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EUROPEAN SPATIAL PLANNING OBSERVATION NETWORK

ESPON Project 1.2.1

Transport services and networks: territorial trends and basic supply of infrastructure for territorial cohesion

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Transport services and networks: territorial trends and basic supply of infrastructure for territorial cohesion

Project report

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Foreword

This is the Final Report of ESPON Project 1.2.1 "Transports services and networks: territorial trends and basic supply of infrastructure for territorial cohesion".

While doing this report for ESPON 1.2.1, our will was to give an idea of the European Space through transport networks, by considering all modes of transport. But our work was not only based on this aspect. Indeed, we have attempted to integrate to our indicators many attributes, concerning socio-economic data. By this way, it was possible not to limit our approach to the transport dimension.

In fact, three main interrogations have oriented our work:

- How may the transport network constitute a key factor of a more balanced, more polycentric, more sustainable spatial development?
- How to develop the accessibility to basic services and to knowledge in order to increase the territorial cohesion?
- What will be the consequences of enlargement on the preceding objectives

The study has a strategic and territorial approach. It is partly based on data and knowledge obtained from other studies in the transport field, but mostly based on the further development and application of approaches readily at hand of the TPG partners. More than deepening specialised transport questions, the aim is to integrate the information into a territorial dimension, which was missing before.

So, the concept developed for ESPON 1.2.1 is a combination of state-of-the-art and newly developed methodologies with the objective to describe different aspects of transport infrastructure and services in Europe and its regions.

The project report and the annex report are available at www.espon.lu

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1.1 Key messages and findings

Three main interrogations have oriented our work:

- How may the transport network constitute a key factor of a more balanced, more polycentric, more sustainable spatial development?
- How to develop the accessibility to basic services and to knowledge in order to increase the territorial cohesion?
- What will be the consequences of enlargement on the preceding objectives?

1.2 Methodological precondition

The analyses in terms of density are insufficient and unsuited to the analysis of the networks which are by nature linear and not surfacic. Even in the NUTS3, the densities at the hectare level are very variable according to the urban or rural area, and a significant number of NUTS contain several cities, which makes the centroid not easily usable as an average or representative value.

A polar analysis and representation is essential because it is more precise and realistic when there are several important communication links taken into account in the same NUTS[1].

Moreover for the representation of the number of minimal paths or flows by edge, taking into account the configuration of the network is necessary under the penalty of losing interesting information. This is also the case for costs or travel times to motorways and stations which would not be representable without that.

1.3 European space imbalance

1.3.1 Geophysics

In the European space, the first imbalance is geographical, depending on the shape, the littoral or continental position of the zone considered, its latitude, its relief. In this field the traditional map is particularly necessary to consider:

[1] It is the general case when one looks at the CESA Graph 4172 p.153

Source: Atlas mondial HATIER 1968-80 : The European space

The European system of transport undergoes strong constraints:

- the space is **cut into a succession of peninsulas**: 20 countries have maritime facades, 2 are islands and 6 are peninsular;
- **several mountainous areas partition the EU**: the Pyrenees, the Alps, Carpates, Appenins…;

- **the EU spreads in latitude from 70° to 35°**[2] ;
- **different types of climate** are present: polar, Mediterranean, continental or oceanic, of plain or high mountain;
- **the majority of mountainous solid masses are in the South** and the plains in the North ;
- **the hydrographical network is essentially directed North-West**, which consecutively influences the spatial distribution of the channels[3] and the harbours[4] ;
- **as regards inland waterways, current imbalance is obvious:** two large rivers navigable in all Europe run towards the West particularly the Danube which irrigates the lately adherent countries and the Rhone;
- **the geographical constraints influenced the settlement**. These geographical imbalances are more or less constraining according to the period, modes of production and techniques ;
- **the development of the road transport** softened this constraint;

The modification of these imbalances hardly seems possible currently.

Moreover, the urban structure has been the main cause of the development of the transport networks and their hierarchisation[5]. Indeed, between cities and transport systems there is a loop of positive feedback.

It should be noted that transport networks were at first national, which explains the variety of forms according to the countries and their own history. This observation applies to railway perhaps more than to road.

To balance the European network implies integrating former national networks that still function nationally for most of them, although they are in a community structure with community interests. This naturally leads to problems of borders especially when there are geographical constraints, and even strategic interests in the past, which can lead to vulnerable edges[6].The development of international exchanges were superimposed with the three types of networks structures (more or less centralized, grid or " ladder shaped"), according to whether the country is or is not an area of transit.

There is another source of imbalance related to the spatial position. A few countries only experience significant flows that may be subject to modal shift. These flows are important for the economic activity of the EU but do

[2] which roughly corresponds to 8 000 km
[3] see part 3 chapter 1.6 on Inlands waterways
[4] see part 3 chapter 1.6 "Seaports" and part 3 chapter 5.8 "Port traffic"
[5] see part 3 chapter 1.3.3
[6] see part 3 chapter 5.7 on Network vulnerability

not benefit the crossed country, and are sources of externalities related problems.

Imbalances linked to the geographical position of a country can not easily be compensated, excepted maybe in the cases where a modal transfer by the maritime mode is possible, partially or completely.

But if the centrality of certain countries is an old and socially still powerful phenomenon, it can nevertheless be compensated by a polycentrism that can develop at various scales. Currently, the cities networks of more than one million inhabitants dominate the space economically, administratively and intellectually. They are relayed by the MEGAs. Polycentrism questions transport at another level namely the "potential polycentrism of proximity”.

1.3.2 Access to cities, services and knowledge

The supply of services and knowledge is mainly urban in our present society if one excludes access to the Internet which is not spatially equal and even less equitable. In terms of transport and network, access to services and knowledge can be identified with accessibility to cities of various sizes. Two main indicators have been computed by the ESPON group 1.2.1.

- access by car to the three closest cities of more than 100 000 inhabitants to respect the freedom of choice of the citizens;
- accessibility by car to cities of more than 200 000 inhabitants.

Although the "pentagon" is overall much more urbanized than the "periphery", one can note that space heterogeneity in term of accessibility exists in all the countries, even in the heart of Europe, which confirms our assumption of the need for a polar analysis.

1.3.3 Access to the transportation networks

The access to the main road networks (motorways and expressways) is punctual : through the exchangers. In the same way, the access to the railway network is only possible in the stations. (cf maps p.229 and p. 231)

The same remark can be made for air and maritime transport.

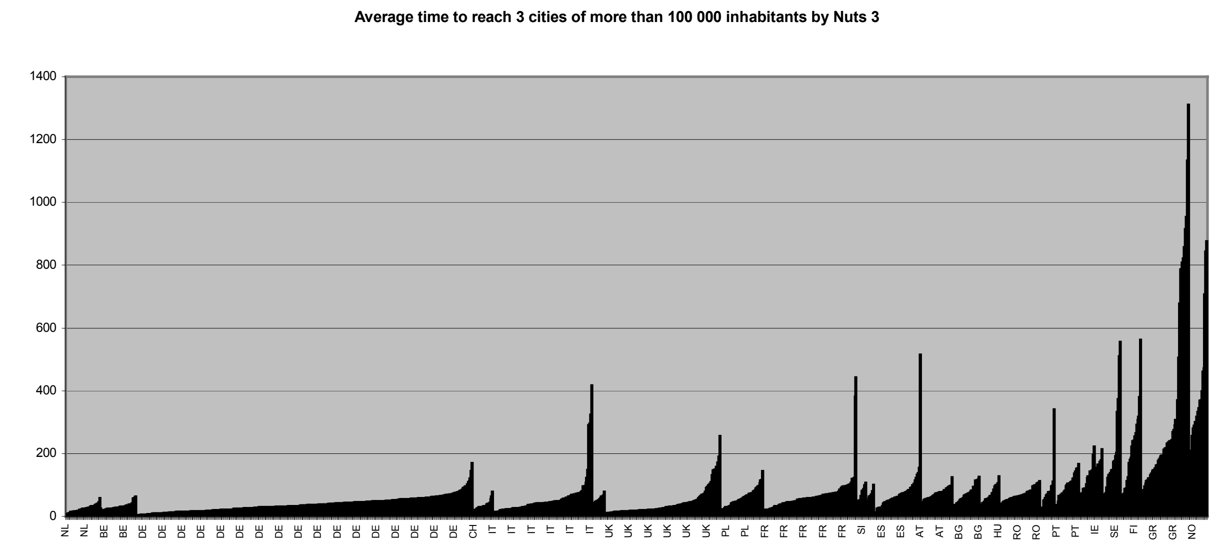

Figure 1 Average time to reach 3 cities of more than 100000 inhabitants by NUTS-3

This reinforces the discontinuous character of space in term of distances, travel times and costs. The phenomenon is even more marked for the air network.

1.3.4 Network hierarchy and fractal analysis

Let us consider the road network (motorways, expressways ...) arranged hierarchically according to the size of the cities that it connects. The networks connecting the cities of various sizes of population have relatively similar structures: overall triangular but increasingly small meshes according to the level of population, common principal nodes... This characteristic expresses the autosimilarity of structure at various levels and the fractal characteristic of the network irrigating space just like that of the human blood circulatory system[7]. The second characteristic is the discontinuity of this network which forms only one grid.

These two characteristics, together with the hierarchy of the networks, lead to the fact that the urban infrastructure can only very roughly be understood through densities and constitute a justification for the fractal approach.

The difference in size of the grid at the same hierarchical level is mainly explained by the population and the GDP: "population cartogram" shows a more regular but still discontinuous grid[8].

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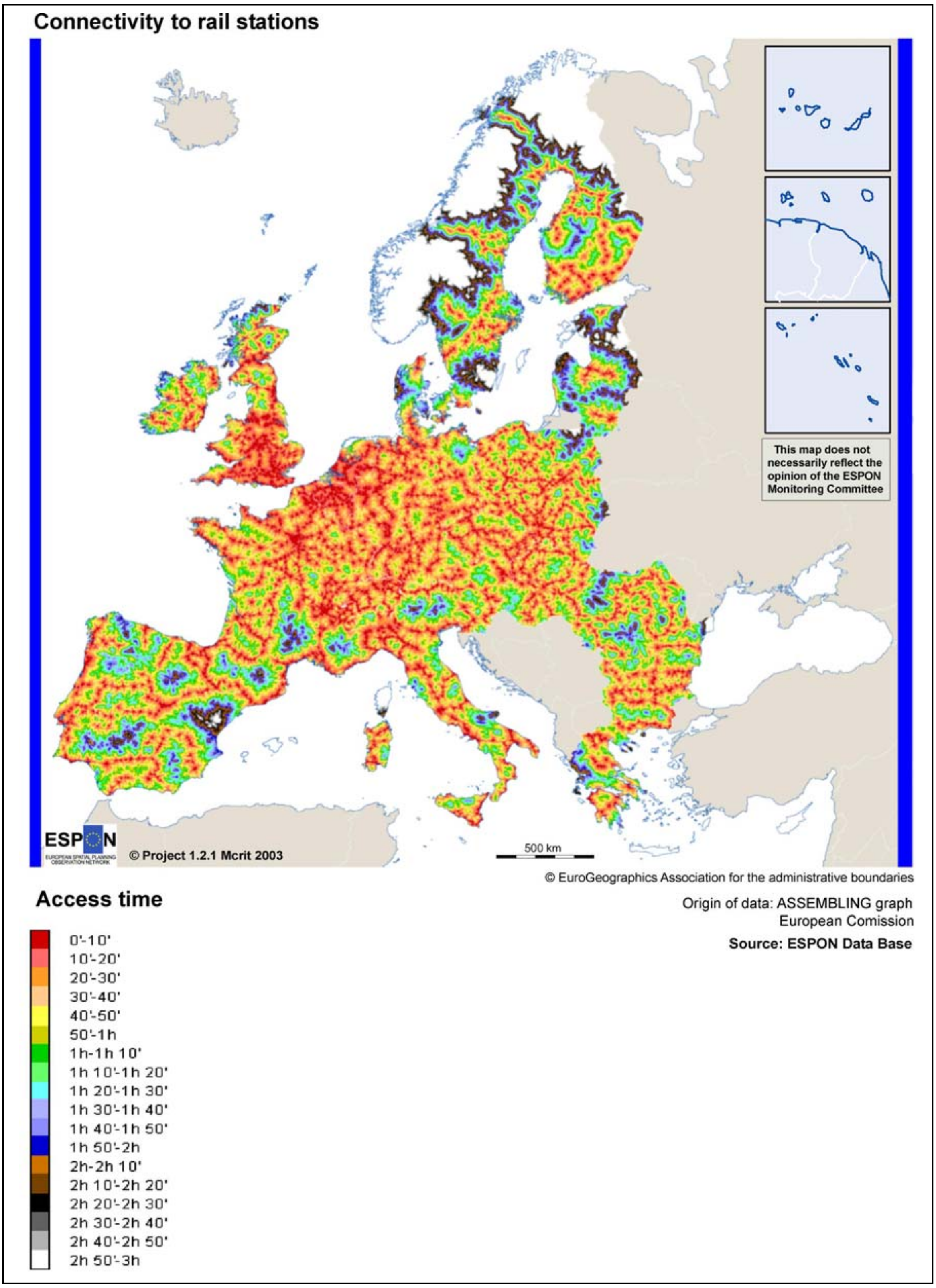
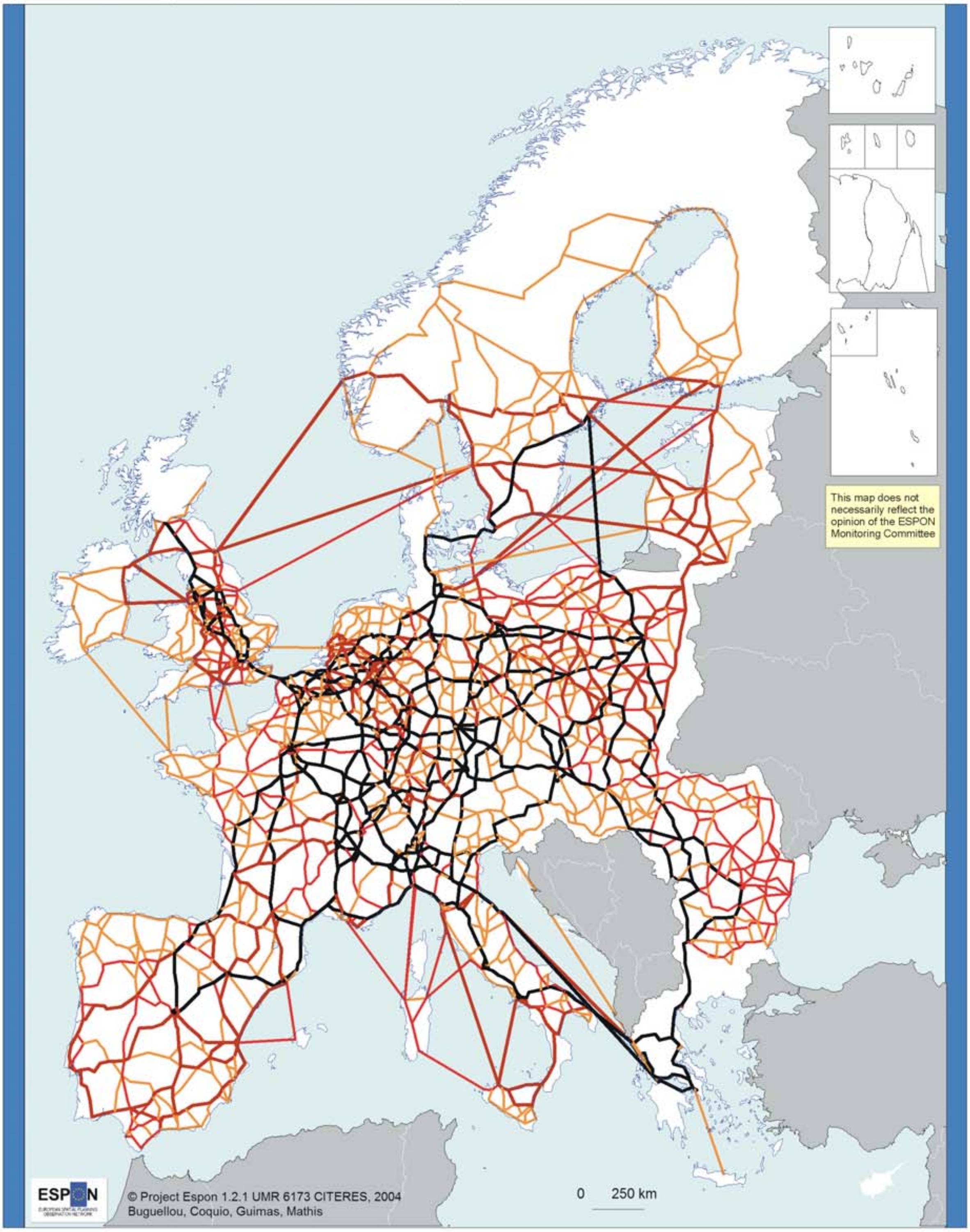
[7] which one does not represent by maps of zonal density.

[8] Cartogram of Europe deformed in function of the population by NUTS2 and weak links in transportation p.233



Connectivity to rail stations

Hierarchy of the european road network
(evaluated through the relations between cities)

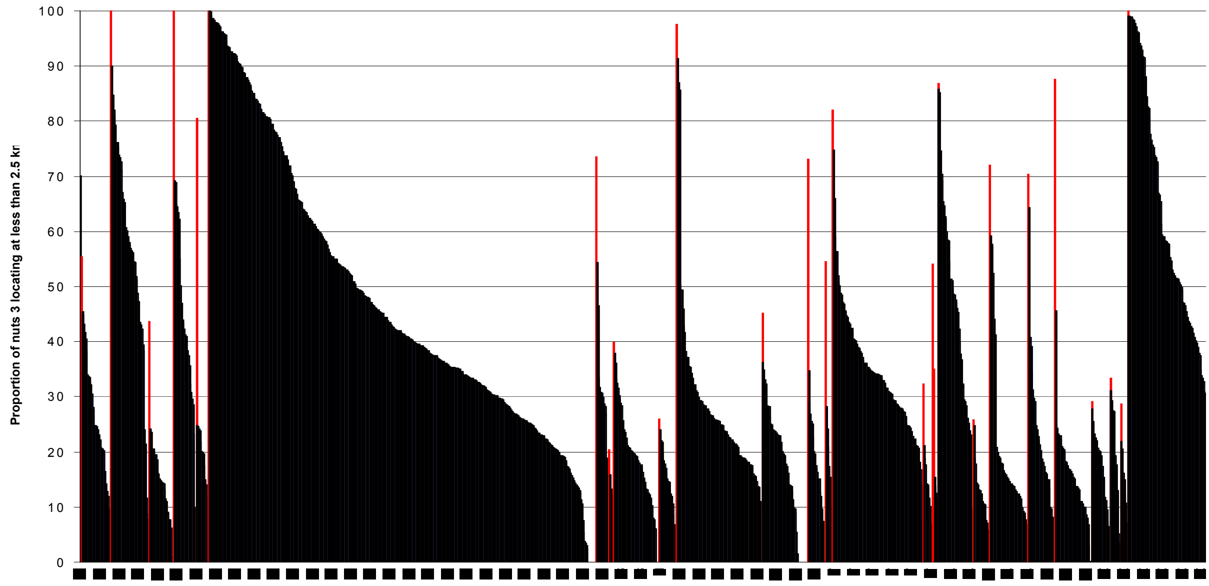


Edges allowing relations of cities of

- **more than 1 000 000 inhabitants**
- **more than 500 000 inhabitants**
- **more than 300 000 inhabitants**
- **more than 100 000 inhabitants**

Source : GISCO GIS, Scene
Graph : CESA graph 4172

If one continues the analysis by using the fractal indicators created by Benoit Mandelbrot, one notes that this heterogeneity is present at all levels as the results of the method of Minkovski (see figure p. 210) show.



Proportion of NUTS-3 locating at less than 2.5 km

The graph shows the heterogeneity well: not only between each country but also within each country.

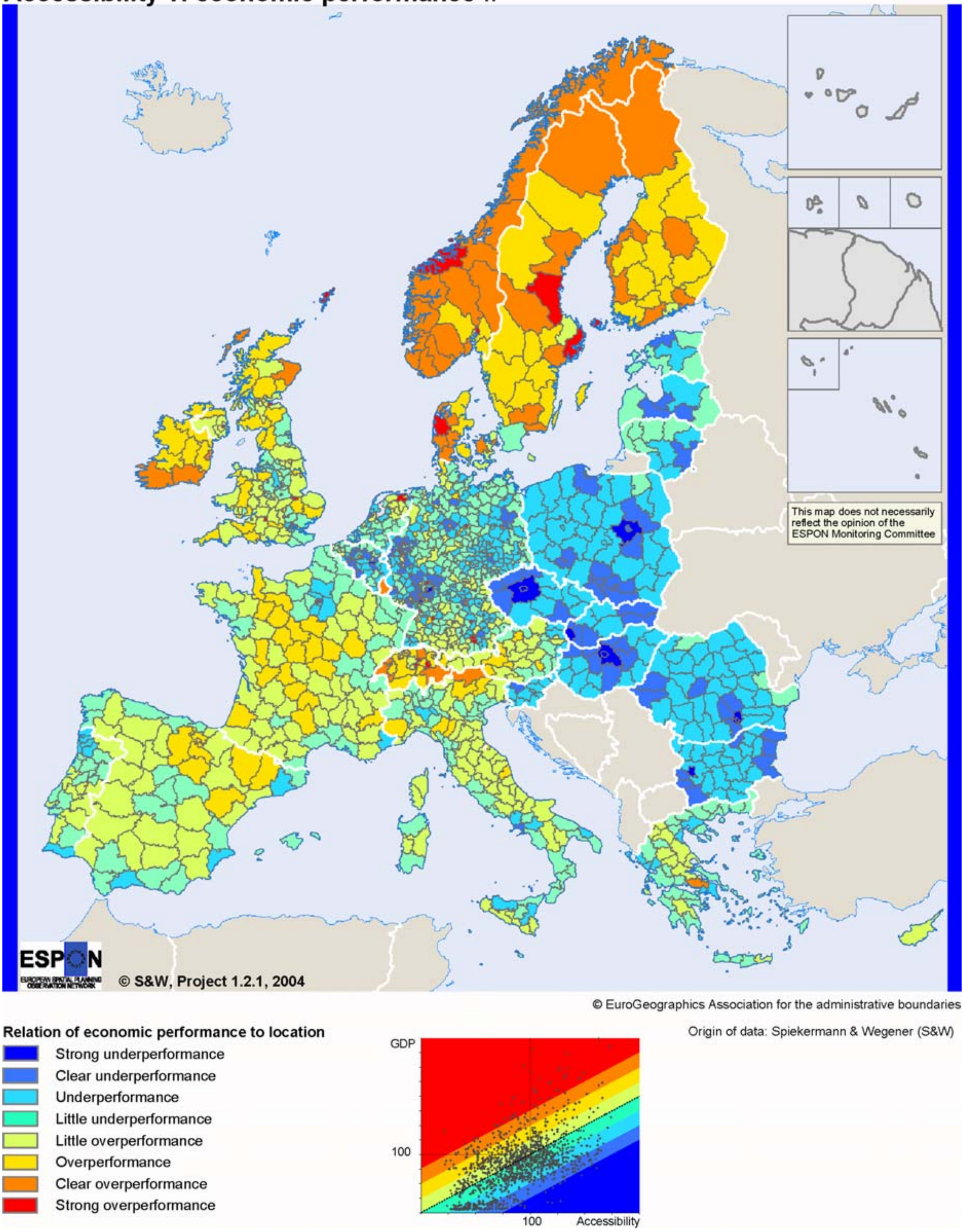
The center-periphery analysis must be largely moderated even in terms of transport. This one is false by NUTS3, and very approximative by NUTS2.

The map of "generalized accessibility" shows it perfectly : neither the center nor the periphery are homogeneous. For example, it is known perfectly that the areas of greater poverty are in urban zones.

One can note the existence of zones with peripheral characteristics in the center, the pentagon, and of "central" zones in the peripheries. However heterogeneity is much more marked in peripheral zones, mainly because their geophysical and human characteristics are very variable taking into account the great dimensions and the division of Europe. Imbalance is not necessarily negative. Indeed, some weakly industrialized and populated littoral zones have a strong touristic potential.

