Cities in Europe*, *The new OECD-EC*, European Commission, Regional Focus 1/2012, 16 p. See also http://www.oecd.org/statistics/datalab/metro-explorer.htm

1.1 The construction of FUA based on commuting flows: from concept to implementation

1.1.1 From the conceptual model…

The definition of travel-to-work areas around urban centres is the most common approach used by the European countries which delineate FUA perimeters. It has been first adopted in the United States, with the Standard Metropolitan Statistical Areas (1959) and the Metropolitan Statistical Areas (1983). During the last decade, a growing number of national statistics institutes have adopted this approach in order to define cities that include large areas functionally depending on core cities. Beyond the great diversity of national definitions, the common concept of areas polarised an urban centre that concentrates jobs has gradually become a reference for countries. At a European scale, FUA-IGEAT and now New LUZ from OECD-EC are also based on this concept and their perimeters depend on the intensity of commuting flows towards this center.

According to this approach, FUAs can be described as envelopes containing the zones which are connected to a centre of jobs through commuting flows. As such, they share common features with the Labour Market Areas (LMA)[3] which are also based on commuting flows between locations. However, both functional divisions do not overlap because of two major differences between them: the definition of LMA does not necessarily require the identification of a centre, and above all, LMAs result in a complete division of a territory, whereas FUAs induce a zoning between urban and rural areas.

1.1.2 … to the implemented model

Depending on how it is implemented, the common conceptual model of FUA (for instance for FUA-IGEAT and New LUZ) can lead to very different delineations of cities. More precisely, the differences observed in the implementation of a same conceptual model may come from three dimensions: the process, the parameters and the sources.

- The *process* in itself can be decomposed into 5 main steps which are described in **figure 3**:

The **construction of urban cores**, which mainly relies on rules about the density of jobs (or by default of inhabitants) and the contiguity of elementary units (EU). Sometimes several centers are considered for a same FUA, in polycentric settlement contexts.

The **selection of elementary units in relation with any urban core**, which implies the choice of a parameter for measuring, for each EU, its dependency level to any possible centre. Some more complex rules are sometimes defined through an iterative

[3] Along with FUAs, the local Labor Market Areas (LMA) represents a major project in defining harmonized local regions based on employment flows. They correspond to relatively autonomous zones for employment areas (criteria of "self-containment" zones), inducing a complete division of territories. Depending on the country, LMA are not necessarily defined as polarised zones. A feasibility study has been recently produced for Eurostat with the aim of defining a methodology for creating harmonised LMA throughout Europe (Coombes M., Casado-Díaz J.M., Martínez-Bernabeu L., Carausu F., 2012, *Study on comparable Labour Market Areas*, Research report for Eurostat, 68 p.). This report is all the more interesting that it deals with the issue of the sources used for quantifying employment flows and questions the sensitivity of these areas to the heterogeneity of LAU2.

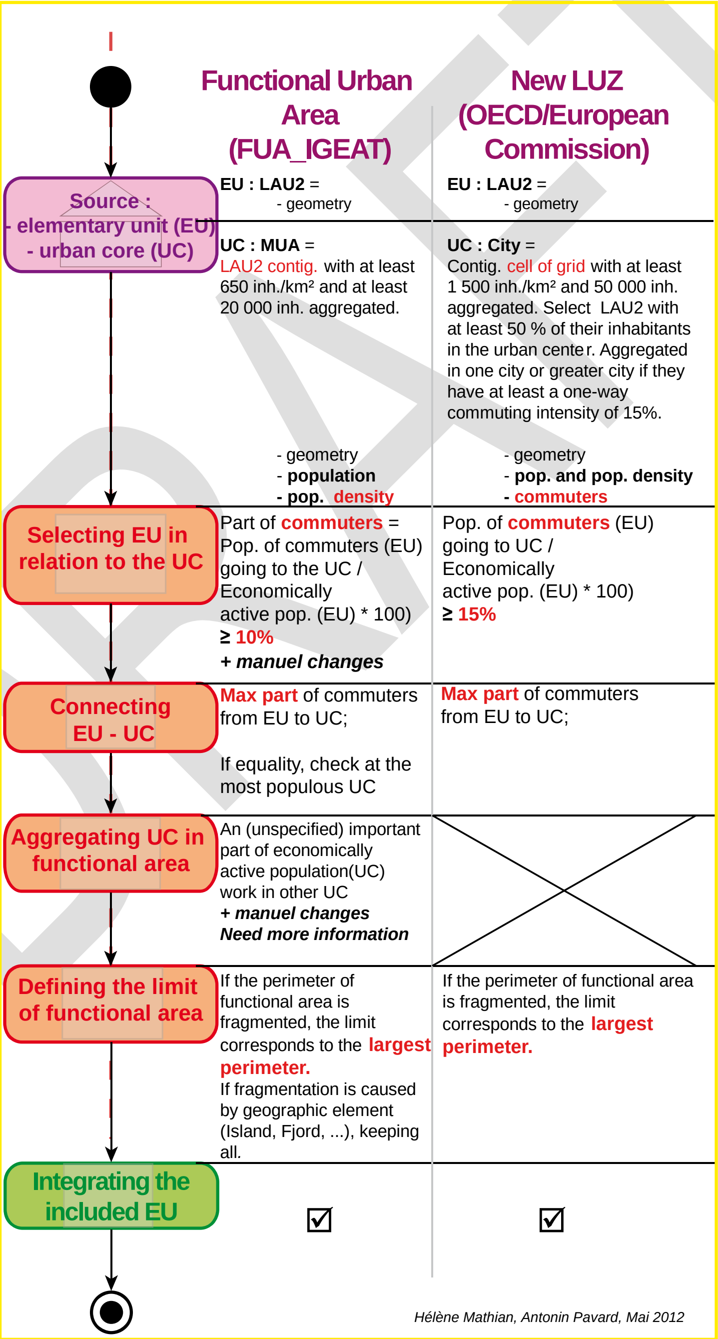
process of selection of EU ("snowball effects"), as for the French national definition. This process allows taking into account secondary employment poles.

The **connection of the elementary units with one or several urban cores**. Delineations can indeed differ according to the way multipolarised areas are considered. This step may especially influence the delineation of cities in polycentric contexts.

The **aggregation of urban cores in functional areas**, in order to define whether Urban Core(s) depend themselves to another Urban Cores.

The **definition of the limits of functional areas** requires defining rules for the "isolated" units, which are not in continuity with the main area of influence.

Figure 3: Different processes for implementing conceptual models of Functional Urban Areas



-*The parameters*: as mentioned above, the key parameter of this process is the dependency level of an elementary unit (or the attractivity level of the centre). This dependency is commonly measured by the ratio of the active population that is working into the centre. The variability of the results thus depends on the choice of a dependency threshold K ("dependency ratio" of the elementary unit i depending of j) which is usually defined as follows:

$$Flow(i,j) / ActivePopulation(i) > K \%$$

However, there is no consensus about the relevant value fixed for this parameter. It can ranges in Europe from 10% to 40% from one national definition to another[4]. This strong variability raises many questions about the sensitivity of the delineations to the specified dependency threshold.

-*The sources*: the data which are required are of two kinds. The delineation of the urban centres as well as the computation of the dependency ratio firstly depend on "stock" data about either total population, active population and/or the number of jobs within each LAU2. The measure of the dependency level also necessitates "flow" data about the number of commuters that live in a LAU2 and work in another one.

These first considerations about the potential sources of heterogeneity aimed at recalling that the setting of a top-down process for constructing harmonised European FUAs requires not only homogeneity of the concepts, but also homogeneity of the processes. Over the last few years, significant progress has been achieved concerning the harmonisation of FUA databases defined from commuting flows. Compared to the first attempts that either concerned the very top of urban hierarchy (FUR and FUA 1.1.1) or mixed functional criteria with administrative ones (Urban audit 2004[4]), new LUZ from OECD/EC (2012) now provide statistical homogeneity for a large set of cities, through top-down process. As such, they have set the foundations for robust harmonised databases, theoretically highly reproducible (same definition of FUAs cores, same attracted areas as LAU2, same commuting threshold). However, important questions still remain about the comparability of these urban objects, in relation to the sources (availability of commuting flows but also strong variability of LAU2 sizes) and to the choice of parameters.

1.2 Heterogeneity of sources: internal and external consistency of SIRE database

The first factor of heterogeneity lies in the access to the data. In particular, the handling of SIRE database from Eurostat is of critically importance for the delineation of FUAs, especially concerning active population and commuters at LAU2 level. However different problems can be encountered when exploring the geometries and the statistical attributes in the sample zones. Many of the problem raised come from the comparison of the two tables of SIRE that provide information about commuters:

[4] Bretagnolle A., Delisle F., Mathian H. (2011), *Larger Urban Zones (Urban Audit) specifications,* Technical Report, 74 pages. Rapport final du projet ESPON Data Base 2013, phase 1, [En Ligne] sur le site d'ESPON.

the tables on flows on one hand and the table of stocks (or static table)[5] on the other (**Figure 4**).

Figure 4: Extracts from SIRE Database (Eurostat), tables on commuters

Table 1 (Flows)

Columns:

#	Name	Data Type	Nulls?
1	CODCOM	VARCHAR2(11)	N
2	DESCODCOM	VARCHAR2(11)	N
3	COMMUTERS	NUMBER(10)	Y

Table 2 (Stocks)

Columns:

#	Name	Data Type	Nulls?
1	CODCOM	VARCHAR2(11)	N
2	BEGVAL	DATE	N
3	DATOBS	DATE	N
4	ORIVAR	VARCHAR2(1)	Y
5	INAREA	NUMBER(10)	Y
6	OUTHOME	NUMBER(10)	Y
7	INHOME	NUMBER(10)	Y
8	OUTAREA	NUMBER(10)	Y
9	OUTCOUN	NUMBER(10)	Y
10	NOTFIXED	NUMBER(10)	Y
11	UNKNOWN	NUMBER(10)	Y

1.2.1 *Availability of data*

There are different problems regarding the availability of data. First of all, there is no data about total employment in LAU2. In theory, this information could have been reconstructed from the flow table, as a sum of total inflows and of intra-LAU2 flows. However, this is impossible since there is no information about intra-LAU2 flows, except for France. Secondly, the availability of data is still heterogeneous from one national statistical institute to another: the commuting data are not available for Latvia, Lithuania and Romania and there is no "stock" table for Germany. Lastly, there is no data for cross-boundary commuters, whose number can be significant in some cities (for instance Vienna and Copenhagen).

1.2.2 *"Internal" inconsistencies*

-When the data are available, major problems are raised by **inconsistencies between static and flow tables** (see Annex 2). Considering the 26 countries where both tables are supplied, the comparison of the total counts from both static and flow tables shows that for a same LAU2, the number of commuters in the flow table represents in average 89% of the total « outarea » population in the static table. This difference might be due to the absence of flow data below a certain threshold of commuters. For some countries (Portugal, Lithuania, United Kingdom), there is a greater difference and this ratio is much lower (respectively 40%, 50% and 75%). Furthermore, strong inconsistencies have been found for Hungary and Slovakia.

As a synthesis, we have defined several criteria in order to check the coherence between flow and static tables from SIRE (number of LAU, number of jobs fulfilled by active residents from another LAU2, etc.): less than half countries (9 countries in 16 from SIRE) meet these criteria.

[5] The flows table describes the number of commuters exchanged between each couple of LAU2. For each LAU2, the static table provides information, among others, about the active population working inside or outside their LAU2 of residence.

