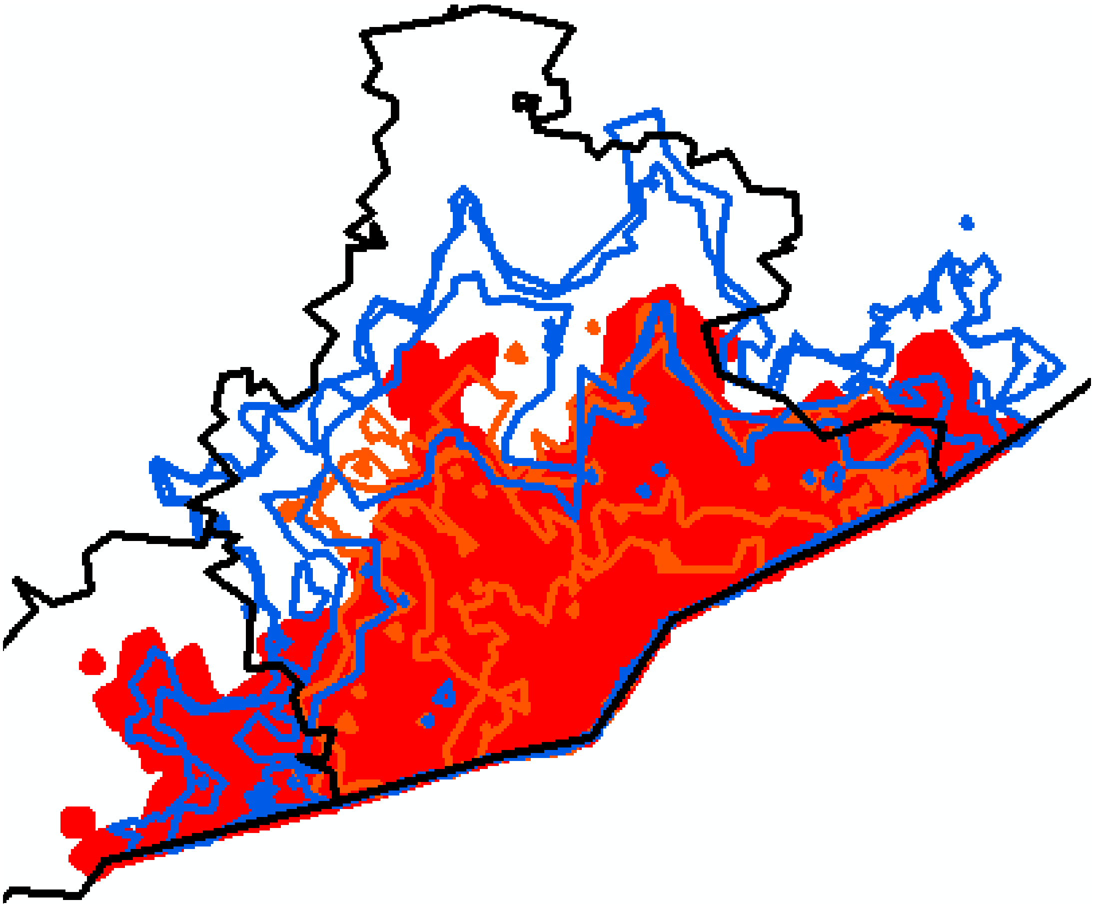


Definition of a Methodology to delimitate metropolitan areas in Europe

Case Study: Accessibility in Barcelona Metropolitan Region by public and private transport

MCRIT

5 April 2013

TABLE OF CONTENTS

Introduction

This report contains MCRIT works carried out in the ESPON 2013 Database project.

This expertise is part of the ESPON 2013 Database project and fits in the work package “Cities”.

“Cities” aims at constructing an information system about regional access to major employment poles, for a sample of European cities. It will result in the definition of a 1 hour isochrones perimeter around these poles, at regional level (metropolitan areas).

Due to this comparative perspective, it was considered essential that the sensitivity of the results to the choice of sources and methods for measuring accessibility was be analysed in depth. This will be done by focusing on the Barcelona metropolitan region example. The analysis has been approached with a view of being transferable to other European cities.

The work was carried out in two phases:

In the first phase Eurogeographics ERM road and rail graphs were used to calculate accessibility zones in the metropolitan area of Barcelona, according to different criteria.

En second phase, much more detailed regional and metropolitan road and rail graphs were applied, as well as Eurogeographics road graph.

Then, a comparative analysis was made leading to a third analysis using Eurogeographics rail and roal graphs combined.

The conclusions of the exercise are listed in the latest section of this report.

The exercise has demonstrated that Eurogeographics, or a similar simplified transport graph at European scale, may provide meaningful results to delimitate metropolitan labour market zones if used to compute multimodal accessibility, with roads giving just access to railway stations, and shortest paths to the metropolitan center being calculated using the rail network, even with default aggregated values (commercial speeds for peak-hour railway services need to be considered, as well as peak-hour speeds and access and parking times for roads).

Barcelona metropolitan delimitation

Barcelona today is a complex metropolis whose limits are very difficult to define in terms of functionality. The municipality of Barcelona covers 100 km^2, but the Metropolitan Area covers 600 km^2 and the Metropolitan Region 3,000 km^2. and this is an unquestionable economic reality

The first metropolitan ring, also called the central agglomeration of the Metropolitan Area of Barcelona (AMB), which with 35 municipalities is the 1st ring of the metropolitan territory. This area forms a single labour market because it is the area in which the population and the economic activities of the central city have been decentralised. This area, with a population of almost 2.4 million inhabitants and shows the highest densities, has a high level of internal and external accessibility.

Figure 1 Barcelona Metropolitan Area(AMB), 35 municipalities

The area of the Metropolitan Region of Barcelona, with almost 4.4 million inhabitants and a very highly contained labour, culture and leisure market, is the area of analysis and planning of mobility and transport. It contains 164 municipalities.

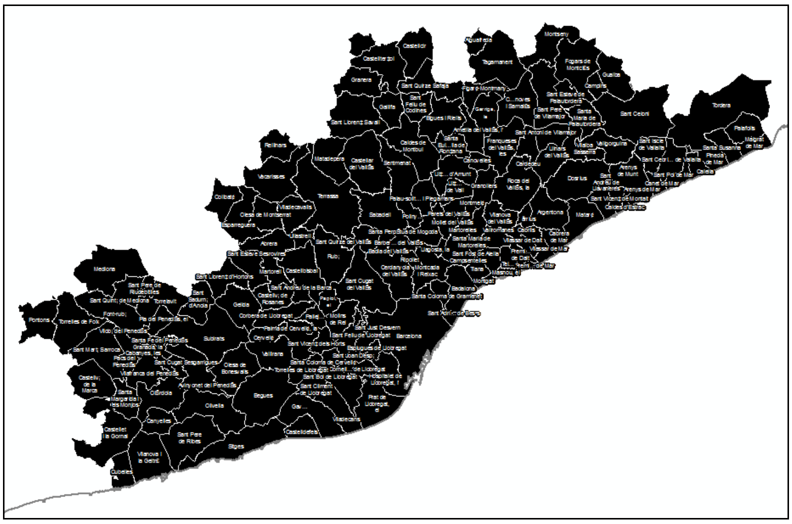


Figure 2 Barcelona Metropolitan Region (RMB), 164 municipalities

Barcelona Urban Morphological Zone (UMZ) is defined as "A set of urban areas laying less than 200 meters apart". Those urban areas are defined from land cover classes contributing to the urban tissue and function

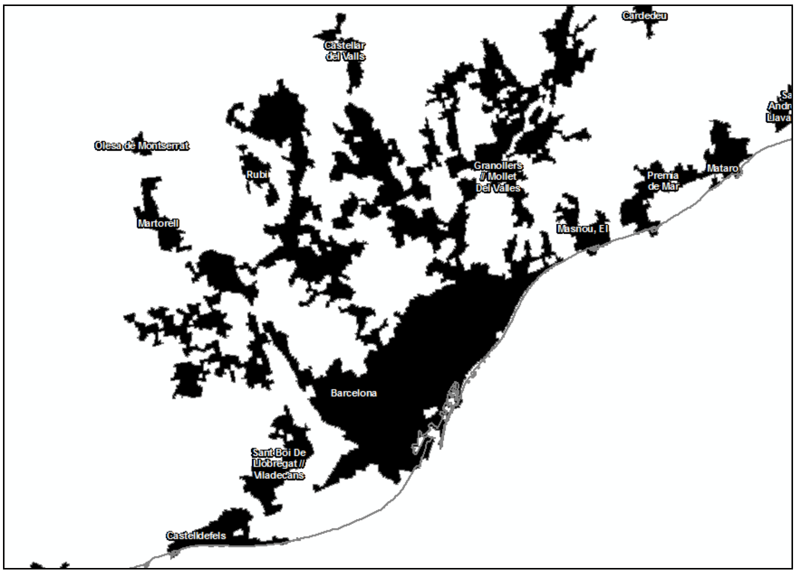


Figure 3. Urban Morphological Zones (UMZ)

The Barcelona FUA (Functional Urban Areas) defined by the ESPON 2013 DATABASE ,are defined as labor basins of the MUAs (Morphological Urban Areas) which are themselves defined as densely populated areas, all this independently from any national, administrative or political definitions, but based instead on pure statistics.

Mcrit

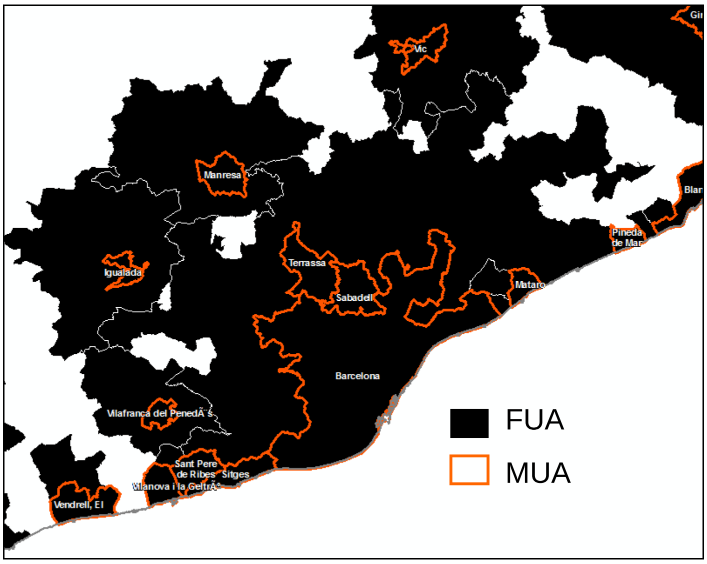


Figure 4. Functional Urban Areas (FUA) and Morphological Urban Areas (MUA)

Larger Urban Zones (LUZ) defined by EUROSTAT (Urban Audit 2004) is an effort to harmonise definitions of urbanisation in the European Union and in countries outside the European Union. are based on various national definitions (functional areas, planning regions, local administrative units, etc.). Only a good knowledge of specifications allows identifying bias resulting from the national heterogeneity of these definitions

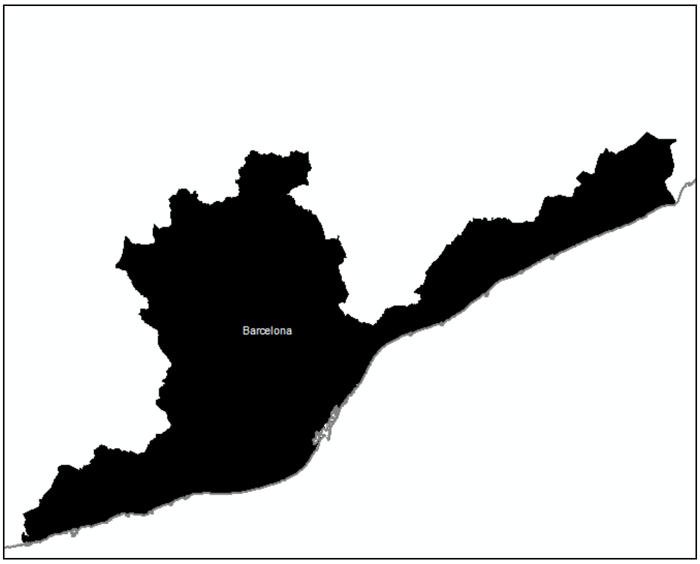


Figure 5. Larger Urban Zones (LUZ)

All delimitations (UMZ, FUA,MUA ,LUZ, AMB i RMB) are overimposed in the next graphic:

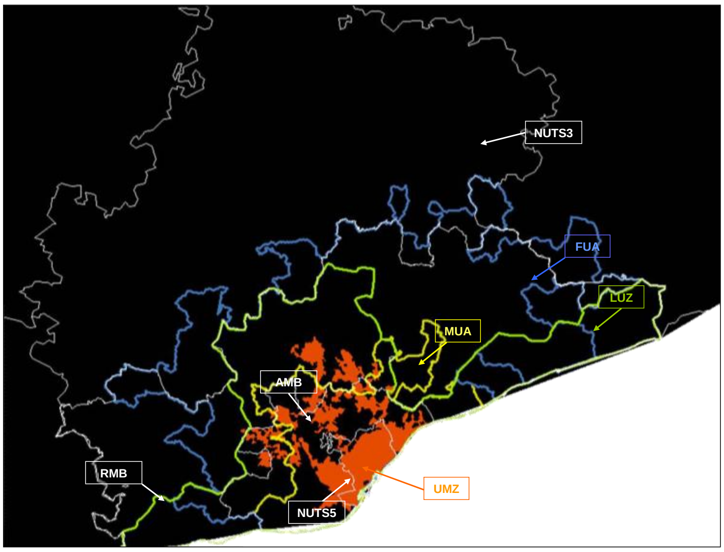


Figure 6. Overlapping areas (RMB,AMB,UMZ,FUA,MUA,LUZ,NUTS5)

Network and Spatial GIS Tools

Different software applications were used (ESRI ArcMap Network Analist, Intergraph Geomedia Transportation and MCRIT BridgesNIS).

Also SIMCAT, developed by MCRIT for the Government of Catalonia and royalties-free, based on Geomedia/BridgesNIS was used

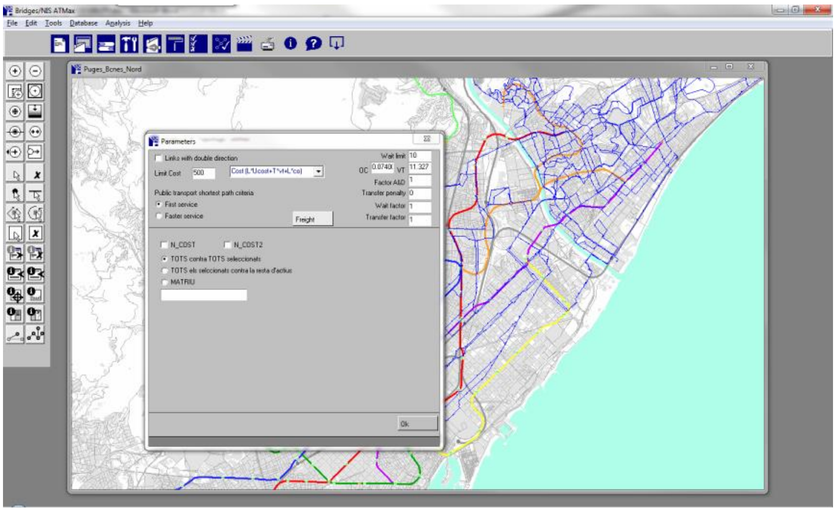


Image 1. SIMCAT Transport Simulation model

The results obtained are however independent from these tools, and could be also obtained using other Geographic Information Systems (e.g. EMME 2, TransCAD...)

Analysis with Eurogeographics ERM graph (First Phase)

During the first phase, a comparative analysis of different road database networks was carried out, and a number of accessibility exercises considering different positions of the centroid representing Barcelona city center and different road speeds: Peak-hour speeds (estimated) and free-flow speeds.

The working process was, in its main steps, as follows:

Catalonia and Languedoc-Roussillon road and rail graphs were extracted from Eurogeographics Euro Regional Map (ERM considering the following graphic entities:

Features	Description	Number	Entity type
Roads	Road network at european level	10.957	link
Intersection of roads	Intersection of the road network at european level	19.421	node
UMZ	Urban Morphologycal Zones from Catalunya and Languedoc-Roussillon	64	polygon

These entities were imported to the GIS

Errors in the graph were corrected (e.g. links not well connected...) by applying authomatic checking routines

We found two type of errors:

1. Errors due to the way the part of the graph we needed for the exercise was cut by you from the rest of Europe (missing links on the boundaries…). Later on, we got a completed graph by you.
2. Missing links in urban areas, needed to complete main streets.

The time to check errors and complete Messing urban links is 1 or 2 days maximum.

The navigation topology was created

A centroid in the geographic center of the UMZ was created, together with its connectors

Features	Description	Number	Entity type
Centroid UMZ	geometrical center of the polygon	1	node
Connectors	link that connect centroid to road network	1	link

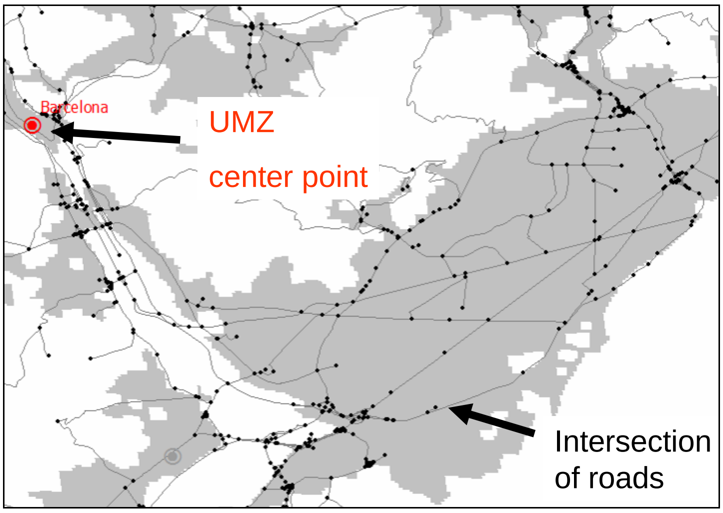


Image 2. Centroid location

The graph was completed with missing links, based on local knowledge. The hierarchy of links was also reviewed.