Finally, this phenomenon is normal and **each modification induces imbalances** that are compensated later, more or less slowly. It is interesting to note that a system in equilibrium is an inert one, which is absolutely not the desired goal. **Imbalance is inseparable from the dynamic.**

Accessibility v. economic performance II



1.4 Polycentrism

Urban polycentrism is a notion which is more and more accepted by the community and recognized as a solution for a more sustainable development. Polycentrism would make it possible to structure the territory better, avoiding too long center-periphery moves and supporting more intercentrum mobility.

But it is necessary for urban networks to be equitably distributed on the territory and for studies not to introduce distortion when taking it into account.

1.4.1 MEGAs air relations networks and problems

The air network dominates for professional mobility of more than 500km in the absence of high speed trains.

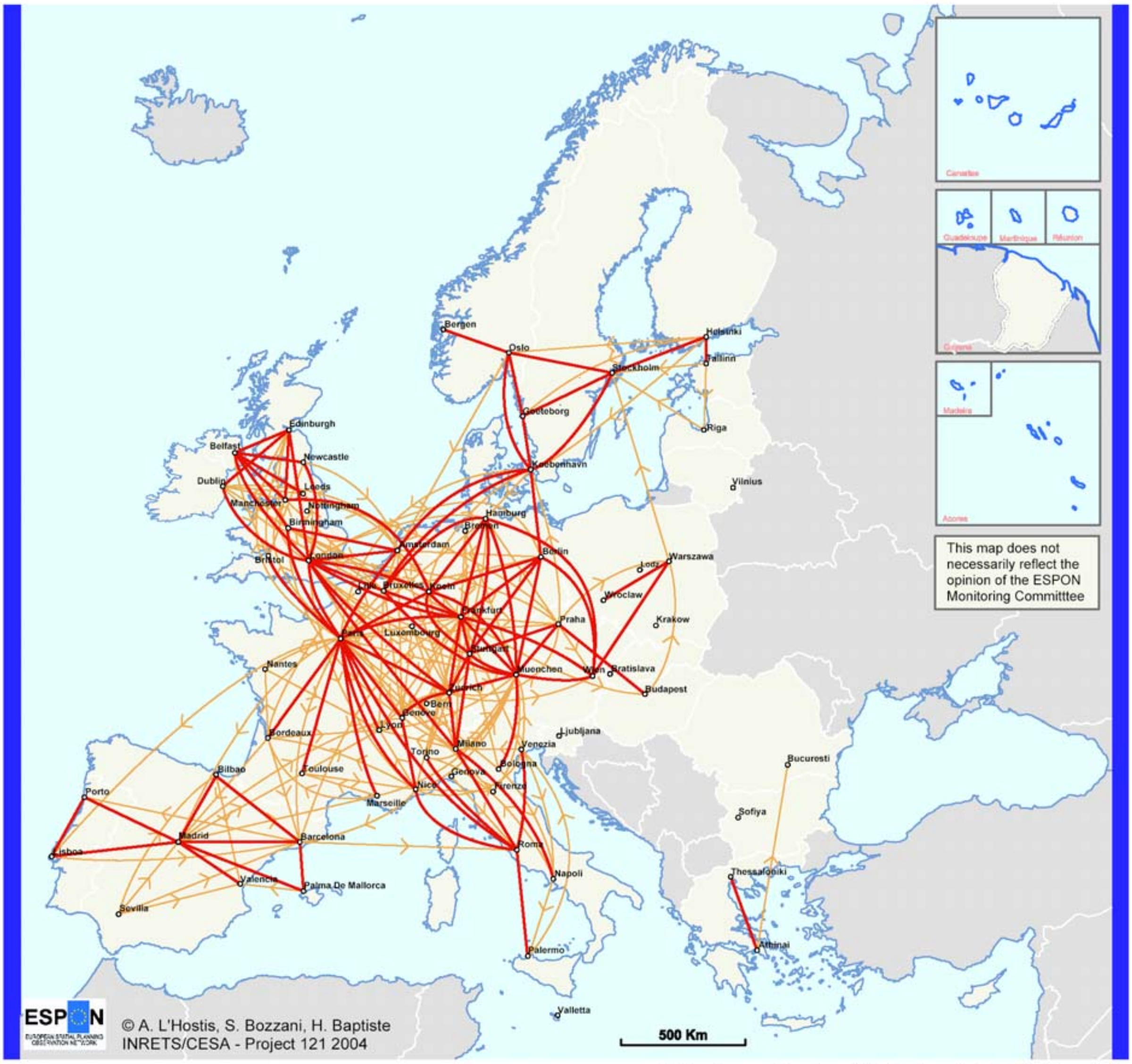
The analysis of the daily accessibilities by air (door to door) is a good indicator. It shows the strong existing potential in the greater triangle Rome-Dublin Edinbrugh-Berlin with some extensions on Scandinavia, Finland and the new members in Eastern Europe.

According to this indicator of time constrained accessibility (from 6h to 22h) allowing for a daily mobility, the Iberian peninsula seems currently to be very poorly connected. It was the cause of a debate with the ESPON Group 1.1.1, which did not take into account in its first evaluations neither Bilbao nor Nantes-Saint Nazaire and still does not do it for the latter whereas cities of less importance appear in their list. It is clear that the Atlantic Arc must see its urban structure reinforced and that the criteria of statistical definition must be improved. Indeed the only indications of mass population/service industry alone are insufficient if one does not take into account the proximity or the distance of cities of the same or higher level. The analysis must be spatialized.

1.4.2 High-speed train networks

The situation of certain cities located on high-speed railway lines is a factor favorable to the development of the polycentrism. In France there is a network of high-speed train cities. It is clear that the system of relations between Paris and Lyon was modified by the high-speed train, including a strong modal shift in favour if rail, as it currently modifies that of cities like Avignon and Marseilles. This characteristic is going to spread partially with the development of high-speed railway lines.

City network daily accessibility by air
between 72 Metropololitan European Growth Areas (MEGA)



A —— B **Return trips possible in both directions**

A —>— B **Return trip possible only from A to B**

Origin of the data: www.amadeus.net april 2003

Structure of the return trips:

1.4.3 Networks of proximity

Proximity is a fundamental factor for a functional network of cities. For the radial analysis the group applied a computation technique and a cartography of the networks starting from cities which makes it possible to see the cities which are at a distance lower than x Kilometers from one another.

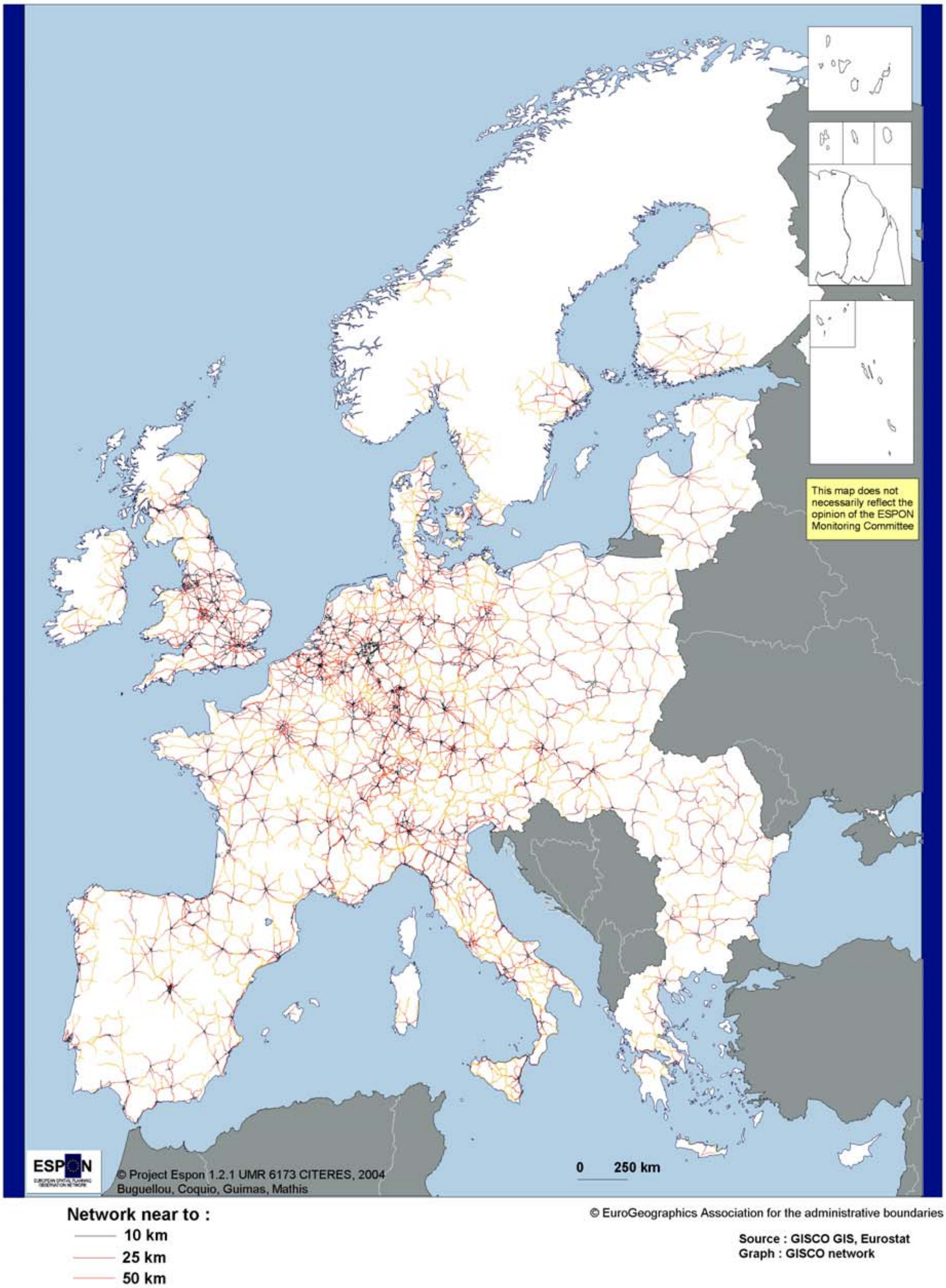
The map has a certain analogy with a neurons network and gives an interesting image of an increase in complexity when the cities are close to each other. England, Belgium, Germany and Switzerland have a very connected urban network. The situation of the West of France, recently adherent countries, Nordic and Iberian countries is very different from the former. This partition is new.

1.4.4 Problems related to polycentrism

If urban polycentrism is a notion that is more and more accepted by the community and recognized as a solution for a more sustainable development, it is really curious to notice that the extreme form of economic polycentrism is only weakly denounced in spite of its numerous disadvantages. Indeed it is a polycentrism of production, that generates an important part of the traffic ; it can be justified at an individual scale, or at the level of firms but not at the one of the European Space, in a perspective of general interest. In this way, firms externalise the stockpiling on the carriers and the environmental costs on the community.

This aspect allows us to raise the question of the internalisation of transport costs, notably those linked to pollution. A major part of mobility is hardly avoidable; this is notably the case of the home-work mobility, or of moves linked to local and regional economic activities. These movements, even if they are sources of pollution, especially in agglomerated areas, can be transferred at least partly to public transport modes.

Network around cities of more than 100 000 inhabitants

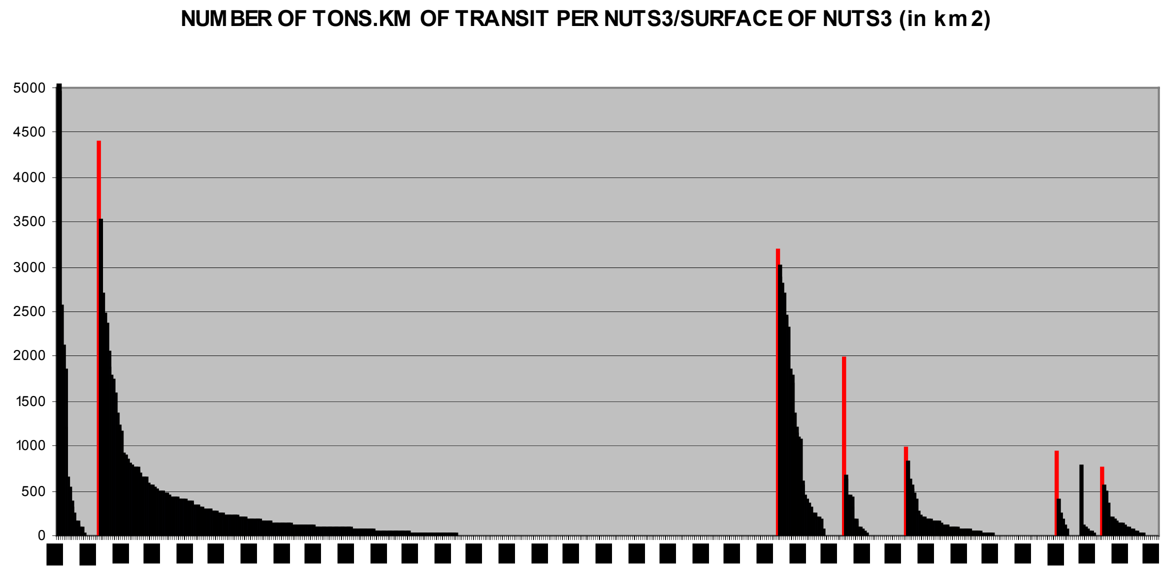


Network near to :
- 10 km
- 25 km
- 50 km
- 100 km

© EuroGeographics Association for the administrative boundaries

Source : GISCO GIS, Eurostat
Graph : GISCO network

1.5 Sustainable spatial development



The graph above indicating the number of tons transiting by NUTS3 allows two important observations once again. First, it is possible to identify countries quantitatively like Switzerland, Germany, Belgium and the Netherlands. Secondly, we can note that imbalance is once again present at several levels, and this could be clearer at NUTS4 or NUTS5 level.

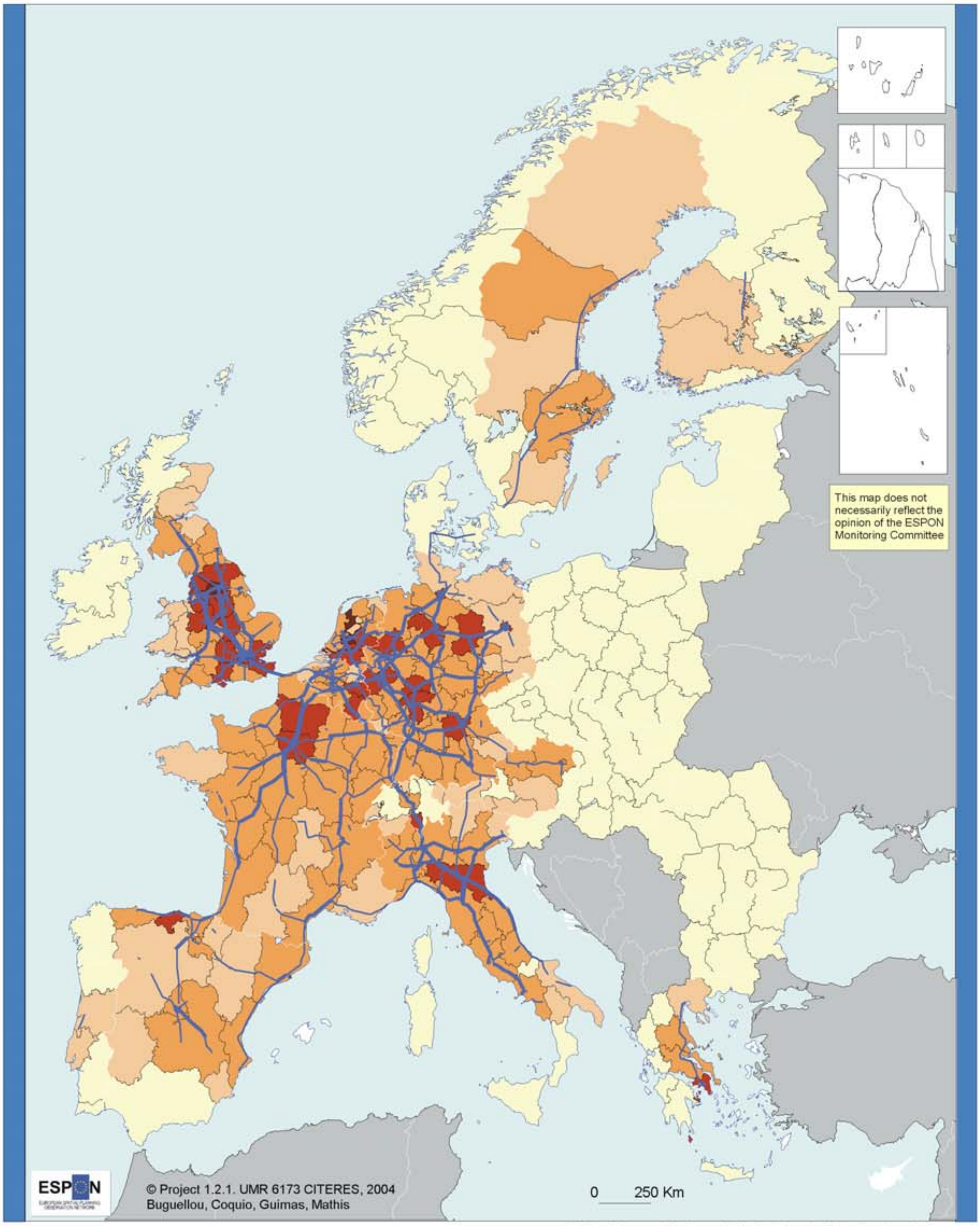
1.5.1 Emissions

The emissions can be divided into two categories: those related to the industrial activity and local transport, the other with International and European transit. The emissions related to this second category are relatively easily quantifiable starting from the number of tons.km by NUTS. Our computation remains however an approximation definitely lower than reality for two essential reasons: we did not have a Numerical Terrain Model allowing us to take the slopes[9] into account and we have not considered the "stop and go" linked for example to congestion[10]. Moreover, we have not considered intra-NUTS2 traffic and car mobility because of the lack of data.

[9] For a slope of 4% the emissions are six times higher.

[10] This calculation is currently possible on the level of a district, of a city by a multi-agent system, but not at the Européen level.

Trucks Emission and NOx pollution



© EuroGeographics Association for the administrative boundaries

Source : GISCO GIS, Base Scenes
Graph : CESA graph 4172 , GISCO graph

NOx pollution in grams per square kilometers

- 50 000 - 65 600
- 25 000 - 50 000
- 10 000 - 25 000
- 5 000 - 10 000
- 0 - 5 000

NOx pollution in grams per km

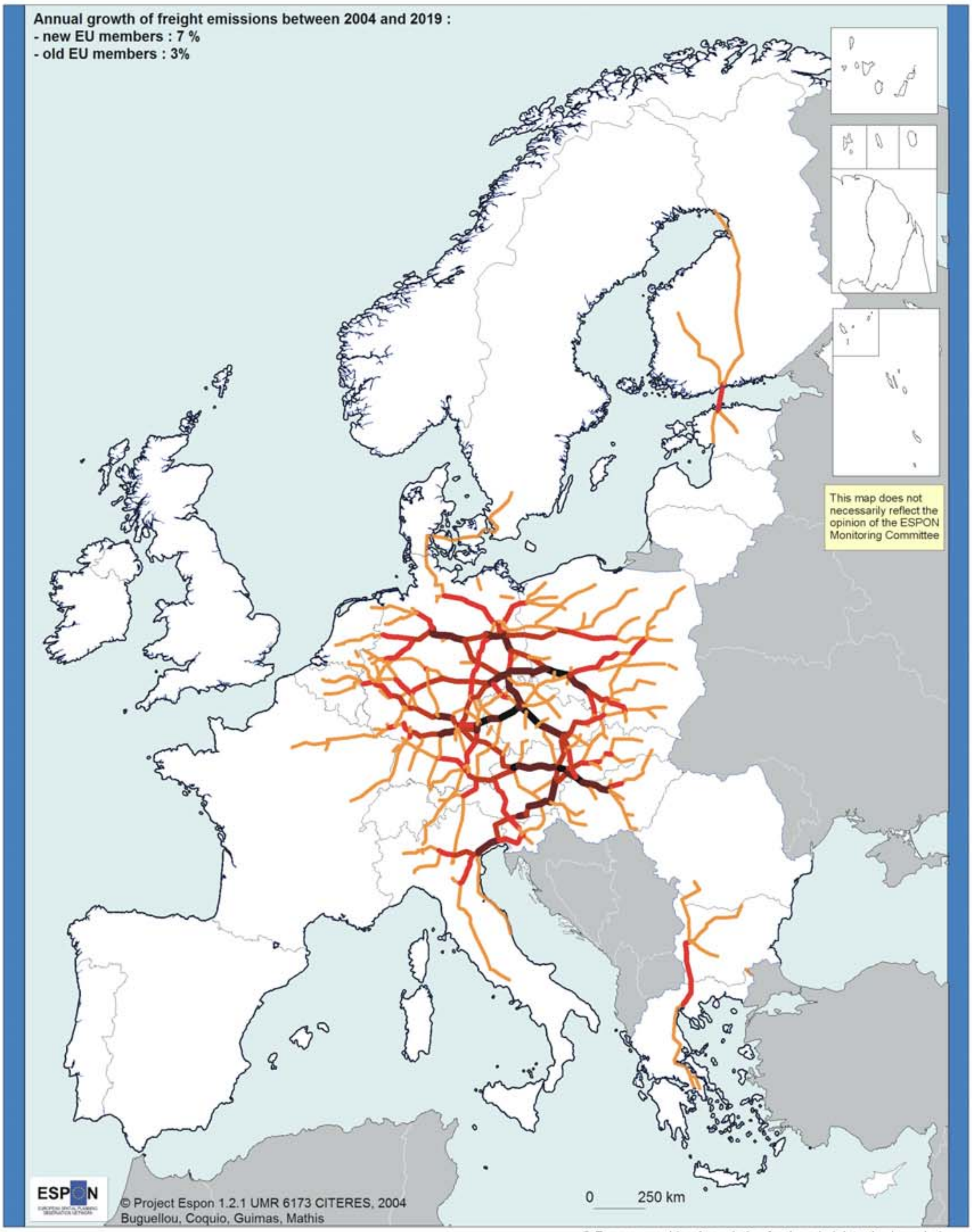
- 500 000 - 1 000 000
- 250 000 - 500 000
- 100 000 - 250 000
- 50 000 - 100 000

1.5.2 Vulnerability and connexity

The strong connexity, an essential property of the transportation system, is the possibility of going from any one point to another and coming back from there. Moreover, one can impose a temporal constraint as for the daily accessibilities by plane which can lead to an impossibility to come back in the same day in certain cases.

Vulnerability of the edges computed in the report is the cost of the suppression of an edge, which means a connexity of order 1 between two nodes. The flows affected on the network are computed from the matrix of exchanges in 1995 projected with uncertainties on the countries recently adhering and the countries outiside the European Community. The vulnerable network here matches here naturally the networks of the major road corridors.

Potential Freight flows between old and new EU members in 2019



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Number of tons per edge per year
(in thousand of tons)

- **30 000 - 38 000**
- **20 000 - 30 000**
- **10 000 - 20 000**
- **5 000 - 10 000**
- **1 000 - 5 000**

Source : GISCO GIS, Scenes
Graph : CESA graph 4172

1.6 POLICY RECOMMENDATIONS

In our domain, the dynamic can be seen as a confrontation between two different temporalities :

- **The temporality of the transport supply** that is expressed in the easiest way by **creations of road and rail infrastructures** (presently, it roughly takes **13 to 15 years**) but also in the functioning of transport modes;
- **The temporality of the transport demand** that is those of firms for goods and that is roughly of **3 or 5 years and sometimes less**, for the creation of a production unit and for a relocation.

That is why our anticipations have to be of great quality in order to integrate three times longer on a temporal horizon and we have to envisage actions in a very short term and with quasi constant networks, that force us to turn to other kinds of solutions like modal transfer, financial incentives, capacities development by speeds degradation as it is beginning to be done in urban areas.

1.6.1 Policy recommendations at the European level

The objective is to have a more balanced, polycentric and sustainable spatial development and to ensure the territorial cohesion of the European Union.

The coherence between economic efficiency and sustainability can be discussed and requires for us at least the introduction of the temporality in the previsions.