- There is no official correspondence table between LAU2 geometry and SIRE attributes. We could use the table developed by Didier Peeters[6] for defining FUAS_IGEAT, but despite the huge work already realised for achieving this table, the join tests realised within our sample zones did not allow to realise a complete correspondence. That problem is increased by the existence of at least three versions of LAU2 geometries for 2000 data, with no reference version for local data. The meeting which has been organised by RIATE at Eurostat (20th June 2012) allowed to solve some of these problems (correspondence table in relation to a reference geometry of LAU2).

- The administrative levels are heterogeneous (LAU2 in general but mixed with LAU1 in Scotland, and only LAU1 in Greece, Bulgaria, Portugal). This heterogeneity may contribute to increase the differences in average size from one country to another that raises Modifiable Area Unit Problems (MAUP).

1.2.3 "External" coherence with national sources

Another major issue relates to the fact that the tables do not provide the complete list of flows. In particular, the lowest flows from each LAU2 do not appear in the tables and the threshold used to select data varies from one LAU2 to another. This is due to the fact that the statistical offices only send the 30 first flows from LAU2. Unlike NUTS2 and NUTS3, Eurostat does not have the means to constraint the data format[7].

Internal and external inconsistencies of the SIRE DB thus represent an important barrier to the construction and study of functional areas for the whole European Union. They can nonetheless be used as good approximations for about half of the countries. For other countries or for more precise studies, they imply to collect information directly from the national statistical offices[8]. In the case of this report, because of time limitations, we have based the following explorations on the SIRE data, in the countries where it seemed the most reliable.

1.3 How to deal with the heterogeneity of LAU2 sizes?

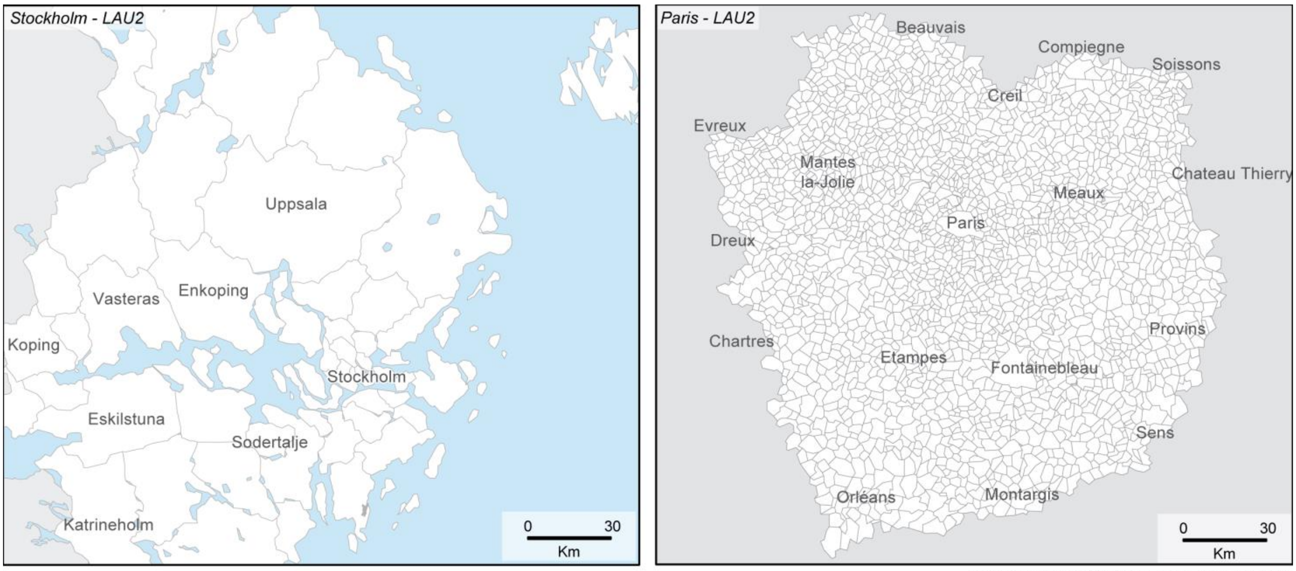
A second important issue concerns the heterogeneity of administrative elementary units. As the **table 1** and **figure 5** illustrate, there is a huge variation in LAU2 size, from 15 km² to 1444 km². Even if common process and parameters are defined for constructing FUA, the heterogeneity of local units (heterogeneity of "granularities") may introduce a typical bias to the results, in accordance with what is known about the Modifiable Area Unit Problem (MAUP)[9].

[6] Peeters D., 2011, *The Functional Urban Areas database*, Technical report ESPON 2013 DB, 18 p.
[7] This information was precised at the Eurostat & ESPON Database meeting in Luxembourg, 2012 June 18th.
[8] This is the work done for the New Luz constructed by the consortium OECD/Eurostat, as mentioned in the Eurostat & ESPON Database Luxembourg meeting (2012 June 18th).
[9] Grasland C., Madelin M. (dir), 2006, *The Modifiable Areas Unit Problem, ESPON 3.4.3, Final report.*

Table 1: Average area of LAU2 (km²), an example for 7 countries (2000)

Country	Average surfaces
France	**15**
Germany	25
Italy	37
Spain	61
Denmark	155
Finland	693
Sweden	**1444**

Figure 5: Heterogeneity of LAU2 sizes: extreme situations in Sweden and in France



Sources: LAU2 of 2001 (SIRE - Gisco,Eurostat, 2008);
A.Pavard, Géographie-cités,2012

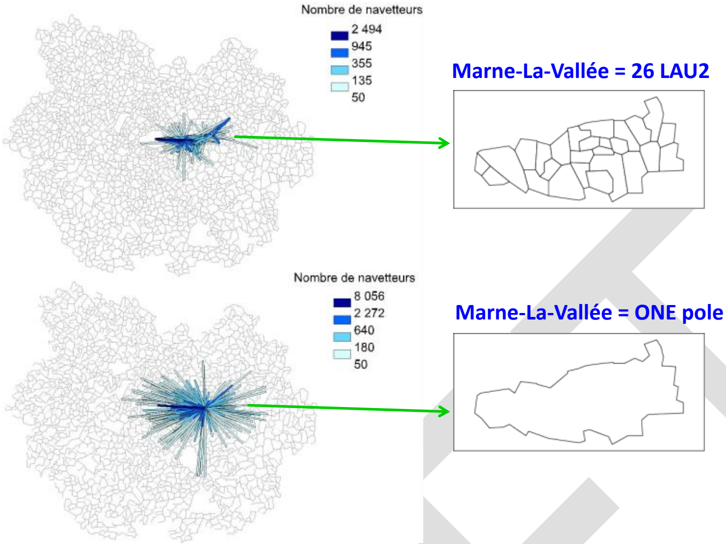
This question is of high importance since the structures of flows are very much dependent on the spatial resolution of statistical units. This bias can be illustrated for instance here by the case of the attractive area of Marne-la-Vallée[10] in the Paris region (**Figure 6**): when the pole is considered as a set of LAU2 (26 entities), the delineation of the area of influence differs considerably from the one obtained with a pole which is composed by one sole entity, even with the same dependence ratio. The polarised area is indeed about twice larger in the second case. Other authors (Coombes et al., 2012, p.33-34) mention the same type of difficulties with respect to local Labour Market. The transfer of the Swedish LMA method to other countries characterized by smaller LAU2 areas (or "higher granularity") stumbles on the very different results obtained about self-containment levels of flows within LMA, from one country to another.

In order to address this problem, researchers working on international comparisons have sometimes chosen to transform elementary units and to construct their own reference unit. For instance, a regional comparison between France (Paris area) and Germany (Rhein-Ruhr cities) shows that whereas the surface of these two regions is quite the same, the French LAU2 (communes) are 10 times smaller than the German LAU2 (Gemeinde) (**Figure 7**). Moreover, there is a local heterogeneity of administrative units in Rhein-Ruhr region (around city cores, NUTS3 instead of LAU2). In that case, transport planning zones in Rhein-ruhr region were aggregated in order

[10] This example comes from results obtained in Laboratory research Géographie-cités (Sandrine Berroir, Hélène Mathian, Lena Sanders) in the Paris region.

to compare flows between spatial units characterized by similar sizes[11]. Of course, this solution is impossible to generalize to the whole Europe. Other solutions could be imagined, for instance by applying higher thresholds in areas where administrative areas are particularly large. However, to our knowledge, they have not been tested yet.

Figure 6: Influence of the spatial resolution of LAU2 on the size of the polarized area



source: Berroir et al., 2007

Figure 7: Heterogeneity of spatial resolution, France/Germany, same scale

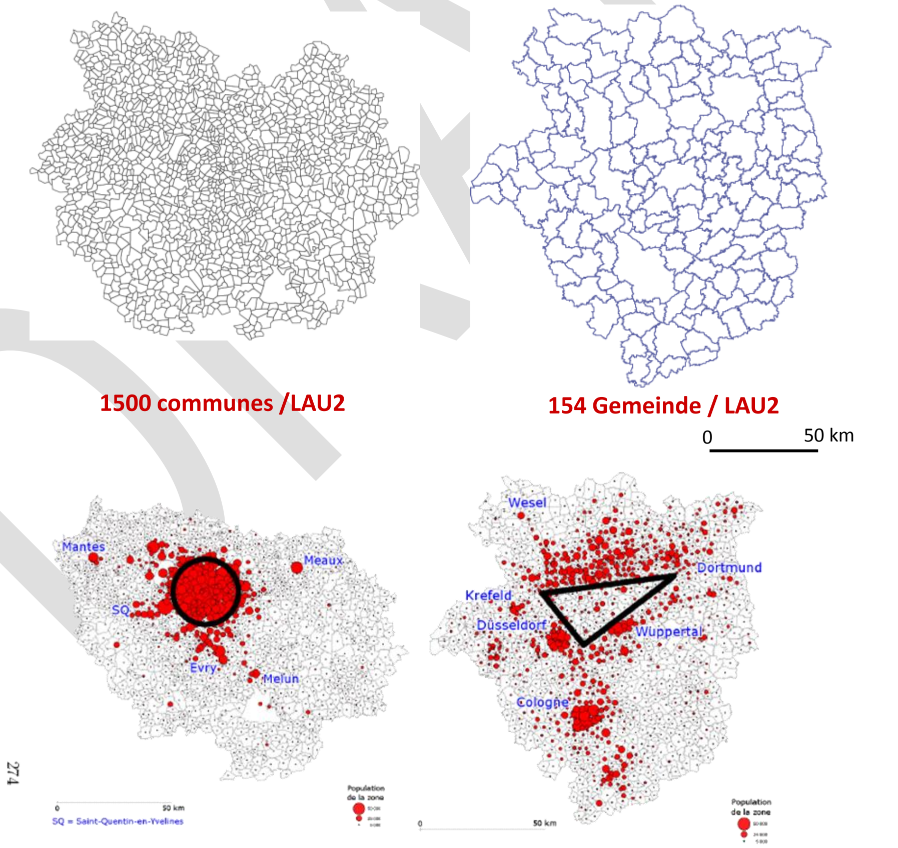


FIGURE 5.4 – Population des zones élémentaires (région Ile-de-France et Région Rhin-Ruhr). Les deux cartes sont à la même échelle, et les deux figures géométriques élémentaires représentées sont de même superficie

Source: F. Le Nechet, 2010

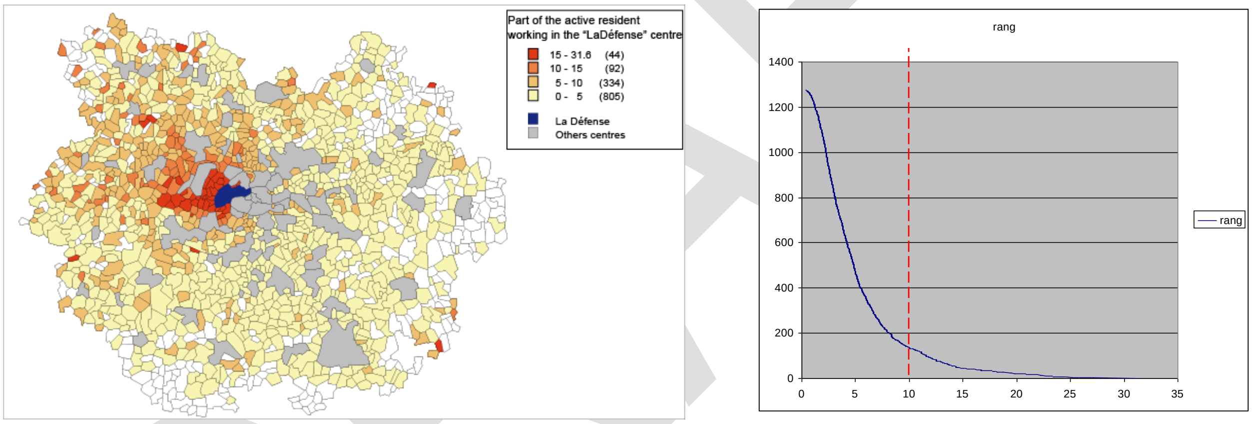
[11] Le Nechet F. (2010), *Public Transport and shape of European cities*. PhD, University Paris-Est, Laboratoire Villes et Mobilité and Géographie-cités.