Based on the road hierarchy assigned by Eurographics to each link, a default free spped was assigned

Road hierarchy	Free speed (km/h)
Limited access/motorway	**120**
Primary route	**100**
Secondary route	**80**
Local road	**40**
Unknown	**40**

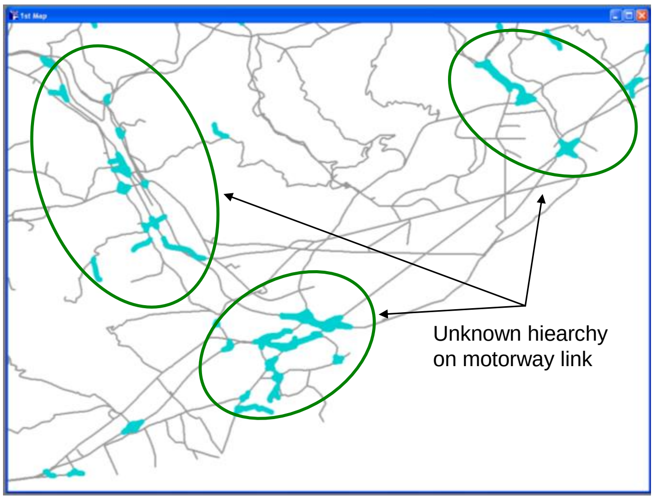


Image 3. Sample of graph errors

Analysis carried out:

- Centroid located in the geometric centre of UMZ and free-flow speeds

- Centroid located in the geographic center of the municipality and free-flow speeds
- Centroid located in the geographic center of the municipality and congestion speeds

Centroid in the geometric centre of UMZ and free-flow speeds

The travel time by private car free flow speed (in minutes) is as follows:

$$T=\frac{L}{Vfl}$$

where,

- *L: path length*
- *Vfl: Speed (free flow)*

From the centroid shortest minimum travel time paths to all road intersections are computed, and results displayed on each road intersection as follows:

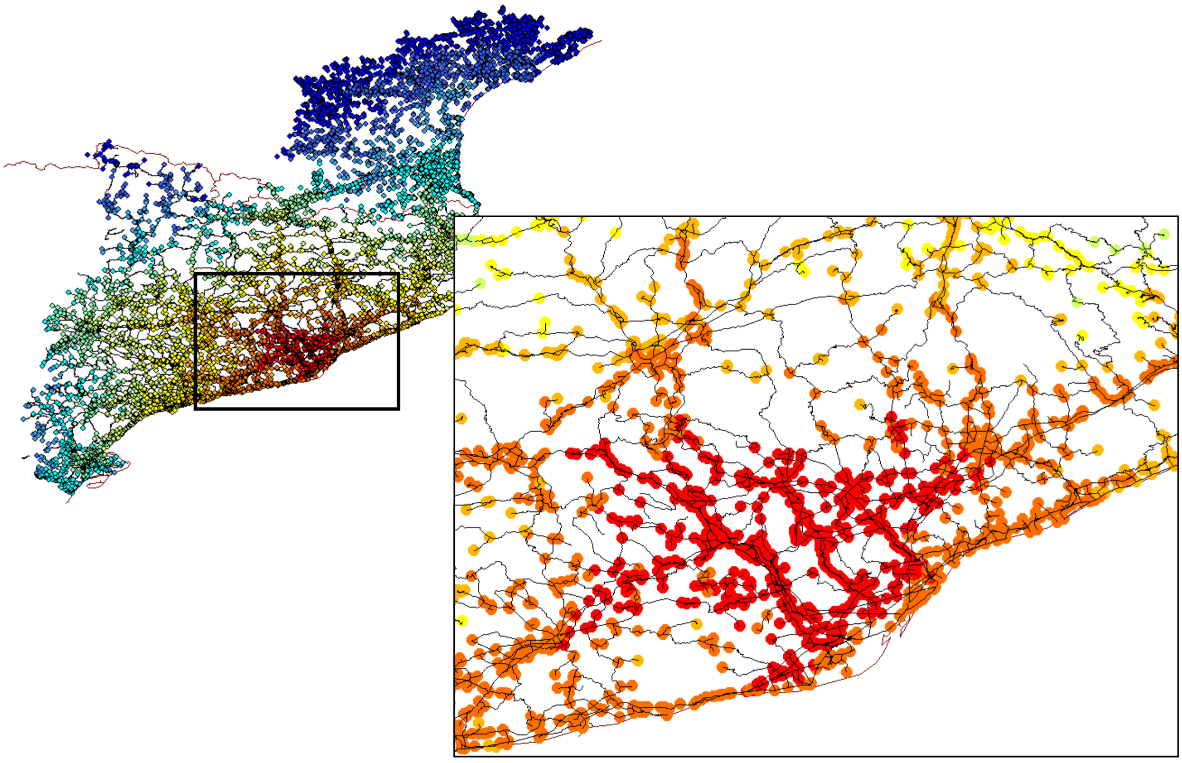
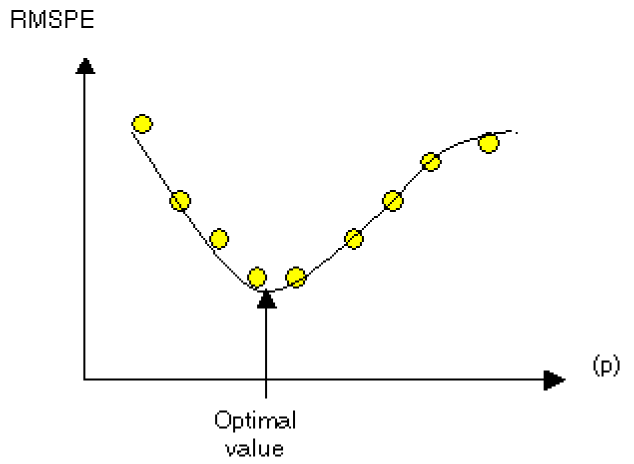


Image 4. Results mapped on nodes representing road intersecions

Values were difused according to IDW d'ArcGIS. IDW (Inverse Distance Weighted) , is a method of interpolation that estimates cell values by averaging the values of sample data points in the neighbourhood of each processing cell. The closer a point is to the centre of the cell being estimated, the more influence, or weight, it has in the averaging process. This method assumes that the variable being mapped decreases in influence with distance from its sampled location. The output value for a cell using IDW is limited to the range of the values used to interpolate. Because IDW is a weighted distance average, the average cannot be greater than the highest or less than the lowest input. Therefore, it cannot create ridges or valleys if these extremes have not already been sampled (Watson and Philip, 1985).

IDW is an standard method for diffusion used in commercial softwares. Differences between IDW and the original method by MCRIT are irrelevant in the context of this exercise. The precise definition of IDW is, according to ESRI, as follows:

The optimal power (p) value is determined by minimizing the root mean square prediction error (RMSPE). The RMSPE is the statistic that is calculated from cross-validation. In cross-validation, each measured point is removed and compared to the predicted value for that location. The RMSPE is a summary statistic quantifying the error of the prediction surface. Geostatistical Analyst tries several different powers for IDW to identify the power that produces the minimum RMSPE. The diagram below shows how Geostatistical Analyst calculates the optimal power. The RMSPE is plotted for several different powers for the same dataset. A curve is fit to the points (a quadratic Local Polynomial equation), and from the curve, the power that provides the smallest RMSPE is determined as the optimal power. Weights are proportional to the inverse distance raised to the power value p. As a result, as the distance increases, the weights decrease rapidly. How fast the weights decrease is dependent on the value for p. If p= 0, there is no decrease with distance, and because each weight λ it will be the same, the prediction will be the mean of all the measured values. As p increases, the weights for distant points decrease rapidly. If the p value is very high, only the immediate few surrounding points will influence the prediction.



Geostatistical Analyst uses power functions greater than 1. A p= 2 is known as the inverse distance squared weighted interpolation.

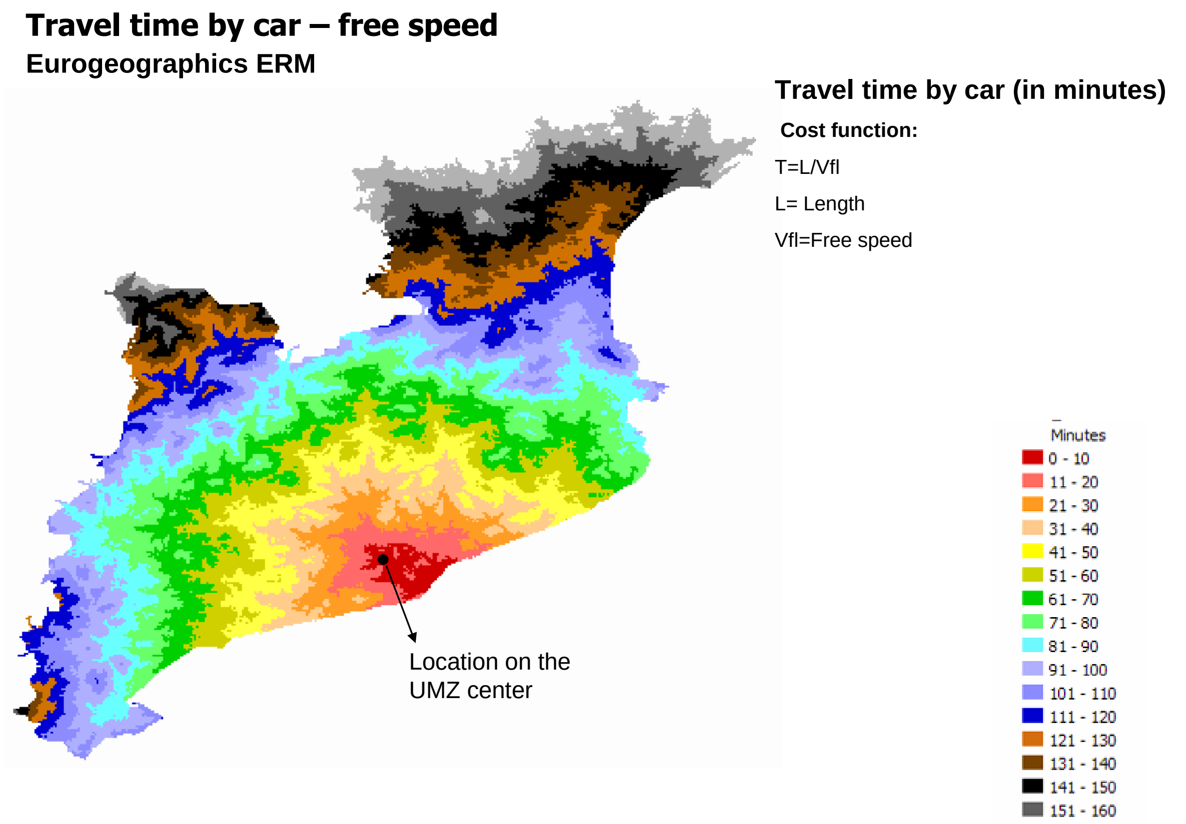


Figure 7. Travel time by car in Eurogeographics ERM with centroid located in the UMZ center

<u>Centroid in the geographic center of the municipality and free-flow speeds</u>

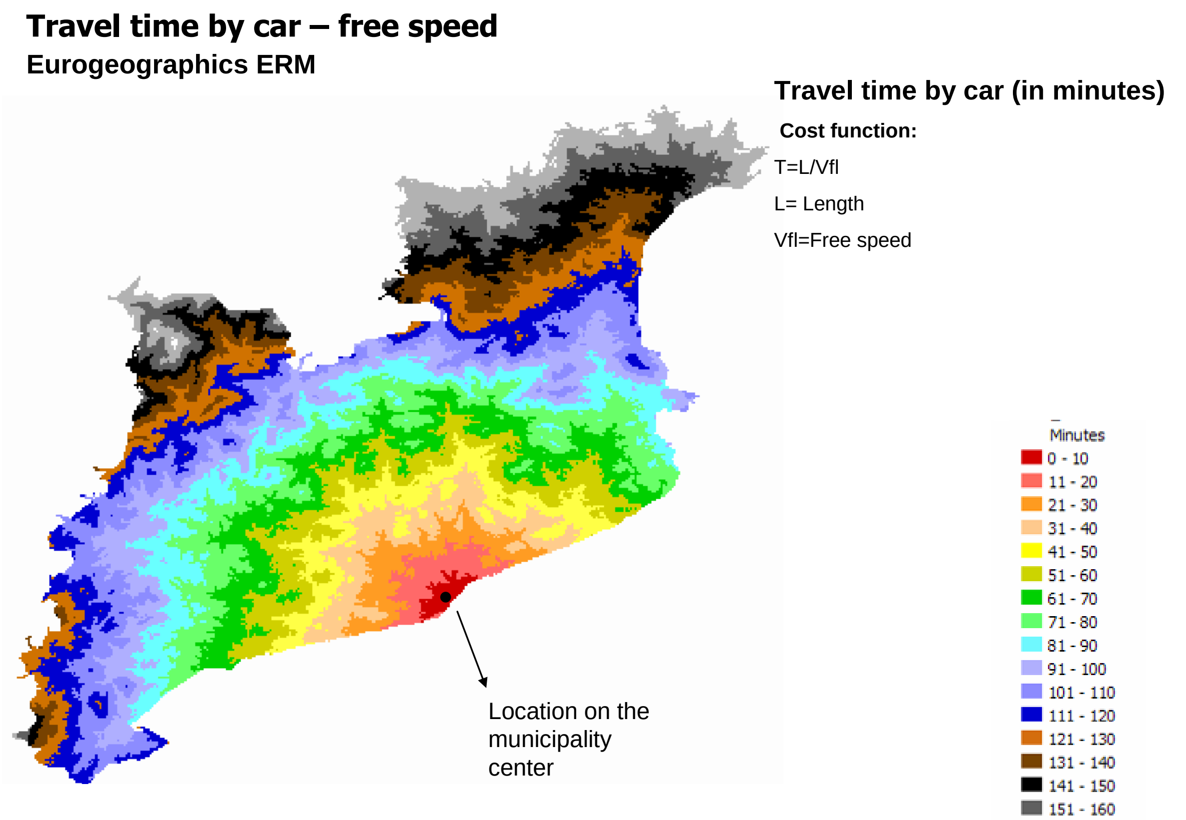


Figure 8. Travel time by car in Eurogeographics ERM with centroid in the municipality center

Analisys considering peak-hour speeds and congestion

The Level of Service (LOS) is a way of telling how bad traffic congestion is. LOS A means there is no traffic congestion and LOS E means that traffic congestion is very bad.

The Regional Government uses this criteria: when level of service is E speed is reduced by 50% for main roads (alfa=12) and for local roads (alfa=4) a 40% reduction is applied.

In main roads:

% capacity	Intensity/Capacity	Level of service (main roads)	f(x) Conical	Speed (Conical)	Speed reduction
0%	0%	A	1	100	0%
10%	10%	A	1,01	99,50	-1%
20%	20%	A	1,01	98,88	-1%
30%	30%	A	1,02	98,10	-2%
40%	40%	B	1,03	97,08	-3%
50%	50%	B	1,04	95,70	-4%
60%	60%	B	1,07	93,71	-6%
70%	70%	B	1,10	90,64	-9%
80%	80%	C	1,17	85,30	-15%
90%	90%	D	1,35	74,29	-26%
100%	100%	E	2	50	-50%

In local roads:

% capacitat	Intensity/Capacity	Level of service (local roads)	f(x) Conical	Speed (Conical)	Speed reduction
0%	0%	A	1,00	80,00	0%
10%	10%	A	1,02	78,61	-2%
20%	20%	A	1,04	76,97	-4%
30%	30%	A	1,07	75,00	-6%
40%	40%	A	1,10	72,60	-9%
50%	50%	B	1,15	69,64	-13%
60%	60%	B	1,21	65,92	-18%
70%	70%	C	1,31	61,21	-23%
80%	80%	D	1,45	55,25	-31%
90%	90%	E	1,67	48,00	-40%
100%	100%	E	2,00	40,00	-50%

These parameters are used by SIMCAT to define congestion speed, based on the Highway Capacity Manual2000, TRB, and calibrated with real data.

Congestion speeds in the ERM graph were applied in the UMZ area.

In relation to TOMTOM Congestion Index, that has a different methodology, it gives 19% of Average Congestion Level across all roads in Barcelona, and 46% Average Congestion Level during morning peak periods on work days, what is the moment we evaluate in the exercise, close to the 50% we adopted.

TomTom Congestion Index TOMTOM

Europe

Rank	CI change	City	Country	Congestion	Morning peak	Evening peak	Highways	Non-Highways
1	▲	Moscow	Russia	66%	100%	138%	62%	68%
2	▲	Istanbul	Turkey	55%	80%	125%	58%	51%
3	▼	Warsaw	Poland	42%	84%	88%	39%	46%
4	▲	Marseille	France	40%	77%	77%	24%	50%
5	▼	Palermo	Italy	39%	64%	64%	27%	49%
6	▲	Stuttgart	Germany	33%	59%	67%	32%	34%
7	---	Paris	France	33%	70%	65%	32%	34%
8	▼	Rome	Italy	33%	76%	63%	25%	37%
9	▼	Hamburg	Germany	32%	49%	55%	27%	36%
10	▼	Brussels	Belgium	32%	75%	81%	26%	37%
11	▼	Dublin	Ireland	29%	62%	62%	22%	39%
12	▼	Stockholm	Sweden	28%	62%	70%	25%	32%
13	---	Berlin	Germany	28%	42%	50%	24%	32%
14	▼	London	United Kingdom	27%	56%	55%	14%	36%
15	---	Nice	France	27%	41%	54%	15%	34%
16	▼	Cologne	Germany	26%	49%	54%	24%	32%
17	---	Lyon	France	26%	58%	56%	21%	34%
18	▲	Leeds-Bradford	United Kingdom	26%	54%	59%	22%	31%
19	▼	Vienna	Austria	25%	43%	50%	17%	32%
20	▼	Milan	Italy	25%	70%	55%	20%	29%
21	▲	Toulouse	France	25%	76%	56%	20%	32%
22	▼	Naples	Italy	25%	40%	45%	13%	37%
23	▲	Luxembourg	Luxembourg	25%	52%	59%	16%	37%
24	▲	Nottingham	United Kingdom	24%	59%	52%	6%	32%
25	▼	Budapest	Hungary	24%	46%	45%	6%	33%
26	▼	Manchester	United Kingdom	24%	62%	59%	16%	33%
27	▲	Munich	Germany	24%	49%	42%	18%	33%
28	▼	Prague	Czech Republic	23%	52%	40%	18%	29%
29	▼	Oslo	Norway	23%	61%	75%	19%	30%
30	▼	Strasbourg	France	23%	41%	64%	18%	30%
31	▼	Frankfurt am Main	Germany	22%	48%	41%	17%	30%
32	▲	Birmingham	United Kingdom	22%	46%	45%	16%	31%
33	▼	Liverpool	United Kingdom	21%	38%	39%	4%	27%
34	▲	Lille	France	21%	53%	48%	16%	27%
35	▼	Newcastle-Sunderland	United Kingdom	21%	41%	43%	15%	26%
36	▼	Lisbon	Portugal	20%	45%	51%	10%	21%
37	▼	Nantes	France	20%	52%	49%	15%	27%
38	▼	Genoa	Italy	20%	37%	38%	11%	32%
39	▼	Turin	Italy	20%	44%	39%	10%	25%
40	▼	The Hague	Netherlands	20%	46%	45%	11%	27%
41	▼	Rotterdam	Netherlands	19%	38%	55%	13%	29%
42	▼	Barcelona	Spain	19%	46%	38%	15%	22%

Travel time by private car peak hour speed (in minutes) is as follows:

$$T = \frac{L}{Vhp}$$

where,

- *L: path length*
- *Vhp: Speed (peak hour)*

According to Heinz Spiess ,"*Conical Volume Delay Functions*" (1990) , peak-hour speed theoretically is as follows:

$$Vel_{HP} = \frac{Vel_0}{f(x)}$$

Speed-flow function being:

$$f(x) = 2 + \sqrt{\alpha^2 \cdot (1-x)^2 + \beta^2} - \alpha \cdot (1-x) - \beta$$

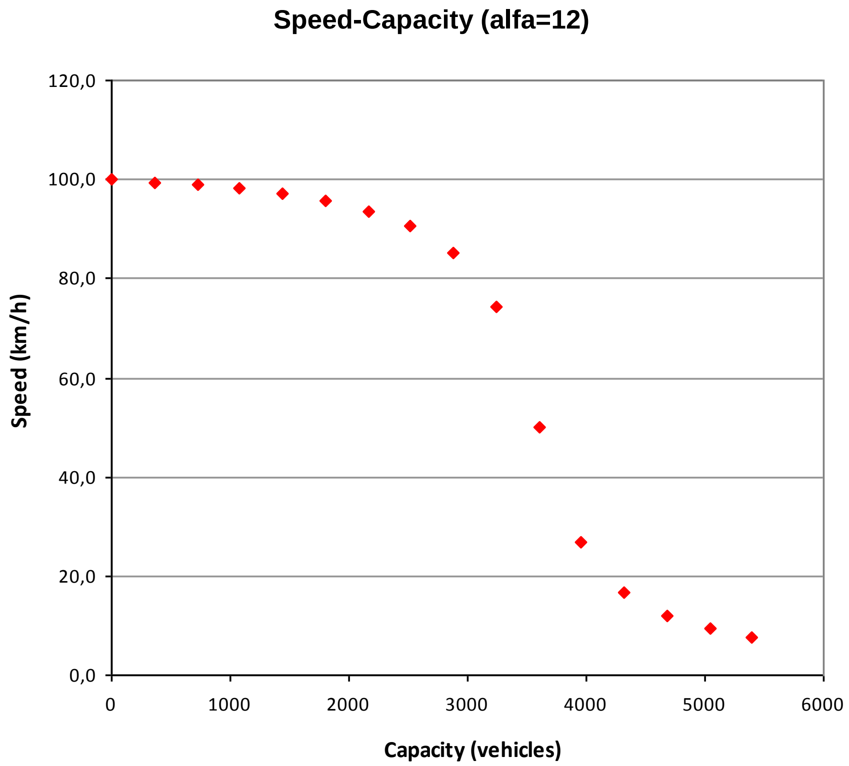
where,

- $\beta = \dfrac{2\alpha - 1}{2\alpha - 2}$

- $x = \frac{v}{c}$
- v *: intensity in peak hour*
- c *: capacity of the link*
- α *parameter to be adjusted*

% capacity	f(x) Conical	Speed (Conical)	Speed reduction
0%	1	100	0%
10%	1,01	99,50	-1%
20%	1,01	98,88	-1%
30%	1,02	98,10	-2%
40%	1,03	97,08	-3%
50%	1,04	95,70	-4%
60%	1,07	93,71	-6%
70%	1,10	90,64	-9%
80%	1,17	85,30	-15%
90%	1,35	74,29	-26%
100%	2	50	-50%

This table is represented graphically as follows:



Graphic 1..Speed-capacit curve adoptedy

Applying this criteria in the UMZ, peak-hour speed is considered to be aproximately 50% free-flow speed for main roads, and 40% in local and county roads, in the UMZ. Outside UMZ peak-hour speeds and free-flow speeds are considered equivalent.