The transport demand comes from individuals and firms and is essentially short term, about 2 or 5 years for enterprises. If this demand is not satisfied, the risks of relocation are very important.

The transport supply firstly consists in roads, railways, ports and airports infrastructures. These ones are characterised by the long term. The current creation of an infrastructure lasts roughly 15 years .A response to demand by a policy of building infrastructures is not sufficient.

A regulation of traffics is possible to increase the capacities, intermodality to facilitate a modal shift diminishes the pollutants, the casualties. On the road, concerning interregional and international travels, the problem in the short or medium-term according to the corridors concerned is saturation.

The increase of the capacities of road corridors is currently impossible in the short term for most highways.

Moreover, the capacities available on the railways are insufficient to permit a modal shift,

The solution is to do the same as in the USA) : limit the speed. So, we propose to reduce the speed by legislation, limiting it in at first time to 70 km/h for trucks and 100 km/h for cars, and then to 60 and 70 km/h. A direct consequence of this limitation is a reduction of the fuel consumption, and thus of the emissions, of casualties, etc…

This is why it is a necessity to promote other policies in the short and medium terms simultaneously.

The modal shift, mainly waterway and maritime way, is the first one. It is the only possibility in the short term because maritime facilities which exist currently, even if they need improvements and the construction of ships, only require three years, studies included. The map below indicates the major maritime routes[11] that must be completed with inland waterways.

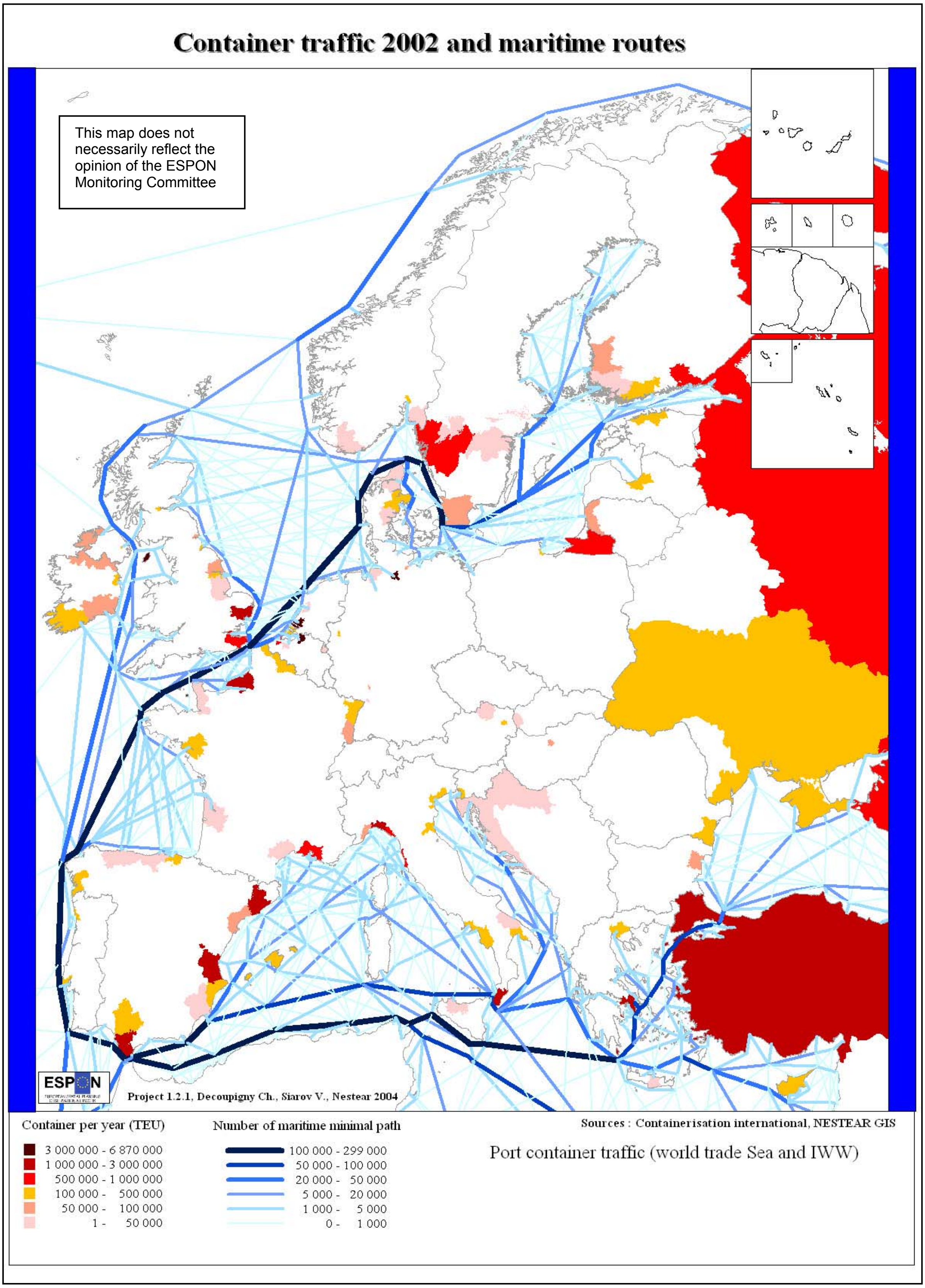
The second is only beginning to be developed, in a timid way: it is the transformation of classical railways into freight-dedicated lines. It can be done by the reusing of traditional lines, vacated by the creation of high-speed rail networks for passengers.

But we are totally conscious of the necessity to furnish the private economic system with modes of high speed. We propose a transport system at a high frequency able to carry goods at high-speed, roughly at the maximal speed of passenger trains using classical lines, that is to say nearly up to 150 km/h. These lines would cross 1000 km in less than 9 hours (loading and unloading included), that corresponds to the obligatory breaks for drivers.

A technical solution already exists and Switzerland has shown on shorter distances the possibilities of this kind of transport, which are most cost-effective for long journeys.

For light but urgent goods, transport by air seems to be a good solution, notably for long distance.

[11] The importance of ports is only shown for European trade.


Container traffic 2002 and maritime routes
This map does not necessarily reflect the opinion of the ESPON Monitoring Committee
ESPON
Project 1.2.1, Decoupigny Ch., Siarov V., Nestear 2004
Container per year (TEU)
3 000 000 - 6 870 000
1 000 000 - 3 000 000
500 000 - 1 000 000
100 000 - 500 000
50 000 - 100 000
1 - 50 000
Number of maritime minimal path
100 000 - 299 000
50 000 - 100 000
20 000 - 50 000
5 000 - 20 000
1 000 - 5 000
0 - 1 000
Sources : Containerisation international, NESTEAR GIS
Port container traffic (world trade Sea and IWW)

Trucks could be used for initial and terminal phases for which it is not replaceable.

For travellers, at the present time, speed is not associated with individual cars but to high-speed trains and the plane.

A policy of internalising the costs of road transport is indispensable.

A policy of infrastructure creation is also necessary. We must diminish the vulnerability of networks by a minimum of modal redundancy when it is possible and a multimodal redundancy when it is not, with the aim of avoiding the recent catastrophes.

Finally, it is necessary to separate the different flows to prevent the transit of trucks in the densest areas, which is the source of supplementary pollution to that already induced by human concentration.

The aim of the policy recommendations at the European level is first of all to draw principles that could guide these recommendations, then to explain the nature of these ones, before applying them, partially or totally to macro-regions of:

- the Atlantic Arc area,
- the Mediterranean Sea area,
- the Nordic area,
- the Central area,
- Eastern Europe.

1.6.2 Policy recommendations for macro-regions

1.6.2.1 Atlantic Arc area[12]

The network of cities of The Atlantic space-the United Kingdom, Eire, France, Spain and Portugal- seems to be divided into two different areas:

On one side the "Finistère" and more generally the peripheral regions have a weak urban armature, even if it is also the case of some internal areas.

On the other side, two kinds of areas seem to present a great density of cities. Firstly, one can find such areas around capitals and metropolises. Secondly, we can see other areas, with a low density of cities, but with a high level of connexion between them.

The Atlantic space is clearly a peripheral area. Nevertheless the transport network can diminish this spatial distance by offering high-speed modes reducing the temporal remoteness.

[12] This area includes the whole France and Great Britain, and so does not correspond to the Atlantic space defined by INTERREG IIIB

The regions supporting the most important part of the transit traffic are located in France, as an obligatory way to reach the North and the South of the Atlantic space.

National capitals also have a fundamental importance because of the radial orientation of flows. They have the role of crossroads.

At a more local level, we can note some discontinuities around national frontiers such as between Spain and Portugal and between France and Spain. The specific geography of the latter area underlines the necessity for trucks to pass by the extreme west (Bayonne – San Sebastian) or east (Perpignan – Barcelona) of the Pyrenees It is the same phenomenon for the Channel Tunnel, the single terrestrial passage between France and Great Britain.

Nevertheless, few corridors appear as playing a major role for international freight transportation, even if they are less visible than for the road case: Paris – Bilbao, Marseille –Paris, Marseille –Ruhr, London – Manchester – Liverpool – Glasgow and Dublin, Lisbon and Madrid

Any increase in traffic in this zone will have significant increases the travel times as a consequence.

Short term recommendations

First of all, a differential pricing policy between the axes concerned could be incitative for a better use of the network.

Secondly we have to facilitate the use of the maritime way and the existing harbour infrastructures.

So, to increase the capacity of the infrastructures we could voluntarily degrade speed by limiting it for the heavy lorries to 60 km/h and for the car to 70 km/h.

Medium term recommendations

A modernization and setting with the B2 gauge would make it possible to create a real multimodal corridor Lille-Hendaye-Bilbao-Oviedo- La Coruna-Vigo-Porto. This line could be extended up to Spain and Portugal in the South and tunnel under the sea Channel in the North.

It is possible on renovated ways to make trains circulate at high frequencies and remaining speeds close to classical trains' speeds for travellers. Thus, it is possible not to modify the profile of the ways.

For travellers, the high-speed railway solution is infinitely faster and more comfortable with the possibility of hiring a car at destination or using public transport.

Long-term recommendations

In the long term, the network has to be completed in order to facilitate fast exchanges of travellers in this area.

The scheme page 43 recapitulates the recommendations for this area spatially, thus giving a vision of a coherent transport system.

1.6.2.2 The Mediterranean area

Road density is very different for regions of the western part of this area (the Iberia Peninsula and the South of France) and the eastern part (Greece and Cyprus).

For the first group the road density is higher in respect to the ESPON space average except for those regions with important urban centres (Barcelona and Marseille), due to the population density distribution.

The second group clearly has a lower value in respect to this average due to the low length of the road network. This is not the case of the rail network density. Due to the topography of this area, most regions are dependent on maritime transport, specially islands. The same happens with commercial airports as most islands are dependent on their regional airports.

Policy recommendations from 121 perspective

At the European scale, the first recommendations from the 121 perspective is to delete the weak links which exist in the main corridors of the current transport network of the Mediterranean area: Trans-Pyrenees passages, Trans-Alpine passages, the Greek connection to the rest of the EU countries.

Some priority projects can solve these weak links in the future, like the high-speed rail line through the west and east part of the Pyrenees and the upgrading of the road connection of the western part of this passage.

The Trans-Alpine connection is regarded in the priority projects except for the French-Italian rail connection to give continuity to the high-speed rail line from Marseille and the North of Italy along the coast.

The connection of Greece to the rest of the EU countries could be improved not only by strengthening the motorways of the sea, but with a corridor along the Balkan coast as an alternative to the TINA corridors

The second recommendation is to strengthen the intermodal connections by a network between the coastal transport nodes and inland transport entry nodes which can act as intermodal nodes.

1.6.2.3 The Nordic area

The Nordic area from the ESPON 121 group perspective includes the Nordic countries –Denmark, Norway, Sweden, Finland– and the Baltic states – Latvia, Lithuania, Estonia. From the perspective of polycentrism, the only weakness regarding the relations at the top level of the urban hierarchy is observed among the Baltic states.

Policy recommendations from the 121 perspective

If one tries to establish the correspondence between the polycentrism option of the ESDP and the transport policy orientations as expressed through the priority corridors, one must admit a deep consistency.

On the one hand, the Nordic triangle and its extensions to Helsinki and Russia in the East and Germany in the South which can be seen as the major axis in the area is taken into account by the corridor IX.

On the other hand, both internal and external links in the urban network in the Baltic states will directly benefit from the development of the corridor I.

In the Nordic space, the huge potential for maritime transport through short-sea shipping intra- and extra-Union can be activated by the development of the Baltic sea motorway project.

Beyond these three major points what can be stated?

In a polycentric perspective the only real weaknesses in terms of relations in the urban structure, assessed through the quality of passenger transport services, can be observed in the Baltic states capitals. To deal with this major stake, transport can play a key role, and the development of the corridor I with the Via Baltica and Rail Baltica projects, will contribute significantly to improve the terrestrial and maritime relations. Nevertheless, the accessibility to the rest of the Union can not be based only on terrestrial networks, for Riga and Vilnius where long distances are needed to reach the closest MEGAs. So we propose to encourage the development of air services in Riga and Vilnius airports. Indeed, the remoteness of their location at the scale of the continent can only be corrected by the air mode. A development of the air services to the closest MEGAs would seek to develop relations to Poland, to Finland and to Sweden in the first place, and to more remote locations at a lower level of priority.

1.6.2.4 The Central Area

In the ESPON 1.2.1 definition of a European macro-region used for the policy recommendations, the central area consists of the countries Belgium, the Netherlands, Luxembourg, Switzerland, Germany and Austria.

Transport infrastructure endowment in the central area is extremely good compared with all other macro regions

Traffic volumes on the network, in particular on the road network, in the central area are the highest in Europe, but are also suffering from transport externalities such as noise, emissions of pollutants or land fragmentation.

Recommendations from the Policy ESPON 1.2.1 perspective

Enable modal shift. Alternatives to road have to be further supported. For passenger transport this is basically rail, in particular, to have a real high-speed rail network. Given the history of recent rail development, particular attention has to be given to trans-border corridors. For freight transport, there are two alternatives: rail and inland waterways. For both, it seems to be less an issue of missing network links, but more a question of missing intermodal terminals and improved logistics to allow the provision of competitive services.

Enable European integration. The central area is an important territory in the ongoing EU enlargement and integration process. However, there is a strong tendency in Europe that road infrastructure is more easily implemented than others even if priorities are in favour of other basic transport policy recommendations for the central area. This means that road infrastructure development does not need support from spatial planning; it will be in place anyhow, but those other modes need specific attention. Therefore, the first recommendation above for the central area, enabling modal shift, should be taken into account when approaching European integration via transport infrastructure.

1.6.2.5 The Eastern area

The Eastern Europe area from the ESPON 121 group perspective includes: the new members such as Poland, Hungary, Slovakia, Czech Republic, the candidates such as Romania and Bulgaria .This space establishes the link between the European Community and the new eastern neighbours such as Russia, Ukraine, Belarus and Turkey.

The density of motorways and expressways by population is very low compared with the European average, there is not a real motorway network as within west European countries.

If the motorways are not developed, the rail presents a good network, the main cities are linked to the international railways network.

Airports are developed in terms of traffic, but also in the capitals of the eastern area.

Seaports endowment is relatively low as compared with the average endowment in Europe.

Policy recommendations from 121 perspective

The stakes of Eastern European transport policy are double. The eastern area must be organized with the other macro regions (the Nordic, Central and Mediterranean area) and the new neighbours (Russia, Belarus, Ukraine and Turkey) to establish links between the European Union and the eastern neighbours. But this area must improve the relations between the countries on its space.

That is why, the pan European corridors appear relevant to serve these objectives.

The corridors 1 connects the eastern area with the Baltic area, the corridors 2, 4 and 7 are the links with the central macro region, the corridors 10 and 5 connect the eastern area with the Mediterranean space.

The corridor 2 permits the transit between the north of the eastern space and the neighbours such as Russia, whereas the corridor 10 creates the link with Turkey.

The corridors 4, 7 and 10 are the links between the central macro region and the black sea and the Egean sea and giving an access on the sea motorways.

The corridors 1, 6, 7 and 10 present a continuity between the North of Poland and the south of Bulgaria and create in particular a virtual corridor between the East of the Mediterranean sea and the Baltic sea.

The modernization of the corridors 1, 2, 7 and 10 are very important for the structuring of this space at the European scale. The multimodal dimension of these corridors is a real opportunity to inscribe and to organize the eastern area within the internationals flows.

1.6.2.6 Synthesis of policy recommendations for macro-regions

The policy recommendations proposed by the ESPON group 121 are reported on the following map. In order to build a coherent policy recommendation we have divided the ESPON space in four regional areas. The gathering of all the regional proposals are shown on the map.

Our priority recommendation list of actions:

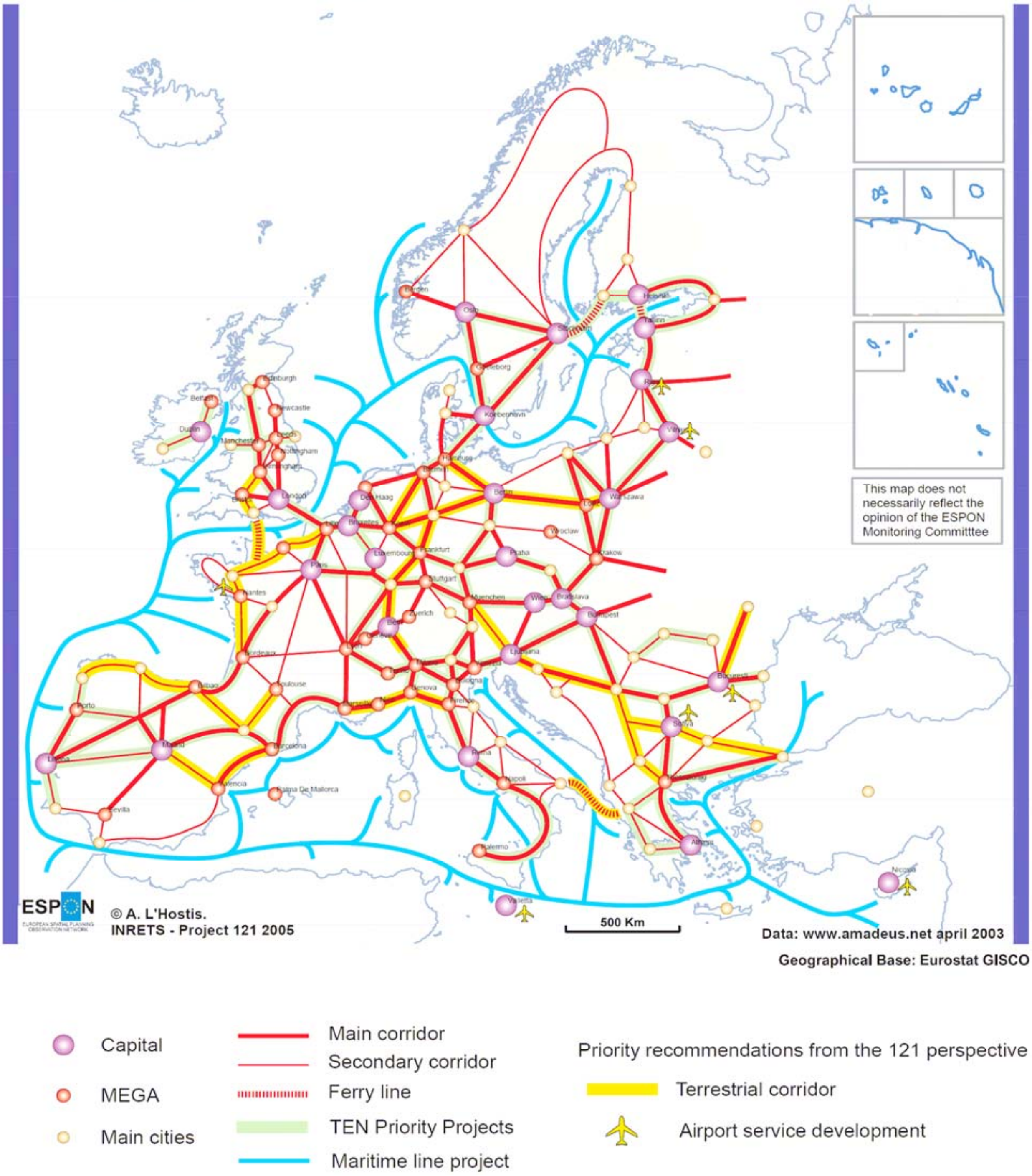
- has for aim to address the ESDP orientations with a particular emphasis on polycentrism ;
- considers the existing European Transport Policy priorities based on the TEN Priority Projects list ;

- is based on the findings of the indicators proposed in the final report.

From the modal point of view, concerning the maritime transport mode our proposal resides in developing the network of communication along all the coasts of the ESPON space. For the most remote MEGAs, according to the indicator of return trips, we propose to develop the air services. This measure concerns Riga, Vilnius, Bucuresti, Sofiya, Nicosia, Valletta and Nantes.

From the multimodal point of view, we proposed to develop a series of new multimodal terrestrial corridors developing the set of TEN priority projects: an Atlantic Arc corridor, new crossing in Pyrenees and Alps, an East-West corridor in Germany and Poland, and a Balkan corridor. According to the global transport policy option developed in this report, these corridors privileges rail, inland waterways and ferries when necessary.

Policy recommendations from the ESPON 121 perspective ("Transport services and networks")



1.7 Conclusion

The result of the diagnosis was relatively known with the classical approaches: a centre-periphery structure, a pentagon so-called blue banana and peripheral spaces less inhabited and less served by networks.

The generally accepted idea was simple: more networks for better accessibility for more GDP !

The reality is more complex: networks generate traffic and even in a central well-served region there are still enclosed zones. The space is heterogeneous at all scales from national to the local ones …

But this heterogeneity, this diversity is also a wealth and must be considered as such.

The European space is structured by the corridors and we have shown the potential and the effective use of the networks with the main classical indicators: travel times, daily accessibilities, externalities for transport modes such as road traffic deaths, emissions of greenhouse gases and air pollutants (which are unfortunately located everywhere and particularly in great cities), …

It is possible to plan the modal transfer for transit.

The enlargement will have impacts in the central countries with traffic increase. And if the infrastructure endowment is not sufficient the firms could relocate.

The temporality of transport supply and transport demand are very different, and that is the main problem.

The road network is almost sufficient in many countries; the building of a motorway or a railway takes a long time. Furthermore, the construction of new facilities will be more difficult tomorrow than yesterday because of the reactions of local populations and the increasing consideration for environmental problems.

It is necessary to act in the short term and to adapt the network use to the traffic evolution, in the goal of promoting modal transfer on maritime traffic and dedicated railways thanks to cost and speed voluntary policies.

Drastic measures are necessary to respect the environment and to avoid the gridlock or the relocation of firms.

The freedom of travel is a fundamental right but the obligatory trips must be limited by a polycentric organisation and also by a better organisation of production systems in the aim of developing a sustainable transport.

Our classical and new results are important but not yet sufficient and too static. Presently, it is necessary to build a prospective model to explore the scenarios set for the future.

2 Scientific summary

We have chosen as a framework for this summary to bring to the fore the main themes studied in this report by dividing it into parts, which correspond roughly to the different stages of the report:

- a review of the main existing indicators ;
- the indicators of transport services and networks ;
- the travel times and costs, furnishing elements concerning accessibility;
- the traffic volumes and flows;
- the transport externalities linked to transport;
- the network vulnerability;
- the interpretation of the results leading to policy recommendations.

The summary will be illustrated by small maps included in the report, with the page number, so that the reader can easily find it in the core of the report.

2.1 Review of main existing indicators

The report contains a brief review of existing indicators for transport networks and services. This review is divided into four main sections:

- indicators describing the supply of transport infrastructure and services,
- indicators for the actual use of transport infrastructure and services,
- the concept of accessibility as a baseline for territorial indicators,
- innovative mapping approaches.

Indicators of transport infrastructure and services supply include four groups of indicators:

- ***Transport infrastructure supply indicators***. Endowment indicators consider the transport infrastructure in an area expressed by such measures as total length of motorways or number of railway stations. Morphological indicators describe features of modal networks and are mainly derived from graph theory or fractal theory.
- ***Transport infrastructure capacity indicators***. Here, one indicator type describes capacities of links, another type shows

capacities of terminals such as airports, ports or intermodal terminals.