1.4. The sensitivity of FUA perimeters to the choice of parameters (dependency ratio)

The last point to be addressed to is the choice of parameters. As mentioned in part 1.2.1., our typology of FUA national definitions reveals a strong diversity of thresholds for the dependency ratio parameter (i.e. the share of active population working in the centre): does this diversity reflect different attitudes considering mobility? How to choose this dependency threshold?

First of all, it is important to precise that the choice of one threshold among others cannot be justified by empirical observation. The example of the western part of the Parisian suburb (**Figure 8**) shows that there is no break or not even a slight discontinuity in the statistical distribution of the dependency ratio of LAU2 that would be in favor of a specific threshold.

Figure 8: The absence of a break in the statistical data of the dependency ratio: the case of La Defense pole (Western suburb of Paris, France)



Source: Mathian, 2012

Secondly, FUA perimeters are highly dependent on the choice of a threshold. As shown by the example of Prague (**Figure 9**), the observation of commuter data enlightens a great sensibility to the threshold of the "dependency ratio" parameter. Low differences in the threshold value bring completely different spatial extensions of the attraction basin. We can enlarge this observation to a set of 6 cities (**Figure 10**, **Table 2**) for which we have compared the extent of the areas polarized by the UMZ, according to two different minimal levels of the dependency parameter (10 and 15% of active population employed in the central UMZ)[12]. These results confirm and precise how important are the differences between both perimeters, since the extent of the polarized areas which are resulting from the choice of the 10% threshold is in average +50% larger than with the 15% level.

[12] These two levels are close to the ones selected for delineating FUA-IGEAT and New LUZ. But the delineation of FUA we propose here cannot be strictly compared to FUA-IGEAT and New LUZ, as methods and sources are not exactly the same.

Figure 9: Different commuting levels and different FUA perimeters for Prague

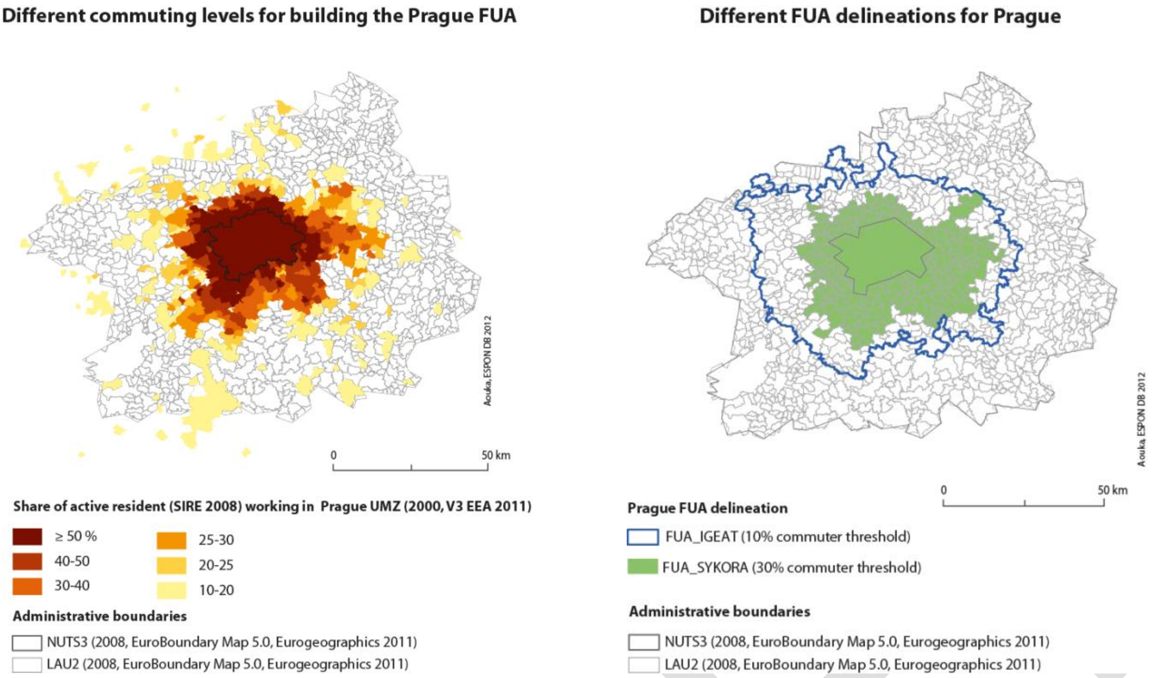


Figure 10: Different commuting levels and different FUA perimeters for 6 European cities

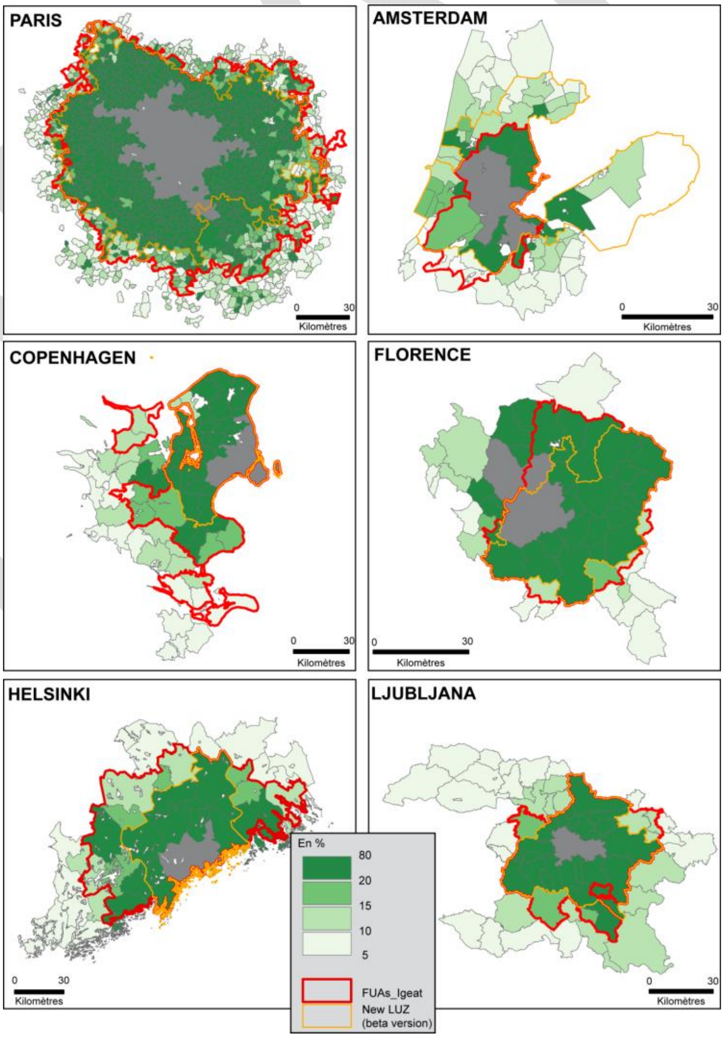


Table 2: Sensitivity of FUA perimeters to different dependency ratio (2000)

FUA	Minimal dependency ratio	Number of LAU2 in the polarized area around UMZ	Area (km²) of LAU2 in the polarized area around UMZ
Amsterdam	15%	27	1014
	10%	50	1977
	Difference. (%)	**85**	**95**
Copenhagen	15%	38	3530
	10%	51	5118
	Rel. diff. (%)	**34**	**45**
Florence	15%	30	2196
	10%	38	2702
	Rel. diff. (%)	**27**	**23**
Helsinki	15%	18	5713
	10%	25	7687
	Rel. diff. (%)	**39**	**35**
Ljubjana	15%	27	2870
	10%	41	5012
	Rel. diff. (%)	**52**	**75**
Madrid	15%	262	9827
	10%	365	16928
	Rel. diff. (%)	**39**	**72**
Paris	15%	1283	12815
	10%	1471	14907
	Rel. diff. (%)	**15**	**16**

As far as possible given the limits of the commuter flows in the SIRE database, we have enlightened the influence of the heterogeneity of LAU2 and of the choice of a dependency threshold on FUA delineation. Of course, both observations are not independent. The influence of the MAUP on the study of polarization structures might be reduced by choosing different dependency thresholds. For instance, the countries with large LAU2 could be associated with higher dependency ratios. To that view, it would be interesting to further explore the relationship between LAU2 size and the extent of peripheral areas, for the same cities (for instance, in France, by comparing delineations based on LAU2 and on LAU1). A complementary approach is to compare the FUA based on commuter flows with delineations based on alternative concepts like FUA based on accessibility isochrones.

2. FUA based on accessibility isochrones to an urban centre

In order to further expertise the issue of harmonization for FUA, we have tested the feasibility of an alternative method based on a time-definition of cities. Starting from the Zahavi law[13] that enlightens the huge stability of the time-budget spent by commuters (around one hour), the method consists in constructing accessibility isochrones around urban centers. Contrary to the FUA mentioned in the first section, this alternative method aims at defining "potential" urban areas corresponding to a theoretical model, which is associated to the average household time budget. Different models are here tested, following an increasing accuracy degree. They are coupled with local transportation networks and accessibility measures. The work aims at constructing an information system about regional access to major employment poles, for sample areas. It will result in the definition of a given isochrone perimeter around these poles, at the level of metropolitan areas.

This second part of the report is not about constructing a new database. It rather aims at assessing the feasibility of an alternative method for a limited set of cities. At this stage, the comparison between FUA based on commuting flows and FUA based on accessibility isochrones should provide materials of reflection in different directions:

-Complementarity between both methods: isochrones-based FUA can be useful to fulfill "holes" where data are missing to construct commuter-based FUA, whether it concerns some Central and Eastern Europe Countries (CEEC) or cross national flows which are fully significant in some areas (Vienna, Copenhagen).

-Cross-assessment of both methods: isochrones-based FUA can bring information about the calibration of the dependency threshold from one country to another, regarding the Modifiable Area Unit Problem.