Peak-hour speeds, based on the previous considerations are as follows:

Road hierarchy	Peak hour speed(km/h)
Limited access/motorway	**60**
Primary route	**50**
Secondary route	**40**
Local road	**15**

Travel time by car – peak hour speed

Eurogeographics ERM

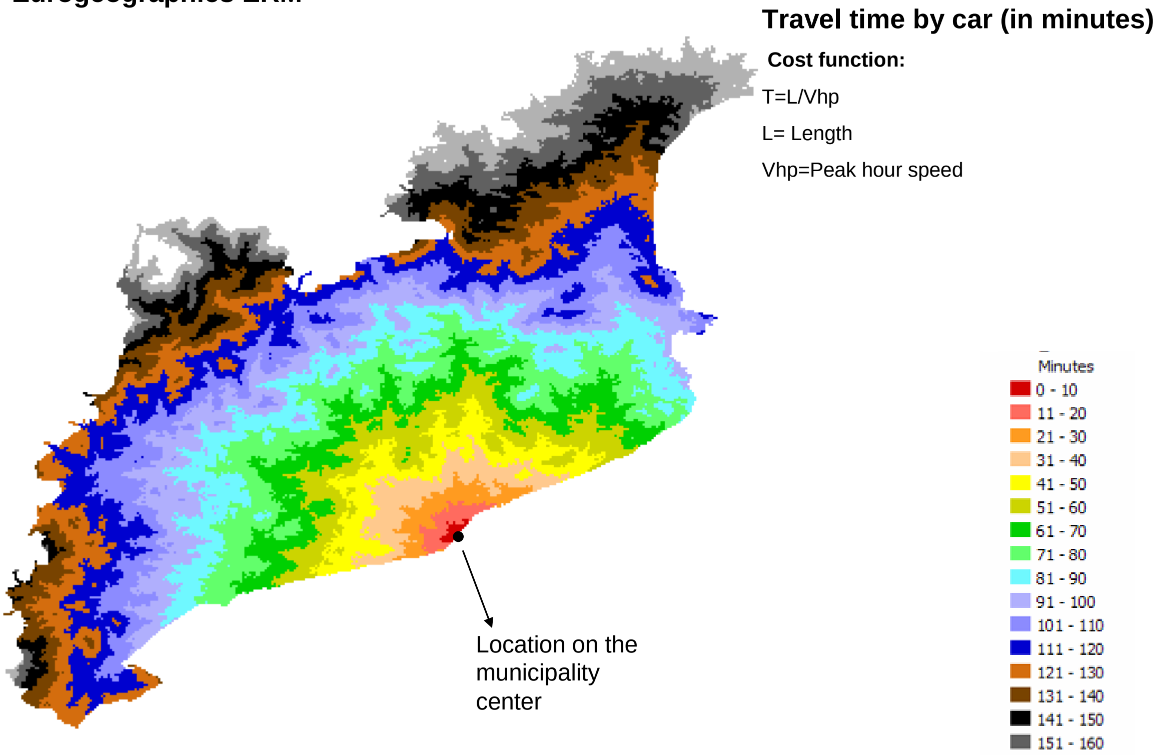


Figure 9 Travel time by car in Eurogeographics ERM with peak hour speed

Results obtained so far using the road graph are very different when analysed at local and regional level, in comparison with labour market zones, but marginal when considered at European scale.

Based on the previous results the main conclusion for the next step on the working process was to further explore other variables than time (e.g. cost, including road tolls) and extend the analysis to the rail and transport public services available in the metropolitan graphs supported by SIMCAT.

Analysis with SIMCAT (Second Phase)

The second phase of the ESPON 2013 expertise developed in the work package "Cities" aimed at consolidating results of the first phase and enriching an information system about regional access to major employment poles.

The exercise calculates perimeters of 1 hour isochrones around Barcelona pole, and compares results using an standard European Road Information System (ERM by Eurogeographics) and the official Catalan Transport Information System (SIMCAT) developed by MCRIT for the Regional Government, for a various set of indicators.

The paramount question to be answered is to what extend calculations using an standard European system such as Eurographics are consistent with results obtained from a detailed regional transport system such as SIMCAT.

SIMCAT at Regional and at Metropolitan level (at NUTS2 and NUTS3) was also used, together with Eurogeographics (at NUTS2 for whole Catalonia):

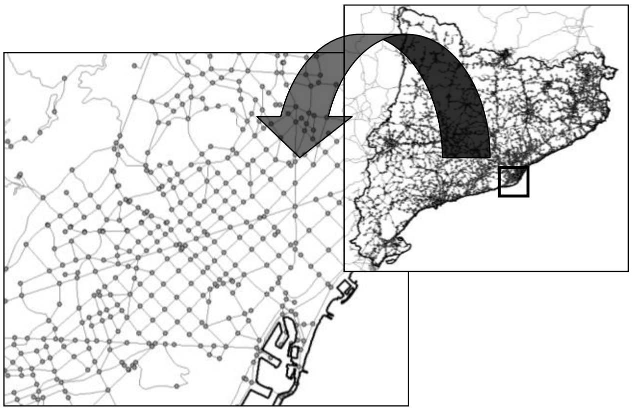
SIMCAT at Regional (NUTS2)

Road links: **20.373**

Road nodes: **12.185**

Main data:

- Speed
- Congestion speed
- Length
- Tolls



SIMCAT at Metropolitan level

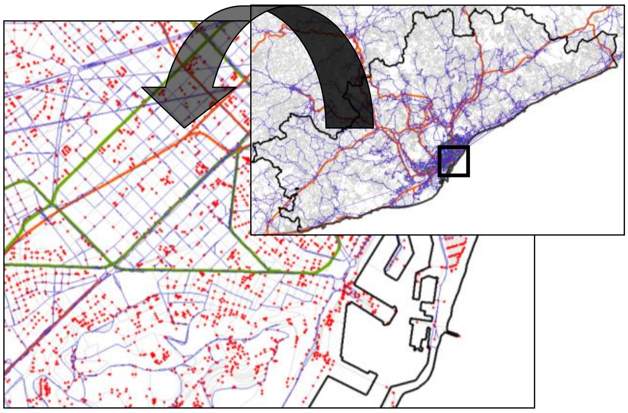
Road links: **490.758**

PT services (**bus, train,metro**) : **2.181**

Road nodes: **300.795**

Main data:

- Schedule of PT services
- Service length
- Private car speed
- Walking speed



A number of calculation scenarios were defined using SIMCAT (considering time and cost as main variables), as presented in the next table:

Travel time (minutes)

	by car				by public transport	
					Percived time	
	Free speed	Peak hour speed	Free speed + access and egress time	Peak hour speed+ access and egress time	Real schedules+ access and egress on foot	Real schedules + access and egress by car
Eurogeographics ERM	X	X	X	X		
SIMCAT Regional	X	X	X	X		
SIMCAT Metropolitan					X	X

Travel cost (€)

	by car				by public transport	
					Percived cost	
	Free speed	Peak hour speed	Free speed + access and egress time	Peak hour speed+ access and egress time	Real schedules+ access and egress on foot	Real schedules + access and egress by car
Eurogeographics ERM						
SIMCAT Regional	X	X				
SIMCAT Metropolitan					X	X

Access and dispersion times by car users (parking) was introduced to make more meaningful the comparison with public transport.

Value of time is 8,7€/h, according to the Transport Authority of Barcelona.

Operational costs for vehicles was adopted based on MAIT (Mètode d'Avaluació de les Infraestructures de Transport) (2010): 0,11€/km, all costs considered.

Formulation of travel time (minutes) by private car free flow speed (in minutes) applied:

$$T = \frac{L}{Vfl}$$

where,

- *L: path length*
- *Vfl: Speed (free flow)*

Formulation of travel time (minutes) by private car peak hour speed (in minutes)

$$T = \frac{L}{Vhp}$$

where,

- *L: path length*
- *Vhp: Speed (peak hour)*

Formulation of travel time (minutes) by car free flow speed (in minutes) including access time and parking

$$T = \left(\frac{L}{Vfl}\right) + Ta + Td$$

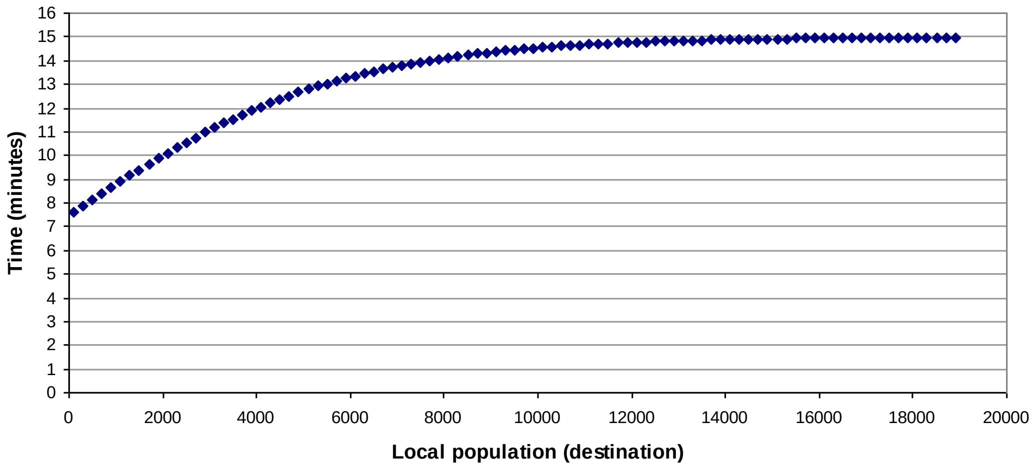
where,

- *L: path length*
- *Vfl: Speed (free flow)*
- *Ta: access time to private car: 5 minutes (constant)*
- *Te:egress time: parking time ,calculated according to the following formula*

$$Td = \frac{15}{1 + K^{a+Pd}}$$

Where:

- *K: constant (200)*
- *a: 0,000065*
- *Pd: population of destination (LAU2)*



Graphic 2..Parking time vrs. Population in destination

Formulation of travel time (minutes) by car peak hour speed (in minutes) including access time and parking:

$$T = \left(\frac{L}{Vhp}\right) + Ta + Td$$

where,

- *L: path length*
- *Vhp: Speed (peak hour)*
- *Ta: access time to private car: 5 minutes (constant)*
- *Te:egress time: parking time ,calculated according to the following formula*

$$Td = \frac{15}{1 + K^{a + Pd}}$$

Where:

- *K: constant (200)*
- *a: 0,000065*
- *Pd: population of destination*

Formulation of travel time (minutes) by public transport - access and egress on foot:

$$T = Tv + Te + Tt + Tad$$

where,

- *Tv: travel time*
- *Te: waiting time (max 10 minutes)*
- *Tt: transfer time*
- *Tad: access and egress time on foot*

Formulation of travel time (minutes) by public transport - access and egress by car

$$T = Tv + Te + Tt + Tad$$

where,

- *Tv: travel time*
- *Te: waiting time (max 10 minutes)*
- *Tt: transfer time*
- *Tad: access and egress time by car*

Formulation of travel cost (€) by car free flow speed

$$C = Tfl * VOT * CO * L + P$$

where,

- *Tfl: free flow time*
- *VOT: Value of time (11 €/h)*
- *CO: Operating costs (0,074€/km)*
- *L: path length*
- *P: Toll cost (€)*

Formulation oftravel cost (€) by car peak hour speed

$$C = Thp * VOT * CO * L + P$$

where,

- *Thp: peak hour time*
- *VOT: Value of time (11 €/h)*
- *CO: Operating costs (0,074€/km)*
- *L: path length*
- *P: toll cost (€)*

Formulation of travel cost (€) by public transport –access and egress on foot

$$C = Tpt * VOT * L$$

where,

- *Tpt: Travel time by public transport*

$$Tpt = Tv + Te + Tt + Tad$$

  - *Tv: travel time*
  - *Te: waiting time (max 10 minutes)*
  - *Tt: transfer time*
  - *Tad: access and egress time on foot*
- *VOT: value of time (11 €/h)*
- *L: path length*

Formulation of travel cost (€) by public transport –access and egress by car

$$C = Tpt * VOT * L$$

where,

- *T: Travel time by public transport*

$$Tpt = Tv + Te + Tt + Tad$$

  - *Tv: travel time*
  - *Te: waiting time (max 10 minutes)*
  - *Tt: transfer time*
  - *Tad: access and egress time by car*
- *VOT: value of time (11€/h)*
- *L: path length*

Next maps with results for all scenarios considered are displayed, for both SIMCAT and Eurogeographics:

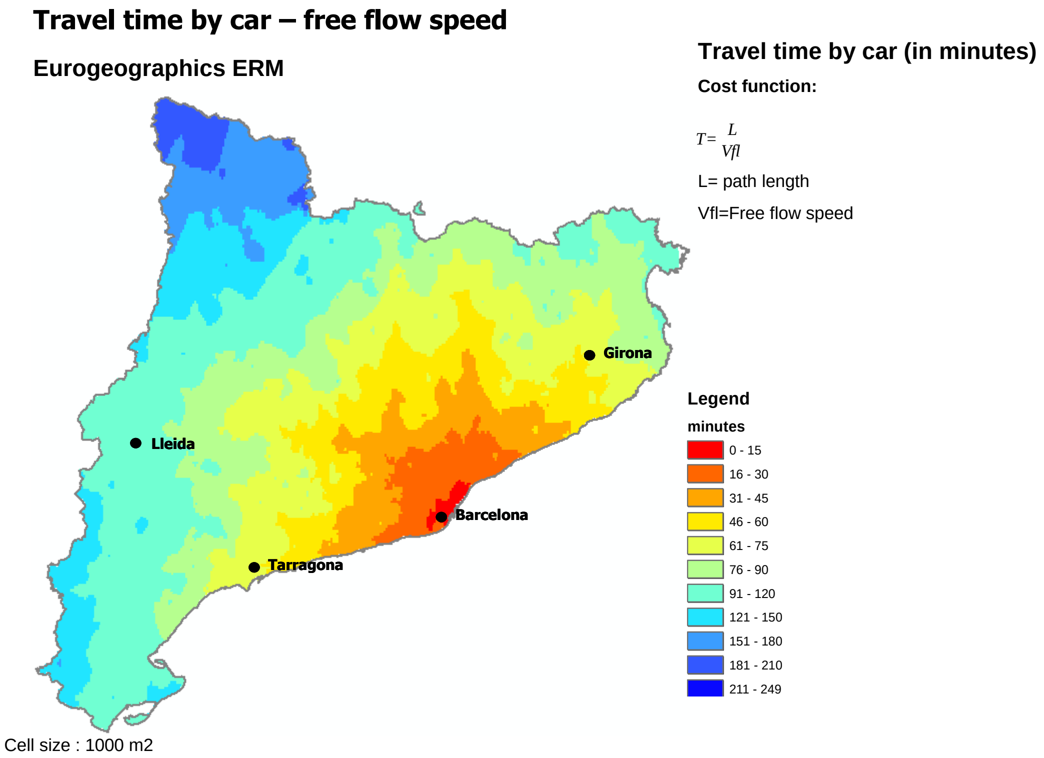


Figure 10. Travel time by car in Eurogeographics ERM with free flow speed

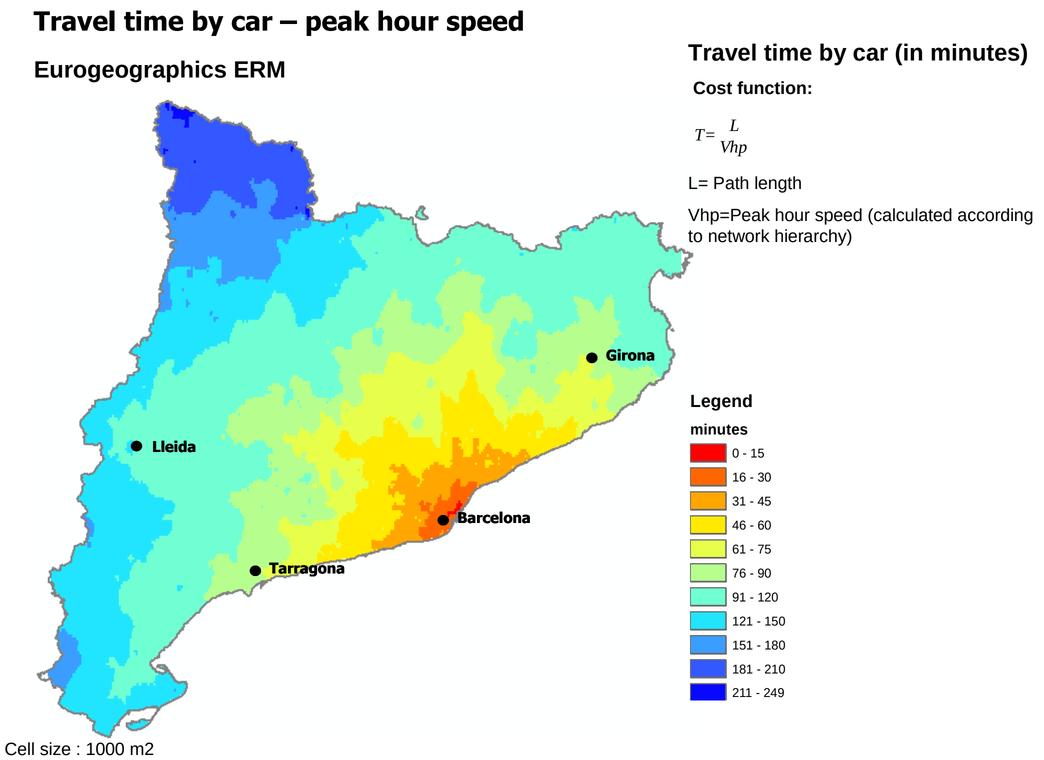


Figure 11. Travel time by car in Eurogeographics ERM with peak hour speed

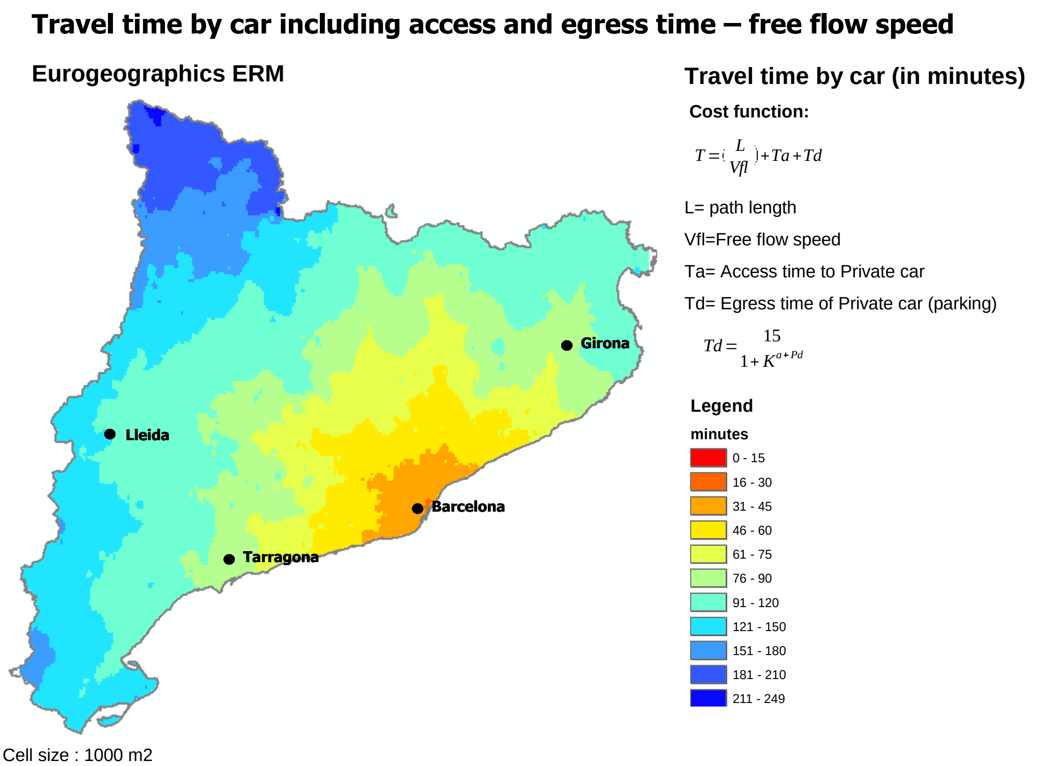


Figure 12. Travel time by car in Eurogeographics ERM with free flow speed and access and egress time

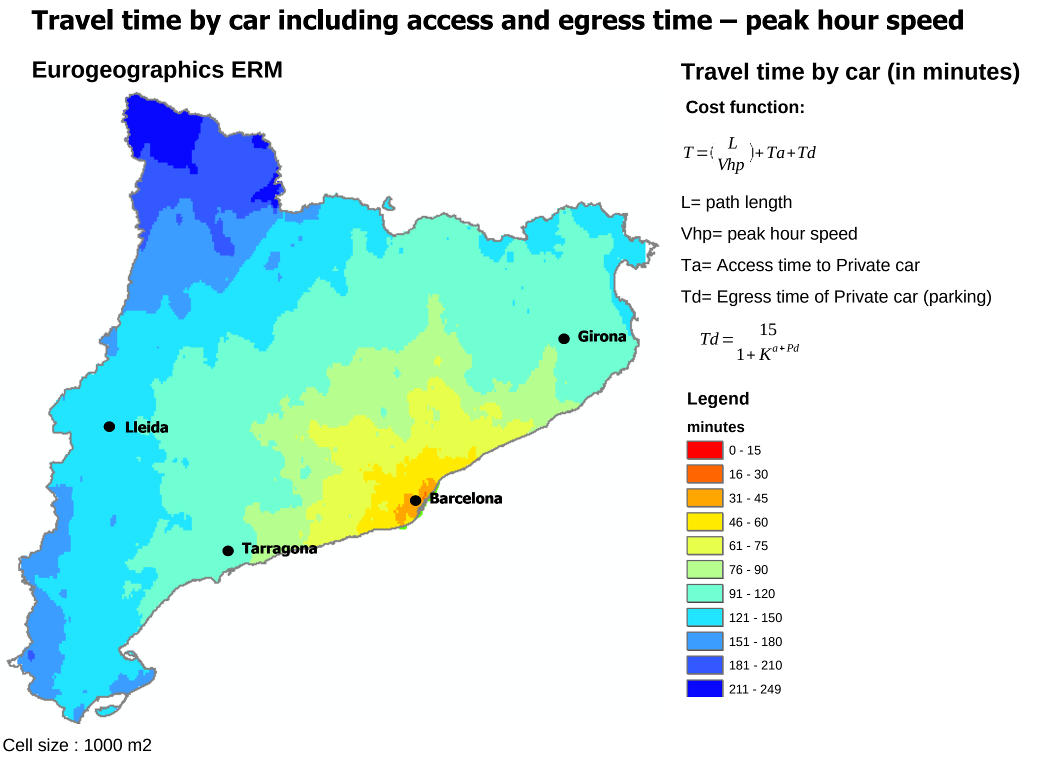


Figure 13. Travel time by car in Eurogeographics ERM with peak hour speed and access and egress time