- ***Transport service indicators***. There are three basic indicator types: basic supply of nodes reflect the level of services available in nodes of rail, air and waterway networks; travel time and travel cost indicators cover the disutility for the user of a certain link or a certain route and can be further differentiated (e.g. by type of vehicle) and finally, issues such as statutory rest periods of drivers, safety or traffic regulations in the form of aircraft grounding or traffic banning during night time).
- ***Network vulnerability indicators****.* The natural hazards Europe has faced during the last couple of years and in particular during last summer and the demolishing of transport infrastructure and services has focused attention on indicators describing the exposure of transport infrastructure to potential damage. However, little more than nothing exists so far in this respect.

For the **indicators of the actual use of transport networks** and services a distinction is made between traffic indicators showing volumes on links or in nodes and flow indicators that always include origin and destination of the flows.

- ***Traffic volume indicators****.* Traffic volume indicators capture the actual use of the transport infrastructure networks and services. There are five indicator types, transport quantities, traffic on links and traffic in terminals, and also indicators describing the environmental effects of traffic in terms of consumption of natural resources and pollution as well as indicators describing transport safety.
- ***Traffic flow indicators****.* Traffic flow indicators are different from traffic volume indicators as they always include origin and destination, i.e. the relationship between two different points in space.

The **concept of accessibility** as a baseline for territorial indicators of transport infrastructure and services is developed in more details in the report. The starting point is that the quality of transport infrastructure in terms of capacity, connectivity, travel speeds etc. determines the quality of locations relative to other locations, i.e. the competitive advantage of locations which is usually measured as accessibility. Investment in transport infrastructure leads to changing location qualities and may induce changes in spatial development patterns.

There are numerous definitions and concepts of accessibility. A general definition is that "*accessibility indicators describe the location of an area with* *respect to opportunities, activities or assets existing in other areas and in the area itself, where 'area' may be a region, a city or a corridor*" (Wegener et al., 2002). Accessibility indicators can differ in complexity. More complex accessibility indicators take account of the connectivity of transport networks by distinguishing between the networks themselves and the activities or opportunities that can be reached by them. These indicators always include in their formulation a spatial impedance term that describes the ease of reaching other such destinations of interest. Impedance can be measured in terms of travel time, cost or inconvenience.

Accessibility indicators can be classified by their specification of the destination and the impedance functions:

- ***Travel cost indicators*** measure the accumulated or average travel cost to a pre-defined set of destinations, for instance, the average travel time to all cities with more than 500,000 inhabitants.
- ***Daily accessibility*** is based on the notion of a fixed budget for travel in which a destination has to be reached to be of interest. The indicator is derived from the example of a business traveller who wishes to travel to a certain place in order to conduct business there and who wants to be back home in the evening. Maximum travel times of between three and five hours one-way are commonly used for this indicator type.
- ***Potential accessibility*** is based on the assumption that the attraction of a destination increases with size, and declines with distance, travel time or cost. Destination size is usually represented by population or economic indicators such as GDP or income.

A review of European accessibility models brought insight into a wide range of approaches with respect to dimensions of accessibility. They differ in many respects, but there are also some similarities:

- More than half of the models use a potential type indicator, the remaining ones use travel costs or daily accessibility indicators. A few models are able to calculate different types.
- Origins are usually NUTS-2 or NUTS-3 centroids and very few studies have a more detailed representation of space.
- The destination activities are usually population or GDP for the potential type models, and a pre-defined set of agglomerations for the travel cost indicators.
- Nearly all models use travel time as their impedance term, only a few apply travel costs.

- Models that consider freight transport use statutory drivers' rest breaks as constraints.
- Barriers are mainly in the form of border delays, only one model uses trade barriers.
- Nearly all models are based on personal travel, only a few consider freight transport.
- Half of the models consider one mode only, in most cases road ones. The other models have networks for different modes, however, only two use inter-modal travel times.

The **innovative mapping approaches** developed in cartography do produce maps that cannot be translated into indicator values. The purpose of those maps is to present a visual image of the relationship between transport and space:

- *Time space map*s offer a technique to visualise effects of different travel times. Time-space maps represent the time space. The scale is in temporal, not in spatial units. This change of the metric results in distortions of the map compared to physical maps. This kind of maps has been produced for different European countries and to demonstrate the 'space-eating' effect of the emerging high-speed rail network in Europe.
- *Crumpled time-space maps* and *crumpled cost maps* are able to show more than one transport mode in a map. The distortion due to different travel speeds or costs is introduced through the distortion of the surface in the third dimension showing the nodes as hill tops and the arcs of the slower modes forming valleys. Crumpled time space maps have been produced for different European countries and to compare the emerging European high-speed rail network with other modes.

To conclude, existing indicators of transport networks and services can be roughly be classified into two groups:

- Indicators derived from published statistics,
- Indicators derived from modelling.

The two indicator groups are very different with respect to data availability. Indicators derived from published statistics are in most cases not available at the regional level required in ESPON. Here, many indicators are obtainable only at the national level. On the other hand, indicators derived from modelling work have already been or can easily be calculated for the desired NUTS 3 level or for links or nodes.

2.2 Indicators of transport services and networks

2.2.1 Transport endowment indicators

We begin our summary by the main findings concerning the transport endowment because it is the main precondition to every analysis dealing with transport. As explained above, we have considered different means of transport. Most of transport infrastructure supply indicators have been calculated for the ESPON space at NUTS3 level. The endowment indicators in this report consider transport infrastructure in an area expressed by such measures as total length of motorway and expressways network and high-speed and upgraded rail lines network. These indicators capture the capacity of these networks, independently from the services actually provided by transport carriers and their quality, and the utility they provide to fulfil the development opportunities of the region.

- Road infrastructures

The most basic one concerns the **evolution of the motorway network** (part 3 chapter 1.1).

Motorways developed first in the most advanced industrialised countries of north-western Europe, and before and during World War II were extended partly for strategic military reasons. After World War II, motorways were built to facilitate and reinforce the rapid economic growth in the countries of the early European Union: France, Germany, Italy and the Benelux countries. With the first enlargement of the European Union, motorways were built to improve the integration of the Mediterranean 'cohesion' countries into the European Union. The same process is now in progress in the new EU member states through the TINA projects. Nevertheless, there remains a large gap in motorway provision between central and peripheral countries. And this gap continues to widen. In the 1990s, about 1,000 km of motorway per year were built in the member states of the European Union; the corresponding figure for all CEC countries together was 100 km.

The **density of motorways and expressways by population** (part 3 chapter 1.2) allows one to take into account the size of population of each zone, thus giving an original picture of the situation and illustrating incidentally the potential problems of capacity. Thus low values can be found in very populated areas.

- Railway infrastructures

For historical reasons, the European railway network is most developed in the countries of northwestern Europe. However, in these countries many rail lines in rural areas have been closed down today because of the competition of the automobile and the truck. As this has not yet started in the accession countries in eastern Europe, the CEC countries have an over-proportional share of rail and inland waterway infrastructure: whereas the CEC countries account for about 21 percent of the population of the ESPON space, they have 29 percent of all railway kilometres on their territory (Eurostat, 2002). However, high-speed rail lines are still concentrated in Western Europe, i.e. in France, Germany, Spain, the United Kingdom and Sweden. (part 3 chapter 1.4)

The **High-speed and upgraded rail lines density** (part 3 chapter 1.5) is a representation of this network in 2001, as it is calculated considering only length of network and not the number of high-speed rail stations.

- Seaports

The **commercial seaports infrastructures** are presented on the map of the part 3 chapter 1.7.

- Airports

The indicator produced concerning the **airports endowment** (part 3 chapter 1.8) shows a hierarchy in their distribution. Most of main airports are located in the centre of Europe and we can see important airports too in peripheral parts of Europe which can constitute hubs, thus explaining the high number of regional connectivity points in these areas. We can note the particular situation of Greece and Nordic countries, which present a very high number of regional airports due to their particular situation. We can see here that particular situations lead to specific transport solutions.

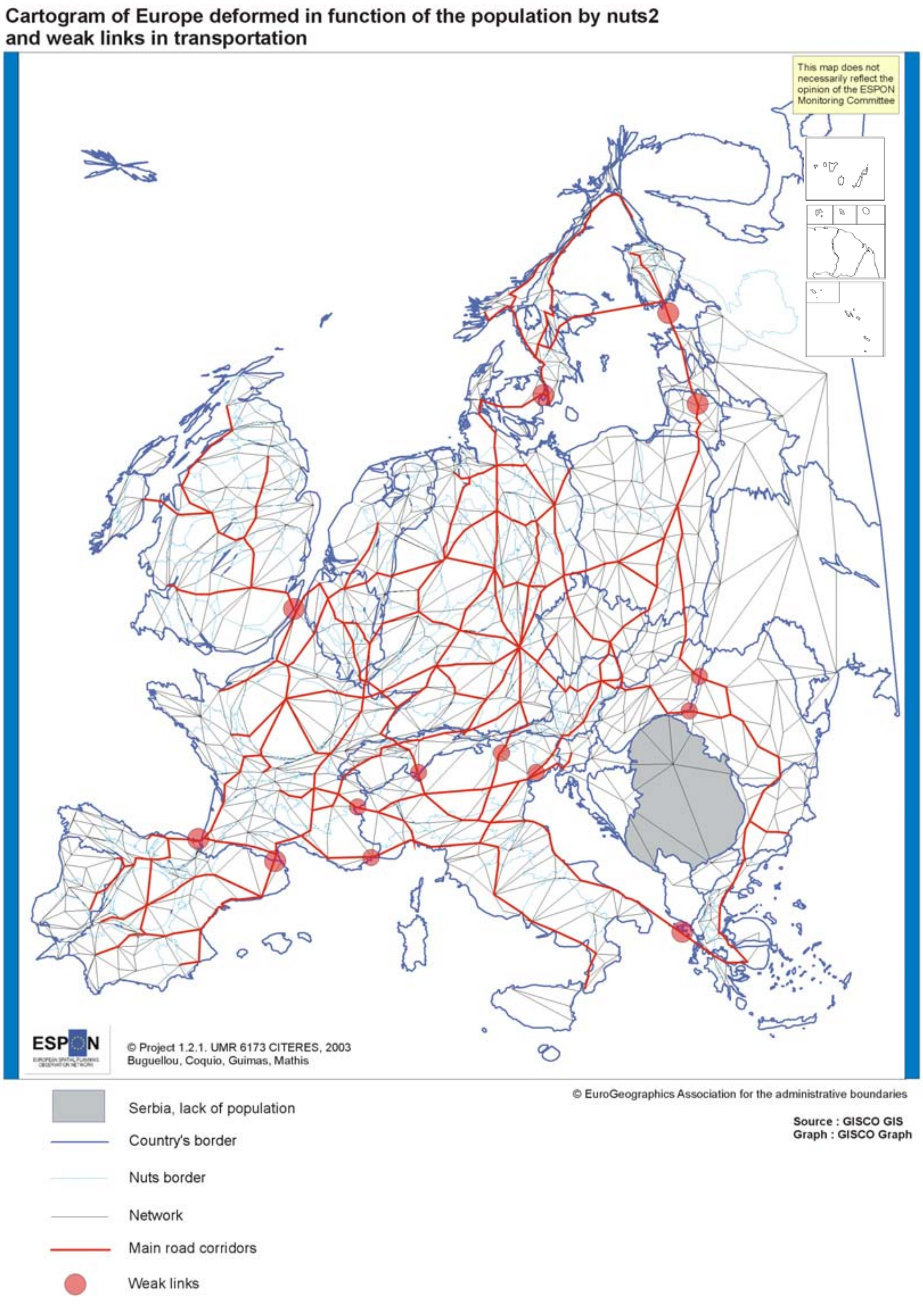
2.2.2 Network morphology

The **theory of Graph** possesses some indicators used to characterize transport networks as centrality, gap, accessibility, "circuity"(curve) etc. But it scarcely treats very little the problem of graph representation and its characteristics slowly lost their interest, focusing instead on powerful algorithms of operational research.

The problem of graph representation has recently become again a field of interest and research again. Conditions of realisations of repetitive and verifiable graphs are begining to be defined. But there is no morphological indicator to characterize the whole graph. The only clarifications are the plan graph (realization on a plan, a sphere, a torus…), the planar graph and the saturated planar graph.

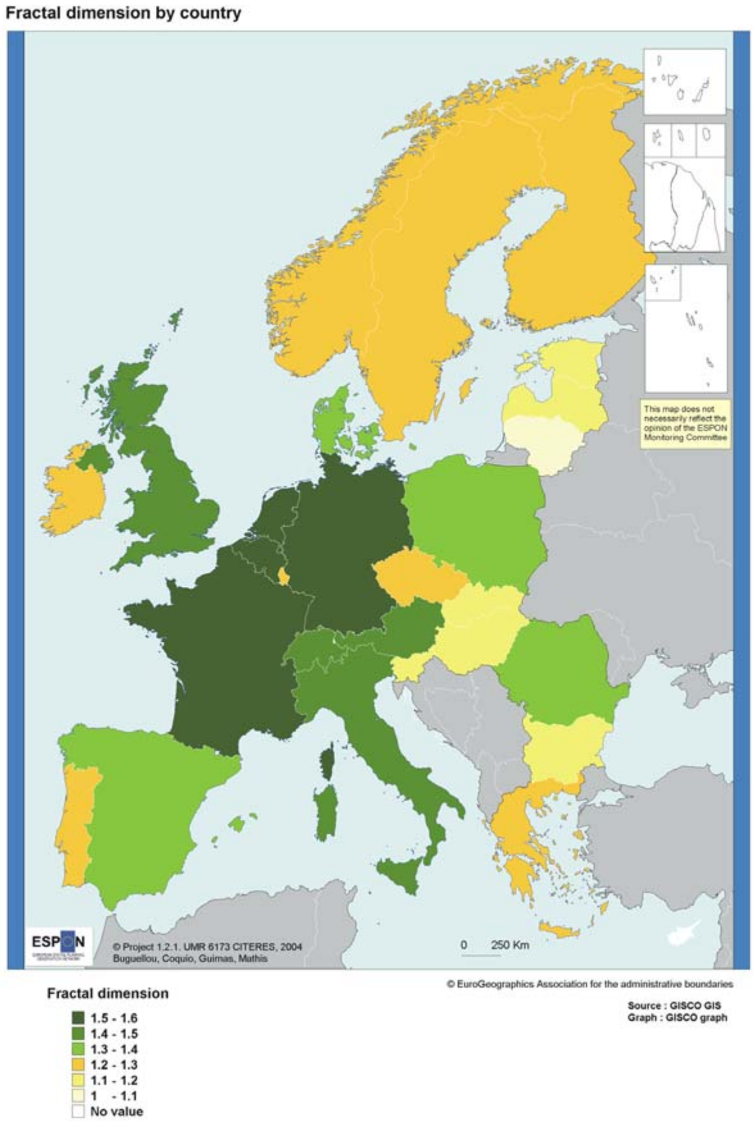
But these properties are not sufficient to characterize morphologically a network represented by a graph. In fact, even properties as simple as those are not necessarily found: a road graph is generally planar but not if it takes into account a motorway graph for example because the two networks are superimposed without intersecting excepted when there is an interchange.

In this aspect, the **cartograms** realized (part 3 chapter 1.10) show that the network distribution seems to be highly correlated with the size of population in each area. This method allows us to give different visions of the territory according to the attribute selected. For example, the map with GDP as its attribute is very different: the distortions are so important that the "new density" of network is not equally distributed as it is for the cartogram population.



Cartogram of Europe deformed in function of the population by NUTS2 and weak links in transportation **(p.223)**

The **fractal dimension of network** (part 3 chapter 1.9) allows us to identify **three groups.** The first one contains the old countries of the European Community (excepted Luxembourg which presents a particular morphology of its network because of its very weak surface), plus the United Kingdom and Switzerland: the network is distributed in a homogenous way on the territory. The Scandinavian countries and Finland are in the second one because the networks are not very developed owing to their weak density of population. The last group contains most of Eastern countries (excepted Poland, Czech Republic, and Romania) which present a hierarchical network.



Fractal dimension by country

Using the **algorithm of expansion or Minkowski's algorithm** (part 3 chapter 1.9.2), we study the relative proximity of the whole territory to road network. This analysis permits us to underline the unbalances between NUTS and to complete the fractal analysis at national level. This indicator reinforces the conclusions made about the hierarchical network (part 3 chapter 1.3.3) and the concentration of roads in the centre of Europe, even if the hierarchic aspect is not visible. The map shows that the European space is heterogeneous. The different regions are in an unequal situation. In the aim to take in account the surface effect, we have realised a little typology with the surface of NUTS and the gradient of curves. We have computed the relation between surface and the expansion by NUTS2 to obtain a global surfaced indicator. We can see the effect of NUTS size clearly : Belgium, Holland, Germany and a part of Austria, England and roman Switzerland, very developed countries but with little Nuts are in the same group: an homogeneous zone. The Spain is a characteristic country with very important settlement on the littoral and in the Madrid region. The Eastern Europe with the new adherents is also characteristic.

Finally, a **radial analysis** (part 3 chapter 9.1.3) allows us to approach the same phenomenon as studied above, but from nodes. This indicator also permits us to analyse the spreading and the local polarization of the road network. It permits us to see the "continuum" of cities, an aspect developed in depth in the section 7 and 8 with the notion of polycentrism. But the radial analysis also shows the specificities of each country. Numerous curves have been made to underline various aspects of this phenomenon. For example, we have two types of curves for Belgium and Bulgaria. Belgium is in the "blue banana" and this network growth is faster than in Bulgaria, less dense and developed in terms of transport network.

So, the indicators produced concerning the transport infrastructure endowment highlight the diversity of the European countries transport networks going from old CE countries to new UE countries with an intermediate position of peripheral areas, in particular for road infrastructure.

After this first approach to the transport in the EU, we have been able to go deeper into the analysis, by working on the accessibility.

2.3 The travel times and costs

The analysis of accessibility gives different types of results, according to what has to be reached: a transport infrastructure, a city of more than x inhabitants, all the MEGAS, one MEGA…In fact, it depends whether we consider the accessibility to one transport infrastructure, one territorial function or to all territorial functions (generalized accessibility).

2.3.1 Generalized accessibility

For the generalized accessibility, we have shown in a global way a centre-periphery dichotomy, and particularly for surface means of transport: road (car or truck), and train. We can note that according to the means of transport studied, the location of the centre is not exactly the same but this one remains in an area between Brussels, Stuttgart and the Ruhr. Numerous indicators illustrate this phenomenon quite well.

With, the **Number of cities of more than 100 000 inhabitants accessible by cars by step of time** (part 3 chapter 2.10), the core of Europe appears in an obvious way on the maps in dark colours and grows little by little when the time considered increases[13], materializing the high level of accessibility of this area. The peripheral areas, such as Scandinavian countries, Finland, Greece, Portugal, Ireland Scotland or Southern Italy, are represented in pale because of the weak number of cities of more than 100 000 inhabitants. This phenomenon is readable whatever is the chosen time (excepted for a very short step of time where we can see the internal disparities of each area more clearly). For this indicator, we can note the very good accessibility of most of Great Britain thanks to the great density of cities).

The map realized after the calculation of the **average time to reach all the MEGAS** (part 3 chapter 2.9.2) clearly shows the importance of the geographical situation of nodes for their accessibility when considering surface means of transport. The most accessible parts of Europe are Benelux, Germany and the East of France. But this last region leads us to moderate our remarks about the geographical position. Indeed, the East of France presents its high degree of accessibility thanks to its proximity to the "the blue banana". So, the degree of accessibility here is also linked to the distribution of the MEGAs all over Europe. The geographical position of peripheral parts (mainly North Scandinavia, Finland, Greece) added to the lack of MEGAs leads to very high average times.

Indicators for potential accessibility have been defined and are demonstrated for the ESPON space at NUTS 3 level. **Potential accessibility by road** (part 3 chapter 4.1) is characterised by a clear distinction between centre and periphery. Accessibility by road is the only modal accessibility indicator that reproduces the 'Blue Banana', the central area nowadays called the European pentagon. **Potential accessibility by rail** (part 3

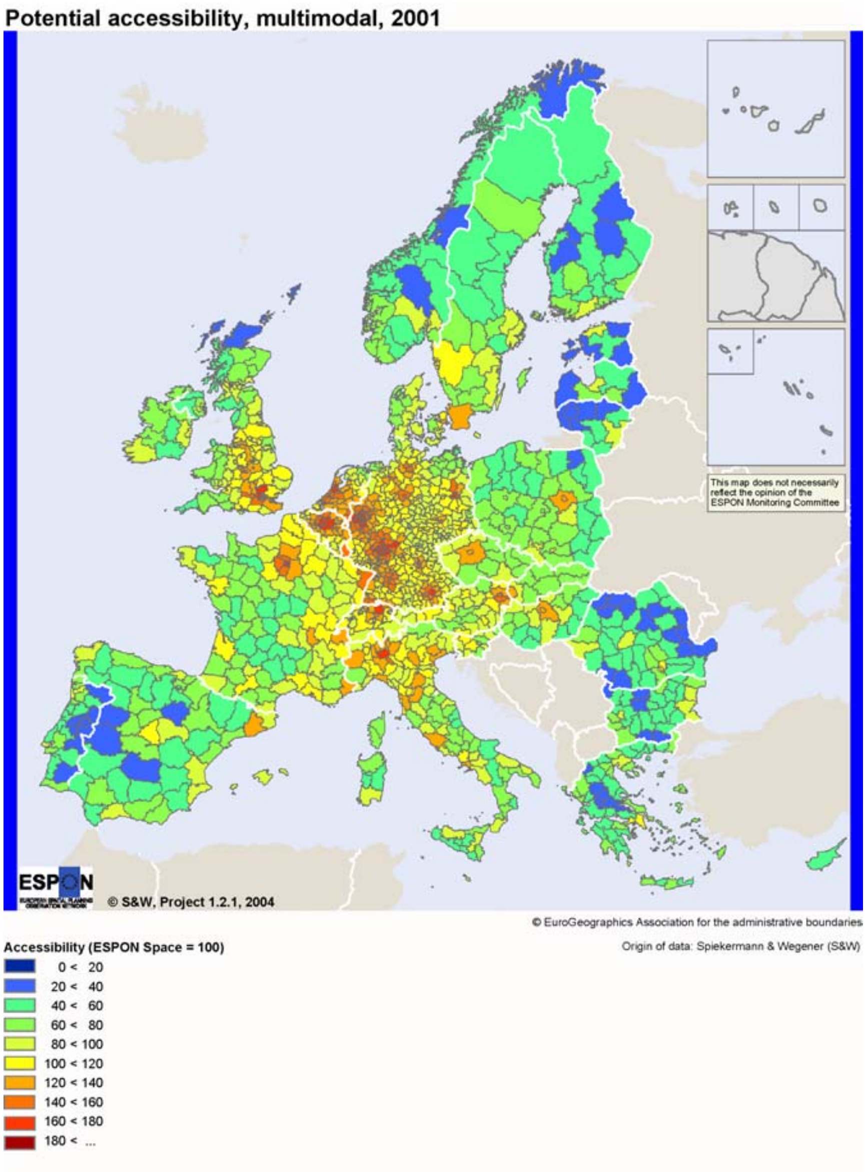
[13] See the annexes to observe all the maps.

chapter 4.2) also provides also a core-periphery pattern in Europe. However, there are two important distinctions from the accessibility by road. The first is that highest accessibility is much more concentrated in the central areas and is visible primarily in the cities serving as main nodes in the high-speed rail networks and along the major rail corridors. Second, it becomes apparent that investments in high-speed rail links and networks can enlarge the corridors of higher potential accessibility by road. This is mainly visible in France where the TGV lines towards the Mediterranean Sea and the Atlantic Ocean lead to corridors of clearly above European average accessibilities.

Potential accessibility by air (part 3 chapter 4.3) shows strong concentration of highest values around major airports, although these are dispersed across Europe. Nevertheless, airport regions in the central EU areas have higher values than airport regions in other parts. The hinterland of the airports is very narrow which is visible by a steep decline in accessibility values when moving away from the airport. Potential accessibility by air yields a completely different picture from the two accessibilities based on surface transport. The map of Europe is converted into a patchwork of regions with high accessibility surrounded by regions with low accessibility. Low accessibility is however no longer a concern solely for those in the 'traditional' European periphery, but is now also an issue for regions located in the European core.