-It can also be interesting to calibrate evolution of FUAs in time, accessibility data being more stable than perimeters created from flows.

We will first recall what are the main theoretical principles underlying this time-definition of cities. Then we will present the process followed to create accessibility isochrones for a sample of cities, which is twofold:

-A simultaneous work on 2 prototypes, Paris (Géographie-cités Laboratory research) and Barcelona (expert on transportation data, MCRIT), has provided the baseline for the construction of a detailed model, to which the other models have been compared. The specific model calibrated for Barcelona (characterized by rich and fine data on multimodal transportation and traffic peak hours) gives a reference model for multimodal transportation[14].

-An implementation to 9 other cities (Amsterdam, Firenze, Helsinki, Ljubljana, Madrid, Napoli, Praha, Stockholm, Vienna) has been conducted in the context of Master theses and workshops and has contributed to improve this methodology.

[13] Zahavi Y. (1974), *Travel time budgets and mobility in urban areas*. Report prepared for the U.S. Department of Transportation and the Ministry of Transport of Federal Republic of Germany, 267 pages.

[14] The MCRIT report on Barcelona is joined here as a delivery.

2.1. Conceptual framework: households time budget and accessibility isochrones

The isochrones-based FUA lies on the concept of accessibility and considers that cities can be delineated as perimeters of daily access to jobs. This approach lies on two main premises: the first one is common to the commuter-based approach and assumes that employment areas around urban centres are relevant to define urban perimeters. The second one argues that the time spent on commuting (time-budget for transport to jobs) is a rather stable parameter, whatever the person concerned, in reference to Zahavi law[15].

The implementation of such a concept in order to delineate FUA has to face different challenges:

-As for commuter-based FUA, the identification of an urban centre, which can be a point or an area

-The definition of a maximal time-budget threshold.

- The consideration of congestion for road trips and of transport frequency for public transport trips

-The combination of different transportation modes

At the scale of metropolitan areas, some of these complex issues (in particular congestion and multimodal trips) have mainly been explored in the frame of monographic studies. At a macro-regional scale, few recent works have already used such a concept for delineating European cities, but without taking into account congestion[16]. The originality of the M4D approach lies on the modeling of congestion (speed parameters) for a significant set of cities. Due to time limitations, we mainly focused here on car accessibility[17] and we did not consider multimodal accessibility.

[15] Raux, C., Ma T.Y.,Joly I., Kaufmann, V., Cornelis, E., Ovtracht, N. (2011) , Travel and activity time allocation : an empirical comparison between eight cities in Europe, *Transport Policy* , vol. 18, n° 2, pp. 401-412 ; Joly I. (2007), *L'allocation du temps de transport. De l'observation internationale des budgets-temps de transport aux modèles de durées*, Thèse de doctorat, Université Lyon 2, http://hal.archives-ouvertes.fr/docs/00/08/75/85/PDF/These.pdf

[16] Federal Institute for Research on Building, Urban Affairs and Spatial Development (2010), Metropolitan Areas in Europe. Abstract of a new BBSR study. *BBSR-Berichte Kompakt* 7/2010. Bretagnolle A., Giraud T., Mathian H. (2008), Measuring urbanization in United States, from the first trading post to the *Metropolitan Areas* (1790-2000). *Cybergeo*, 427, http://cybergeo.revues.org/index19683.html; Gloersen E, (2012), *La Finlande, la Norvège, la Suède face au projet d'une Europe polycentrique : La centralité à la marge de l'Europe*, Presse universitaire de Rennes, Collection Espace et Territoires, 190 pages.

[17] However, we carried out a feasibility study for the Paris region that underlined the potential of rail-route calculation website for modelling public transportation accessibility See Fancelli S. (2014), *Cartographie d'accessibilité sur la base de calculs de temps de transport en utilisant les données diffusées par internet*. Stage de Master 2 numérique Carthagéo, supervisors A. Bretagnolle, M. Guérois, A. Pavard, ENSG, Laboratoires Géographie-cités et COGIT.

2.2. Sources: which databases for comparing network structures and traffic information?

The construction of accessibility isochrones supposes to use information about the structure of transportation networks and/or the time spent on this network. It is first important to enlighten the choice of both sources of data.

2.2.1. Euro Regional Map (ERM): a relevant database for collecting the networks structure

Three main criteria guided the selection of transport networks:

-the spatial and semantic harmonization at the European scale,

-the spatial resolution (adapted to intra-urban studies)

-the cost of such databases.

The Euro Regional Map (ERM) database produced by EuroGeographics meets the need for spatial harmonization as it stems from the collection of the information delivered by the National geographical institutes of 31 countries (UE, EFTA, Moldavia), this information being then harmonized by EuroGeographics. The resulting database contains vector geometries and data about road, rail and maritime networks on a 1:250 000 scale (Figure 11). It has been made available by EuroGeographics for the ESPON projects, for the year of reference 2000.

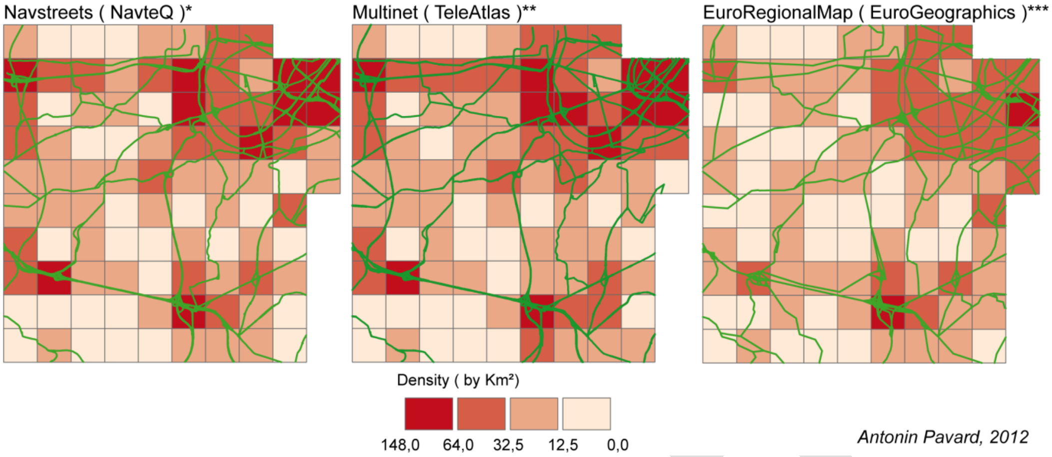
Figure 11: Geometries of networks in ERM

Geographical information	Types
Road sections	Lines
Road intersections	Points
Road interchanges	Points

The main question about the relevance of this database relied on the spatial resolution of the road networks, which had not only to be sufficiently detailed to allow route calculations at a metropolitan scale, but also to be generalized enough to allow the construction of a model for comparisons.

Several comparisons between ERM road network and two other databases, Navstreets from NavteQ and Multinet from TeleAtlas, have been conducted through qualitative and quantitative analysis on different samples (Figure 12, Annex 3), along with other comparisons with national sources (Annex 4). They have proved the ERM database to be globally consistent for a study at this metropolitan scale. More specifically, the expertise helped to identify some missing data (Croatia) or some heterogeneity in data structure (the road hierarchy is not the same in Spain, for instance). At last, these comparisons helped to select the road levels that seemed useful for modeling isochrones (motorways, main roads and secondary roads).

Figure 12: Comparison of network road « densities » between ERM, Navstreets and Multinet database (south-west of Paris)



2.2.2. Data on traffic speeds

A second challenge consisted in identifying public and private databases about transport networks that are harmonized at European level and that provide data on traffic congestion. Three main databases have been expertized, from different points of view (physical attributes, Figure 12, and functional attributes, Figure 13). The different criteria (including the price conditions), summarized in the table 3, have been taken into account for the choice of the Navstreets database.

Figure 13: Comparison of time accessibilities between ERM, Navstreets and Multinet database (south-west of Paris)

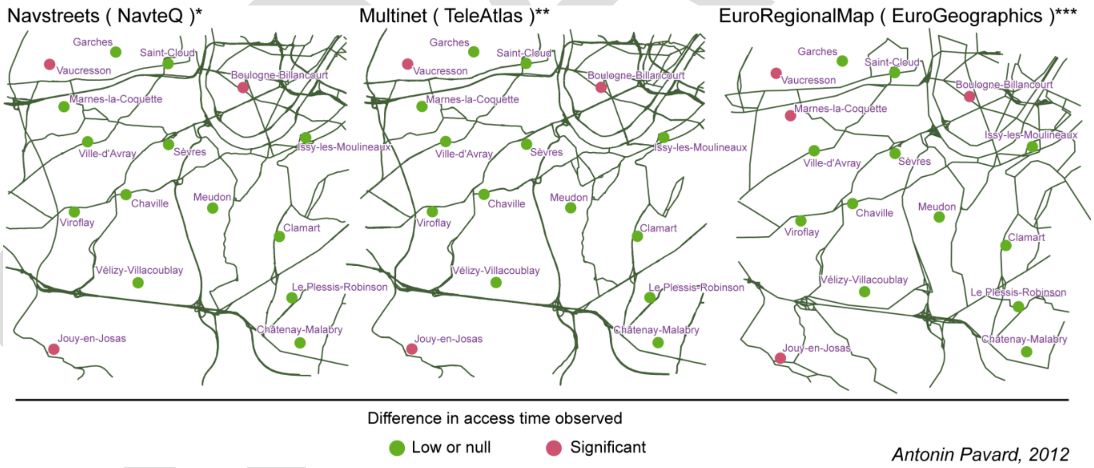


Table 3: Information about the cost of three transport database for detailed studies on 3 cities (Paris, Barcelona, Berlin)

Data	Area	Gisco Or ERM	Multinet	Navstreets
Network	Europe	Free	100000 €*	125280 €*
	For one Nuts 3	Free	NR	1500 € to 5800 €* (Corse / IDF)
Traffic	-	-	+ 30%	+ 30%
Reduction for research center	-	-	No	- 70%

* Excluding VAT

2.3. A feasibility study for modeling isochrones including congestion: process and parameters

The modeling process of theoretical isochrones around city centres depends on different choices, among which:

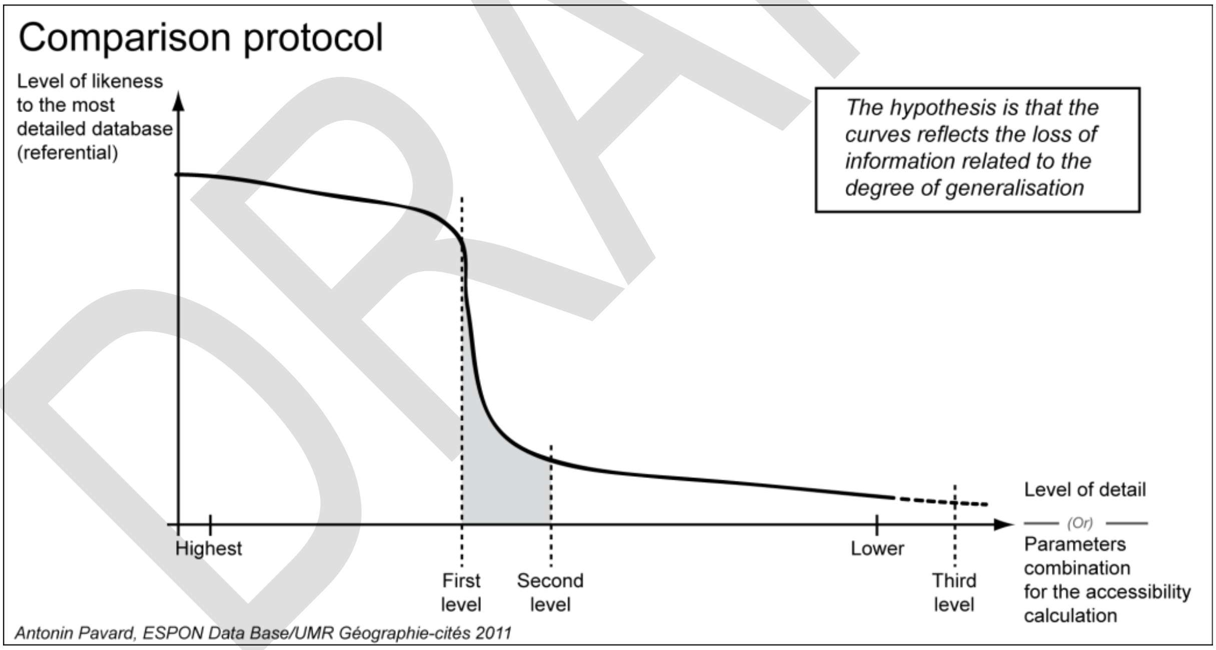
-the definition of a centre

-the choice of a method for computing the shortest time travel paths

- the estimation of speed parameters

Furthermore, the model has to be generic and easily transferable to other sample zones. As far as road congestion is considered, the approach used in the study consists in choosing a reference situation, which is the most detailed one, and to compare it to the different congestion models tested. The reference situation is based here on Navstreets traffic speed data, for Barcelona, Berlin and Paris. The following steps consists in evaluating the sensibility of the accessibility measures to the choice of the transport network database and of the congestion parameters, in order to explore the transfer from the very detailed database on Barcelona, Paris and Berlin to lower detailed database available for the sample zones (**Figure 14**).

Figure 14: Sensitivity of accessibility measures to the choice of the transport network database and of the congestion parameters

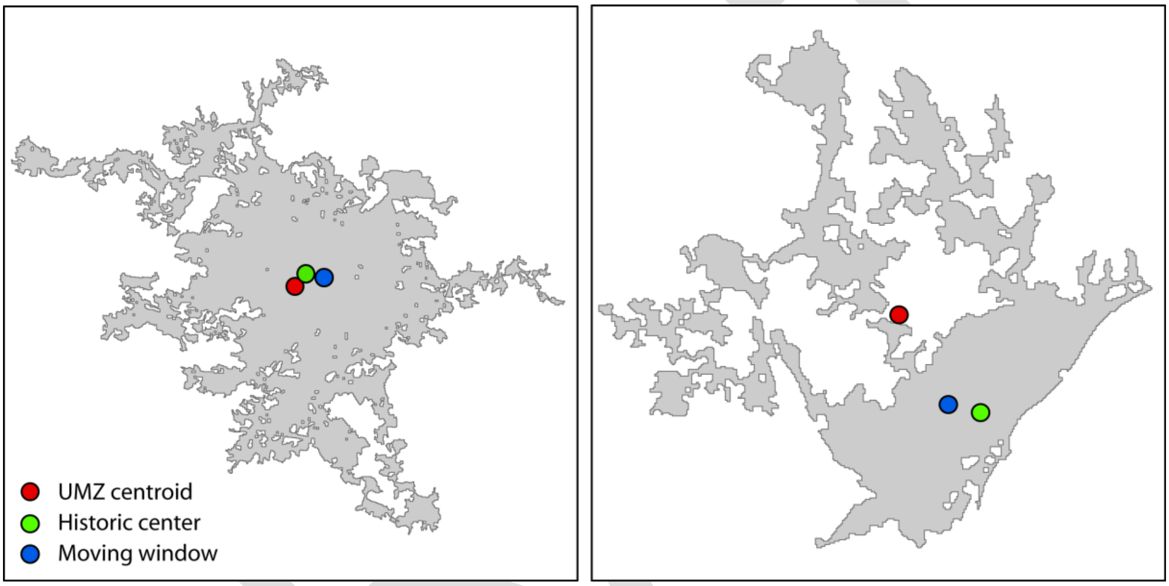


2.3.1. Definition of a centre

The identification of a center is not a trivial step and may greatly influence the choice of other parameters (especially the maximal time-budget) and the resulting isochrones perimeters. In the frame of this study, different decisions were necessary in order to compensate for the lack of harmonized data about jobs and to simplify the process focused of the modeling of congestion. Indeed, a double simplification was decided: first, as for FUA based on commuting flows, the method relies on the identification of a unique center and does not take into consideration secondary centers that may be significant in larger cities or in polycentric contexts. Second, this center is not seen as a zone but as a punctual location that reflects the main concentration area of jobs.

This being so, different methods have been compared and tested on a set of about 10 cities, in order to select a central point defining the center. Some of these methods could be automated (UMZ centroid, population density peak) (**Figure 15**, Annex 4), but the most reliable one still remains the expert-based identification of a historical center, even if the population density peak gives a good approximation of the historical center in the majority of cases.

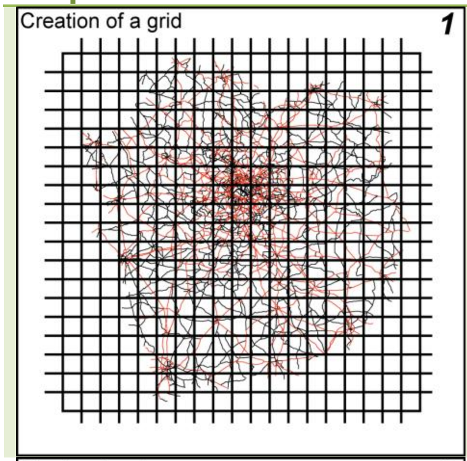
Figure 15: Comparison of different methods for defining a centre (Examples of Paris and Barcelona)

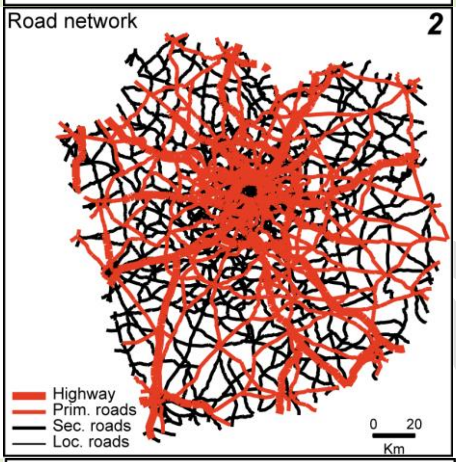


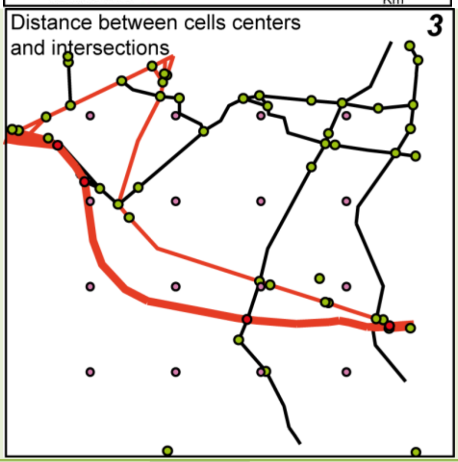
2.3.2. From network to territories: shortest time travel paths computation

The modeling of the different paths towards the centre of the city requires further choices. The combined use of a road graph network and of a raster diffusion method has proved to be the most suitable method among others. The figure 16 illustrates the three main steps of this approach, following the assumption that individuals generally choose the shortest time travel.

Figure 16: Shortest time travel computation: a method combining road graph network and raster diffusion

<table>
<tr><th>Steps</th><th>Descriptions</th></tr>
<tr><td>
</td><td>1 - Creation of a grid composed by cells of 1Km squared

2 - Attribution of a constant speed for each cell --> 20 Km/h</td></tr>
<tr><td>
</td><td>1 - Using a corrected road graph.

2 - Calculating the time to travel each section with a specific speed.</td></tr>
<tr><td>
</td><td>4 - Calculating the distance to the nearest intersection for each cell of the grid

5 - Calculating the time to go to this intersection from the cell (with the speed 20 km/h).</td></tr>
</table>

A. Pavard, 2012

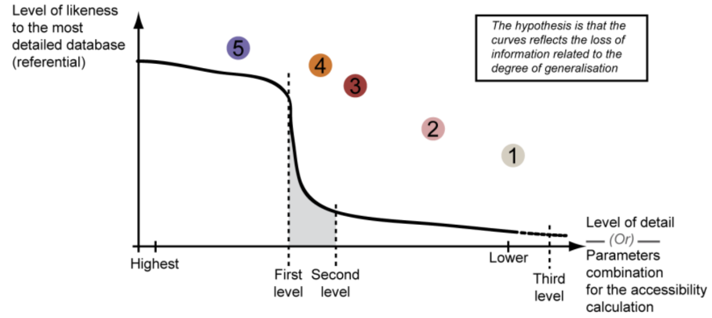
2.3.3. Speed parameters estimation

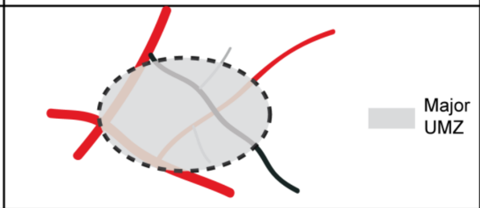
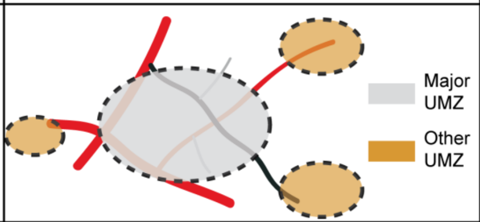
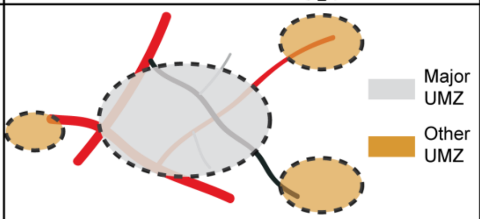
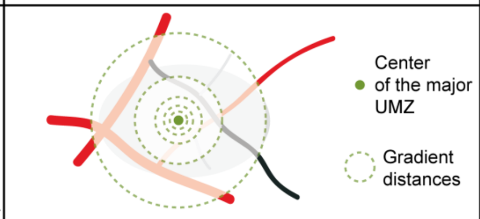
The estimation of speed parameters has been approached through different models, following an increasing degree gradation in the complexity of the method. **Free-flow speeds** have been defined according to national legislations and to the road hierarchy. For the more complex issue of **peak-hour speeds**, three main methods have been assessed and compared (**Figure 17**). Given the very high cost of the Navstreet database, such a validation of a congestion model and ways to improve it is of critical importance.