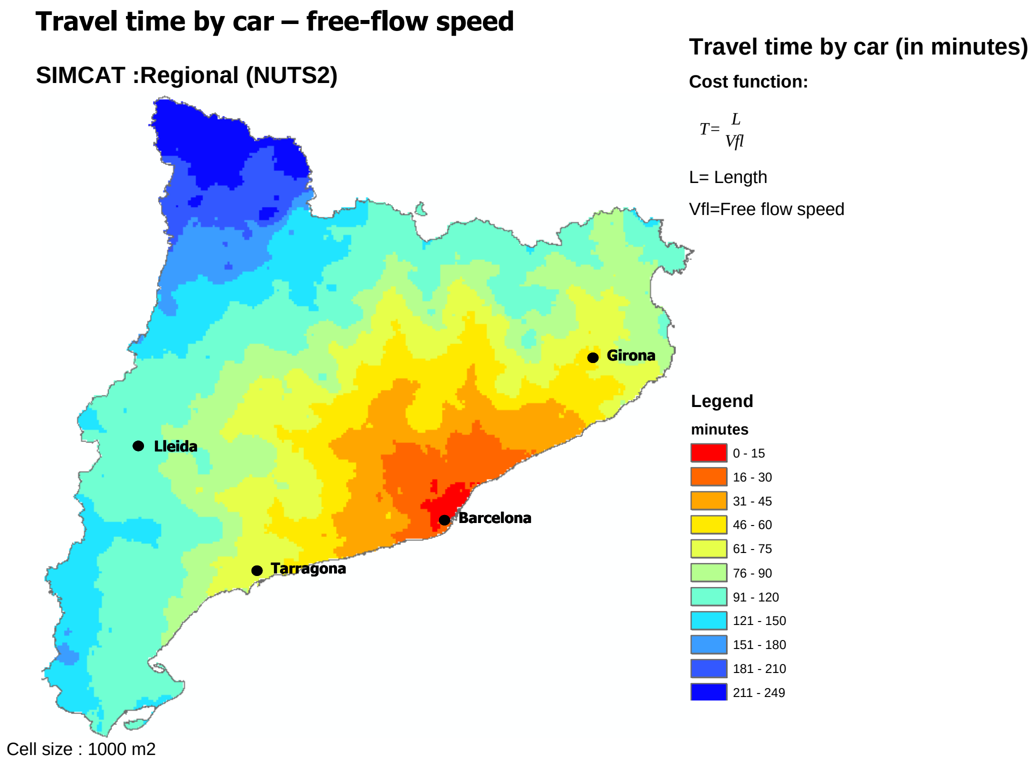


Figure 14. Travel time by car in SIMCAT Regional with free flow

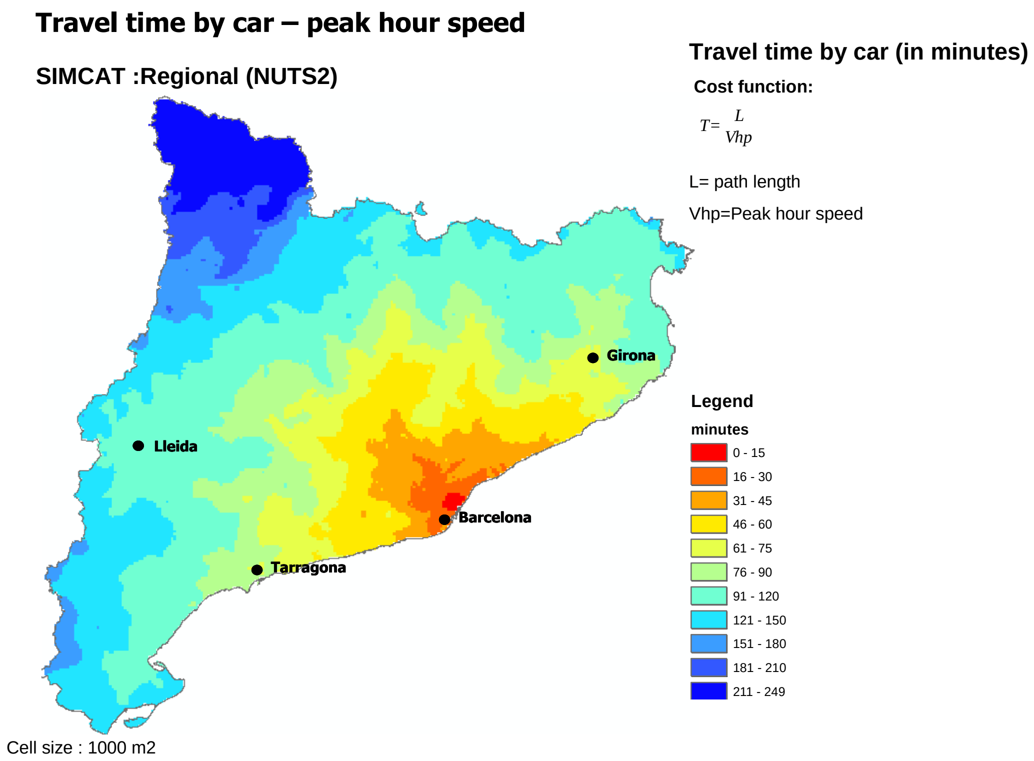
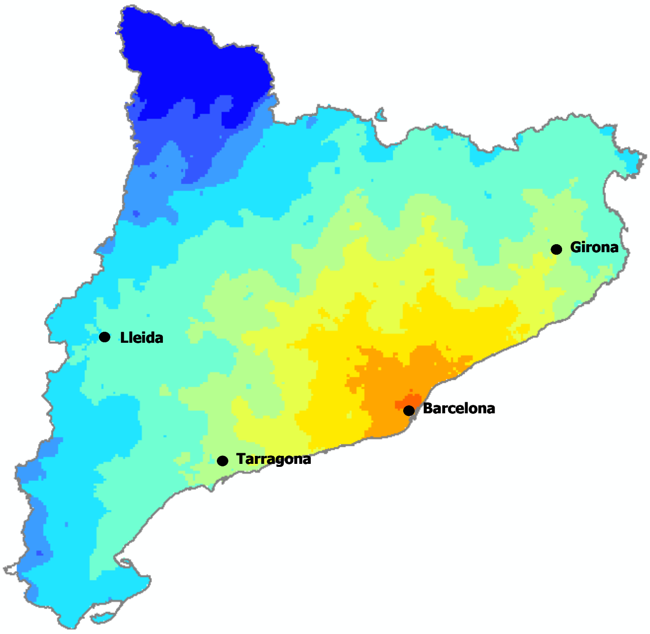


Figure 15. Travel time by car in SIMCAT Regional with peak hour speed

Travel time by car including access and egress time – free flow speed

SIMCAT :Regional (NUTS2)



Travel time by car (in minutes)

Cost function:

$$T = (\frac{L}{Vfl}) + Ta + Td$$

L= path length

Vfl=Free flow speed

Ta= Access time to Private car

Td= Egress time of Private car (parking)

$$Td = \frac{15}{1 + K^{a+Pd}}$$

Legend

minutes

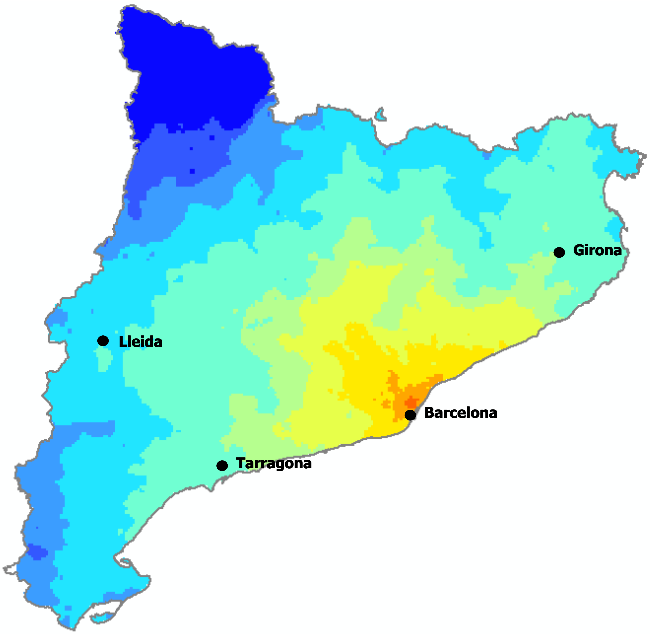
- 0 - 15
- 16 - 30
- 31 - 45
- 46 - 60
- 61 - 75
- 76 - 90
- 91 - 120
- 121 - 150
- 151 - 180
- 181 - 210
- 211 - 249

Cell size : 1000 m2

Figure 16. Travel time by car in SIMCAT Regional with free flow speed and access and egress time

Travel time by car including access and egress time – peak hour speed

SIMCAT :Regional (NUTS2)



Travel time by car (in minutes)

Cost function:

$$T = (\frac{L}{Vhp}) + Ta + Td$$

L= path length

Vhp=Peak hour speed

Ta= Access time to Private car

Td= Egress time of Private car (parking)

$$Td = \frac{15}{1 + K^{a+Pd}}$$

Legend

minutes

- 0 - 15
- 16 - 30
- 31 - 45
- 46 - 60
- 61 - 75
- 76 - 90
- 91 - 120
- 121 - 150
- 151 - 180
- 181 - 210
- 211 - 249

Cell size : 1000 m2

Figure 17. Travel time by car in SIMCAT Regional with peak hour speed and access and egress time

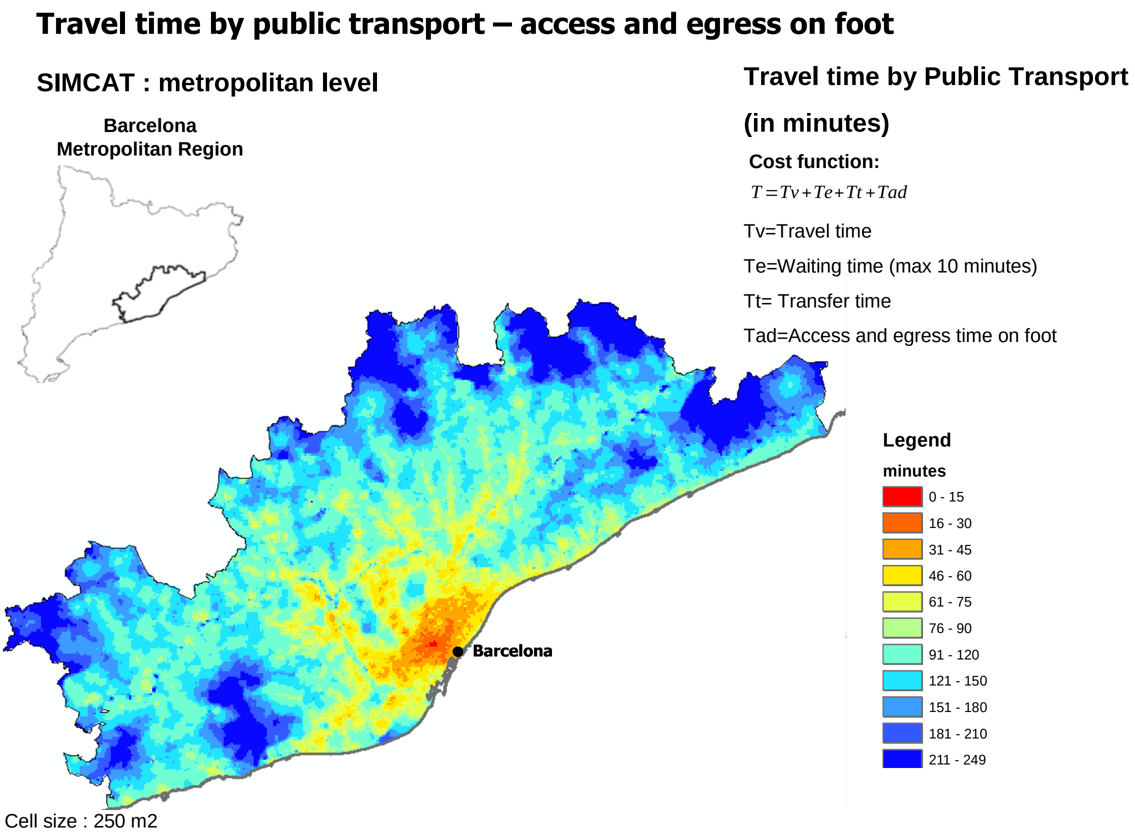


Figure 18. Travel time by car in SIMCAT Metropolitan level with access and egress on foot

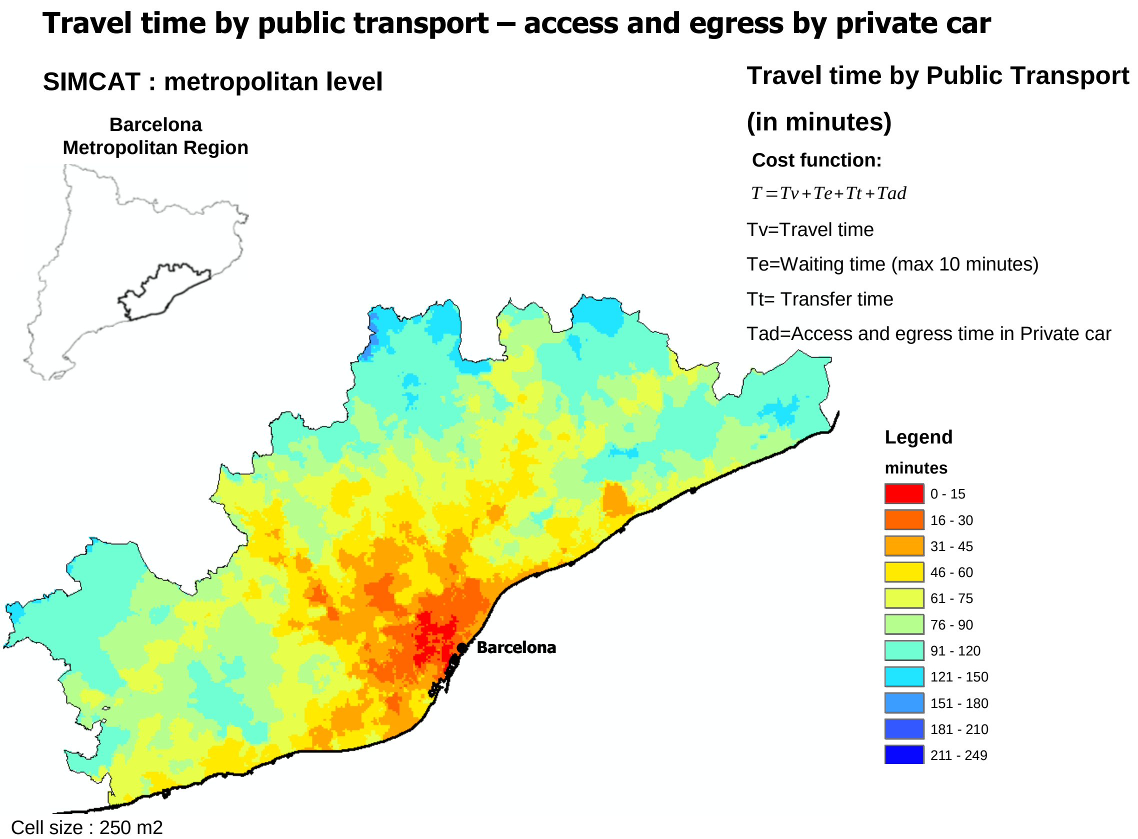


Figure 19 Travel time by car in SIMCAT Metropolitan level with access and egress by car