Multimodal potential accessibility (part 3 chapter 4.4) locates regions with clearly above average accessibility mainly in an arc stretching from Liverpool and London via Paris, Lyon, the Benelux regions, along the Rhine in Germany to Northern Italy. However some agglomerations in more remote areas such as Madrid, Barcelona, Dublin, Glasgow, Copenhagen, Malmö, Göteborg, Oslo, Rome, Naples Thessalonica and Athens are also classified as being central or at least intermediate because their international airports improve their accessibility. At the same time the European periphery begins in regions that are usually considered as being central. Several regions in Germany, Austria and France have below average accessibility values, some of them are even extremely peripheral. Many regions in Portugal, Spain, Ireland, Scotland, Wales, Norway, Sweden, Finland, Southern Italy and Greece have very low accessibility values. These regions do not have good access to international flight services. Nearly all regions of the candidate countries do have below average accessibilities. The only exceptions are the capital cities and partly their surrounding regions because of international airports and important connections. For all other regions the combined effect of low quality surface transport infrastructure and lack of air accessibility leads to the low performance in terms of accessibility. In general, the enlargement of the European Union leads to a decrease in average accessibility.

Multimodal potential accessibility, 2001 (p.288)



Daily accessibility is based on the notion of a fixed budget for travel in which a destination has to be reached to be of interest. The indicator is derived from the example of a business traveller who wishes to travel to a certain place in order to conduct business there and who wants to be back home in the evening (Törnqvist, 1970). Maximum travel times of between three and five hours one-way are commonly used for this indicator type.

Daily accessibility by road (part 3 chapter 3.1) is characterised by a clear distinction of regions with high motorway and expressway density and high population density in NUTS3 nearby. Centre regions in EPON space (central Europe : the so called European pentagon), the middle-South of

England and the north of Italy) and peripheral regions are clearly differentiated on the map.

'City network' daily accessibility by air (part 3 chapter 3.3) is based on timetables and on the possibility to make typical business trips in a single day with a minimum of 6 hours spent at the destination city; with trips belonging to the time interval 6h to 23h. The indicator is broken down into three levels of accessibility: no existing flight, existing flights but no possibility of making business trips, business trips possible. The results show deeply asymmetrical situations that validate the method and illustrate dysfunction in the supply structure that cannot be revealed by the more classical indicators of shortest time and frequencies. The functioning of a city network supposes the activation of a limited set of links in which each city is at least connected to its closest neighbours. Supporting a 'city network' in Europe could mean reinforcing some specific air or rail-air relations the weakness of which are revealed by this indicator.

2.3.2 Accessibility to transport infrastructures

The connectivity indicator (ICON) shows that the proximity is less a question of physical distance than a question of adequate connections to the main communication networks. It evaluates the accessibility of any place based on its minimum access time by road to the closest transportation nodes (e.g., the closest motorway entrance, the closest railway station, the closest commercial port...) and is evaluated as an aggregation of the values (ICONi) obtained independently for each considered transportation network (i=1...N), in proportion to their relative contribution to regional transportation endowment.

Cost to transport terminals by car consists in the connectivity by road to all transport nodes (motorway access, high-speed rail stations, commercial airports and ports) that provide the required level of service (ICON formulation and values of services and transport network contributions are explained in the report). Due to the high proportion of connectivity to road network given in the calculation most of regions in ESPON space show a good connectivity to transport terminals.

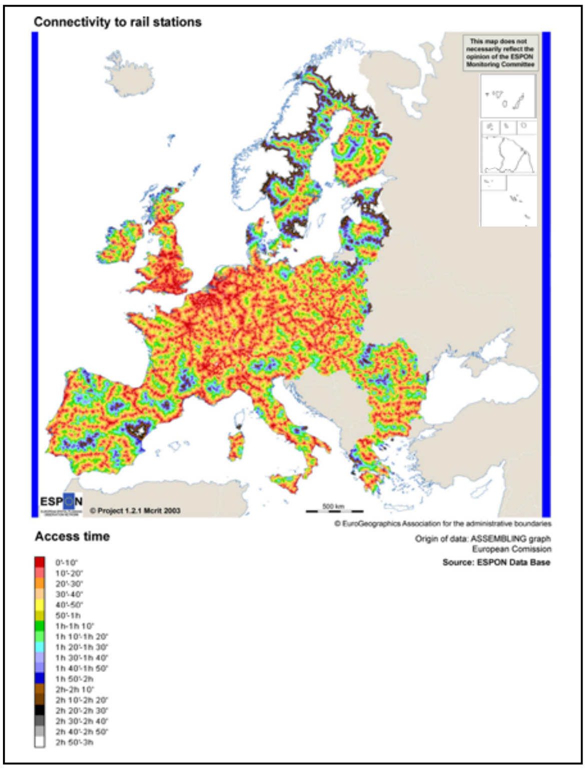
In general, regions in EU15+Norway and Switzerland show a better connectivity than in Accession countries, but in some cases peripheral regions show best connectivity due to ports and airports infrastructure (coastal Bulgarian regions, etc.).

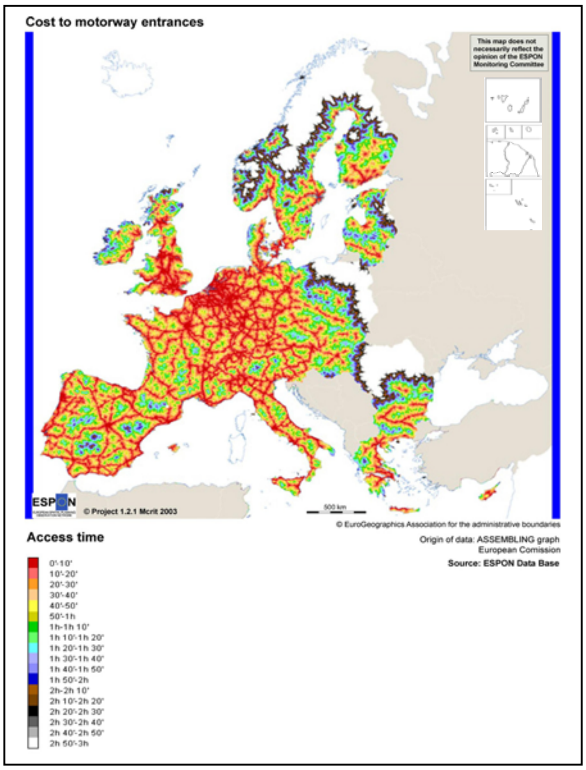
Cost to motorways by car (part 3 chapter 2.1) shows the minimum time to motorway access and is characterised by a clear difference between EU15+Norway and Switzerland regions and the ones of Accession countries, and coincides with the map of motorways and expressways density indicator.

Cost to high-speed rail stations by car (part 3 chapter 2.2) reflects the regions that have a high-speed rail station well connected by road with at least 75 trains/day. Apart from the connectivity it gives an idea of the high-speed rail stations endowment, in terms of high-speed rail stations and not length (like the high-speed rail lines density indicator calculated in this report).

Cost to commercial airports by car (part 3 chapter 2.5) shows the minimum time by road to commercial airports with at least 0,5 Mpassengers/year. The map indicates the situation of commercial airports with a high flow of passengers per year and its connectivity to the road network.

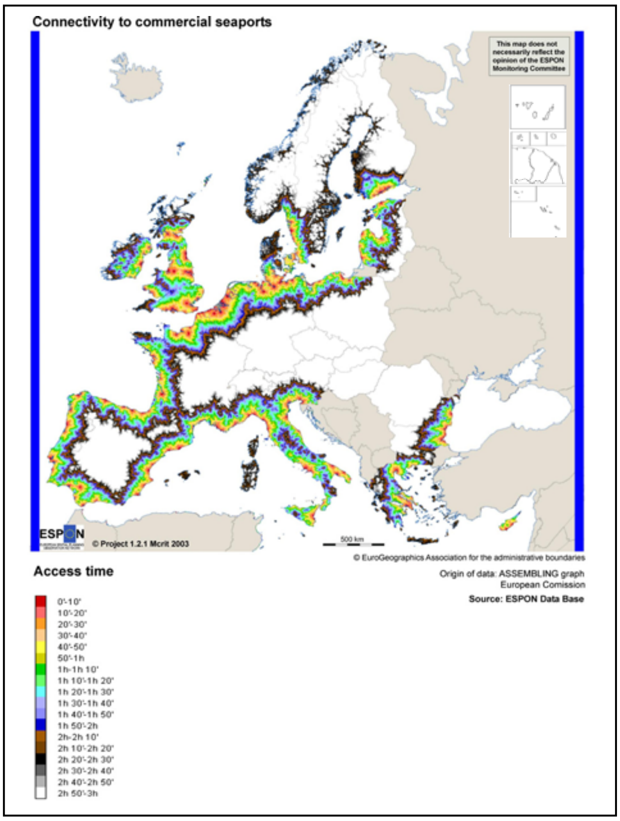
Cost to commercial ports by car (part 3 chapter 2.4) shows the same concept as the previous indicator but considers commercial ports. In this case it shows the minimum time to commercial ports with 0,5 Mtonnes/year.





Connectivity to rail stations (p.231)

Cost to motorway entrances (p.229)



Connectivity to seaports (p. 233)

Accessibility to a territorial service

If we focus on a territorial service however, by considering the travel times to cities, which could play a pivot role, or to transport terminals, we bring to the fore the particularities of each area more effectively. The classic centre-periphery scheme becomes more complex, the situations appear very various with very specific cases (i.e. islands, mountains, densely populated areas in peripheral areas or on the contrary regions with problems in the core of Europe).

The **average travel time by cars to reach the three nearest cities of more than 100 000 inhabitants** (part 3 chapter 1.3.1) underlines the important isolation of certain internal areas, due mainly to a particular geographical situation as for mountains in Spain, France, Italy and Austria or plain in Poland, Latvia and Estonia. The littoral effect is really more contrasted. If in some areas the littoral lands are far away from a city of more than 100 000 inhabitants, in others the localisation of many important cities is near or on the coast, as for example around the North Sea, the western Mediterranean Sea, the South-East of Italy, etc…, and leads to a very low average time.

On a national scale this indicator shows three groups of countries:

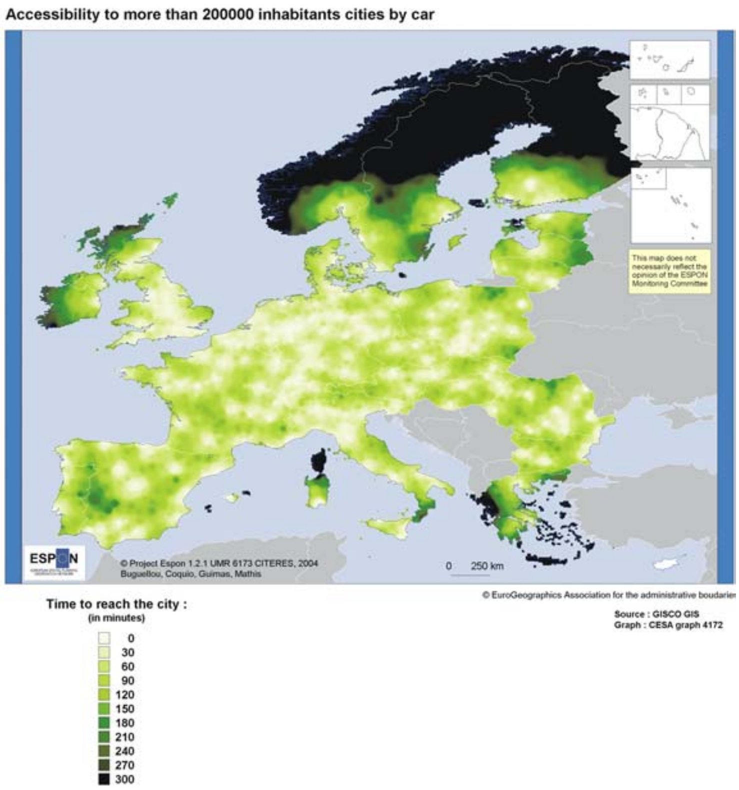
- Nineteen countries have a slow growth of this average travel time, always inferior to 2 hours
- Four countries present an average value of roughly 3 hours
- Two countries have a medium value superior to 5 hours.

We can note that all the Scandinavian countries and Finland are part of the last two groups, as a consequence of their low human density, to the low number of important settlements.

The fact that Greece belongs to the last group is probably due to its large number of islands. The necessity to take a ferry to reach major cities, and its slow speed, are the main cause of this apparent isolation. The aggregation by NUTS2 shows internal differences, underlining the relative homogeneity/heterogeneity inside the countries themselves. The different peaks show the existence of very isolated NUTS in some dense countries. They generally concern specific areas such as islands. (For example, the French peak represents Corsica). The great heterogeneity of Greece is coherent with its specific morphology as mentioned above. At the greater scale of NUTS3 , the amplitude of imbalance increases and the maximal values are clearly more important. The countries that still presented heterogeneous distribution at the scale of NUTS2, see their internal imbalance accentuated in an obvious way. This is the case for example of Norway, Sweden, Finland and Greece.

But, in spite of this scale's modification, some countries continue to be homogeneous. This is the case of Germany and of the Benelux countries, probably because of the regular network of important cities and the good accessibility of each NUTS of these countries.

Subseqently, the **travel time by cars to reach the nearest city of 200 000 inhabitants** (part 3 chapter 1.3.2) show that inside some countries themselves we can observe the differentiation between centre and periphery. This is the case for example for France with a high value of the indicators for the regions of Limousin and near the Massif Central or on the boundaries between Spain and Portugal. It is nevertheless not the case in the "blue banana" where the indicators have a low and homogeneous value inferior to 1h30. We can formulate a similar observation around and inside the mountainous areas such as the Pyrenees, a part of the French Alps and the Austrian Alps. The situation of coastal areas is different with, in a general manner, a greater accessibility than inside countries. It is the case in an obvious way for Spain, because of the presence of many big cities near the sea. Furthermore, it is interesting to note that we can nearly see the beds of the main European rivers as the Po, the Danube or the Rhine because of the pale colours around them, materializing the proximity in terms of travel time to a metropolis.



Accessibility to more than 200000 inhabitants cities by car (p. 185)

The Number of cities of more than 100 000 inhabitants accessible by cars by step of time (part 3 chapter 2.11) underlines the fact that the specific geographical conditions seem to play a major role. For example, the mountainous areas like the Massif Central , the Alps in Austria or the Carpates have a low accessibility, by contrast with river basins as in the northern Italy with the Pô. The case of coastal areas is more contrasted, according to local particularities. The differences between areas of the "blue banana" and other areas in terms of spatial density of big cities (without taking into account the transport and temporal aspect) mechanically drives the opportunity to reach more of these cities in a restricted area of diffusion. This partly explains the level of this indicator for Great Britain, isolated in terms of transport because of its insularity, but with a high network of cities and a great density in the whole country.

Finally, for the **time to reach the nearest MEGA by trucks** (part 3 chapter 2.10.1) we can note that some regions seem to be weakly accessible to these MEGAs. The north of Scandinavia and Finland, the west of France, the boundary between Spain and Portugal, the Mediterranean islands, the north west of Greece, and the north of Romania present very high values concerning their travel time to the nearest MEGA. We can note that all these regions are located in peripheral parts of Europe where the network of important cities is less important than in the core of Europe. This phenomenon is probably a direct consequence of the unbalanced spatial distribution of MEGAs all around the European territory.

Secondly, we can nearly see the "**Blue banana"** going from Milano to London and presenting a high number of MEGAs (Milan, Stuttgart, Zurich, Brussels...). But if we look more precisely, we can observe that this dark area (according to the chosen typology of colours) does not exactly have the classical shape of the "banana". It is a bit deformed, with an extension to South and west up to cities such as Marseille and Nice in the South-East of France. Thirdly, we can note the difference between West and East Germany, linked to the former partition of this country. Finally, let us notice the high accessibility to MEGAs of the main part of Poland, which presents values nearly as high as the core of Europe.

While considering these **MEGAs**, we can raise **the interrogation of the role** that can be given to them. Indeed, they can play a role of pivot to fight again the centre-periphery situation. Their role is particularly important in peripheral parts of Europe, where they can constitute relays for their hinterland. From a transport point of view, they can constitute « gates » for their hinterland to reach the whole European space. It is here that fast means of transport become essential, because they can attenuate the classical centre-periphery scheme, transcending the national frameworks and reinforcing the balance and the cohesion of European spaces.

The indicator developed in part 3 chapter 2.9**, travel times by air or rail between MEGAS**, deals precisely with air relations between MEGAS (with a modification of the list proposed by Espon Group 1.1.1) from a polycentric perspective. It has as its aim to show the possibilities of relations of less than one hour between MEGAs. Thus, the map realized expresses a factor of integration of the European territory. The connexity of the system of relations allows the continuity of one-hour relations in the core of the continent from Rome to Edinburgh and from Bordeaux to Helsinki. The Baltic States are linked to the Union through relations between Tallinn and Helsinki and Stockholm.

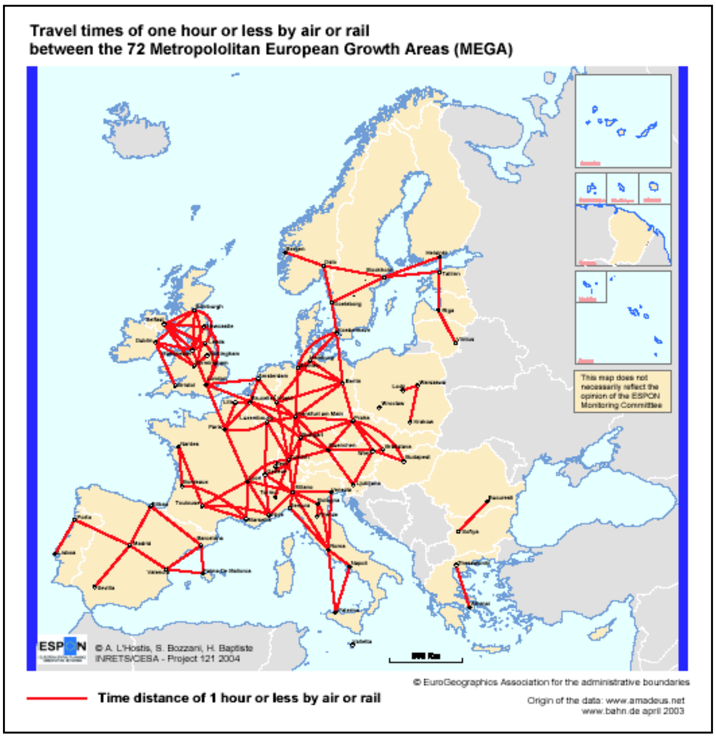
According to that criterion, Poland, Romania, Bulgaria and Greece are poorly connected to the centre and poorly connected one to another. Furthermore, the Iberic peninsula has no one-hour connection with the rest of Europe.

Another interesting indicator concerns the **daily accessibility by air between MEGAs.** Firstly the pentagon is clearly visible on the map with high levels of connection in the core region extended to Rome. Secondly, the cities of the eastern and accessing countries show a relatively much lower level of accessibility, with the exception of Praha.

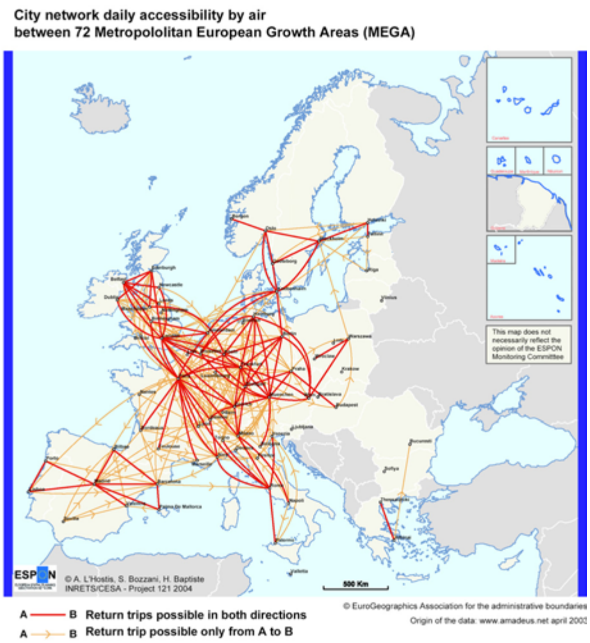
The coherence of the Nordic network appears clearly with the role of gateway of Kobenhavn. The Baltic States are clearly related to the Nordic triangle, even if the connections could be improved as for example, from Stockholm to the Baltic states capitals. Indeed, the connections between the Baltic States and continental Europe according to this indicator are inexistent.

In the Iberic Peninsula, a high level of integration is reached between Madrid and the major Spanish and Portuguese cities, but the gap with continental Europe is here, confirming the findings of the travel times indicator (part 3 chapter 3.3). To summarise, from the point of view of the city network daily accessibility indicator, this modified list of MEGAs shows a more integrated European territory than the initial list of 62 cities. The geographical coverage of the distribution of cities is better, especially in the peripheries, allowing to better illustrate the existing links between the periphery and the core, and also to identify the weak relations, such as between the Iberia Peninsula and the rest of the continent.

It must be stressed that the indicator is based only on air relations. In the cases where air relations are poor but distances are short, such as in the Swiss urban system for instance, the rail mode will fill in the gaps revealed by the air indicator. For some other specific cases, the high speed rail can also replace the air mode in inter-MEGAs relations as in the typical example of the Lille-Paris relation.



Travel times of one hour or less by air or rail between 71 MEGAs in 2003 (p.248)



Daily accessibility by air between 71 MEGAs in 2003 (p. 273)

To summarize the main findings of this part dedicated to accessibility, we have seen that the **classical centre-periphery scheme could not be denied but that it was completed by other features**. Indeed, some peripheral nodes can improve highly their accessibility greatly thanks to fast means of transport and some parts of the centre of Europe can be quite far (in time) from main urban dynamic centres.

But let us remember that nodes and areas generate flows on the network, owing to the demand of transport, highlighted by some indicators developed….

2.4 The traffic volumes and flows

The nodes and areas generate flows owing to their internal characteristics and their accessibility to other areas, leading to flows on the network.

For example, the **number of tons exchanged by each node of the graph** (CESA graph 765) shows the heterogeneous distribution of origins of flows in the European space. The capitals are important sources, compared to medium-sized cities. The map realized also clearly shows the differences of generation between the West and the East[14]. We can underline here the fact that the spatial distribution of European cities is not favourable with a homogeny distribution of flows.

Indeed, the **hierarchy of the road network** (part 3 chapter 1.3.3) according to the potential relations between major European cities (in terms of population) underlines this phenomenon.

It raises the problem of spatial equity in terms of accessibility. The superior network (two first classes) does not cover peripheral areas, where population is sometimes dense without being concentrated in big cities. But by showing potential relations between main production areas, the map shows interesting elements. A new structure of transport network takes shape, not only concentrated in the West of Europe. **Vienna and Bratislava become major crossroads** for the exchange with Hungary, Bulgaria, and Romania and more generally all the European South-East, at least until the passage via the Balkans is really open and safe. The apparition of **a triangle linking Warsaw, Berlin and Vienna** traduces the potential strong relations between these cities and, in corollary, the risk of the saturation of roads.