Figure 17: Different peak-hour models for estimating road congestion in metropolitan areas

Different accessibility models

Comparison protocol



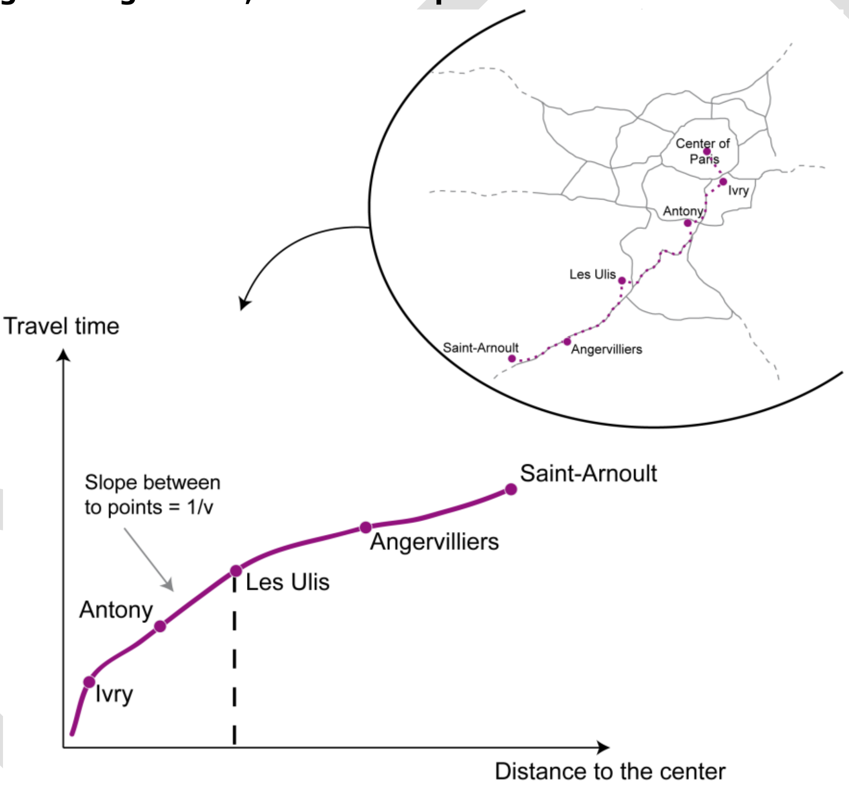
Model name	Specificities	Sources and parameters
A Accessibility with free speed ERM	Attribution of speed limits according the Highway Code and the classification of the roads: Highways; Principal Roads; Secondary Roads; Local Roads	* National Highway Code; * EuroRegionalMap Network V31, Eurogeographics, 2009;
1 Accessibility with simple congestion index ERM	 Major UMZ	* National Highway Code; * EuroRegionalMap Network V31, Eurogeographics, 2009; * Congestion index in the major UMZ: travel time multiplied by 2
2 Accessibility with average congestion index ERM	 Major UMZ; Other UMZ	* National Highway Code; * EuroRegionalMap Network V31, Eurogeographics, 2009; * Average congestion index established by TomTom to TeleAtlas applicated in all UMZ (major UMZ plus other UMZ in the study area). This congestion index depends of the classification of the roads.
3 Accessibility with peak congestion index ERM	 Major UMZ; Other UMZ	* National Highway Code; * EuroRegionalMap Network V31, Eurogeographics, 2009; * Maximal congestion index estalbished by TomTom to TeleAtlas applicated in the major UMZ. And, average congestion index applicated in other UMZ in the study area).
4 Accessibility with gradient congestion index ERM	 Center of the major UMZ; Gradient distances	* National Highway Code; * EuroRegionalMap Network V31, Eurogeographics, 2009; * Maximal congestion index estalbished by TomTom to TeleAtlas applicated in the major UMZ. And, average congestion index applicated in other UMZ in the study area).
B Accessibility with free speed Navstreets	At each section is assigned its official speed limit according to the Highway Code in effect in the area.	* Navstreets, Navteq, 2012
5 Accessibility with congestion index Navstreets	At each section is assigned a specific congestion index estimated from several sources (GPS data, information provided by local authorities, etc.).	* Navstreets, Navteq, 2012

Antonin Pavard, 2013

The simplest model considers **congestion as a discrete function of the distance to the centre** and consists in **implementing a peak-hour index inside the agglomeration (UMZ)**: this index has been first estimated by considering 50% of the free-flow speeds (Model 1, see MCRIT delivery about Barcelona) and then refined by using an average congestion index defined by experts for each of the main European cities[18] (Model 2-3).

A second method which has been tested for Paris, Helsinki and Stockholm (master theses Carthageo) considers **congestion as a continuous function of the distance to the centre**. It relies on the construction of a congestion gradient which is based on the measure of different travel times for routes converging towards the city centre (**Figure 18**, and Model 4 on **Figure 17**), thanks to route calculation websites. It could help to identify either thresholds in the variation of congestion or constant parameter to implement more realistic congestion indices. The main limitation of this method is that it considers that distance to the centre is the only explanation to congestion variations, whatever geographical areas around the center.

Figure 18: Congestion gradient, from description to model



H. Mathian, A. Pavard, 2013

A third method (Model 5) **draws directly the accessibility map from the Navstreets data about congestion**, attributed to Navstreets road network. The main limitation of this method is of course linked to the data prices. The results obtained through this last method were used as a reference situation for 3 cities (Paris, Berlin, Barcelona), in order to evaluate the previous models (especially model 4).

A last model was designed for Barcelona, taking into account not only road networks but also rail networks.

[18] TomTom Europen Congestion Index, 2013 : http://www.tomtom.com/lib/doc/congestionindex/2013-0129-TomTom%20Congestion-Index-2012Q3europe-mi.pdf

All these models could not be tested for each study case, for reasons of time or cost of data (**Figure 19**).

Figure 19: Case studies and the implementation of the congestion models

	With the network EuroRegionalMap					With the network Navstreets	
	Free Speed	Simp. Cong. index	Average cong. Index	Peak cong. Index	Gradient	Free speed	Congestion
Amsterdam	X		X	X			
Copenhagen	X		X	X			
Madrid	X		X	X			
Naples	X		X	X			
Florence	X		X				
Vienna	X		X	X			
Prague	X		X	X			
Ljubljana	X	X					
Helsinki	X			X	X		
Stockholm	X			X	X		
Barcelona	X	X		X	X	X	X
Paris	X	X		X	X	X	X
Berlin	X			X	X	X	X

2.4. Results

2.4.1. Accessibility isochrones

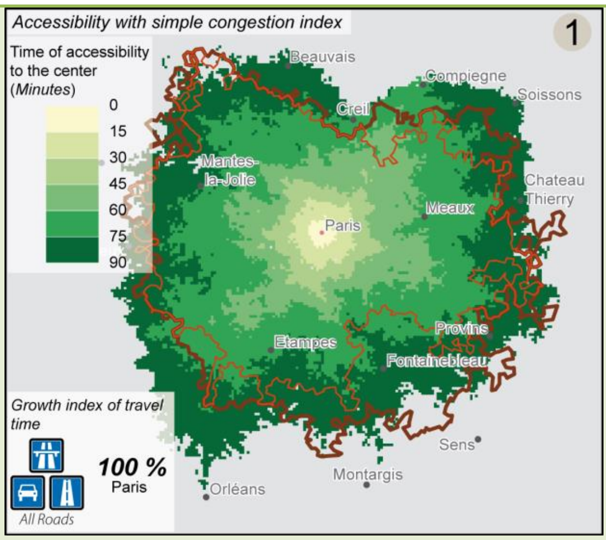
The comparison between the resulting isochron-based delineation and other urban delineations helped to better assess the results associated to that model.

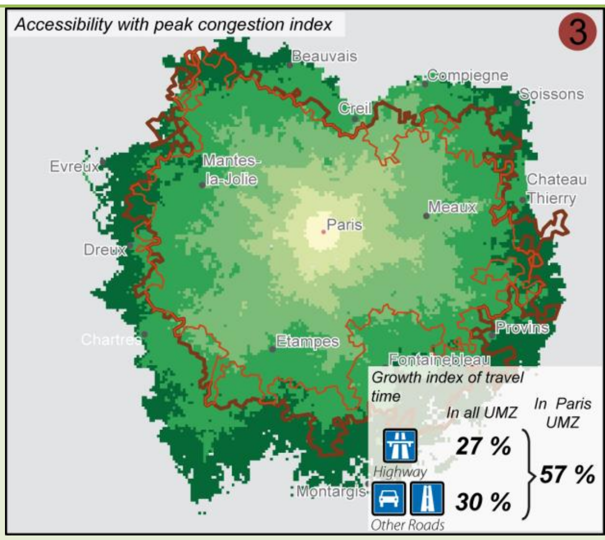
A first assessment lies on the comparison of the 1 hour isochrone resulting from the peak-hour model (with the simplest estimation of congestion, Model 1) and a set of observed time travels in real peak-hour conditions, provided by route calculation websites. In the Paris case, the observed time travel is under-estimated of about 60% by the model 1 for a set of 20 destinations distant from 40-50 km to the center. This significant difference led us to refine the estimation of congestion (Model 2-3).

Secondly, a comparison between isochrones results for Paris and Barcelona on one hand, and urban statistical delineations (UMZ, FUA_IGEAT) on the other hand helped us to reconsider the estimation of maximal time budget for a center-periphery travel, from 1 hour to 1h15 or 1h30 (Figure 20).

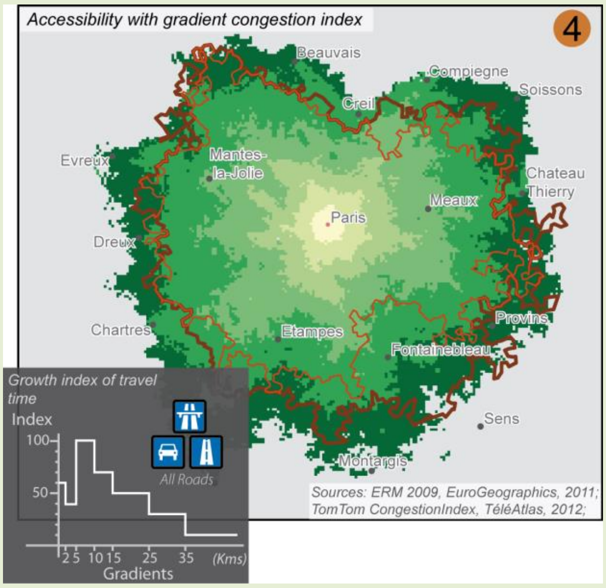
Thridly, a comparison between the diffident models in terms of surface (Figure 21) or population (Figure 22) shows that the impact of the method is important. The ratio between the surface of the Paris FUA delineated with the 1h30 isochron is 2,5 between the minimal and maximal surface given by each of the models. Concerning population, the difference between minimal and maximal population is around 10%.

Figure 20: Comparison of the 3 congestion models: the case of Paris

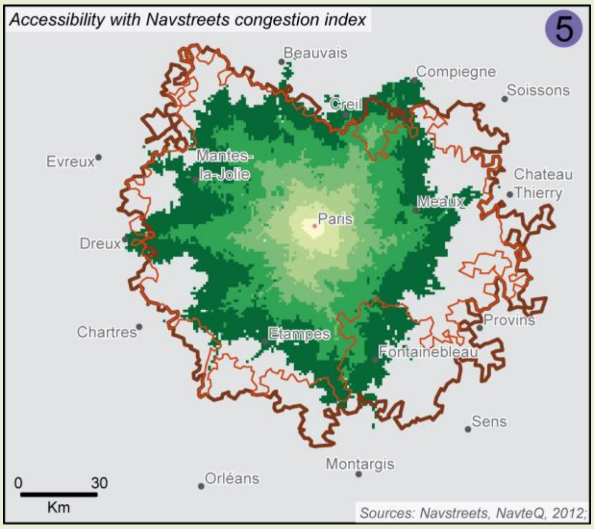




The use of UMZ as speed reduction zone has of course a strong influence on the shape of the isochrones. This influence is all the more important that the UMZ presents stretched and irregular shapes.



The results obtained with the gradient congestion model are quite close from the results obtained with Tom-Tom peak-hour congestion levels



The isochrones drawn from Navstreets data are far more reduced than in the previous models. Different solutions could be imagined in order to upgrade them (for instance a better consideration of traffic slowdowns at street intersections).