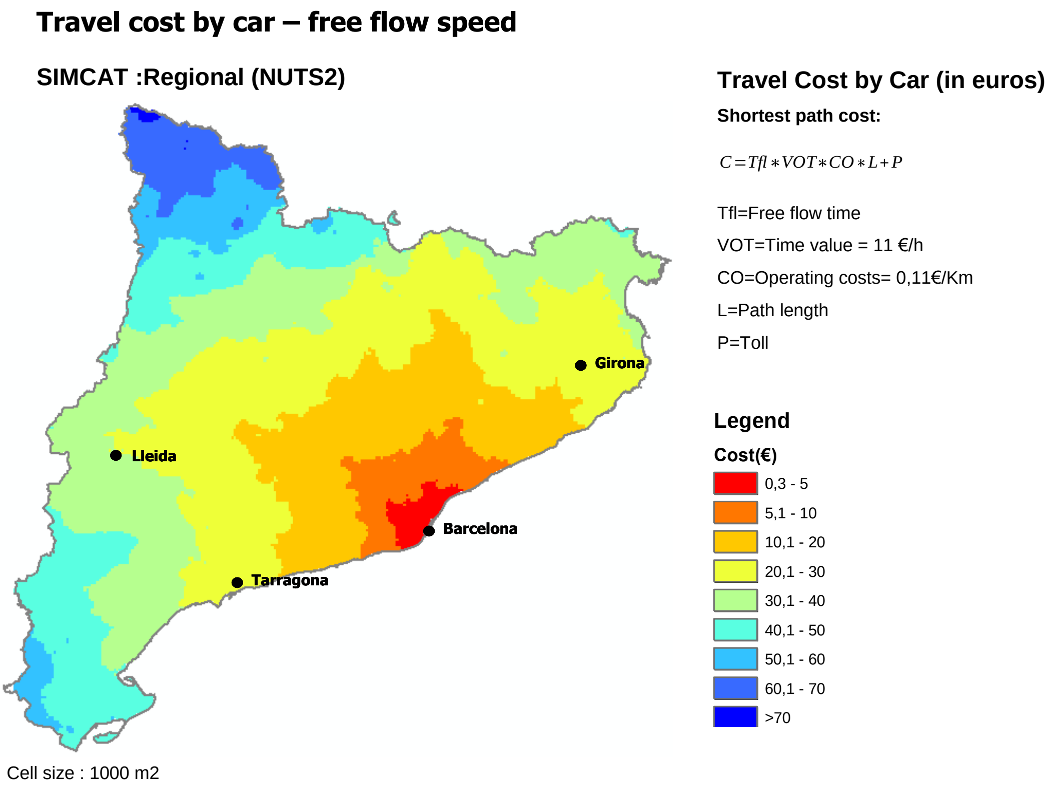


Figure 20. Travel cost (€) by car in SIMCAT Regional with free flow speed

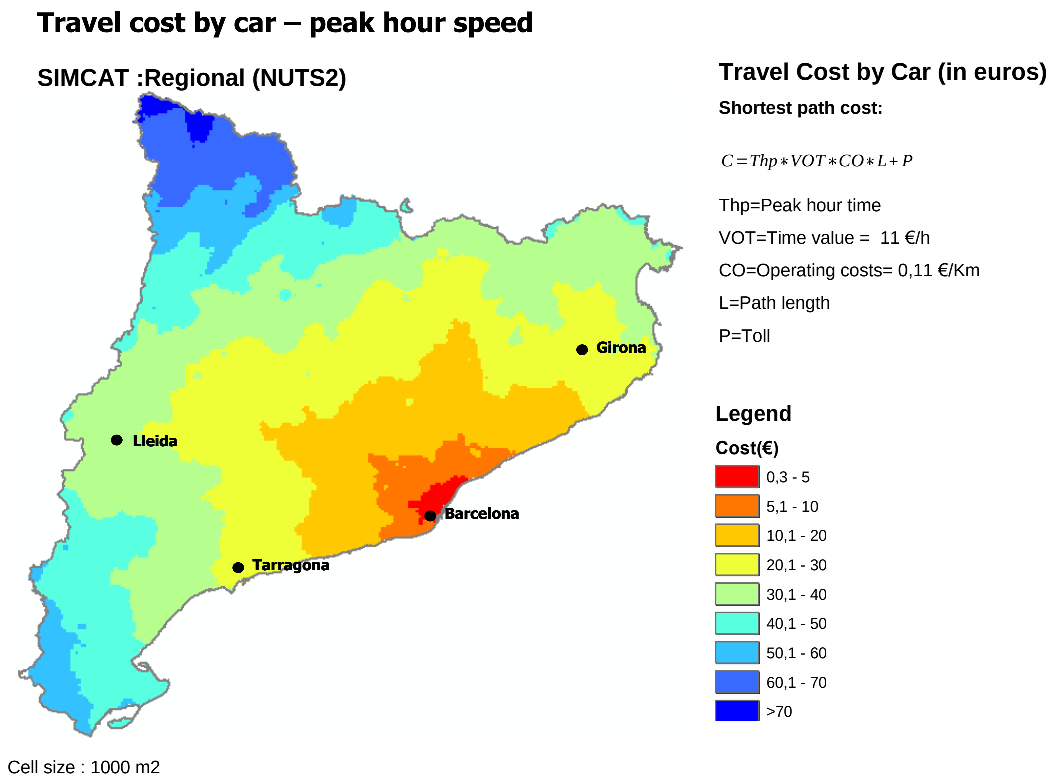


Figure 21. Travel cost (€) by car in SIMCAT Regional with peak hour speed

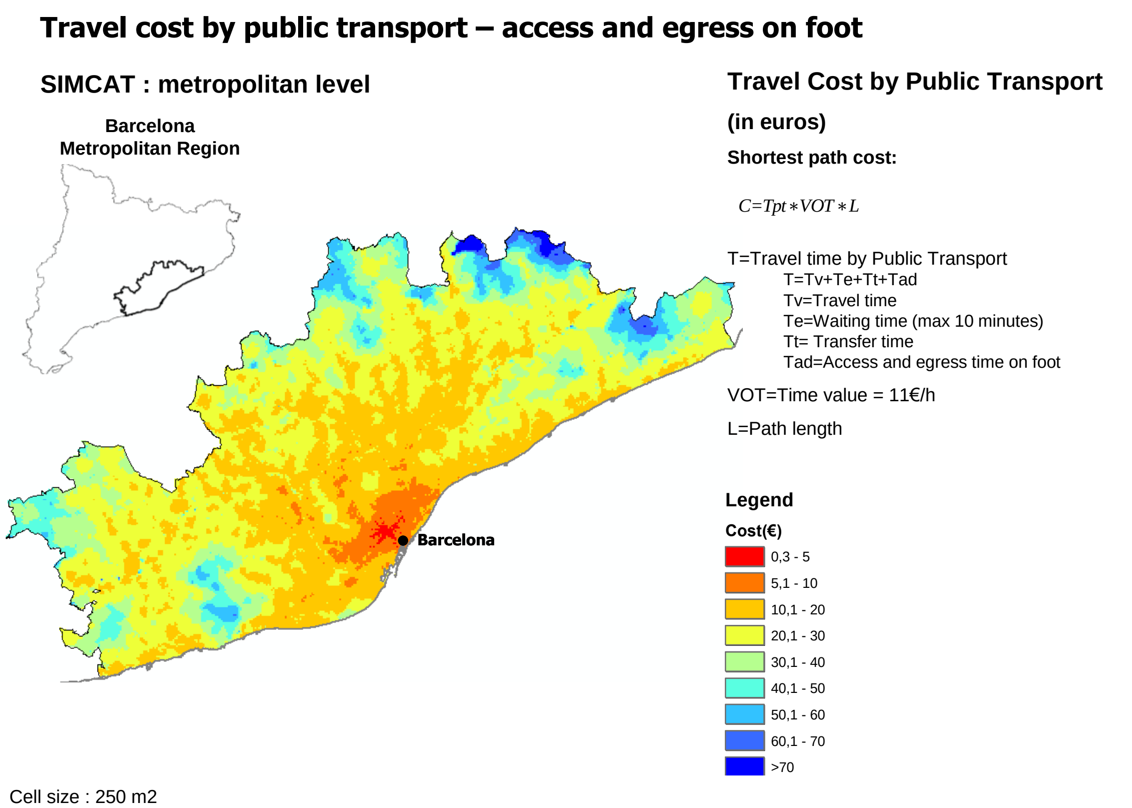


Figure 22. Travel cost (€) by car in SIMCAT Metropolitan level with access and egress on foot

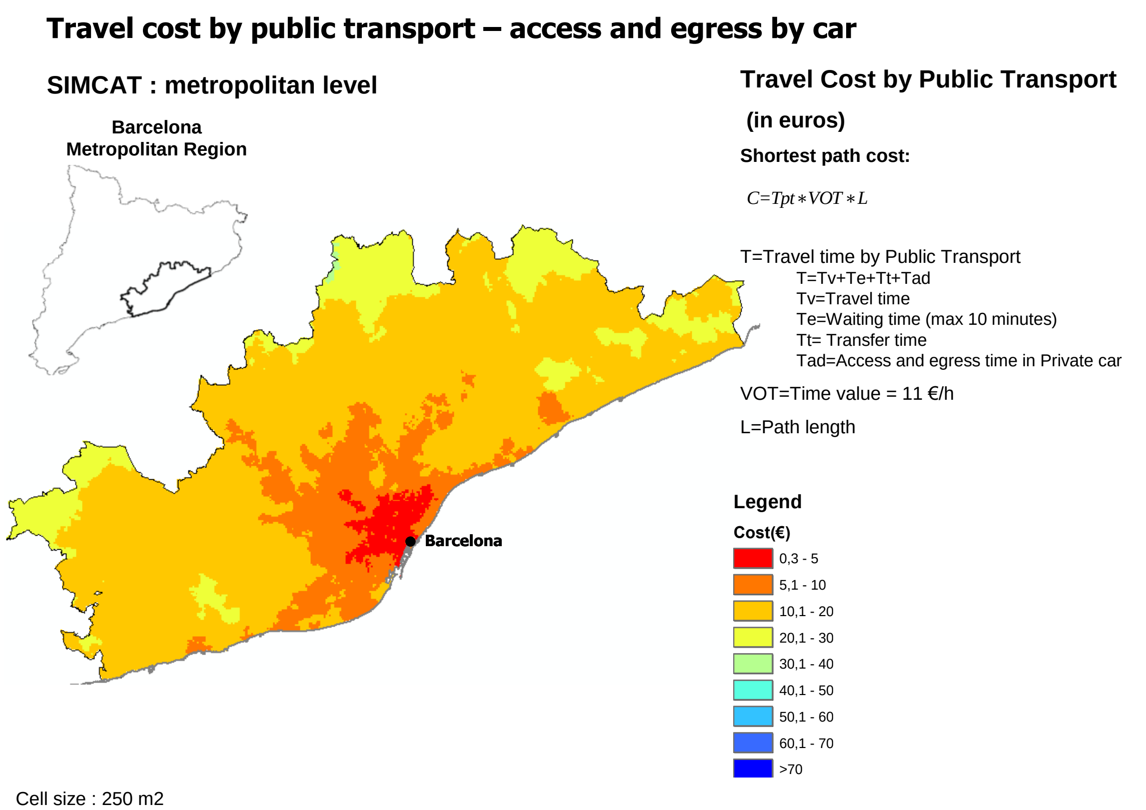


Figure 23. Travel cost (€) by car in SIMCAT Metropolitan level with access and egress by car

Comparative analysis of results

Comparison of free-flow and peak-hour speeds in Eurogeographics and SIMCAT

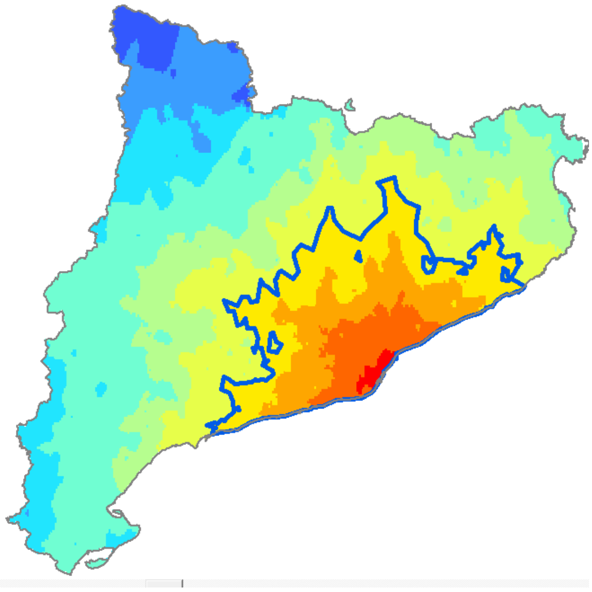


Figure 24 1 hour pivate car free flow speed Eurogeographics ERM

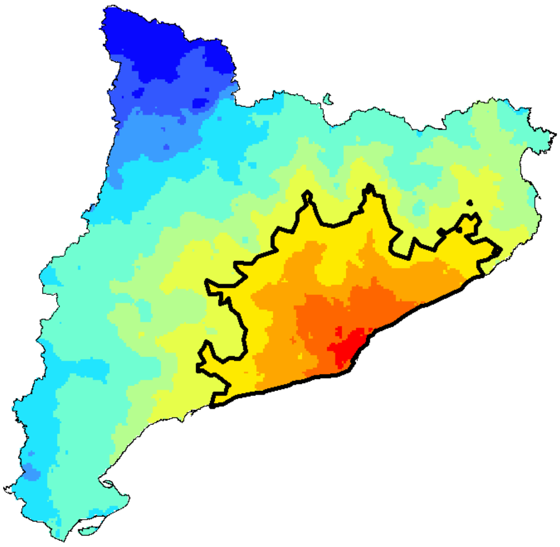


Figure 25 1 hour pivate car free flow speed SIMCAT Regional

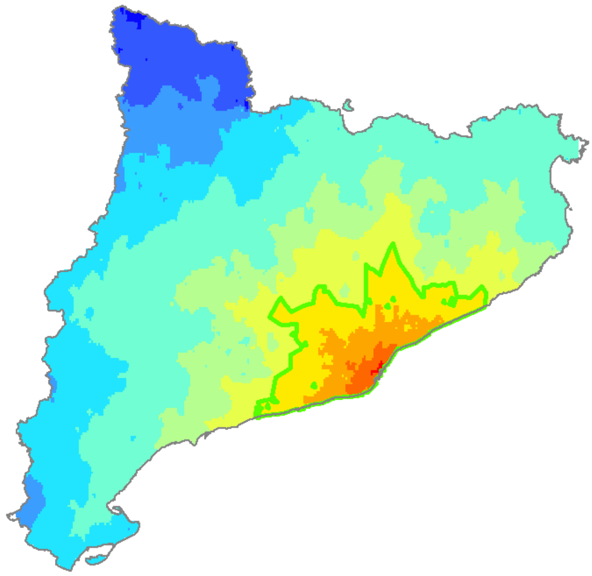


Figure 26 1 hour pivate car peak hour speed Eurogeographics ERM

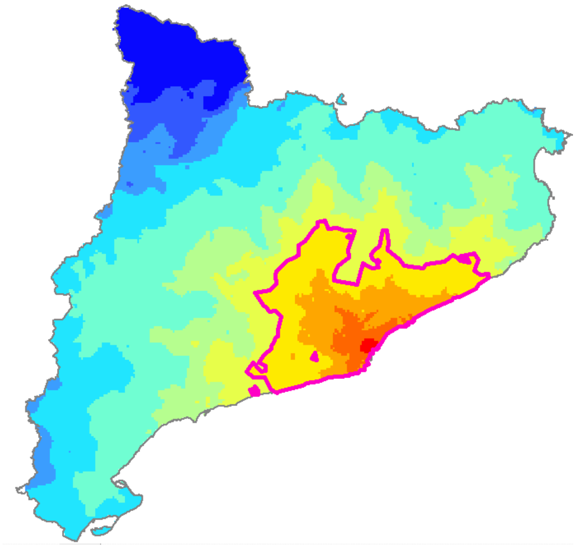


Figure 27 1 hour pivate car peak hour speed SIMCAT Regional

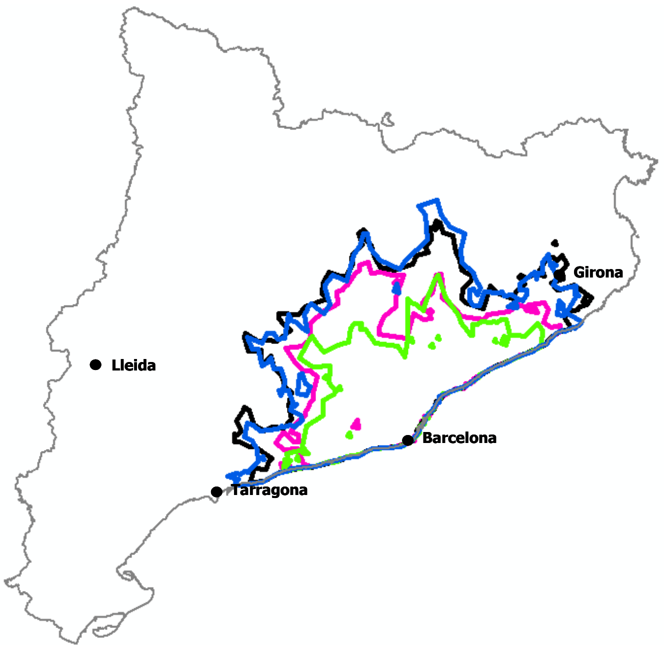
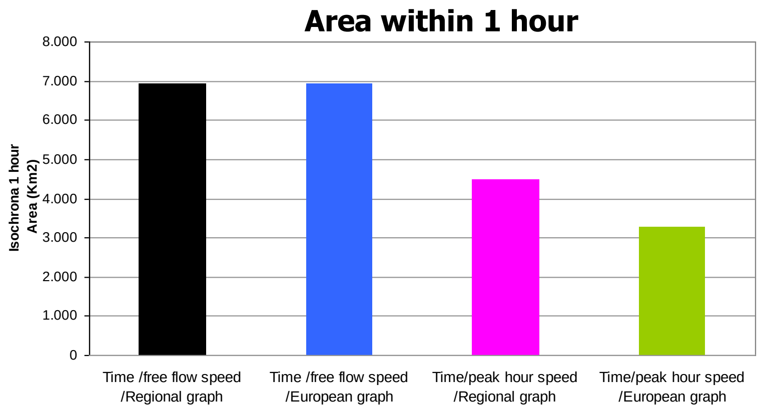
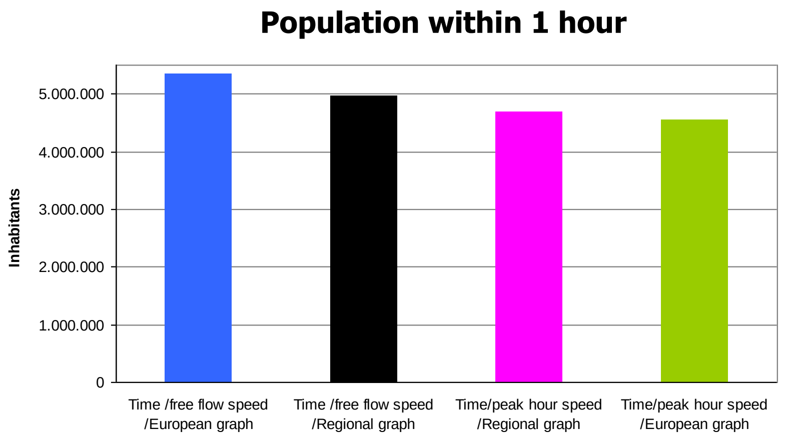


Figure 28. 1 hour travel time by car overlapping areas



Graphic 3. Area within one hour travel time by car



Graphic 4. Population within one hour travel time by car

Considering access and parking time in Eurogeographics and SIMCAT:

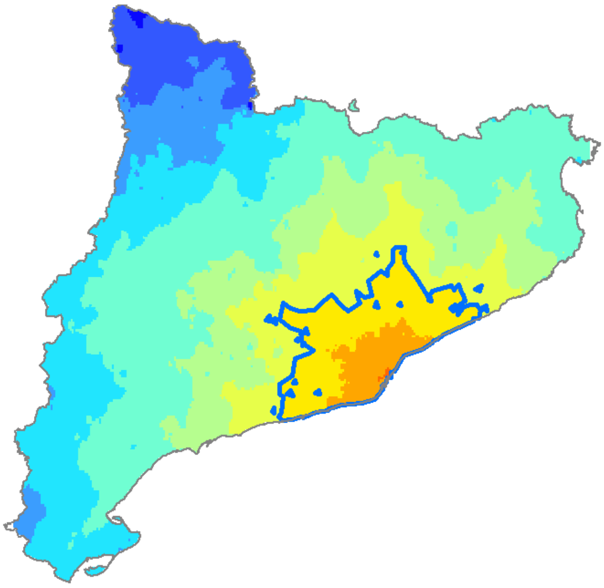


Figure 29. 1 hour pivate car free flow speed (access and parking time) Eurogeographics ERM

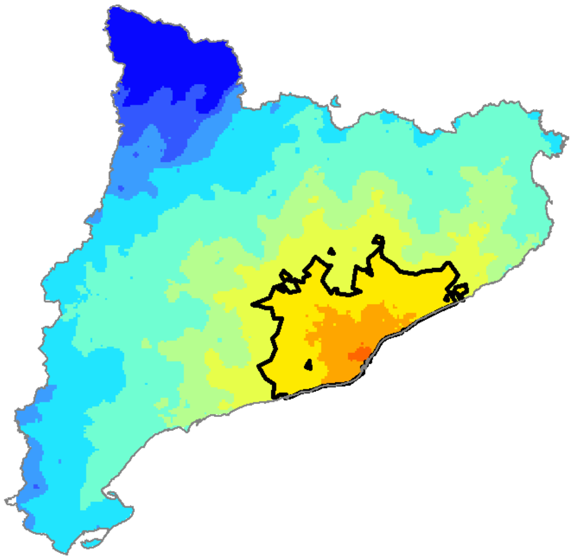


Figure 30. 1 hour pivate car free flow speed (access and parking time) SIMCAT Regional

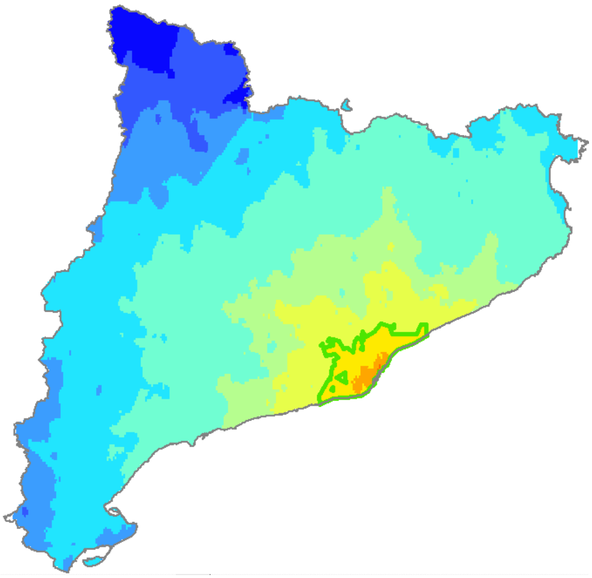


Figure 31. 1 hour pivate car peak hour speed (access and parking time) Eurogeographics ERM

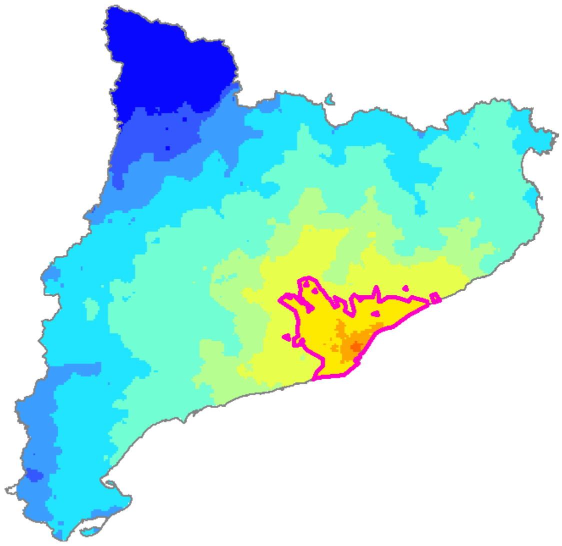


Figure 32. 1 hour pivate car peak hour speed (access and parking time) SIMCAT Regional

Figures 28, 31 and 32: consider that with peak-hour speed, ERM (in green) and Simcat (in red) overlap quite well, except in the north of Barcelona.
This is caused because the links have a different hierarchy in the ERM graph, with a lower speed than the real one. The definition can not be authomatic.