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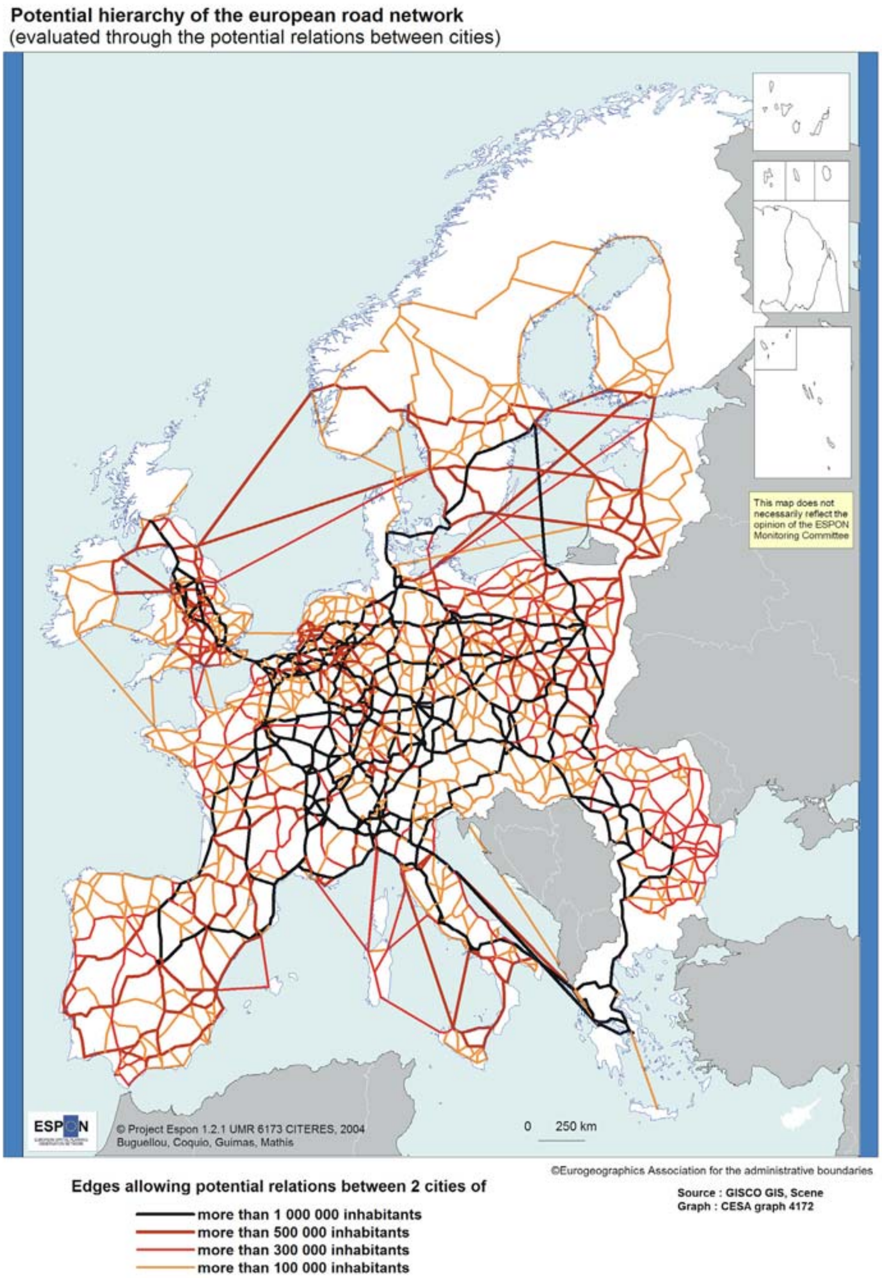
[14] Highly linked to the Scenes database structure.

Nevertheless, the interactions between the transport and the urban network lead to the development of important corridors whose orientation is globally radial, and potential problems of vulnerability and capacity[15].

Hierarchy of the European road network (p. 188)



[15] Ideas that will be developed at the end of this summary.

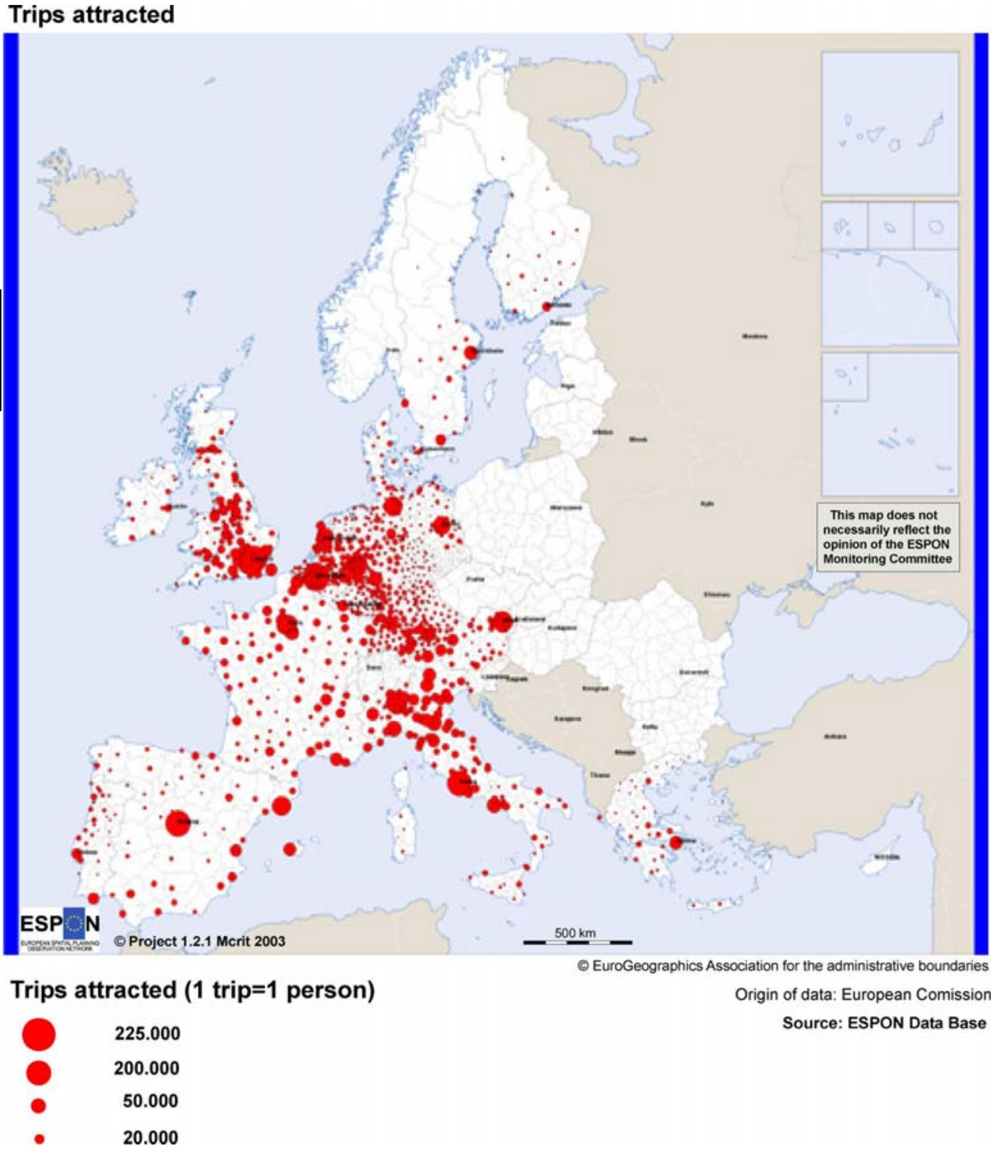
2.4.1 Demand of transport

Let us begin by the distribution of the demand.

First of all, **the personal trips generated** (part 3 chapter 5.1) by NUTS2 maintain that NUTS2 with higher generation of trips are those containing country and macro-region EU15 capitals. As an exception, Poland and Romania generate more trips than the rest of the accession countries due to their high population. Scandinavian countries and Finland generate fewer trips than regions of EU15 countries because of their low population density.

Secondly, **personal trips attracted** (part 3 chapter 5.2) have been calculated for all NUTS2 in ESPON space. NUTS2 with higher attractiveness are those allocating country and macro-region capitals (in general very populated), especially if from EU15, and accessible from all points of the territory. This is the case of Paris, London, Milan, Köln and Berlin in Europe, and Warsaw in the accession countries. Some periphery regions have a high attractiveness due to the pressure of tourism (like the Spanish western and Southern coast).

Note that due to the lack of data of tourist pressure for the new EU countries no leisure and visit trips have been calculated for them, and therefore the total number of trips attracted is much more lower than those of EU15 countries.



Trips attracted (p. 294)

Traffic volume indicators capture the actual use of the transport infrastructure networks. Km per person per mode by purpose is an indicator of transport quantity. Two indicators have been calculated for NUTS2 of ESPON space: km per person by road in obligated (or business) trips and in leisure trips (vacation). All of them indicate the average distance by road of generated trips in each of the ESPON space regions, and give an idea of the destination of the generated trips.

Km per person by car in obligated trips (part 3 chapter 5.3.1) is characterised by periphery and centre of the ESPON space. Peripheral regions drive to regions with higher population and GDP, which are situated mostly in the centre of ESPON space.

Km per person by car in leisure trips (part 3 chapter 5.3.2) is characterised by eastern periphery and the rest of the ESPON space. Regions in the periphery of the ESPON space drive to regions with high population and touristic attraction, mostly situated in the centre and south of this space.

The freight volume generated is presented on the maps of the chapter 5.4 in the part 3.

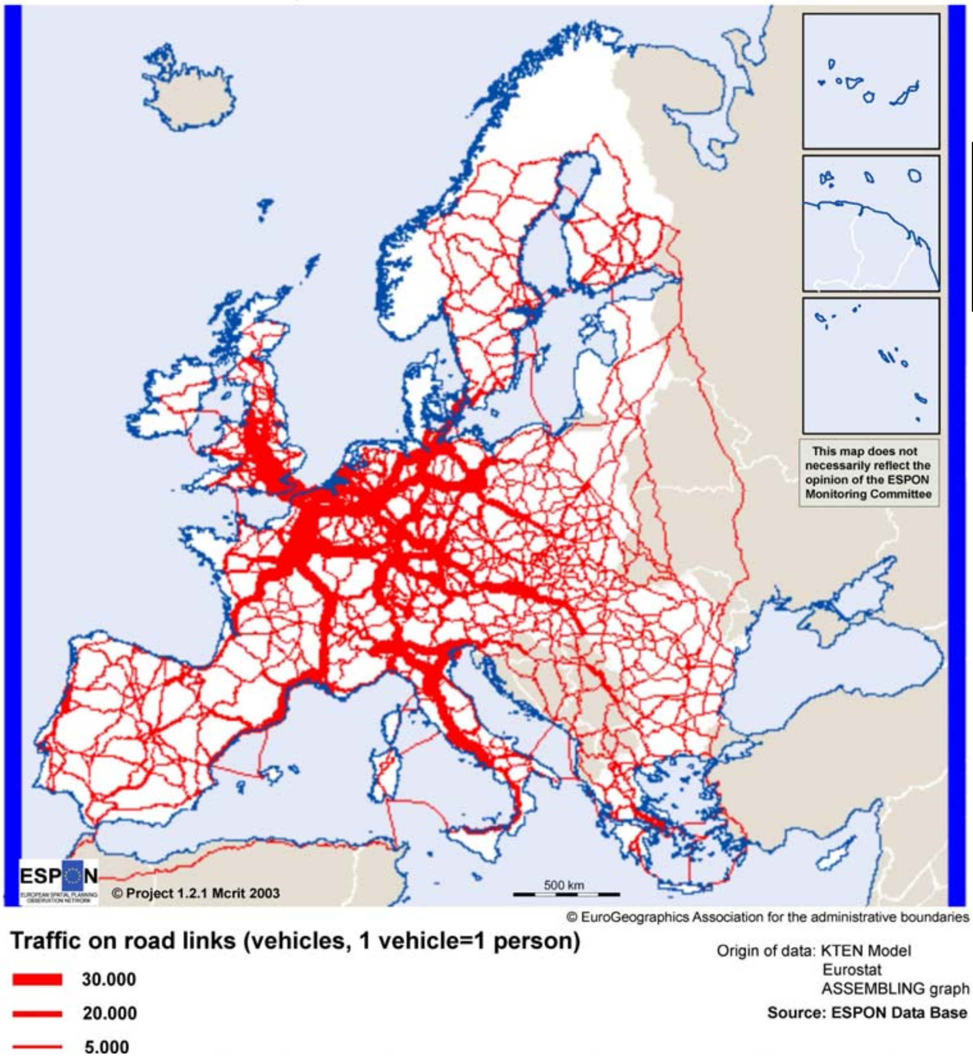
Airport traffic (part 3 chapter 5.9) has been mapped for all NUTS 3 regions of the ESPON space. Different categories of commercial airports have been distinguished: most major and secondary hubs are located in EU country and macro-region capitals, like London, Paris, Frankfurt and Milan, Madrid, etc. There are also airports, most tourist meeting points, with high traffic volume in the periphery, like Palma de Mallorca, Malaga and Athens as a tourist hub for destinations within Greece, and the ones in the Scandinavian countries. Regional airports have lower traffic and usually provide services to the country's capital airport and to some of the major hubs. It should be noted that in EU countries there is a complete hierarchy of all airports, whereas in most of the accession countries this is still to be completed. There are just the airports in the capital acting as a hub for the few (if existing) regional airports, which are spread all over the territory (this is the case of Poland and the Baltic countries).

2.4.2 Flows volumes

All these demands lead to traffic on links. For example, with **car traffic on road links** (part 3 chapter 5.3), main corridors are highlighted between most EU central countries capitals. It is not only the fact that they are bypasses to go from any point in the territory to another, but their highest generation and attraction index. For this geographical reason, road networks in peripheral regions do not have such heavy traffic on their links, in some cases reaching values 100 times lower, which leads to less negative externalities, as will be developed after.

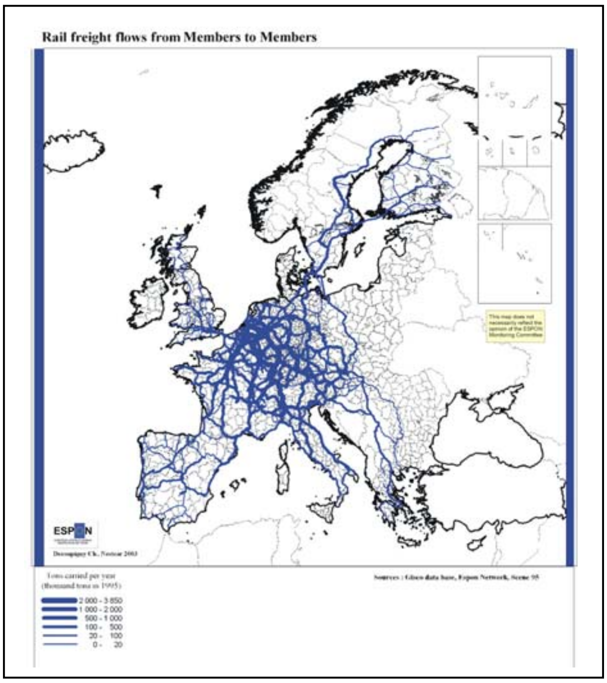
Concerning **freight traffic on road** (part 3 chapter 5.6), we can see is that main corridors are located in EU15 countries, mainly Benelux, Germany, Italy and France. By showing the road traffics involving new EU countries, the map allows us to locate the regions which can see their traffic increase in a significant way, with the enlargement of the EU. These ones are in eastern Germany, Austria, and the North-East of Italy.

Traffic on road links / Purpose: business



Traffic on road links / purpose: business (p. 306)

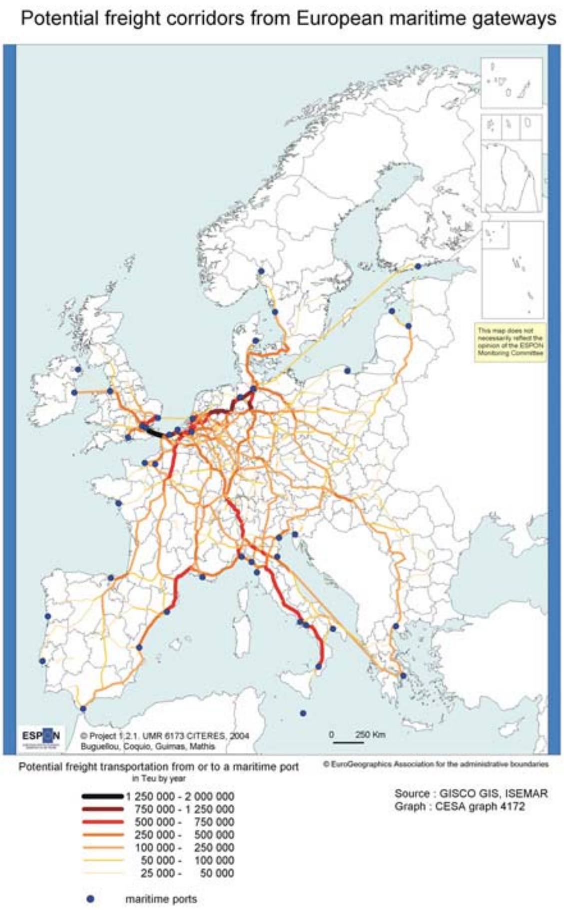
The **Freight traffic on rail** (part 3 chapter 5.7) is roughly similar in its general form to the freight traffic on road. However, in the case of the rail freight flows from CEE to CEE we do not see in Germany the corridors toward the East. We observe that the highest traffics are found in Benelux, Germany, North Italy and France and the high volumes of traffic in the eastern countries.



Rail freight flows from EU of 27 (p. 319)

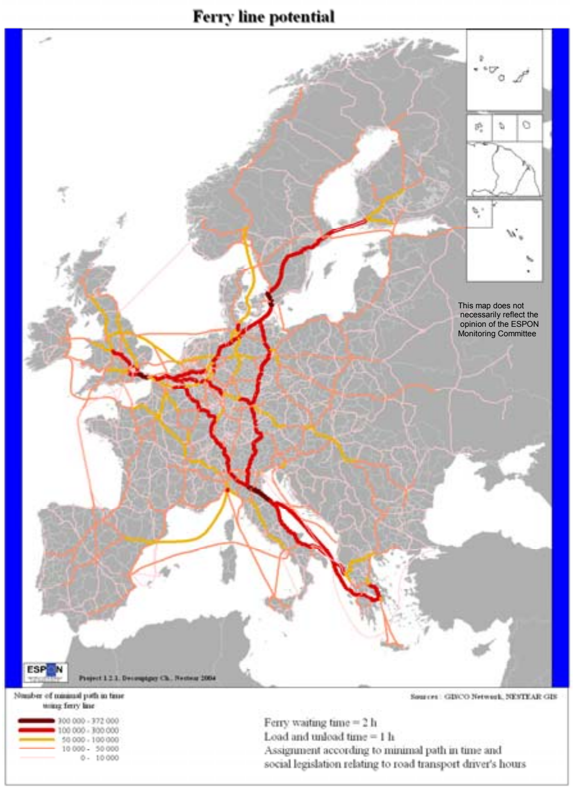
The indicator of **flows between MEGAs** (part 3 chapter 5.10) shows the proximity between them. Indeed, we can see high values of traffic for edges linking: Milan and Turin, Berlin, Hamburg and Bremen, London, Manchester, Birmingham, Glasgow and Edinburgh, and finally Göteborg and Stockholm. The values in the eastern part of Europe are very low but this is mainly due to the structure of the Scenes database, which gives very low values of exchanges for this area. While looking at this map, we could say that Benelux and the Rhine valley are at the crossroads of these flows but we have to be aware that it is not possible here to know if the traffic on these edges is due to relations inside this area or to exchanges between MEGAs located outside this area.

The potential freight corridors from European maritime gateways (part 3 chapter 5.8.3) shows the corridors potentially used from European maritime gateways. These ones are mainly located in Benelux, Germany, France, Switzerland and Great Britain. Using our method, we stressed the importance of big cities through the use of a gravity model. These cities are located on corridors, and this is why the map is very similar to the different maps in this report showing the corridors. But here the importance of the links located near the sea is accentuated and this is why we can see the high values for the edges concerned . The most stringent case is for the links located near the Mediterranean Sea (from Valence to Gioia Tauro). Finally, we can observe that the road corridors starting from Atlantic ports have lower traffic values than for North Sea and Mediterranean ones and there may be opportunities to develop their traffic.

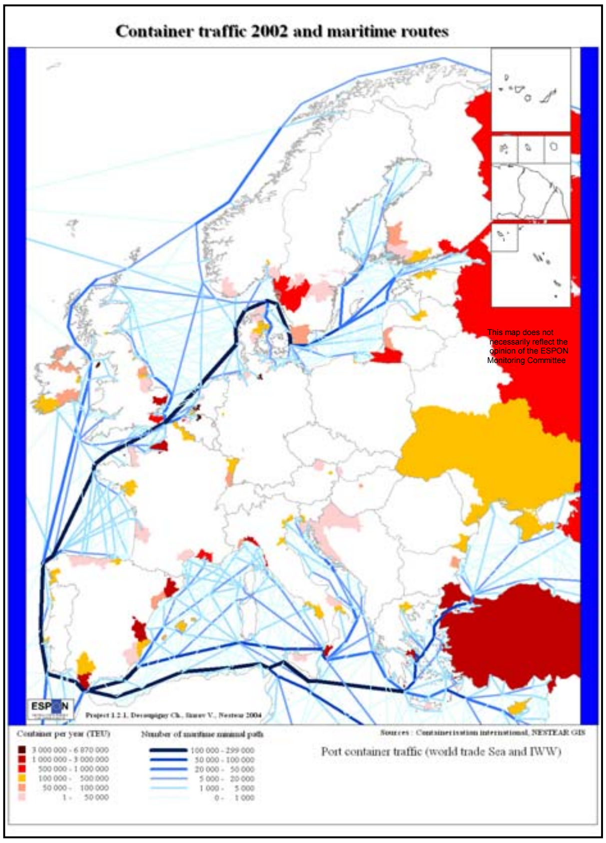


Potential freight corridors from European maritime gateways (p. 340)

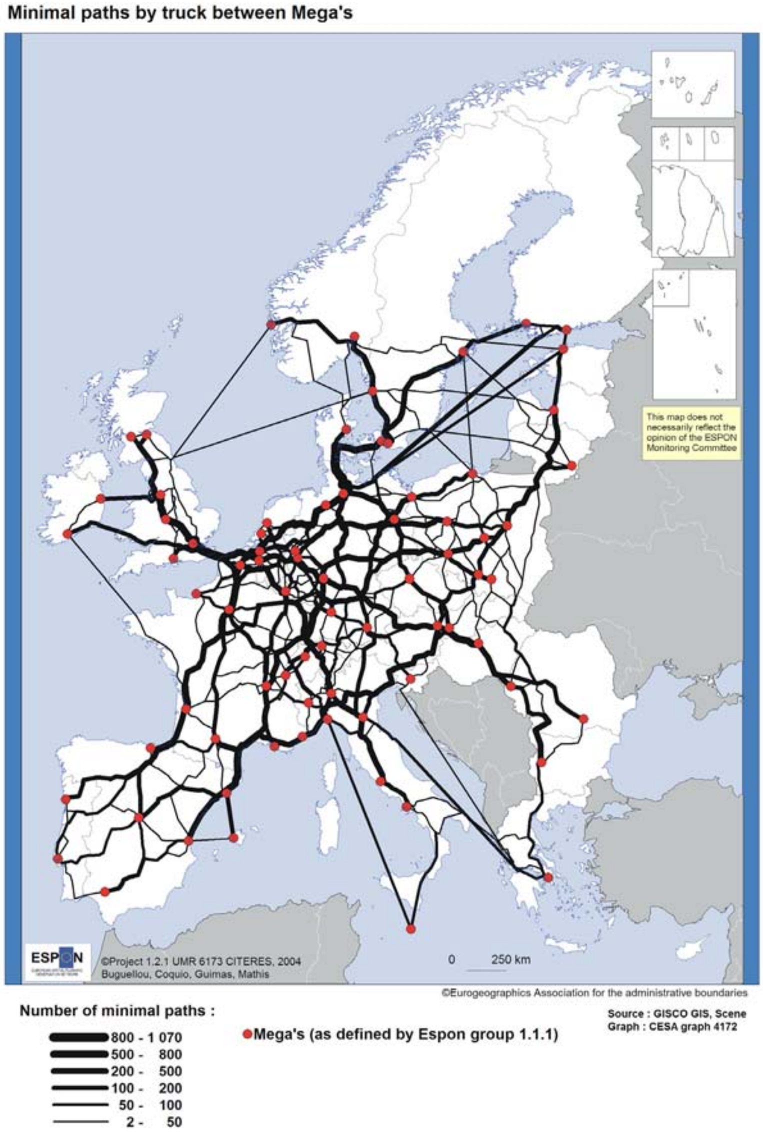
Ferry line potential (p. 327)



Container traffic 2002 and maritime roads (p. 329)



Finally, the indicator presenting the **potential relations between MEGAs** (part 3 chapter 5.10), not depending on their proximity, allows us to show where the crossroads are located in Europe. It is clear that the area containing Benelux, the East of France, the West of Germany and Switzerland contains most of them. Secondly, this indicator adds a prospective view to the work by showing in a better way the relations with and between new European Union countries MEGAs more explicitly. Thirdly, the map shows "narrow passages" for these potential relationships: the Channel Tunnel, the Pyrenees tunnels, the "Nyborg-Stagelse" bridge.