Sources : ERM 3.1 (Eurogeographics, 2011) ; TomTom CongestionIndex, TéléAtlas, 2012 ; Navstreets, NavteQ, 2012

Antonin Pavard, 2013

Figure 21: Surface cumulated by isochrones in the case of Paris

	ERM Free Spd.	Nav. Free Spd.	Simp. Cong. In.	Pk. Cong. In.	Grad. Cong. In.	Nav. Cong. In.
15 min	450	200	90	160	150	55
30 min	2 380	1 485	505	840	740	330
45 min	7 735	5 655	1 300	2 640	2 275	1 010
60 min	16 655	12 265	4 030	8 050	6 840	2 460
75 min	23 545	19 575	10 800	16 950	14 940	5 660
90 min	25 640	24 510	19 630	23 335	22 080	10 430

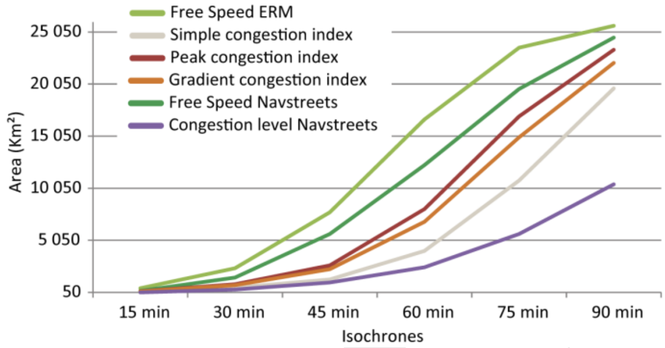


Figure 22: Population cumulated by isochrones in the case of Paris

In absolute

	ERM Free Spd.	Nav. Free Spd.	Simp. Cong. In.	Pk. Cong. In.	Grad. Cong. In.	Nav. Cong. In.
15 min	5 045 000	3 185 000	1 970 000	2 885 000	2 730 000	1 360 000
30 min	9 055 000	7 960 000	5 325 000	6 670 000	6 320 000	4 245 000
45 min	10 680 000	10 300 000	7 715 000	9 060 000	8 980 000	7 090 000
60 min	11 780 000	11 310 000	9 515 000	10 575 000	10 480 000	9 030 000
75 min	12 435 000	12 000 000	11 030 000	11 720 000	11 585 000	10 280 000
90 min	12 645 000	12 580 000	11 970 000	12 350 000	12 220 000	11 130 000

In percent

	ERM Free Spd.	Nav. Free Spd.	Simp. Cong. lvl	Pk. Cong. lvl	Grad. Cong. lvl	Nav. Cong. lvl
15 min	40	25	16	23	22	12
30 min	72	63	45	54	52	38
45 min	84	82	64	73	73	64
60 min	93	90	80	86	86	81
75 min	98	95	92	95	95	92
90 min	100	100	100	100	100	100

Sources: JRC population density grid for 2001

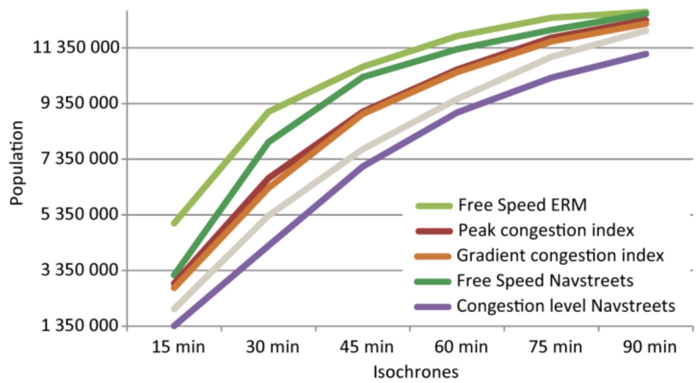
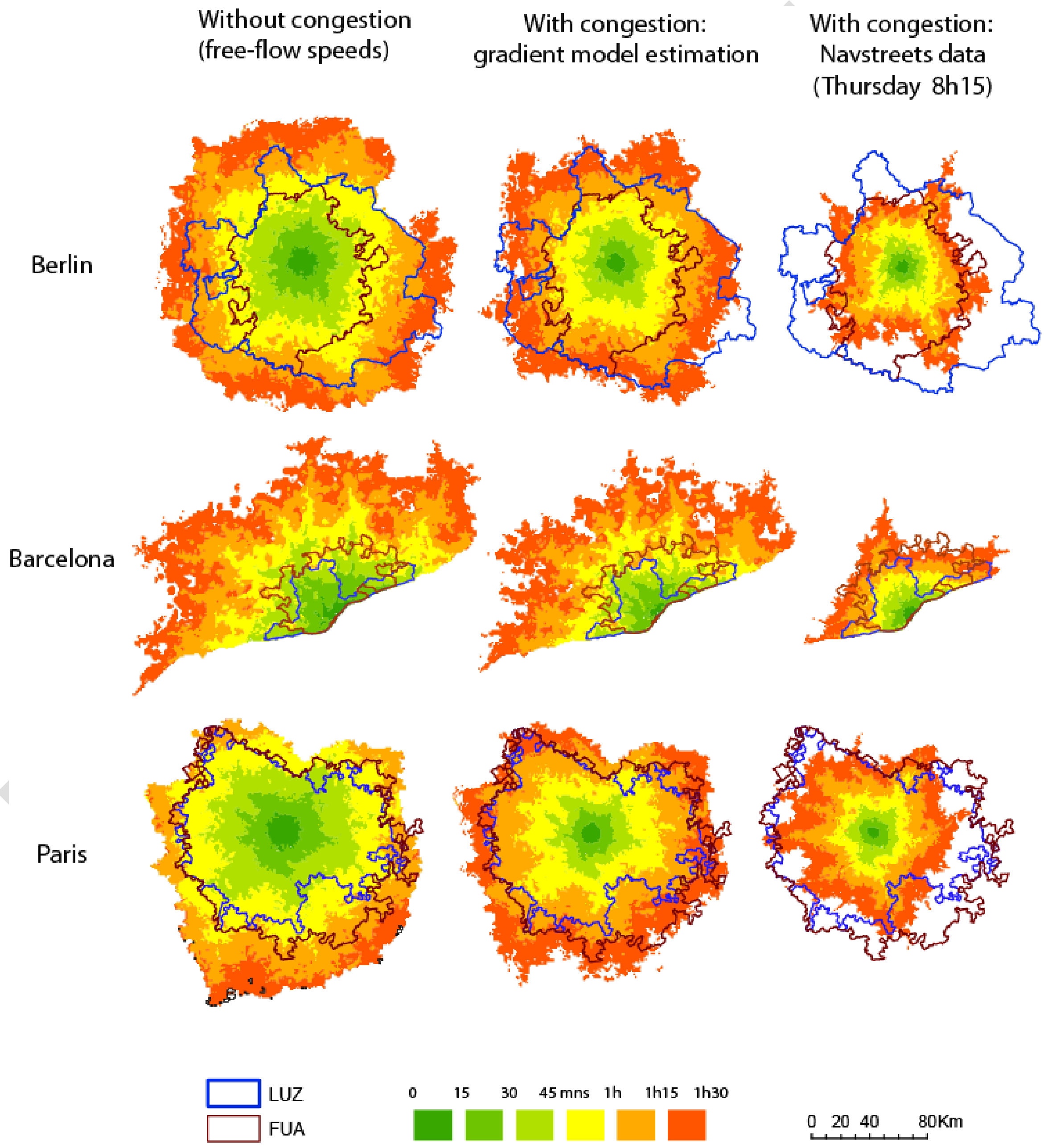


Figure 23 illustrates the comparison between the gradient congestion model and the Navstreets congestion data. It highlights the importance of taking into account congestion speed instead of free-flow speed. In Paris, Berlin as in Barcelona, the distance that can be reached within 1 hour is about 70 to 80 km with free-flow speed and peak-hour index model, 45 km with the congestion gradient model and 30 km with Navstreets model. While the gradient congestion model appears to be more relevant than the UMZ peak-hour index model, it could be improved in order to better approach Navstreets estimations, for instance by taking into account the way traffic slows down at streets intersections.

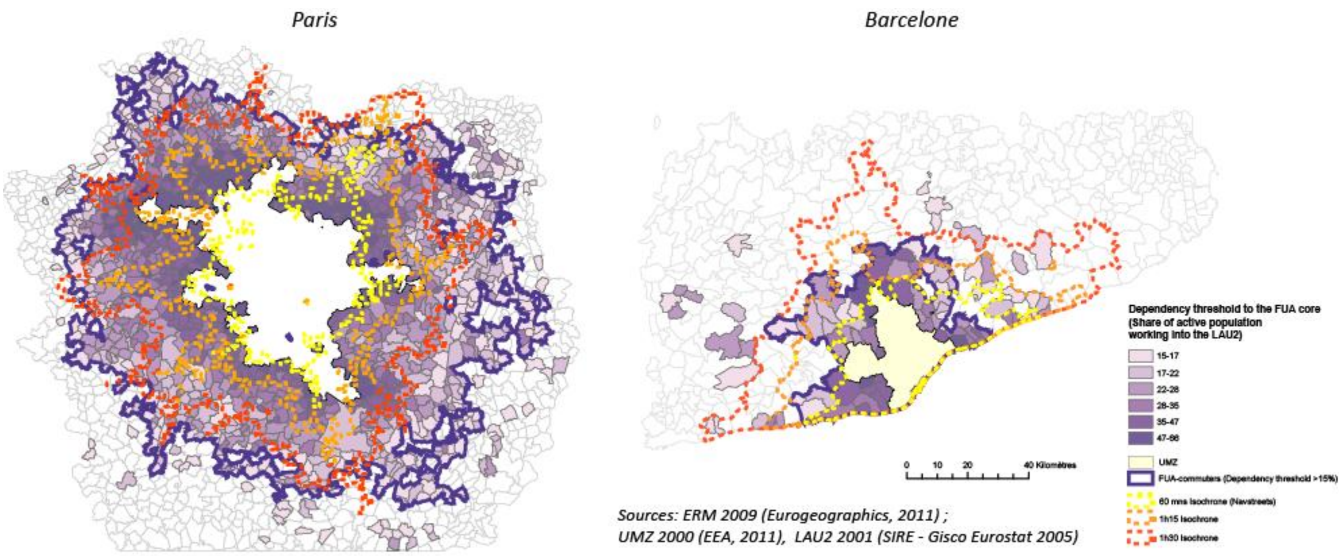
Figure 23: Isochrones without and with congestion (Barcelona, Berlin, Paris)



2.4.2. Comparison between accessibility isochrones and commuting flows isochrones

The last issue addressed in the study was that of the comparison between accessibility isochrones and commuting flows perimeters. A first overview of how the "commuters-FUA" and the "isochrones-FUA" match each other has been given, especially for the case of Paris and Barcelona (Navstreets model) (Figure 24). It shows that the "commuters-FUA" perimeters either fits with the 1h15 isochrone (Barcelona) and or are larger than the 1h30 isochrone (Paris).

Figure 24: FUA based on isochrones (Navstreets model) compared to FUA based on commuters: the case of Paris and Barcelona



Sources: ERM 2009 (Eurogeographics, 2011) ; UMZ 2000 (EEA, 2011), LAU2 2001 (SIRE - Gisco Eurostat 2005)

In future, these first exploratory results deserve to be looked at in more depth, in order to study the differences between both perimeters on a larger set of cities. This would allow testing more systematically two or three main hypotheses about the main factors underlying these differences (either the size of the spatial units, or the value of travel time, between countries or between large or smaller cities).