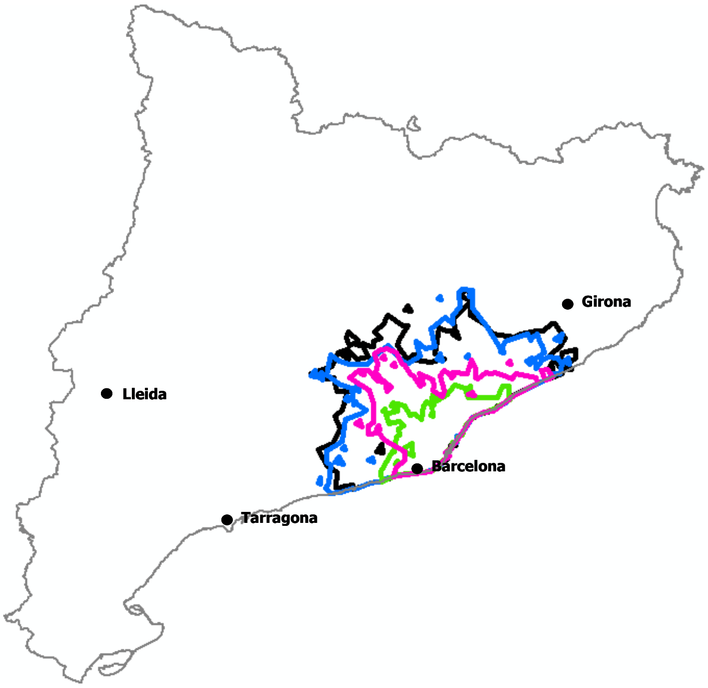
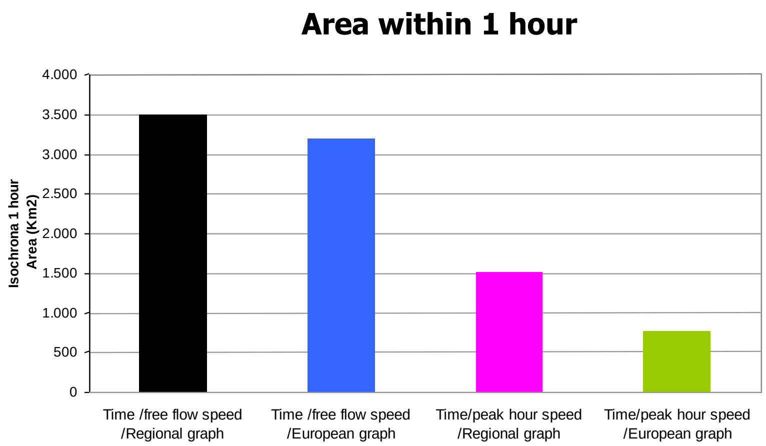
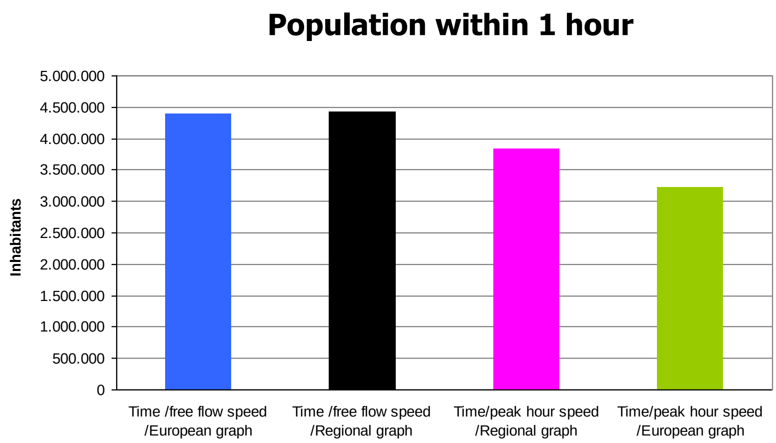


Figure 33. 1 hour travel time by car with access and parking time overlapping areas



Graphic 5. Area within one hour travel time by car (access and parking time)



Graphic 6. Population within one hour travel time by car (access and parking time)

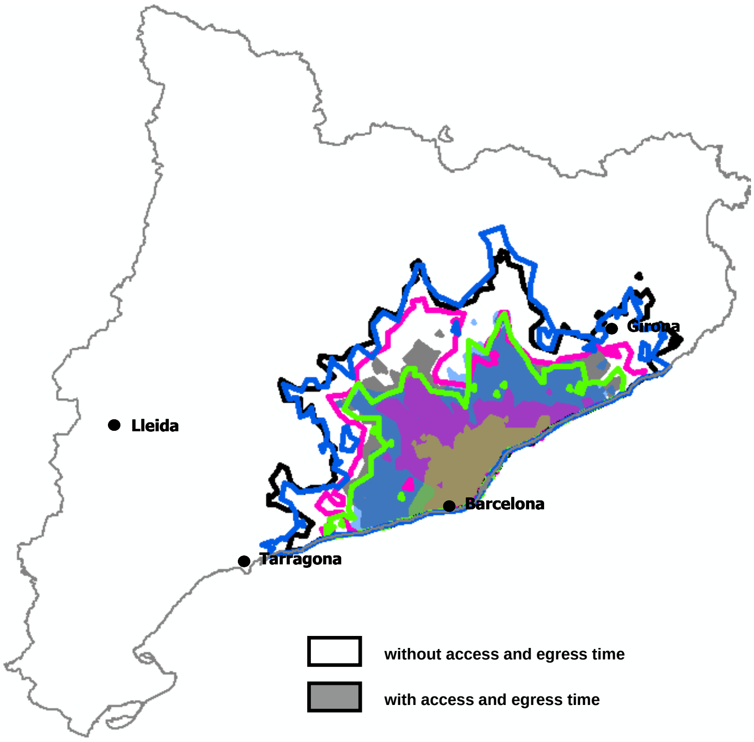
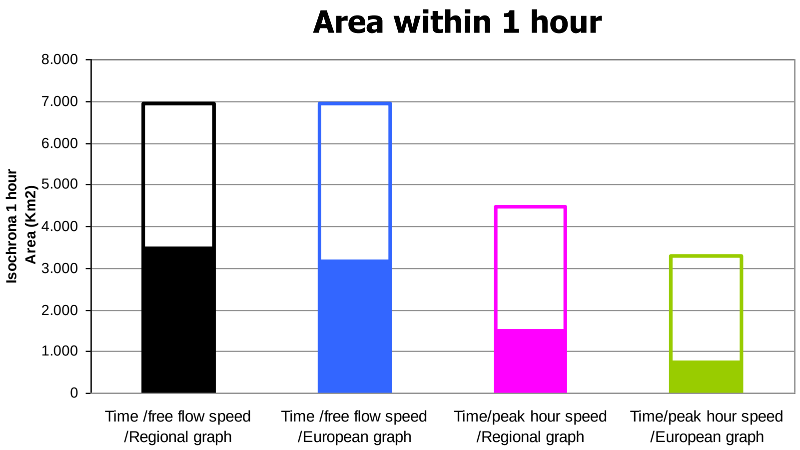


Figure 34. 1 hour travel time by car with and without access and parking time overlapping areas



Graphic 7. Area within one hour travel time by car with and without access and parking time

Considering public transport in SIMCAT, results are as follows:

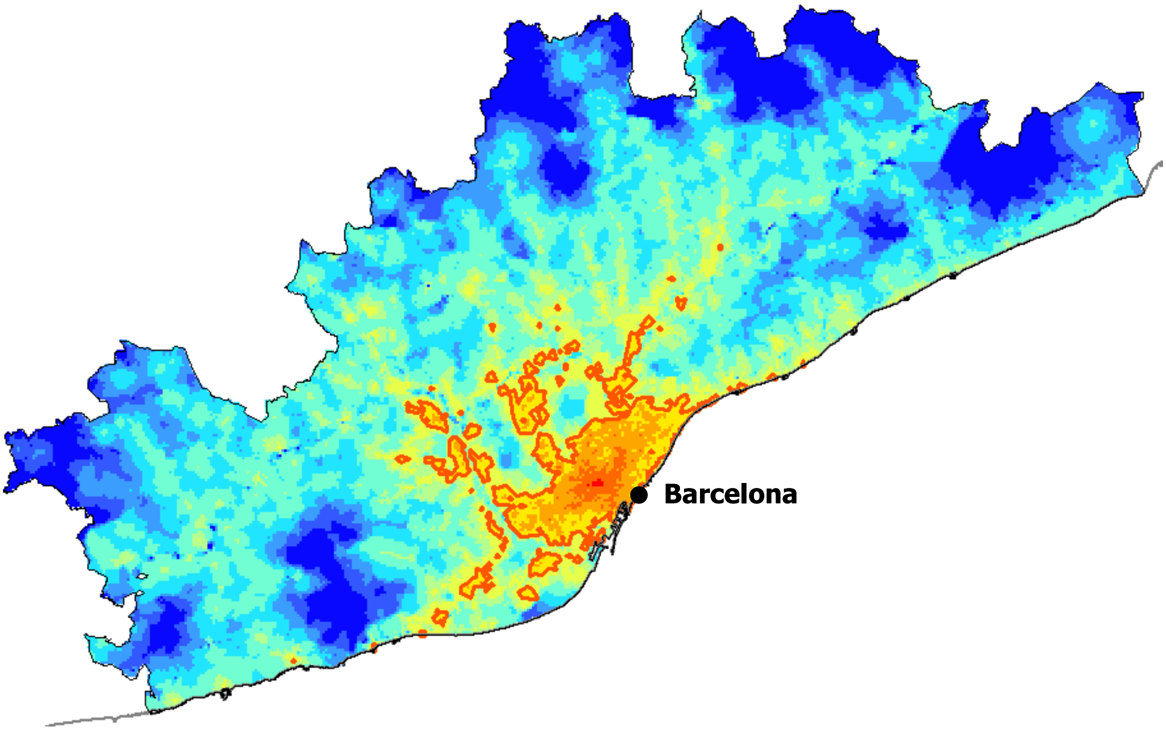


Figure 35. 1 hour travel time by public transport, access and egress time on foot. SIMCAT Metropolitan level

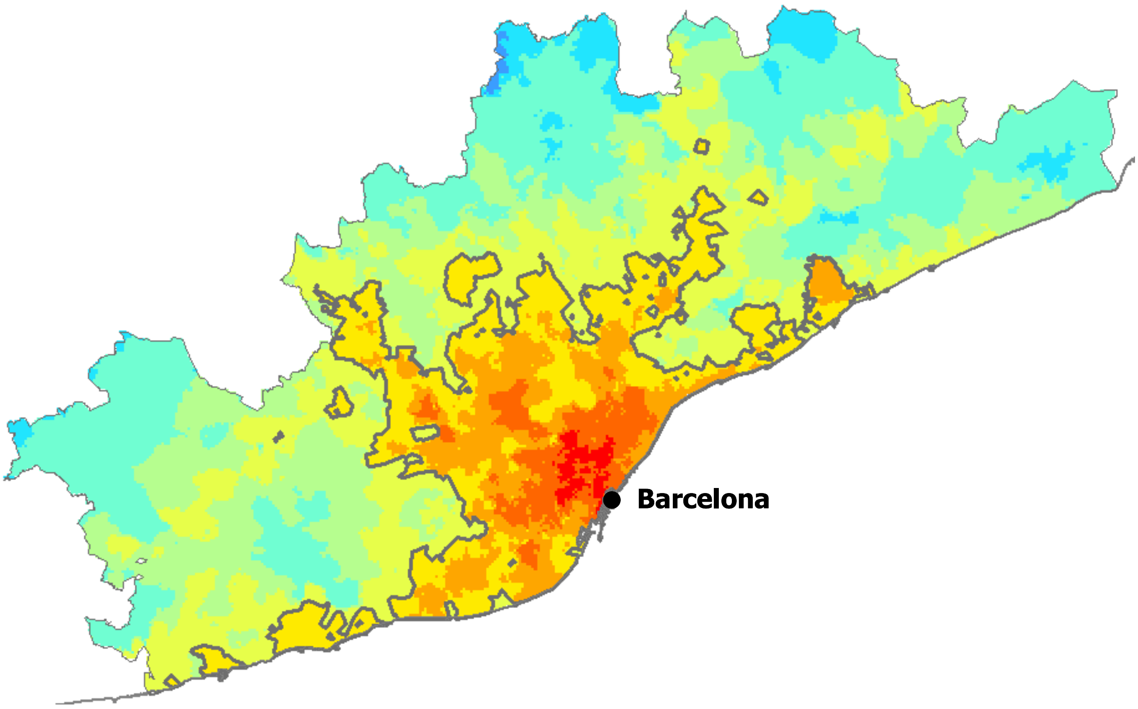


Figure 36. 1 hour travel time by public transport, access and egress time by car. SIMCAT Metropolitan level

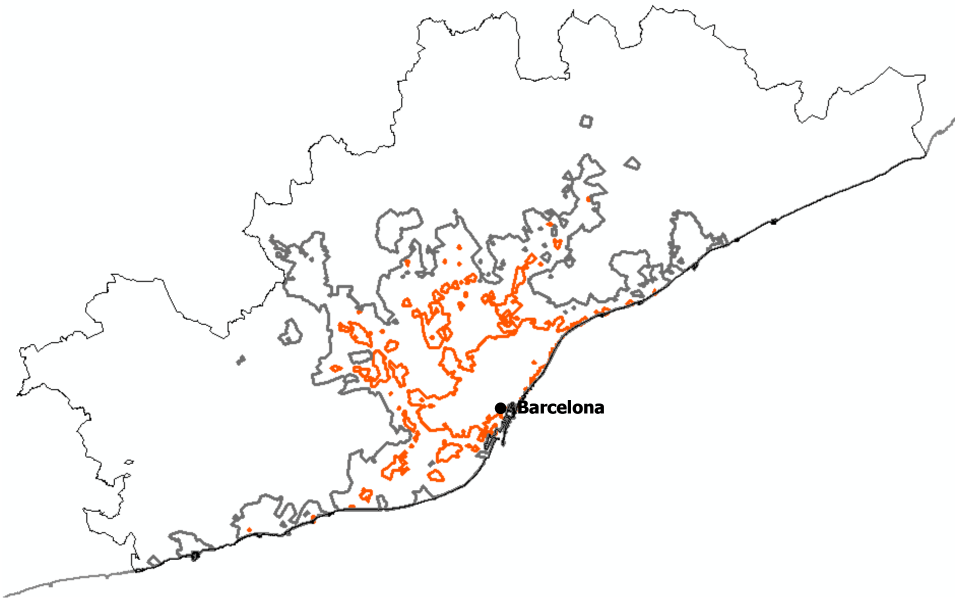
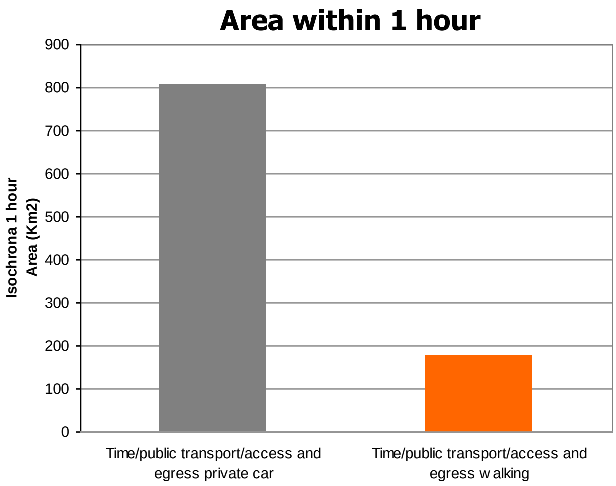
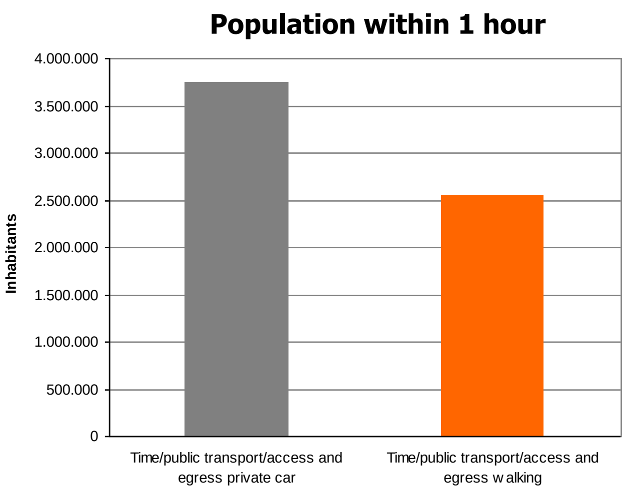


Figure 37. 1 hour travel time by public transport, access and egress time on foot and by car, overlapping areas



Graphic 8. Area within one hour travel time by public transport



Graphic 9. Population within one hour travel time by public transport

Considering cost (instead of time), 10 euros zones accessible by car with free-flow speed in SIMCAT

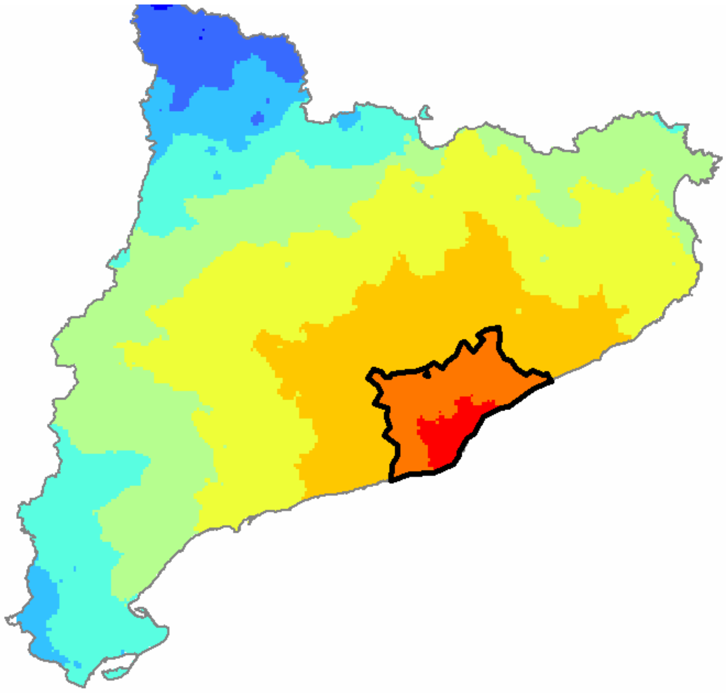


Figure 38. 10€ budget travel cost by car with free flow speed. SIMCAT Regional

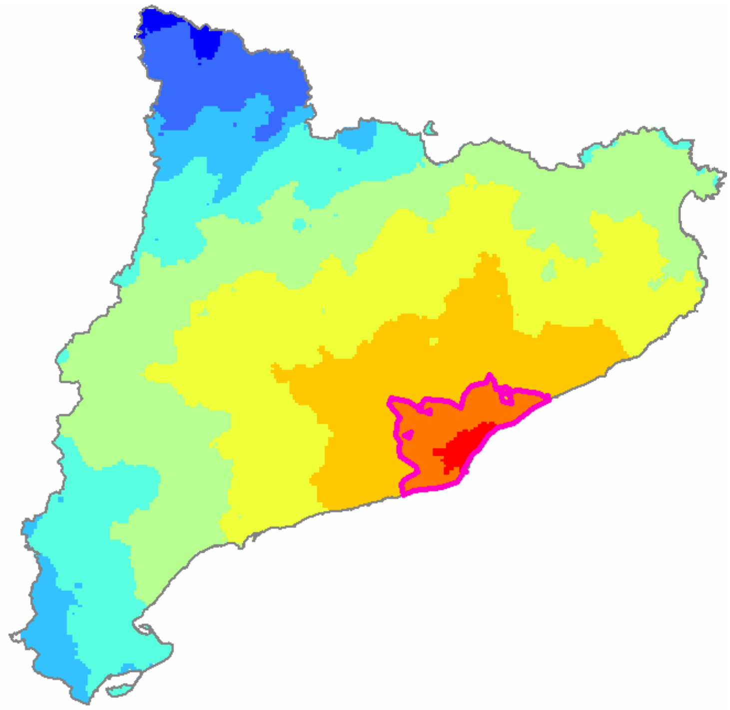


Figure 39. 10€ budget travel cost by car with peak hour speed. SIMCAT Regional

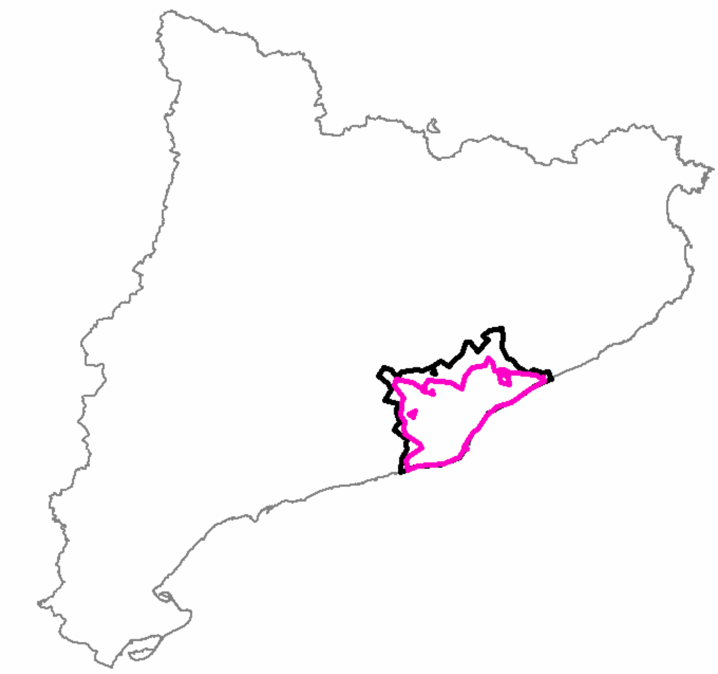
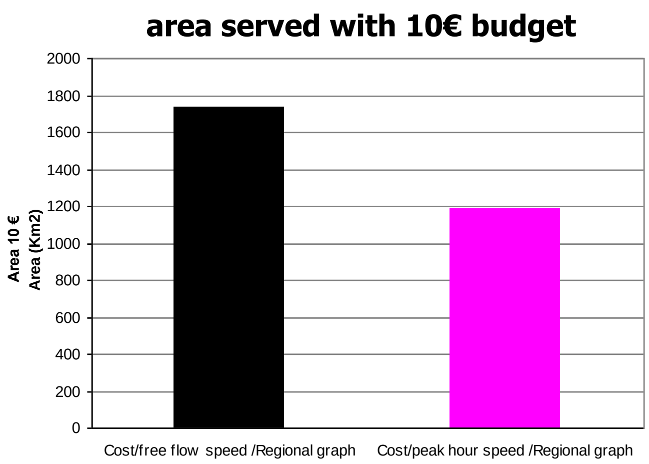
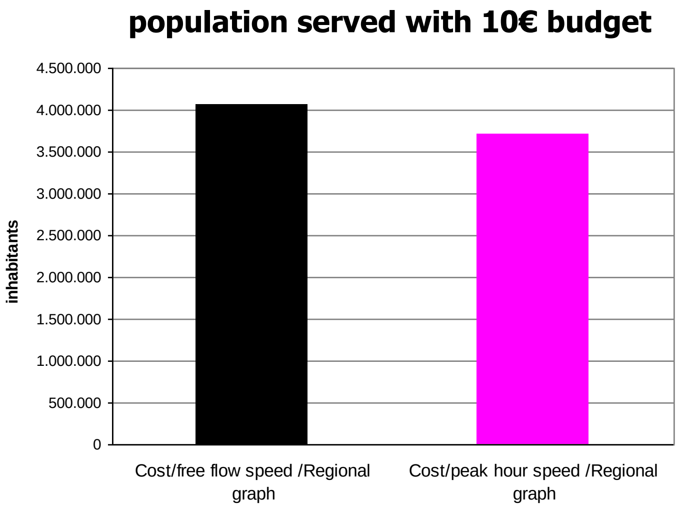