Minimum paths by trucks between MEGAs (p. 346)

The evocation of these problems of vulnerability leads us to go deeper into the analysis and concentrate on major territorial stakes linked to transport, mainly externality and vulnerability problems. Indeed, for the territorial stakes linked to transport, we have focused on work on problems of externalities and on vulnerability. We would have liked to deal with capacity, but this has been impossible due to the lack of data.

2.5 **The transport externalities linked to transport**

Transport is facilitating social and economic relations and, at the same time, is generating environmental externalities that reduce and constrain the capability of a given region to attract new activities, as well as to some extent the productivity of the already existing activities. Accidents, emissions, land occupation and land fragmentation are the most important strategic impacts of transport in this respect. Others are energy consumption or noise exposure.

Deaths and injuries in road accidents are one of the most direct negative impacts of the transport system on human beings. **Road traffic deaths** (part 3 chapter 6.1) have been selected here as a transport externality indicator. Data for the indicator at NUTS-2 level are presented. They show that there are extreme differences between the European regions ranging from 22 deaths in accidents per million of inhabitants in Ceuta Y Mellila in Spain to up to 369 in Alentejo in Portugal. The highest figures exist in regions of Greece, Spain, Portugal, France and Eastern Germany. Road traffic deaths are also very high in regions of the candidate countries, mainly in Latvia, Lithuania, Poland and in the western parts of the Czech Republic. Most regions in the UK, the Netherlands, western Germany and in the Nordic countries have relatively low figures.

The **transit flow per area** (part 3 chapter 6.3). When working at the NUTS2 level, we see, logically that the NUTS2 presenting the highest values are in the EU 15 countries, and mainly in Benelux, Germany, France, Switzerland and Austria. But we can see that the distribution of these flows is very different from one country to another. For example, there are in France two or three corridors for transit flows and some parts of the territory are not used for this kind of traffic. On the contrary, the distribution of flows in Germany is more evenly distributed through the territory.

The results for NUTS3 areas give to us some complementary data. Even if the values are highly dependent on the size of the NUTS, which is not equal, we can see once again at this level the different kinds of distribution of flows in the countries.

Nevertheless, this analysis must be taken with many precautions. Indeed, The surface of NUTS2 and NUTS3 is very different in the European countries. It is very small in Germany, Switzerland and Belgium and is quite important in countries such as France, Spain, and Poland. Moreover, the NUTS can have various shapes, which can influence the results in a significant way. For example, if we only keep the values in tons.km (without taking into account the surface of the areas) , the results are very different: all the little NUTS have low values because the number of kilometres cannot be high.[16]

So, the results produced here are interesting but show clearly that the nodal analyses are very important to compensate the disadvantages of classical

[16] These results are available in annexe

analyses by surfaces (by NUTS), which give false conclusions if they are taken alone[17].

The **number of tons of goods going through nodes** (part 3 chapter 6.2) indicates the main corridors of Europe which lead to potential high negative externalities for the areas concerned: the Rhone and Po valleys, the Cologne-Nuremberg axis, the British corridor...we can say that the central part of Europe is the area suffering the most from concentration of emission of pollutants because of the number of inhabitants and cities. We can add to this area the south of Great Britain, which presents very high values, mainly for London and Birmingham. Secondly, thanks to the calculation of the number of tons per node, we show the crossroads of main European flow axes, which would not have been possible by simply working on edges. So, cities such as Nuremberg, Bologna and Frankfort present very high values, together with other important cities (Paris, Milan, London).

Finally, we must add that the results for these cities would have been much higher if we had been able to take into account the infra-regional freight and individual vehicles flows which seriously accentuate the problem of congestion and externalities in a general manner. Moreover, the map shows very low values for Eastern countries but flows concerning these countries are going to grow considerably in the future[18]. Moreover, it is interesting to note the great heterogeneity inside the different countries themselves. For example, we can note very high peaks in the United Kingdom, in Germany or in France. These peaks correspond to national capitals like London in England or Paris in France and to major crossroads like Nuremberg in Germany, that concentrate an important part of flows from Eastern countries.

In a general manner, nodes of Western countries are really more used than Eastern ones, due simultaneously to the density of cities in these parts of Europe, the importance of their level of emission/reception and their specific role in terms of transit because of their specific geographical localisation in the whole territory and in the global network.

The **emission of air pollutants** (part 3 chapter 6.4) addresses the regional and local impacts of transport emissions and will be calculated as CO and NOx emissions of road transport.

The emissions of pollutants induced by transport constitute one of the main negative externalities on the social, natural but also economic environment.

[17] It is why we have chosen to make a nodal analysis showing the number of tons of freight going through nodes

[18] We can add to complete this remark the very low values in the Scenes database for freight emissions and receptions.

They are linked to the kind of traffic (local, regional, national or international), the speeds and the traffic concentration. The major impacts are concentrated on the strongly urbanised spaces, the transit corridors, the areas of goods' production and the crossroads.

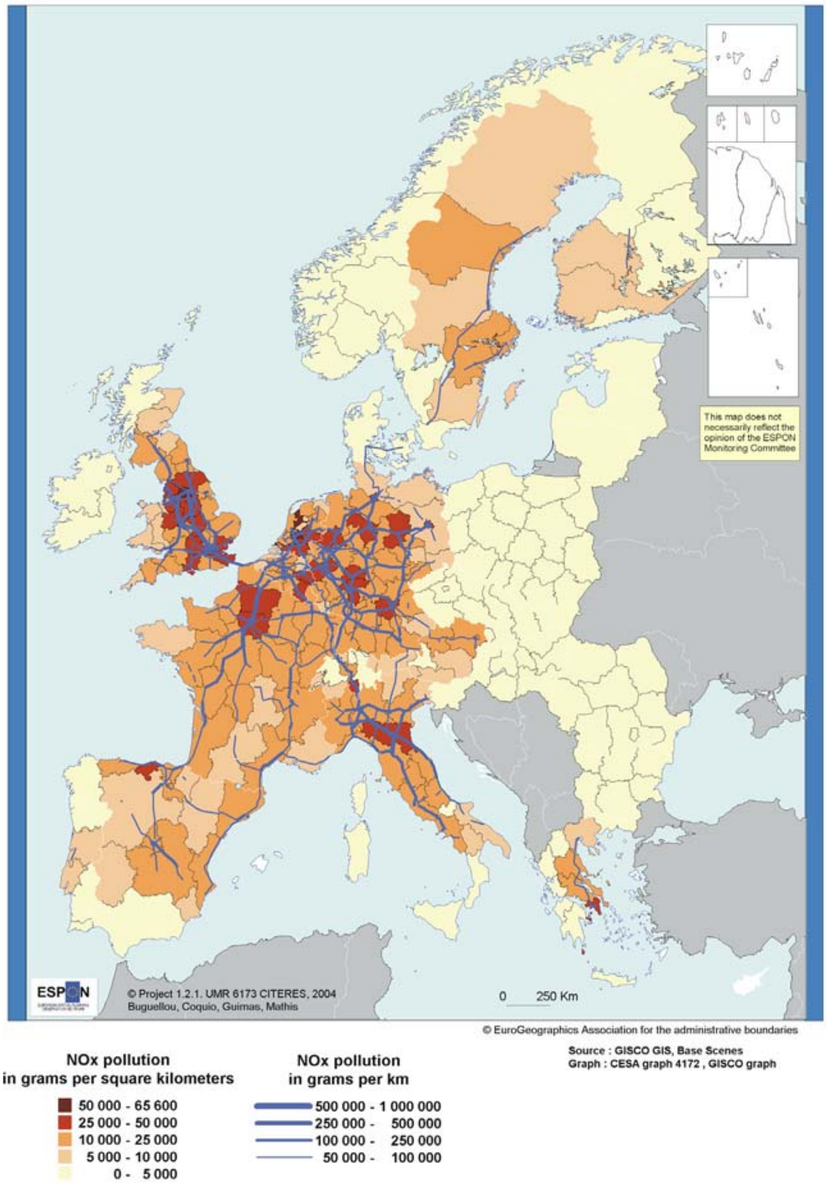
Concerning the specific cases studied, we can observe that the CO pollution is relatively diffused on the whole territory. Nevertheless, the externalities are particularly strong in England, notably along the axes between London - Liverpool and London - Leeds. The core of Europe also suffers from a high pressure, as in the plain of the Po and along the Via Emilia (crossroads of Bologna in Italy).

Furthermore, in these areas where pollution by CO is concentrated, we can distinguish another kind of spatial repercussion. Thus, we can see radial moves around certain capitals, as around Paris, Madrid and Athens. In France, Spain and Greece, pollution is less generalised but centralised around capitals: places of concentration of people, activities, and transport infrastructure.

A few transit corridors are noticable, such as the French A10, the axis Milan – Saint Gothard – Base, the valley of the Rhone.

A weak level of pollution appears in the "Finistères" (i.e. peripheral areas) and Eastern Countries. These low values express a weak level of goods' exchange.

Trucks Emission and NOx pollution



NOx emissions of trucks (p. 363)

Finally, the indicator **potential territorial externalities of road transport network for freight** (part 4 chapter 2.2) shows clearly the areas where the intensity of traffic is high and the density of network high-ranking: Benelux, the Rhine valley in Germany, Paris and the London-Manchester axis. After these areas with very high values we can observe other zones with quite high results: North Italy, a large part of France and Germany and the East of Spain.

To sum us, the potential externalities are not distributed in a homogenous way on the European territory: the areas presenting a good accessibility seem to be those which suffer the most from transport externalities.

2.6 Network vulnerability

The effectiveness of a network depends on its functionality, on its connectivity but also on its continuity and on its durability and thus, on its vulnerability to the risks. Various phenomena can cause problems in the accessibility of some areas. The intensity of this difficulty depends simultaneously on the probability on the problem, on its intensity, on its size and on the importance of the link it concerns.

In this logic we have decided to realize two different studies.

The first concerns the relative role played by each node and each edge. It permits us to underline the respective weight of these elements of a network according to global connectivity and to the level of their use for freight transportation.

The second is about specific hazards, anthropogenic such as a collapse in mountains or a car accident in a tunnel but also natural such as the flooding of rivers or snowstorms. In these cases, we have dealt with the consequences in terms of transfer of flows in the network consequently to this kind of situation.

Of course neither the list of these risks not the example chosen to describe it, claim to be exhaustive. The aim is just to give a preliminary idea of the consequences of such phenomena.

Since the third interim report, we have been able to produce tools permitting us to evaluate the importance of an edge (or a set of edges), a node (or a set of nodes) through the effects of their removal (expressed in tons.min or tons.km).

2.6.1 Systematic evaluation of nodes' and edges' respective weight

2.6.1.1 Suppression of the edges

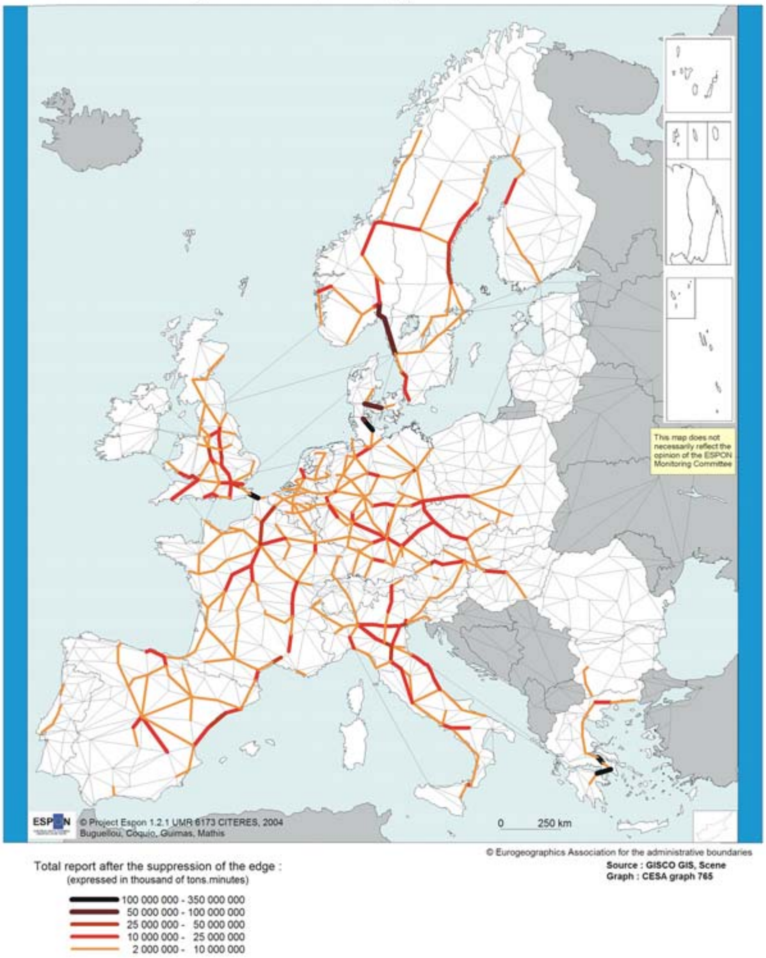
The first observation of the map realized for the **suppression of the edges** (part 3 chapter 7.1.1) gives an impression of relative homogeneity of the main edges' distribution (in the sense of importance explained above), that seems to cover all the European countries, except for a few Eastern countries. For these latter, the low level of freight emission/reception, according to the database used, is the discriminating factor and the conclusion has to be moderated because of the lack of updated data, accentuated by the great growth of the level of importation/exportation of these countries. If the quasi-totality of the main European corridors are represented, it can be interpreted as real coherence between the reality and our model. It is interesting to note moreover, the natural importance of the edges linked (directly or by the intermediary of another edge) to the main

European metropolis such as Paris, London, Madrid, Roma, and so on. The high level of emission/reception of goods of these capitals explains this phenomenon to a great extent, accentuated by the fact that, in general, these kinds of cities are very accessible in terms of transport because of the density of the high speed roads around them, which are simultaneously the causes and consequences of their development.

We can also note that some edges represent very important links because of their **specific role in the local connectivity of the network**. It concerns mainly roads around mountains (as to the east and to the west of the Pyrenees), bridges (as in Denmark) and tunnels (such as Frejus and Saint Gothard in the Alps or under the English Channel). This is illustrated by some "peaks" corresponding to these fundamental links, for example for the United Kingdom, in Germany to reach the Scandinavian countries or in Greece with the Corinthian Gulf . On the other hand, it is interesting to note than, in Germany and countries of the Benelux for example, the average costs of rerouting are finally quite weak: the density of network compensates for the important quantity of goods going through this country by the weakness of the supplementary time. This indicator, by allowing a measure of the network's heterogeneity, is a good tool to point out the place **where it is necessary to build a new or a redundant road for the global security of the network**. Of course this is only the result of modelling, with a partial (even if we to try to be as realistic as possible) network that sometimes allows low rerouting whereas the level of capacities in local network does not permit it in reality. The data must be considered as a general outline of the situation and should not be used in a literal interpretation.

Network road vulnerability for truck transportation (1) (p. 367)

Network road vulnerability for truck transportation (1)



2.6.1.2 Suppression of the nodes

With the indicator of **suppression of the nodes** (part 3 chapter 7.1.2), we can note that the jamming of major European capitals does not induce a high rerouting in terms of tons*minutes supplementary, contrary to the suppression of an edge linked to one of them, as it is shown in the previous map. This is due to the fact that other possibilities of routes are often available around these big metropolises, because of the density of the local network. The goods can take others roads, without a too important increase in travel time. This does not diminish the importance of these cities in freight transportation but only their role in terms of transit (because, as mentioned in the method, we do not take into account the emission /reception from/to these cities)

Once again, the roles of specific areas are underlined. Nodes associated to a bridge for example appear as fundamental to the good distribution of freight.

The nodes linked to the Channel are also part of this category because of their connectivity role.

Lastly, the case of **Nuremberg**, in Germany shows the importance of this node as a European crossroads, as a kind of door open on the Eastern European countries.

2.6.2 Vulnerability to a selection of natural or anthropogenic hazards

2.6.2.1 Suppression of hazardous link (part 3 chapter 7.2.1)

This indicator permits us to evaluate **the potential consequence**, in terms of flow distribution, **of the suppression of certain important links** in the cases of the **destruction of a bridge or obstruction of a tunnel** (as after the catastrophe in the Saint Gothard in Switzerland in October 2001), of major European rivers flooding (such as the Elbe in Germany in August 2002) or of snow storm and ice (as in the Pyrenees in January 2003). It permits us to anticipate the transfer of total (i.e. local and national) freight flows on the network in terms of tons.

We have selected six links for this exercise, weak in terms of vulnerability because a technical, technological or human error could provoke a temporarily or definite stop to their functionalities, whatever the reason or the means are. We have decided to work on:

- Nice-San Remo
- Narbonne-Perpignan (to the west of the Pyrenees)
- Irun-Hendaye (to the east of the Pyrenees)
- Nyborg-Slagelse
- Tunnel of the Saint-Gothard (in the Alps)
- Tunnel of Fréjus (in the Alps)

In a general manner, we can note that for each case the **rerouting begins far away from the removed edge**. It concerns mainly the international transport by heavy trucks, drivers preferring to reroute on the nearest corridor rather than to use local network, which is not very fast. The use of local network depends greatly on the local level of exchange (i.e. inside a given NUTS or between two adjacent NUTS).

When suppressed links concern tunnels, as for Frejus and Saint Gothard, the tranaport is in the direction of **the nearest tunnel**.

Concerning the Pyrenees, the rerouting is mainly on **the opposite side** of this massif: the west side when we suppress the link between Irun and

Hendaye and the east one when we remove the link between Narbonne and Perpignan.

2.6.2.2 Vulnerability to flooding (part 3 chapter 7.2.2)

In a general manner, the transfer of flow is more local than for the previous maps dealing with hazardous single links in spite of the fact that more edges are suppressed at the same time. It can be explained by the relative importance of these links in freight transportation. Indeed, the majority of remaining edges exposed to the flooding risk do not correspond to fundamental links for the global connectivity of the network.

The rerouting provokes the use of new edges located at the limit of the catchments areas. It seems coherent with the fact that the network is truncated inside the local basin. At the same time we can distinguish the main bridges, that is to say those that lost the greater number of tons.

The global transfer, expressed in tons*kilometres is really greater than in the previous case, that is to say, the suppression of a single link. It is logical considering the fact that, for flooding risks, all the edges included in the zone of flood are no longer usable. This figure is really important in the case of the Rhine, the Danube in its German part and the Po.

In terms of blocked tons, the values are higher for the three examples. It can be explained by the suppression, in our exercise, of some very important cities. It is notably the case of the Po with Turin, the Rhine because of the proximity of the Ruhr, and the Danube because of the high density of emission/reception in this area due to the important density of people in this area. For the three others case studied the local situation (no major cities suppressed or low flow of goods originally) explains these results.

2.6.2.3 Vulnerability to snow and black ice (part 3 chapter 7.2.3)

As in the previous case of flooding, transfers of flow **are more local** than in the case of the suppression of bridges and tunnels, probably because of the weak level of road infrastructures existing in the mountains. The rerouting concerns essentially **the network around the massif** (or the parts of the massif) studied with a massive use of roads in the valleys.

2.7 Interpretations and recommendations

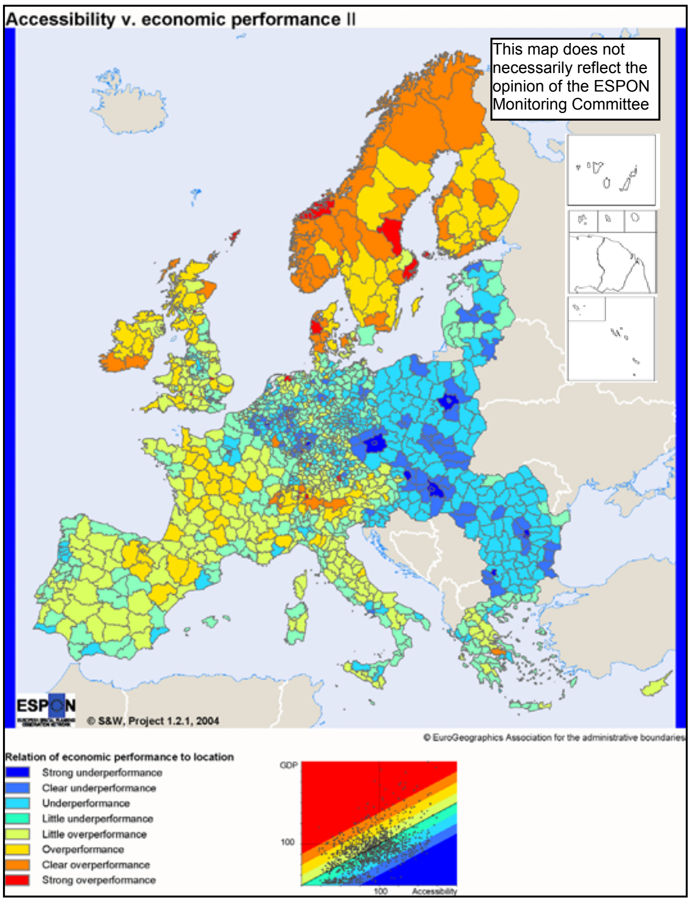
2.7.1 Typologies

The first chapter of part 4 is on typologies related to transport issues. Whereas part 3 already allows us to distinguish for instance central and peripheral regions, this chapter now combines regional transport indicators with non-transport indicators such as population density or economic performance in order to achieve a more sophisticated level of typologies.

Typologies are proposed through the combination of at least two different indicators. We propose here three different typology approaches:

- a typology confronting the infrastructure endowment with the density of population ;
- a typology of regions according to two dimensions, accessibility and economic performance ;
- a typology of regions suffering from transport externalities produced by road traffic flows.

Accessibility and GDP per capita in NUTS-3 regions (p. 402)



2.7.2 Major territorial imbalances

The corrections of imbalances, which seem necessary, not only require us to identify them, to measure them, but also to know the main causes and evaluate whether they are corrigible or not. Starting from the geographical characteristics of the European space, we will focus successively in this part successively on the hydraulic networks, the urban localizations, the road and railways networks, the centralization and the polycentrism, the modal transfers and the problems of pollution, the consequences of enlargement, and finally the temporality of supply and demand, which is an essential constraint for the policy recommendations.

2.7.3 Policy recommendations

The final chapter gives policy recommendations based on the analysis. It commences with the European level and then looks in more detail at several of macro-regions covering the whole ESPON space:

- Atlantic area ;
- Mediterranean Sea ;
- Baltic Sea area ;
- Central area ;
- Eastern Europe.

The policy recommendations are based on the objective to have a more balanced, polycentric and sustainable spatial development and to ensure the territorial cohesion of the European Union.

3 Networking with other TPG

ESPON Project 1.2.1 is very well integrated in the ESPON community. Networking within ESPON took place at various levels, namely at the level of project co-ordinators, the level of National Focal Points, the level of overall networking at the first ESPON Seminar in Mondorf, at the level of bilateral contacts to other TPG and at the level of involvement of project partners in numerous other ESPON projects relevant for 1.2.1.

The project coordinator of 1.2.1 attended all ESPON coordinator meetings and participated in the discussions. The events also provided an opportunity to approach other selected projects in order to discuss common issues.

The French National Focal Point is part of 1.2.1. Its responsibility is to take care of the cooperation with other projects and to communicate important issues back to 1.2.1.

Several members of 1.2.1 attended the first ESPON Seminar, which took place on 21-22 November 2002 in Mondorf, Luxembourg. The participants of 1.2.1 were involved in the discussions and in the specific workshops organised there. In addition, contacts with other relevant projects have been established.

Bilateral cooperation on data issues, concepts, indicators and typologies were sought with a number of projects, in particular with 1.1.1, 2.1.1 and 3.1. A very important aspect of the bilateral cooperation with other projects is the fact that several 1.2.1 project partners are at the same time partners in other ESPON projects.