Conclusion

The aim of this technical report was to compare two methods commonly used for delineating FUA and to question the complementarity between both methods.

As far as possible given the limits of commuting flows data in the SIRE database, we have first carried out a review about the lack of international comparability of the FUA based on commuting flows. In particular, we have recalled the influence of LAU2 international heterogeneity on the size of the polarised areas. We have also shown that minor differences in the choice of the dependency threshold (10 or 15%, for instance) could significantly change FUA delineations. To go further, **it might be important to reduce the effects of LAU2 heterogeneity by choosing varying dependency thresholds, according to the national average size of LAU2**. An essential prerequisite for this work would be the update and upgrade of SIRE database in order to allow the use of robust and complete data on employment and commuting flows at a local scale.

An alternative approach has been to compare the FUA based on commuting flows with delineations based on accessibility isochrones. For the first time, an original methodology has been implemented to several metropolitan areas in order to include traffic congestion in the modeling of isochrone perimeters. **A congestion model based on a center-periphery gradient of traffic speeds seems relevant compared to models based on a peak-hour index inside the built-up area and free-flow speeds outside**. Different options for discussion could be considered for improving such a congestion model. First we assume that the model could better include the way traffic slows down at streets intersections. To test this hypothesis, it is necessary to better identify the areas where the traffic speed have been overestimated by the model. The local comparison between Navstreets traffic speeds and the estimated traffic speed should be led on a common network, which implies to transfer Navtreets traffic attributes toward ERM network[19]. Secondly, a better access to local data about employment is necessary to improve the delineation of the "center" of jobs. On the other hand, to complete road traffic speeds modeling, it is necessary to extend this model to rail traffic[20]. Such an upgrade of the congestion model is worth conducting in order to analyse the differences observed between commuter-based FUA and accessibility-based FUA with a larger sample of cities. Such an analysis is necessary to better understand the main factors underlying these differences (either the size of the spatial units or the value of travel time).

In the end, like for UMZ and built-up areas, this work has led to a fruitful reflection about the international harmonisation of urban objects. It is now well-known that a minimal step lies in the detailed documentation (metadata) associated to the urban data. A further step lies in the setting of homogeneous sources and of homogeneous modeling processes. We discussed here the interest of adjusting the model

[19] A first work has been carried out in the context of a master thesis, in order to evaluate the possible match between Navstreet and ERM networks, in collaboration with the COGIT research team from the National Géographic Institute. A test on a South-East Paris zone has been conducted with the help of the matching algorithm Netmatcher (COGIT, Geo-Oxygene platform). Around 60% of ERM network (length of road sections) could be qualified by traffic data from Navstreets (Dumont, 2014).

[20] A feasibility study using rail-route calculation websites has been conducted in the context of a master thesis, in the case of the Paris region and on the basis of the Transilien Website. The construction of LAU2 origin-destination matrices with travel time allowed modeling public transportation accessibility in Paris region (Fancelli, 2014).

parameters (dependency threshold) according to the diversity of spatial unit sizes and of settlement contexts. At last, beyond the issue of urban objects delineation, such a work is also worth extending since it contributes to lay the foundations of intra-urban comparable studies about the spatial organisation of commuting flows and of accessibility to work in European cities.

Annexes

Annex 1. The selected sample zones and data

Selecting the sample zones

The sample of countries and cities is representative of major differences in urbanisation context (monocentric/polycentric pattern, population densities, sprawl dynamics, more recent in Eastern Europe)/or in available data (metadata, completeness degree, updates, etc.). Two types of sample zones have been defined. A first type consists in "prototype zones", represented by two cases, Barcelona and Paris. These two cases are characterized by a large number of data (transportation, commuting…) and by a high level of knowledge and expertise (Barcelone for the MCRIT, Paris for Geographie-cités). The second type of sample zone contains large cities (more than 1 million inhabitants), characterized by urban sprawl and major commuting. We have selected 2 cities in Eastern and Central Europe (Prague, and Ljubjana), where urban sprawl is still low, 7 cities in Western Europe (Amsterdam, Berlin, Copenhagen, Firenze, Madrid, Napoli, Vienna) and two cities in Northern Europe, characterized by a sparse urbanization (Helsinki, Stockholm).

Selecting the study area for each sample zone

Three different criteria have been taken into account:

- The current delineations of FUA_IGEAT and LUZ_Urban Audit 2004
- The range of the area that can be approximately reached from the city center within a time distance of one hour and a half
- The presence of secondary growth pole at the fringe of the urban agglomeration

Selected data

For each of these zones, four types of data have been systematically collected and integrated in a GIS for the four sample zones:

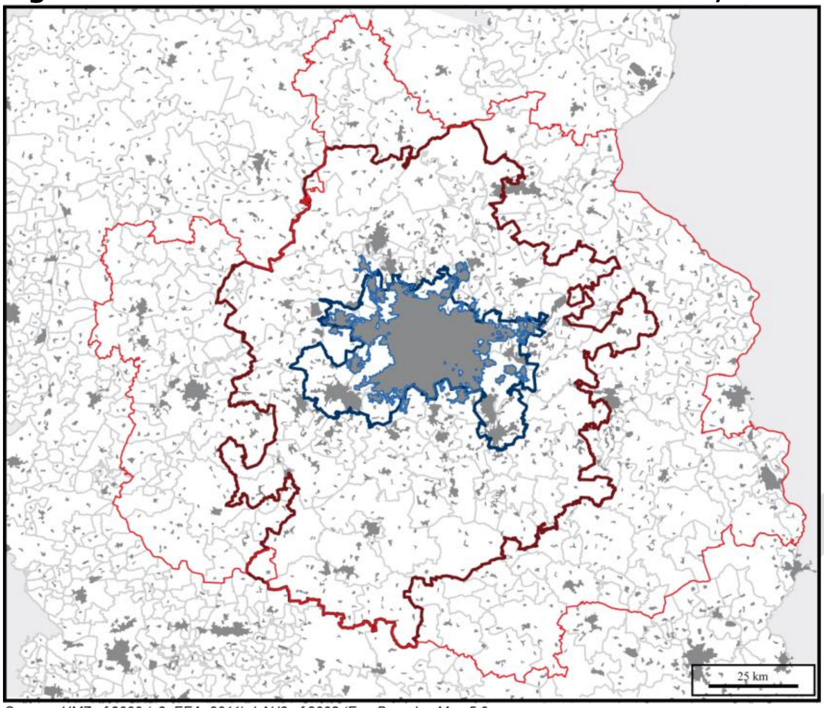
✓Urban delineations (MUA, FUA_IGEAT, UMZ, Urban Audit 2004 LUZ) (see the following figure for Berlin)

✓LAU2, LAU1 and SIRE

✓Transportation networks (see December 2011 Deliverables)

✓Several databases have been collected and concern urban delineations, local administrative units, transportation graphs and maximal speed, active populations and commuters (Table 6). The collection of data about speeds is limited to Barcelona, Berlin and Paris.

Figure 25: Data collection of urban delineations, Berlin sample zone



Source : UMZ of 2000 (v3, EEA, 2011), LAU2 of 2008 (EuroBoundaryMap 5.0, Eurogeographics, 2011), MUA and FUA of 2006 (D. Peeters, IGEAT), LUZ (Urban Audit, Eurostat, 2004)

Gassin, ESPON 2012

Delineations

- UMZ (Urban Morphological Zone) of Berlin
- MUA (Morphological Urban Area) of Berlin
- LUZ (Larger Urban Zone, Urban Audit 2004) of Berlin
- FUA_IGEAT (Functional Urban Area, Peeters, 2011) of Berlin
- LAU2 (Local Administrative Units)
- Built-up area
- Outside study area

Table 4: Database catalogue

DB_TAG	DB Name	VERSION	CREATION Year	COVERAGE Year	RESPONSIBLE
UMZ	Urban Morphological Zones	13/1/00	1/12/10	1990 - 2000 - 2006	European Environment Agency
		15/1/00	1/11/11	1990 - 2000 - 2006	European Environment Agency
Popugrid01	JRC Population grid	4/1/00		2001	European Environment Agency
		5/1/00	1/9/09	2001	European Environment Agency
Grid_LAEA	EEA reference grids	1/9/11	1/9/11	No time	European Environment Agency
LUZ	Large Urban Zones	1/6/10	26/6/05	2004	Eurostat
MUA	Morphological Urban Area	3/7/05	3/7/05	2000	IGEAT
FUA	Functional Urban Area	1/12/10	1/12/10	2000	IGEAT
		3/7/05	3/7/05	2000	IGEAT
CLC	Corine Land Cover	15/1/00	1/8/11	2000 - 2006	European Environment Agency
SIRE	European infra-regional information system	20/6/05	20/6/05	2000	Eurostat
		30/6/05	30/6/05	2000	Eurostat
ERM	EuroRegionalMap	3/1/00	1/3/10	2010	Eurogeographics
		3/1/00	1/3/09	2009	Eurogeographics
EBM	EuroBoundaryMap	5/1/00	1/1/11	2010	Eurogeographics
		4/1/00	1/1/10	2009	Eurogeographics
COMM_CENS	Local Administrative Unit	2001		2001	GISCO (EUROSTAT)
	Local Administrative Unit	2006		2006	GISCO (EUROSTAT)
	Local Administrative Unit	2008		2008	GISCO (EUROSTAT)

Annex 2. Consistency of commuting data in SIRE database

4 criteria were selected to check if there is an adequate match between the file of « flow data » (origin-destination commuters) and the file of « static data » (active population).

Criteria 1 : OK if the number of LAU2 of origin in the « flow file » is more than 98% the number of LAU2 in the « static file ».

Criteria 2 : OK if the number of LAU2 of destination in the « flow file » is more than 98% the number of LAU2 in the « static file ».

Criteria 3 : OK if the number of jobs occupied in another LAU2 from the same country (outarea) in the « flow file » is more than 90% of the same counting in the "static file"

Criteria 4 : OK if the ratio number of jobs occupied in another LAU2 of the « flow file » / number of jobs occupied in another LAU2 of the « static file » is less than 120% (remove of Hungria and Slovaquia where strong inconsistencies are observed).

9 countries meet these criteria, from which we chose our sample of cities.

Table 5: Synthesis from four criteria of adequate match between « flows » and « static » files of SIRE database

Country	Criteria 1 : adequate match between LAU2 of origin	Criteria 2 : adequate match between LAU2 of destination	Criteria 3 : adequation between number of jobs occupied in another LAU2	Criteria 4 : adequation between number of jobs in the flow file / the static file	Meet 4 criteria
AT	OK		OK	OK	
BE	OK	OK		OK	
CH	OK			OK	
CY			OK	OK	
CZ	OK		OK	OK	
DK	OK	OK	OK	OK	OK
EE	OK	OK	OK	OK	OK
ES	OK		OK	OK	
FI	OK	OK	OK	OK	OK
FR	OK	OK		OK	
GR			OK	OK	
HR	OK	OK	OK	OK	OK
HU	OK		OK		
IE	OK			OK	
IT	OK	OK	OK	OK	OK
LI	OK			OK	
LU	OK	OK	OK	OK	OK
MT	OK	OK	OK	OK	OK
NL	OK	OK		OK	
NO	OK	OK	OK	OK	OK
PT	OK			OK	
SE	OK	OK	OK	OK	OK
SI	OK		OK	OK	
SK	OK	OK	OK		
UK	OK	OK		OK	

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