Figure 40. 10€ travel budget by car, overlapping areas



Graphic 10. Area within 10€ travel budget by car



Graphic 11. Population within 10€ travel budget by car

Considering cost (instead of time), 10 euros zones accessible by public transport in SIMCAT

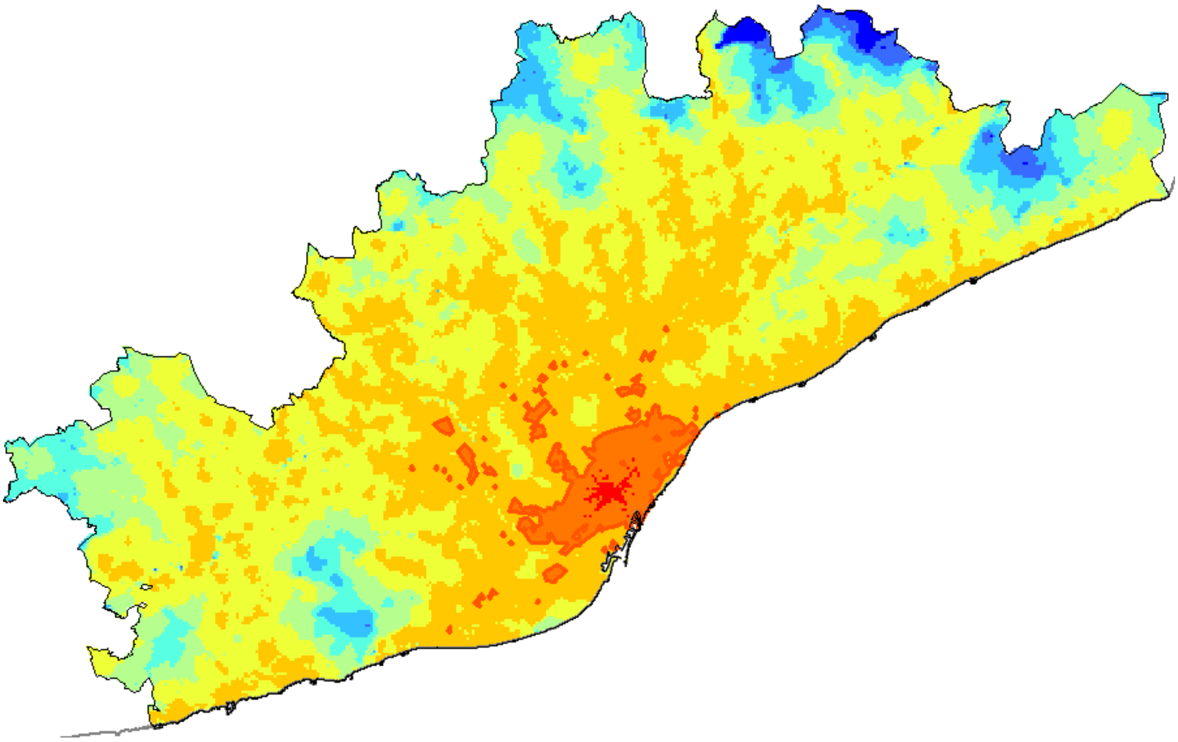


Figure 41. 10€ budget travel cost by public transport, access and egress on foot. SIMCAT Metropolitan level

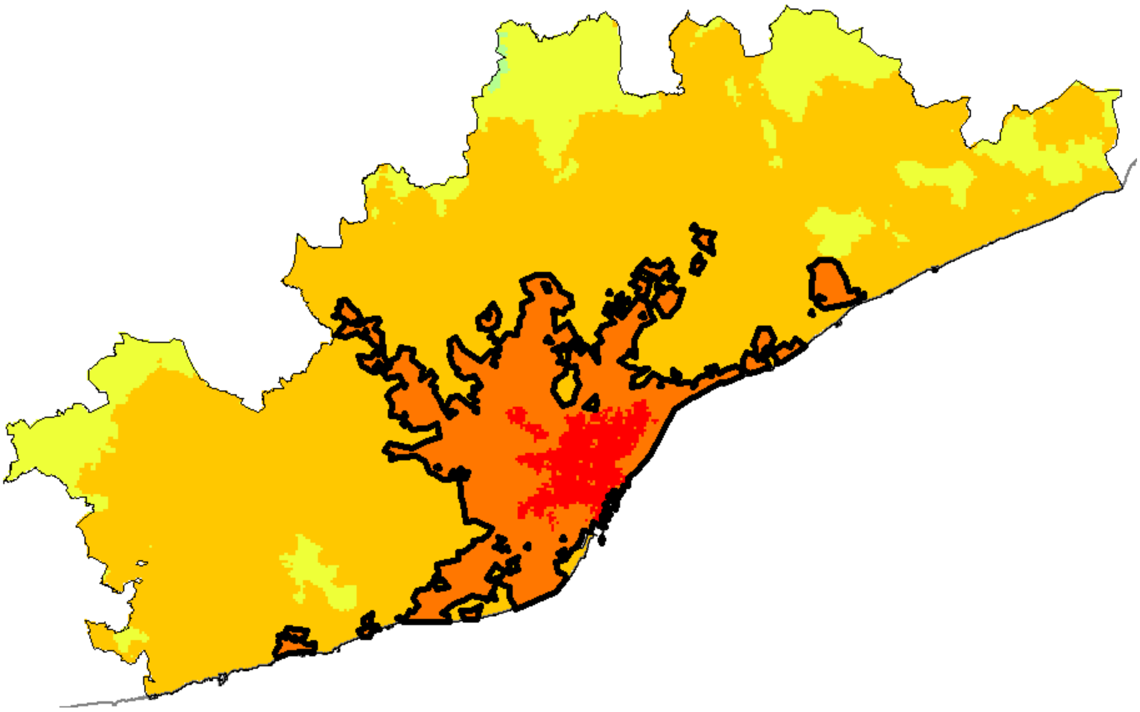


Figure 42. 10€ budget travel cost by public transport, access and egress by car. SIMCAT Metropolitan level

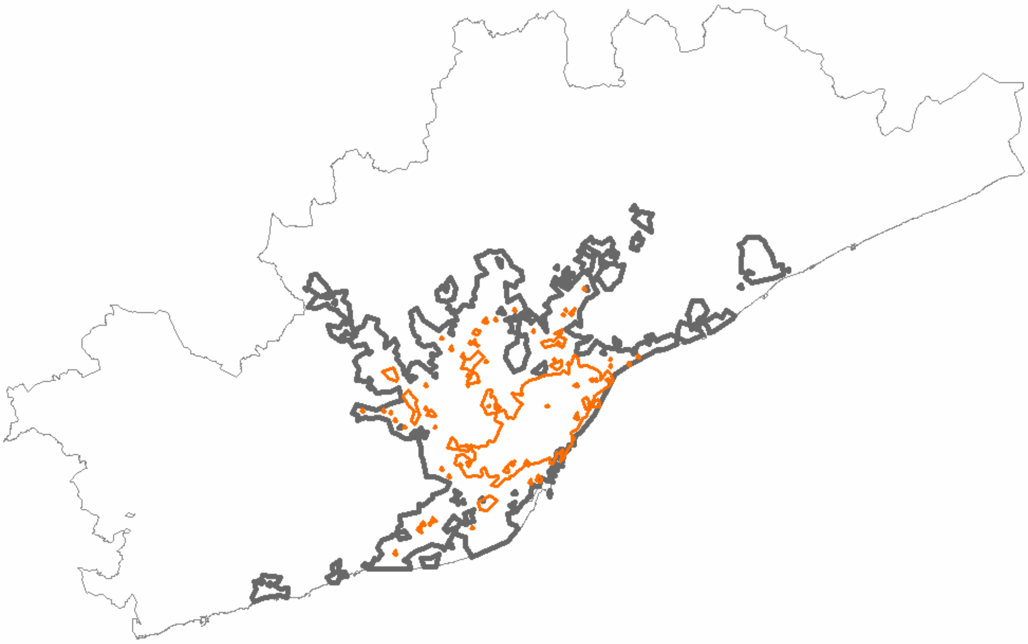
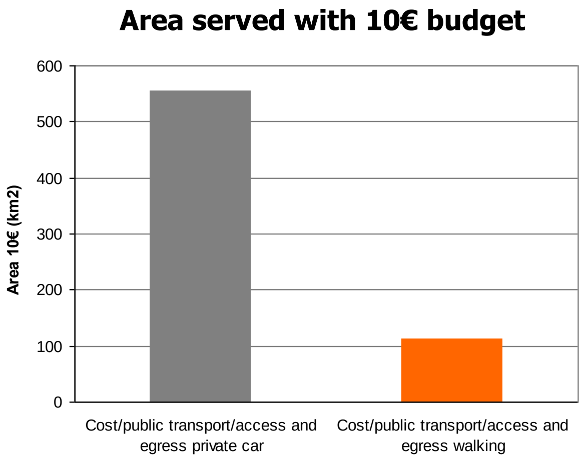
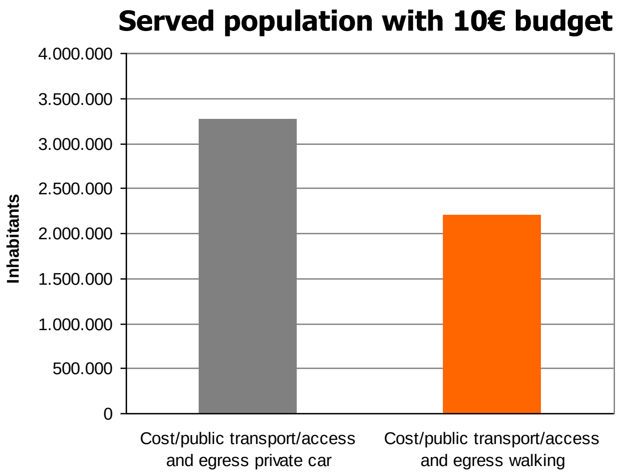


Figure 43. 10€ travel budget on foot and by car, overlapping areas



Graphic 12. Area within 10€ travel budget by public transport



Graphic 13. Population within 10€ travel budget by public transport

Conclusions from the First and Second Phases

Road-based simple accessibility indicators present similar results when using either detailed metropolitan graphs or European simplified graphs, because it is the layout of graphs what really determines the results.

When peak hour speed (instead of just free-flow), as tolls, and specially access and parking times, results become increasingly different between metropolitan and European graphs.

At European level, the interest of using a simplified road information system to calculate functional metropolitan areas seems unclear. Results will not necessarily be more precise than using UMZ or even any easier rule (e.g. 30 km from the centre of the capital).

Public transport related indicators (bus, metropolitan rail services) are far more related to labour markets that road-based indicators. At 1 hour door-to-door travel time by public transport we can reach most of the so-called AMB (metropolitan functional area of the city).

Based on this conclusions, in a third phase road and rail Eurogeographics graphs are combined to make the best possible use of them to deliminate meaningful labour market zones based on accessibility calculations.

Multimodal Analysis with Eurogeographics (Third Phase)

Eurogeographics, *Euro Regional Map (ERM)* includes the following entities:

Features	Description	Number	Entity type
Rail	Railway network at european level	2.749	link
Stations	Railway stations at euroepan level	377	stop

These entities are imported into the GIS

Features	Description	Number	Entity type
Centroid municipality	geographical center of the municipality	1	node
Connectors	link that connect centroid to rail network (METRO simulation)	5	link

Commercial rail speeds are defined based on the hierarchy of the link:

Rail hierarchy	Commercial speed (km/h)
High speed line	**220**
Main line	**90**
Main line FGC-Manresa	**40**
Main line FGC-Vallès	**50**
Branch line	**90**

The multimodal chains being established are as follows:

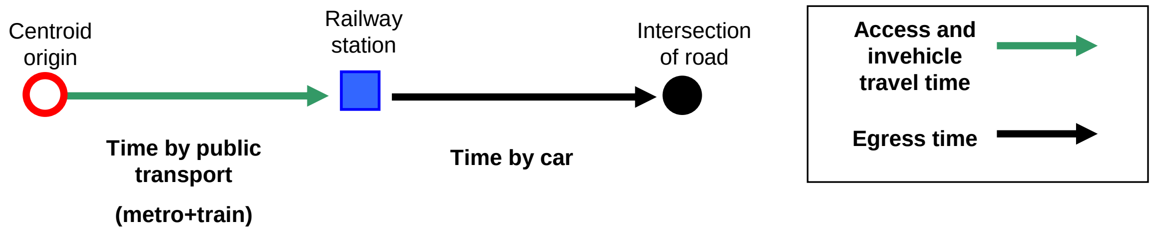


Image 5. Scheme multimodal graph

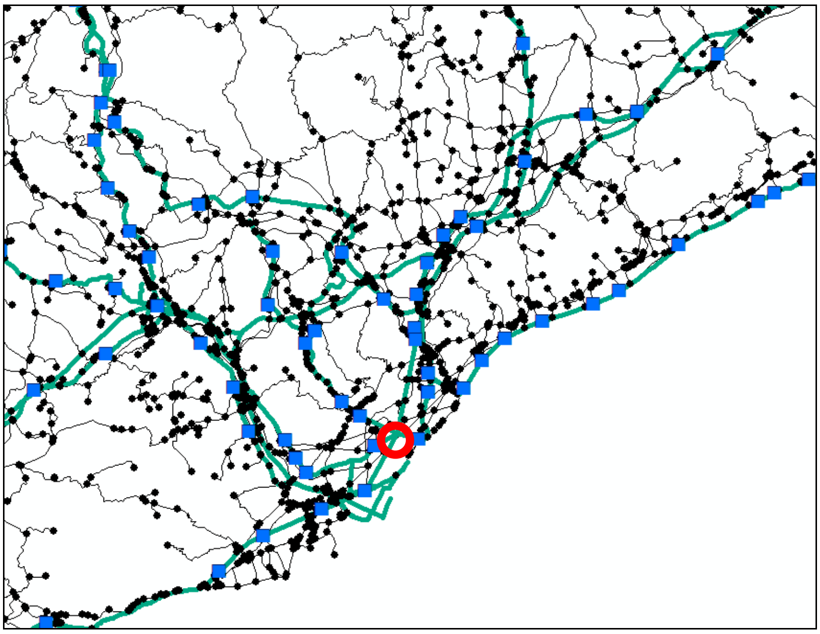


Image 6. Multimodal graph sample (displaying the rail stations and the road intersections)

The generalised travel time is calculated as follows:

$$T_A + T_B + T_C$$

$$T_A = \frac{L}{V_m}$$

where,

- *L: path length*
- *Vm: METRO commercial speed*

$$T_B = \frac{L}{V_t}$$

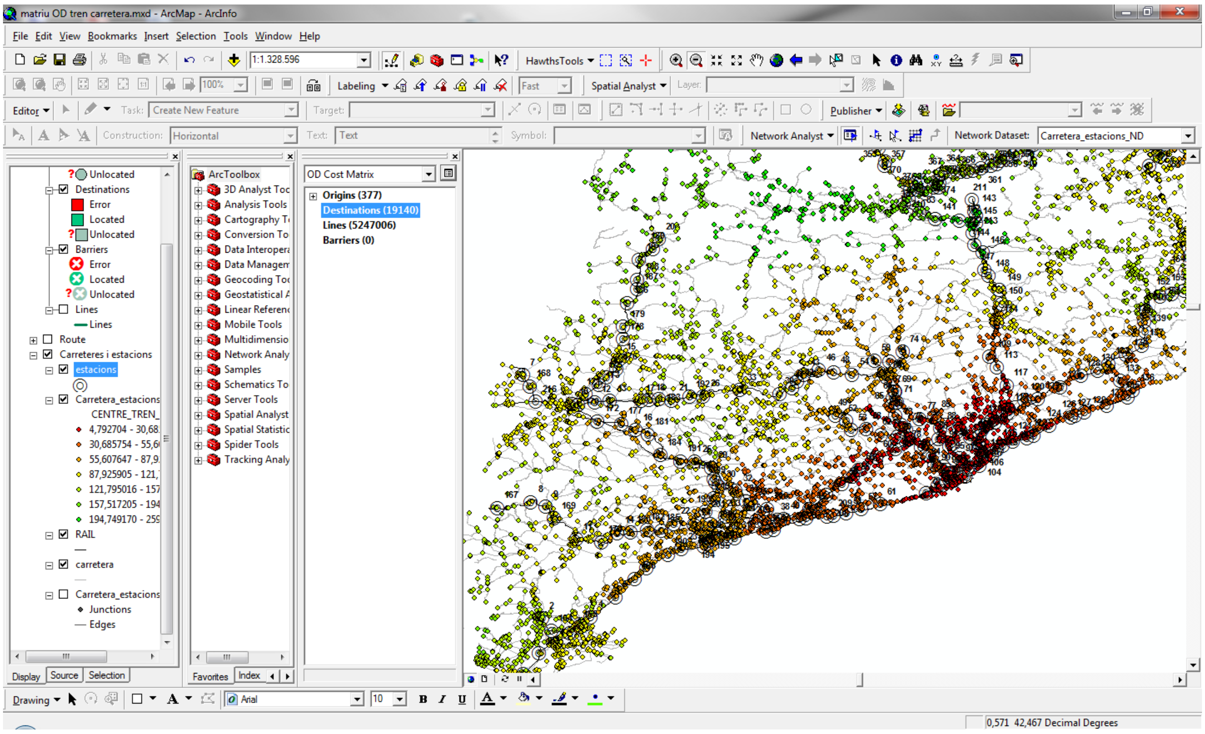
where,

- *L: path length*
- *Vt: train commercial speed (free flow)*

$$T_C = \frac{L}{V_{fl}}$$

where,

- *L: path length*
- *Vfl: free flow speed*



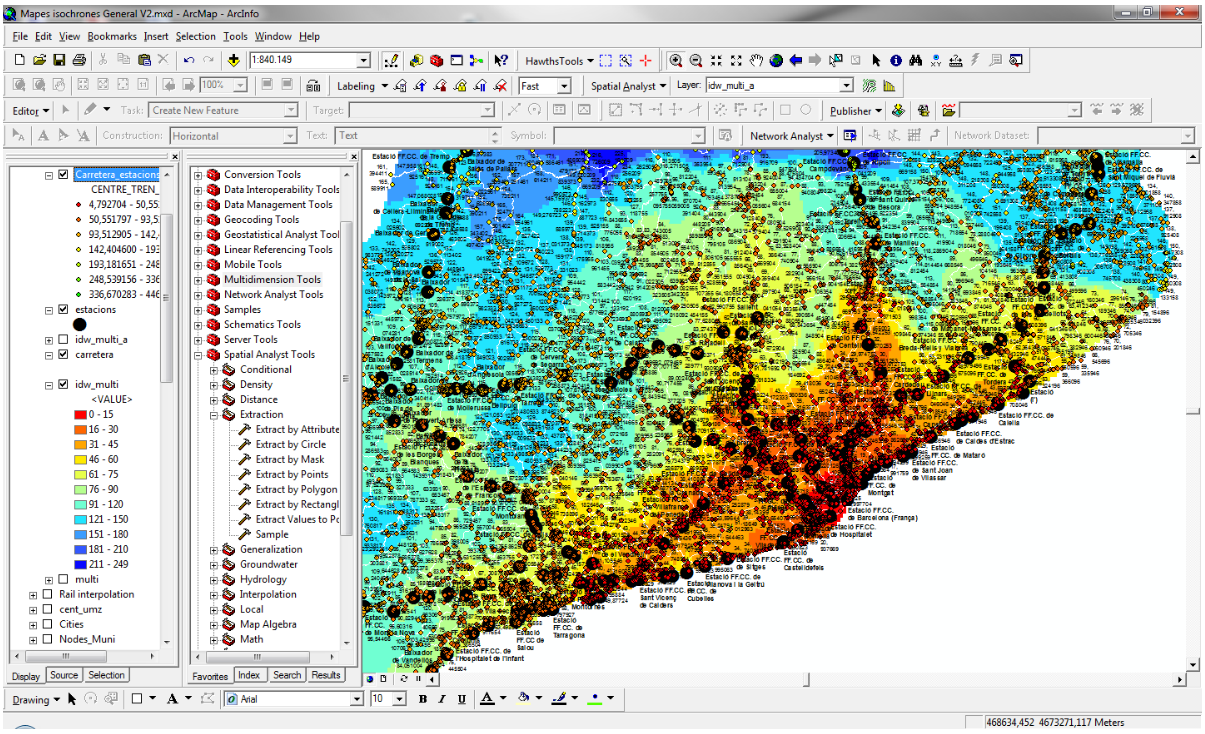


Image 7. Matrix OD results sample

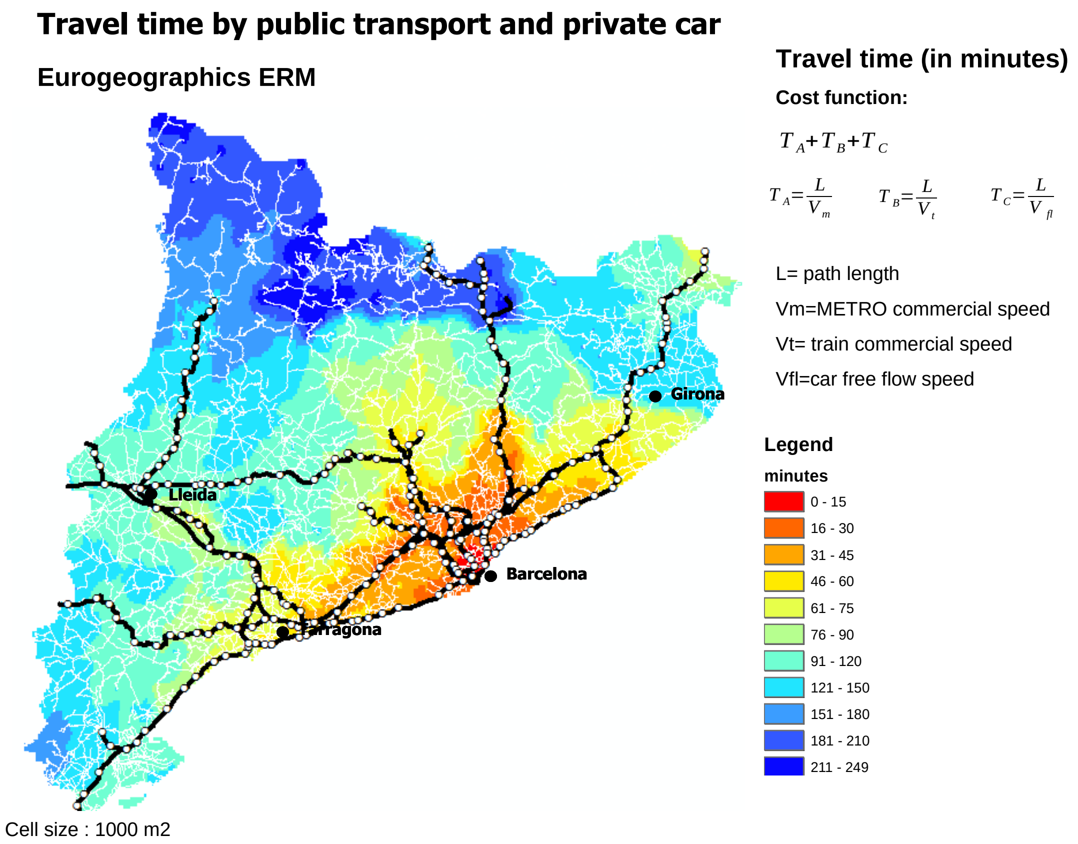


Figure 44. Travel time by rail and road in Eurogeographics ERM

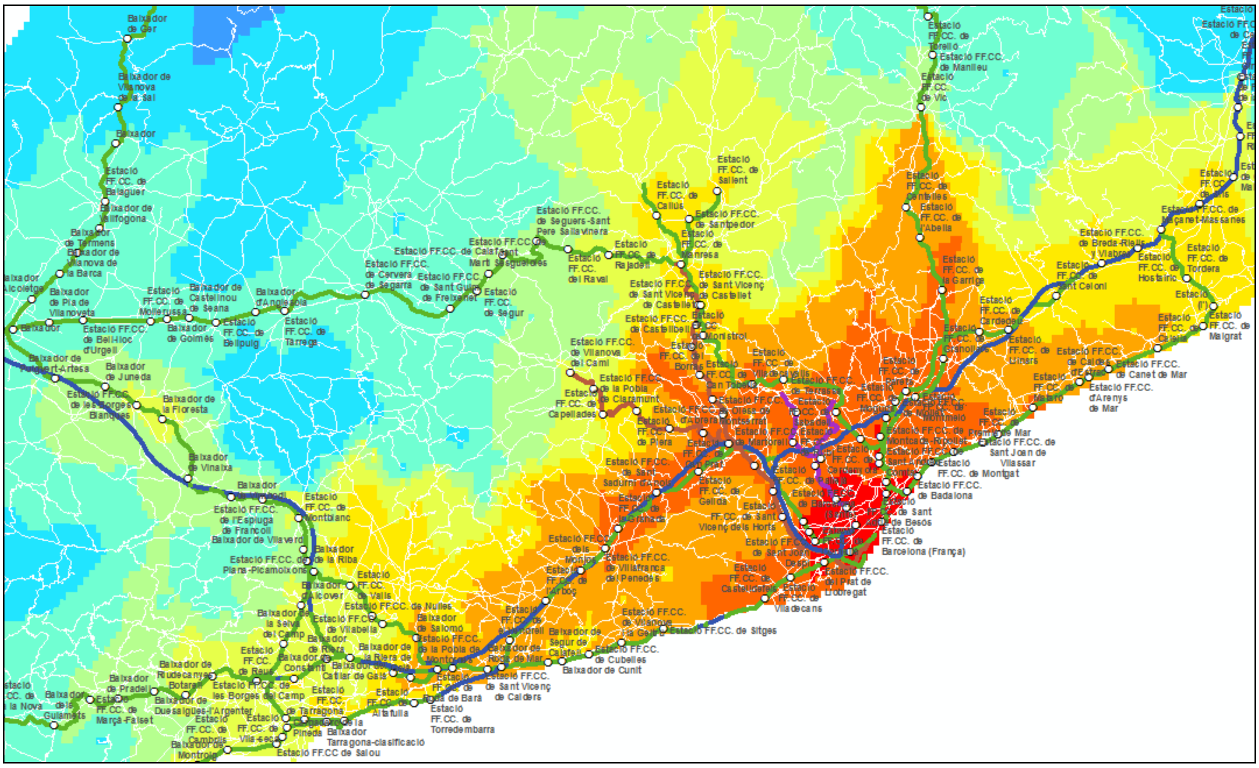


Figure 45. Zoom: Travel time by rail and road in Eurogeographics ERM

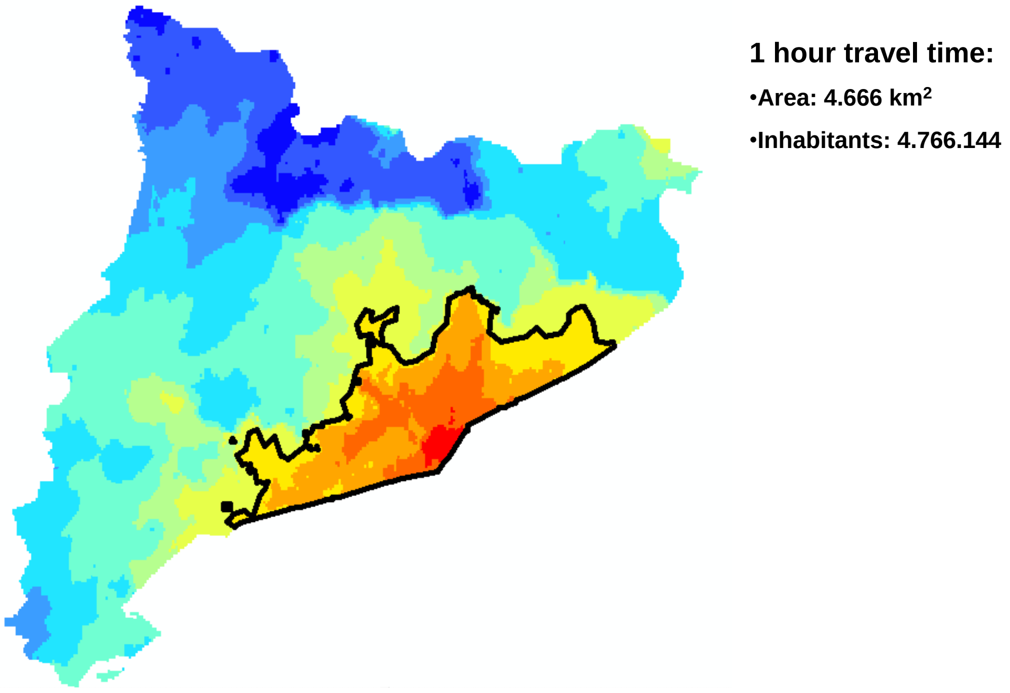


Figure 46. 1 hour travel time by public transport and private car, Eurogeographics ERM

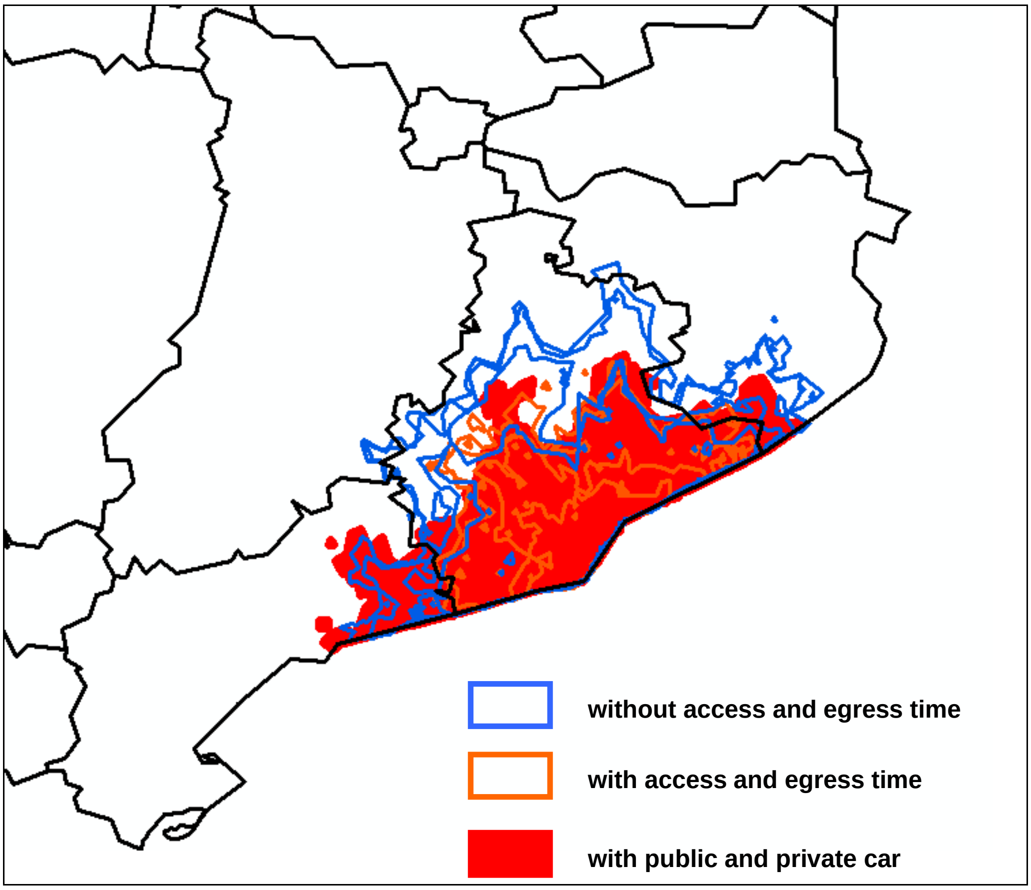
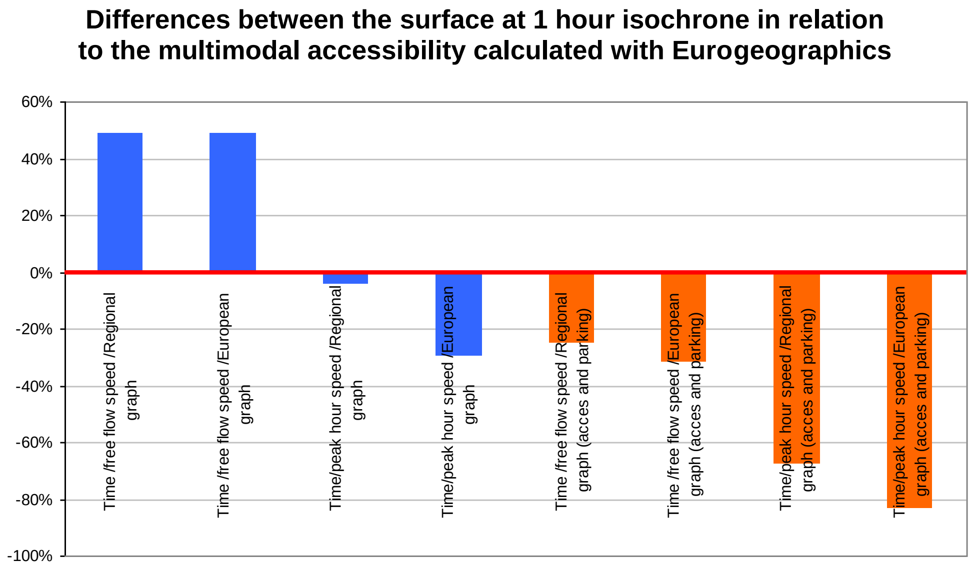
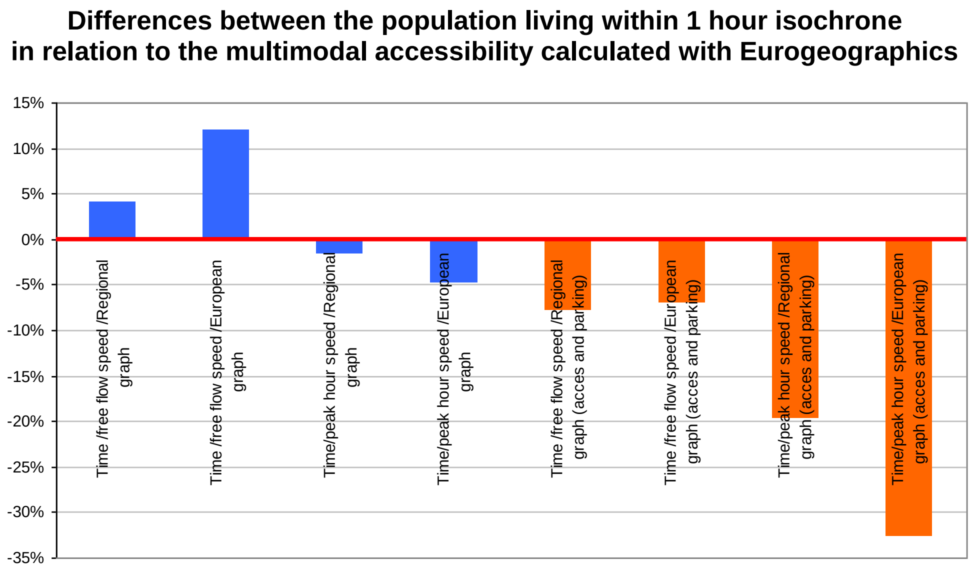


Figure 47. 1 hour travel time by rail and road on Eurogeographics ERM. Overlapping areas



Graphic 14. Differneces on surface at 1 hour



Graphic 15. Differences on population living at 1 hour

Conclusions

It is confirmed that Eurogeographics, *Euro Regional Map (ERM)* delivers more meaningful results when used in a multimodal approach.

Since rail is the main transport mode serving labour market areas at metropolitan scale, rail accessibility delivers better and more consistent results that just road accessibility.

In a multimodal approach, roads have to be included in the analysis to provide access to railway stations from any point of the territory. Default values for peak-hour speeds, access and parking times should also be considered.

Time is a meaningful variable, assuming rail fees to be relatively isotropic and no tolled motorways, or short distances being travelled by road, usually no motorways, just to get access to railway stations.

Next map shows the 1 hour public (rail) and private transport time in Barcelona againts the official metropolitan region; differences are minor and, to a large extend, better represent the actual metropolitan labour market.

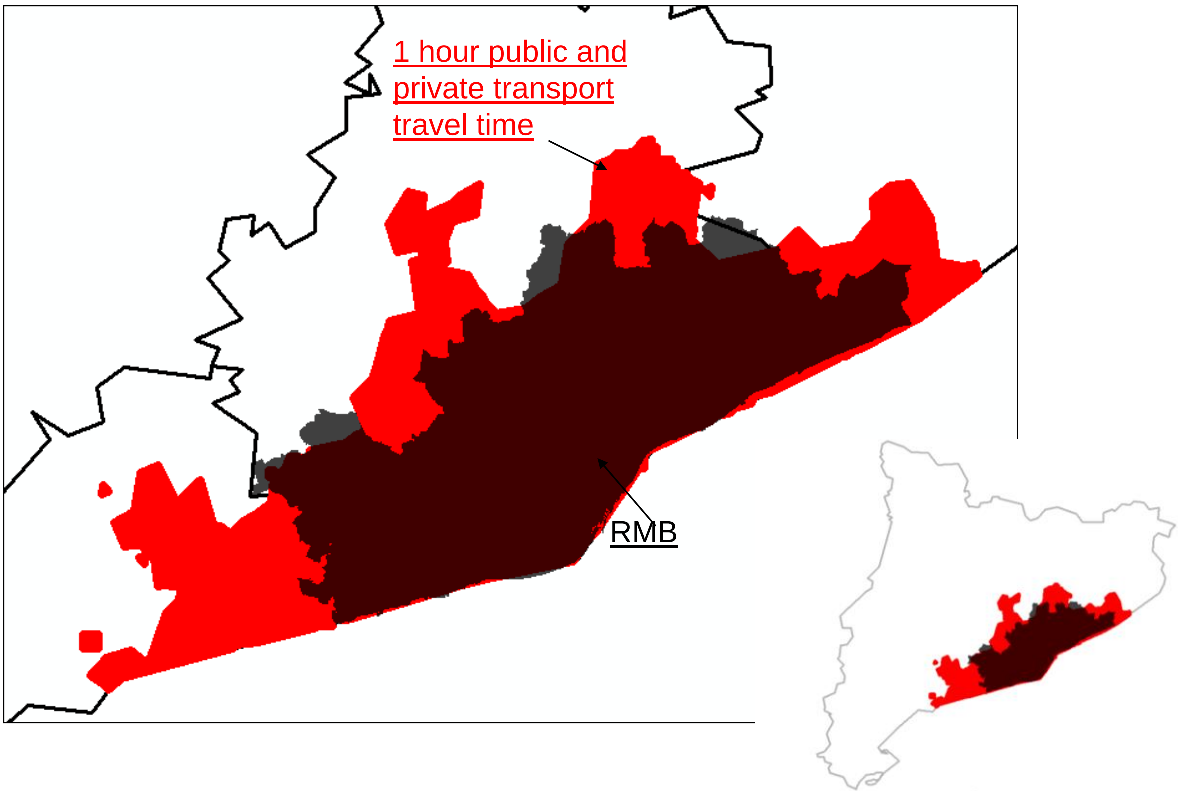


Figure 48. 1 hour travel time by public and private transport and Barcelona Metropolitan Region, Overlapping areas

As a next step of the working process should be applying the methodology just defined to the whole European territory using European rail and road graphs such as Eurogeoraphics or similar.

Mcrit