- *ESPON Project 1.1.1: "The Role, Specific Situation and Potentials of Urban Areas as Nodes in a Polycentric Development"*

There is a clear relationship between ESPON projects 1.1.1 and 1.2.1. Both projects deal with the concept of polycentrism from very different viewpoints and to a different degree. ESPON project 1.1.1 has the task to come up with an operational definition of the concept of polycentrism in which territorial indicators on transport infrastructure and services such as accessibility play a role. On the other hand, ESPON project 1.2.1 has to take account of the concept of polycentrism when developing territorial indicators for describing transport infrastructure and services.

A close co-operation between the two projects is guaranteed, because S&W is a partner in ESPON 1.2.1 and responsible for transport issues and accessibility in ESPON 1.1.1. In addition, an exchange of ideas, concepts and methodologies between the project partners of both projects took place at the 1st ESPON Seminar on 21-22 November 2002 in Luxembourg.

- *ESPON project 2.1.1: Territorial Impact of EU Transport and TEN Policies*

There is a strong linkage between ESPON projects 1.2.1 and 2.1.1. Both are dealing with transport aspects of territorial development in Europe. Whereas ESPON project 1.2.1 belongs to the thematic projects of the programme, ESPON project 2.1.1 belongs to the group of projects dealing with policy impacts on territorial development. Consequently, ESPON project 1.2.1 focuses on analytical approaches in the field of transport infrastructure and services and ESPON project 2.1.1 is concerned with forecasting methodologies dealing with spatial impacts of TEN-T developments. In both projects, transport infrastructure endowment indicators and the concept of accessibility play key roles and thus constitute common features.

A close co-operation between the two projects is guaranteed, because S&W is a partner in both. An exchange of ideas, concepts and methodologies between the project partners of both projects took place in a specific session at the 1st ESPON Seminar on 21-22 November 2002 in Luxembourg.

One outcome of the co-operation is that the forecasting models of 2.1.1 will be based on similar concepts of accessibility as those being developed in 1.2.1.

4 Data gaps and further research issues

4.1 Data gaps

Currently, basic data (transport networks, administrative boundaries, population and GDP, basic traffics in main terminals) are already available and, based on these, strategic indicators can be calculated and mapped. But while working on ESPON Project 1.2.1, we have faced some difficulties linked to the availability of data.

First of all, we were not able to integrate the **capacity of links** in our calculations. This was really a pity because numerous indicators developed in this report have been calculated thanks to models, integrating the travel times. The calculation of travel times is very often the basis for numerous developments of indicators. But, even if we would have the capacities, we would have faced other problems linked to other data gaps:

- a **matrix origin/destination of individual vehicles,**
- data for displacements at a local level
- **costs of links**

Indeed, most of databases found only concern displacements of trucks and do not integrate the local levels, which can lead to numerous problems of capacities, due to the multi-level structure of flows.

To calibrate our models, we would have liked to have data about the **traffic on roads and railways.**

Furthermore, some **data are not updated or not harmonized** (i.e. population of cities, matrix O/D), which can lead to problems for the indicators developed.In addition, to have data of **timetables of planes or trains** would have allowed us to take into account more effectively the aspects linked to multimodality.

In this report, we have taken into account the main gateways in the European space but this would have been better if **data of flows from main ports and airports and traffics (of freight and passengers) between airports** had been available.

Finally, to have access to a **High-resolution DTM** would have been interesting, mainly for the calculations of transport externalities indicators and for the choice of scenarii for vulnerability problems, linked to natural hazards.

The availablity of such data would allow us to continue researches in this field of study, and to be able to build more interesting tools.

4.2 Further research issues: the setting of a European Spatial Transpot Prospective model

Currently, we are out of line with the classical transport models. It is necessary to have a real prospective transport model. The field of legitimacy of the classical econometric transport model is very clearly defined. The structure must be constant to have a valid projection. Furthermore, a model tested on a constant trend of the past can not give others results than the same, amplified or reduced. Currently, the hypothesis of such a model is not respected because the structure changes in the reality. During the 30 last years, the trend was roughly constant: road growth, rail decline and increase of GDP. If a global econometric model is tested on this period, it will not show other results because it is mechanical.

But now, the structure of data change with the environmental problems and the network gridlock. So, the road transport can not continue to increase at the same ratio. We must take into account these evolutions. And that is why the building of a prospective tool for European transport is a very interesting research issue. To do this, we can use numerous new techniques: percolation, cellular, Multi-agent system…

This model must take the European special networks into account with their features and attributes to test various scenarii in the short and long term.

The principle of this model would be quite simple:

- <u>The data</u>

- The matrix of goods exchanges inter and intra NUTS ;
- The flows matrix of person transfers and trips inter and intra NUTS ;
- The infrastructure networks : roads, motorways, railways, ferries and waterways, airways with their attributes ;
- Data concerning the distribution of population and enterprises
- The prospective and proactive scenarii required by the partners and the Commission.

- <u>The model structure</u>

The model would be based on Multi-agent systems. Each agent would behave according to principles that we would define. He would choose his best path and used it. But this choice is one among many and it is possible that this path and mode are not available, because of congestion problems. To analyse that, we must have a very exact representation of networks.

<u>Thus</u> ,

- the logistic agents select with their own criteria the path and mode, according to their own strategy;
- The flows of travellers and goods are assigned on the network (at the first iteration) from the present time. The modal assignments are not homogeneous between the various origins-destinations (existence or not of specific networks, interoperability)

After that, the modal flows are assigned to the specific networks (spatial assignment) from the current situation with optimum criterions of paths: cost, travel time…

- <u>Outcomes</u>

If the capacity is not saturated, the spatial affectation is possible. If it is satrurated, the surplus is assigned to either other paths or other modes according to travel times and/or costs and free capacities of other modal networks. Next, all the network attributes are computed again: free capacities, gridlock, speeds, and emission of pollutants. So, we have results on the costs and travel times…and the optimum paths.

Moreover, the dynamic evolution of the data base would be simulated either by European, national, regional or local projections (trends) and/or by scenarii: voluntarism, modal transfer, sustainable transport, test of cost speed rule changes.

In the field of transport infrastructure, the "short term" with the same infrastructure is fifteen years, the necessary time between the decision and the realization of an infrastructure. But the short term for transport is long term for the firms and so the flows of goods and trips evolve during this period. If the gridlock expands, with too few possibilities of modal transfers, the firms relocate permanently. This scenario must be taken into account. In the long term in addition to the previous scenarii, the infrastructures are variable: new motorways and railways lines, goods specific high speed railways with high frequency, ferries..

So, the proposition of this model is the logical outcome of Project 1.2.1 ; it is the result of the work done to update the various modal networks and their attributes.

Part 2: CONTEXT AND METHOD

1 Introduction: the concept of ESPON 1.2.1

The research questions of ESPON 1.2.1 are related to the basic supply of transport infrastructure and services within the EU territory as well as territorial trends of transport infrastructure network and services. Transport infrastructure comprises the transport modes of road, rail, air and waterways, but also issues of inter-modality. In particular, the following points have been considered in the project:

- **Identification, gathering of existing and proposition of territorial indicators and data and map-making methods** to measure and display the basic supply of transport infrastructures and services as well as the trends and impacts of the development of transport infrastructure network and services.
- **The most important features of the present infrastructure networks with regard to territorial issues**, i.e. the location and capacity of primary and secondary networks, the spatial patterns of access points, the flows between the access points identified (usually in an hierarchical order) and the number of users (and types of users), which have access in real terms (different quality) to the networks.
- **Specific typologies and territorial patterns** in the transport infrastructure networks and services, referring to in particular the typologies used in the ESPON project 1.1.1 on polycentrism.
- **The most relevant transport services of general interests**, referring to migration and regional development potential, which influence the development of territories and regions lagging behind as well as territories and regions with a peripheral location or specific features.
- **The role of services of general interest as vectors for territorial cohesion**: constitution of trans-European networks of services of general interest.
- The different kinds of complementarities and exchange processes that exist between different kinds of infrastructure in different parts of Europe in support of sustainable transport.
- The importance of access to transport networks and services as a location parameter for investments and the economic development of cities and regions.
- The correlation between transport infrastructure trends and a polycentric development model.

- A further operationalisation and territorial diversification of the policy aims and options adopted in the ESDP, including an adaptation to the territorial diversities in an enlarged EU.

Consequently, the study has a **strategic and territorial approach**. It is partly based on data and knowledge obtained from other studies in the transport field, but mostly based on the further development and application of approaches readily at hand of the TPG partners. More than deepening transport specialised questions, the aim was to **integrate the information into a territorial dimension**, which was missing before.

The concept developed for ESPON 1.2.1 is a combination of state-of-the-art and newly developed methodologies with the objective to generate an indicator database describing different aspect of transport infrastructure and services in Europe and its regions.

2 Key transport policy issues

This chapter discusses key issues of current transport policies in Europe. It reflects the major objectives of transport policies, i.e. the liberalisation and harmonisation of the transport market, the modal shift between modes and the implementation of the trans-European transport network (TEN-T). Finally, the chapter assesses the current approach of transport policy towards territorial development and discusses ways to link transport and spatial policies.

2.1 The general policy context

ESPON project 1.2.1 on transport network and services "*has for major objectives to improve the decision support tools so that policy makers can more easily find the proper ad equation between policy goals and transport policy measures*". Therefore the policy scope and key issues related to it must be analysed and discussed at preliminary stages of the ESPON project.

However it is also clear that it is not easy to define precisely this policy scope, because transport is closely related to many economic and social activities and rarely justified as a final "product": transport policy interferes with many other policy objectives so that it is difficult to present a consistent framework for transport policy objectives as a whole. Transport has economic, financial, spatial and social dimensions and all of them must be taken into account in this policy scope.

Another difficulty of such an analysis is the institutional context dimension of the problem: transport is a sector of fierce competition between companies across the world, in sectors like maritime or road transport, but in the same time it is also a sector of strong intervention of public organisations, and in particular for the promotion of public transport for passengers. This means that decision makers have quite different systems of reference for transport operations and transport performances and such disparities must be taken into account when considering decision making processes and decision support systems.

At the international scale the evolution of European institutions in transport regulation will then be a focal point of interest for this research work. This has several consequences:

- first that **the national institutional level must be considered in parallel with an increasing role of European role for market regulation** but also for infrastructure implementation: opening to the East with integration of ten new member states, Euro-Mediterranean policy, connection with new neighbouring states of Russia, Balkans and Central Asian countries cannot be forgotten ; in market regulation, environmental concern brings more and more constraints in order to limit negative impacts on environment

- but also that the **increasing role of local institutions must be taken into account**, whether they are communes, association of communes or regions ; decentralisation, and "subsidiarity" principles which are parts of many national policies and European policy recognise and favour such evolution making the decision process more complex and influencing the definition of decision tools.

In a general manner one can say that **transport is becoming a more and more sensitive problem from a political point of view**, which implies that transport will be more present in the democratic debate. Transport major issues and transport major projects, including infrastructure projects must now give rise to a democratic debate before the final decision is made, and the solution is rarely in the hands of a single institutional organisation: it results from different institutional cooperations at national, international and local levels, with more and more often participation of citizens. All these elements must be part of the policy scope and framework in which the project on "transport network and services" is integrated.

Being aware of all these dimensions of the problems, the present document certainly does not ambition to address all these aspects and can refer to many research publications that have treated this problem in the IV and Vth framework research programme:

- TENASSESS and CODETEN have addressed the problem of transport policy in relation with infrastructure development,
- FORESIGHT is an ongoing project, which considers the relation between transport and non transport policies. EUNET and SASI have proposed accessibility indicators for regions,
- Several transport scenario projects (SCENARIOS, SCENES, TEN priority corridors) have included for Western and Eastern Europe policy objective scenarios,
- ASSEMBLING focussed on the definition of a transport observatory, and classified policy indicators relevant for transport. INFOSTAT, and ETIS relative to information system in Europe have also included as well as CONCERTO, ATIS, ALPNET for the Alpine region.

Finally from DG Regio side the relevant project on cohesion and GIS on which ESPON programme has been based must also be referred to.

The aim of this document is then to give only few selected elements of transport policy context and refers to more recent policy statements of EU Commission mainly the White Paper in transport policy (and the related proposals for the TEN review) published in autumn 2001 as well as recent considerations about the ESDP (Europe Spatial Development Programme).

This document starts indeed from the basic assumption that there have been mainly two different approaches in the policy scope of transport policy, which have been largely independent in their definition and their context. Although efforts have been made to make them compatible, the institutional organisation both at national and EU levels made it difficult to reach a good coordination between these two approaches.

- **At the EU level** the White Paper has been prepared by DG TREN and is mainly focussing on market regulation, with only few considerations about the spatial impact of the measures proposed. DG TREN has indeed no legitimacy to address regional policies and transport market rules are general rules, which have to apply to a large diversity of regional situations. When dealing with infrastructure development, then the geographic dimension is certainly included, but each project will then refer to specific studies and coordination context with the member states ; so far it does not really refer to a spatial policy but just to general interconnectivity, interoperability, intermodality considerations.
- **On the other hand the DG REGIO** is first concerned with regional development, cohesion policy. Although the spatial development objective of European space is not part of EU domain of competence there is an increasing convergence between members states to develop a common understanding of European spatial development. The inclusion in the Maastricht Treaty of TEN network to strengthen European cohesion has certainly helped in this mobilisation. So far interventions from DG REGIO were mainly justified through structural funds policy, where regional approaches are privileged. Although in structural funds transport operations have taken an important share it was sometimes difficult to link these operations with the general transport policy ; they concern more capillarity networks, specific accessibility problems, local and regional objectives and were not intended originally to meet these general transport objectives. With the cohesion funds related to transport projects it became more and more difficult to distinguish between local or regional objectives and European policy: major infrastructure links, in particular in Spain, have

been substantially funded with cohesion funds ; they improved major European connections, and had a clear direct European scale impact.

Tomorrow things will become more and more interrelated between transport, regional and spatial policy because:

- **ESDP Scheme becomes more and more a reference for policy makers** and co-decision procedure consultation of regions through the Committee of regions and the European Parliament will probably strengthen this. Moreover, ESDP is clearly related to TEN development and consequently to TEN operating system and therefore to general transport policy regulation ;
- **the EU enlargement brings to the fore the problem of extension of TEN network to the East** ; already during the transition period the TEN priority corridors (Crete conference) have become a central reference to CEEC national planning scheme: today extension of TEN towards the Balkans region (Strategic network for Balkans of the Commission) and Mediterranean area is also considered. The PETRA of Helsinki conference was a first scheme of Mediterranean corridors, which will now be analysed in depth in the new MEDA programme ; for these operations there will be a clear mobilisation of all financial means of EU.
- **the renewal of structural funds policy is necessary** with the stakes of the definition of new EU institutions (results of EU convention).

Consequently it is very important to "bridge" the transport policy approach of the market regulation with the regional approach of the European space, and the ESPON project on "transport network services" will mainly focus on this point in order to be able to construct relevant decision support tools for policy makers to facilitate dialogue process and emergence of solutions.

Table 1 European transport policy goals, aims and actions

Policy goals	Policy aims	Policy actions
Economic and technologic competitiveness	Promoting Economic growth Inducing Market efficiency Assuring Fair competition Supporting technologic development More balanced spatial development More homogeneous economic endowment (transport...) Legal harmonisation Protecting natural biodiversity Renewing resources Improving environmental quality Increasing human safety	Legal regulations (deregulation, liberalisation...) Planning documents (TETNs, Europe 2000+, Towards Sustainability...) Investment programmes (loans to specific infrastructure projects) Subsidies

Table 2 Policy aims

Growth	Sustainability	Cohesion
TRANSPORT POLICY AIMS		
Market conditions for provision and management of infrastructure (transport impact on growth through improvement of private investments profitability)	Apply the "polluter pays" principle and adequate payment mechanisms	Provide adequate access to social and economic opportunities for all European inhabitants
Fair competition between modes	Introduce global and long-term considerations in transport planning (Strategic Environmental Analysis)	Facilitate the development of international trade and mobility to enhance economic and social integration within the single market
Make long-distance and international transport costs equivalent to those in competing areas (USA, Asia...)	Apply Environmental Impact Analysis	Use the design and implementation of major transport investments to enhance social cohesion
Maximize economic returns on investment, operation and maintenance of the multimodal TEN		Help the accession of the CEEC and the economic development of neighbouring areas (Mediterranean and CIS areas)
Internalise network costs and benefits effects on project appraisal, in particular in cross-border areas		
Stimulate multimodal chains		
Integrate EU in world logistic trends		
Provide adequate links between long-distance flows and their local and regional components		
SPATIAL DEVELOPMENT POLICY AIMS		
Dynamic, attractive and competitive cities and urbanised regions	Polycentric urban development: a Basis for better accessibility	Efficient and sustainable use of infrastructure
An integrated approach for improved transport links and access to knowledge	Endogenous development. Diverse and productive rural areas	Natural and cultural heritage as a development asset
Diffusion of innovation and knowledge	Urban-rural partnership	Preservation and development of the natural heritage
	Creative management of the cultural heritage	Water resource management
		Creative management of cultural landscapes

Table 3 Environmental policy aims

ENVIRONMENTAL POLICY AIMS	
	Better land-use planning
	Better infrastructure investments
	Infrastructure charging: road taxes and different forms of road pricing
	Progressive technical improvement of vehicles (exhaust and noise emissions, fuel consumption, performance, final disposal)
	Driver information and education in car use
	Improved public/collective transport
	Discouragement of road traffic in cities
	Development of economic and fiscal incentives (car pooling, positive discrimination of car poolers)
	Development of interactive communication infrastructures
	Composition and consumption of fuels: alternative fuels, cleaner fuels, complete move to unleaded petrol by 2000

Table 4 TEN policy aims

TENs Aims	Competitiveness	Cohesion	Sustainability
Inducing multimodality	Productivity improvements by better modal specialisation (adaptation of each mode to its comparative advantages)	Intermodality in EU hubs will facilitate better accessibility from peripheral areas to larger EU markets.	Potential increase of traffic attracted by environmentally friendly transport modes (e.g. rail in relation to road for medium distance trips in the centre of Europe).
Citizens networks (local-regional connections to TENs)	Improvement of access to TENs, making TENs more profitable and facilitating a better use of TENs excess of capacity for regional traffic, when feasible.	Accessibility diffusion to larger landlocked areas through regional capillarity	Land-taking reduction by using existing excess of capacity of different scale networks
Fair pricing	Capacity optimisation on congested TEN links	Subsidies to peripheral relations can become explicit	Internalisation of the external costs of transports.

Table 5 Strategic Policy Goals

GOALS	Main Policies	Main conventional indicators
Economic and technologic COMPETITIVENESS	Community Competition Trans-European Networks Research and Development	GPD growth GDP growth by sectors Aggregation: CBA (Cost-Benefit ratio) in financial and economic terms (...)
Social and political COHESION	Structural Funds Common Agricultural Policy	GPD distribution by groups (regions and income groups). Development "gaps". Aggregation: CBA by sectors and regions, in socio-economic terms Multicriteria analysis for non-monetary elements (..)
Environmental SUSTAINABILITY	Environmental policy	Reduction of externalities costs in terms of GPD (safety, land-taking, pollution...). Cost of externalities in terms of GPD. Aggregation: CBA including the cost of externalities. Muticriteria analysis for non-monetary elements (...)

2.2 Major transport policy objectives

The major transport policy objectives have been recently expressed from the Commission point of view in the recent White paper called "European transport policy for 2010: time to decide".

In doing so the Commission stresses a certain number of orientations and delimitates its domain of intervention: it is clear that European market regulation should take in the future more and more importance over national market regulation, but in the same time the application of subsidiary principles for regional and national interventions is also reaffirmed. For external relations with countries outside the European Union, the document claims a stronger coordination and a more extensive representation of the Commission in order to present a common position for all member states.

This evolution is indeed the intention to launch a new step in European transport policy, with a stronger political will, in order to progress in the direction of liberalisation and harmonisation. The proposals made by the Commission are based on a diagnosis, which is a kind of mixed diagnosis, which points successes, and failures of the past European policies. An important success is the opening of the market in many transport domains although the open access is not yet a reality for all the modes and in particular for rail. Failures are increased congestion and a domination of road with its impact on environment.

The major orientations can be summarised along the following lines with special focus on environmental impacts and sustainable development:

- to continue a policy of liberalisation, but also to progress in parallel with measures of harmonisation ;
- to promote alternative modes such as rail transport, inland waterways and short sea shipping in order to rebalance modal shares;
- to eliminate the bottlenecks and give a new impulse to development of trans-European network.

Safety, promotion of new technologies, improved participation of users are also strong points of the EU orientations, which have a global impact on transport performances but not obviously an effect on spatial distribution of activity. Rationalisation of urban transport is also mentioned but it is clear that this aspect of transport policy is more relevant to local authorities.

Some figures are given in the document about the expected traffic growth per mode, with an elasticity which will be still higher than 1 as regards GDP. Global quantitative objectives are mentioned concerning possible influence on traffic growth or modal shift, but these objectives remain fairly general and are not detailed in the way which would point changes in flows distribution and spatial impacts.

The document published in 2001 is certainly a comprehensive approach of transport sector but is expected to be completed by a more detailed one relative to proposals concerning the TEN (published soon after), a document on pricing (expected to be published in 2002) and more detailed studies on the traffic forecasts.

2.2.1 Liberalisation and harmonisation: the market regulation

Liberalisation has been the "master word" for the implementation of the single market in transport. It has progressed in the nineties in road sector and air sector but it is not yet achieved for the other modes:

- Increased competition in road transport has led to a reduction in prices, increasing the competitiveness of road versus the other modes.
- Progresses have also been made in air transport with predefined steps leading progressively to an open air market.
- Inland waterways have made clear progresses towards liberalisation although it started later than the two first modes . Adaptation of the fleet was considered in parallel as an accompanying measure to give a new competitive impulse to inland waterways supply.
- Maritime transport, between EU member states and within EU states (short sea shipping) is also liberalised but the concept of public service to serve the islands has still to be preserved.
- Rail transport is probably the most difficult mode to liberalise because there is a close direct link between rail operators and rail network, and because rail companies have been closely linked to the national states and administrations? A whole strategy of liberalisation had first to be set up: what decision to take about infrastructure management ? Should it remain public or not ?

The example of rail shows clearly that liberalisation cannot be the sole orientation and that more precisions had to come about market competition and regulation. The White Paper has been prepared to answer to this question introducing in the same time more room political choices and decision: "time to decide" means also more political choices in order to promote sustainable development. In this document some dangers of an excessive liberal approach are stressed related to the domination of road and increasing congestion with the negative consequences in environment: although "free choice" remains a basic principle with fair competition, this is not clearly sufficient:

- Liberalisation does not mean necessarily privatisation but competition rules must prevail between companies for private and public services.
- Progresses must be made in parallel on the harmonisation front: this concerns taxes (petroleum taxes) which still differ considerably from one country to another but also social rules such as working or driving hours ; these types of rules have also an impact on safety and reinforcement of their application is necessary.
- For rail, but also in a more general manner for ports, airports terminals, a major distinction is made between infrastructure management and transport operations ; liberalisation means also "open access" to the network as it has been decided for many other "network services" so that the "rail model" in Europe significantly differs from the "rail model" in the states. With a clear separation between infrastructure management and rail operation an "integrated solution" of privatisation of rail is not the orientation, which prevails in Europe. Especially after the difficulties UK experiences had to face.
- An important point is made on pricing and in particular in pricing the use of infrastructures ; after the discussion on Eurovignette, a tax per vehicle/km is now the orientation with different systems being experimented, being aware that some states have already a toll system generalised for their motorways. If the principle of internalisation of external costs is reaffirmed with strength, the choice between "social marginal cost" pricing and "total cost pricing" is still not very clear ; some experts have pointed out that the choice of "social marginal cost principle" might turn out to favour road versus rail, and that in any case the principle of pricing was not neutral as regards modal choice.
- For sensitive areas (limited in the White Paper to "Alps and Pyrenees"), cross financing of investments of infrastructures is proposed in order to shift resources from road to rail or from more pollutant solutions to less "pollutant" solutions ; in this case the Swiss model is taken as an example and this has certainly a consequence on pricing.

In other words more importance is given to long term choices with also more stringent norms for safety and protection of environment, which in turn has an impact on operating costs, infrastructure costs and on market regulation. From a spatial point of view this will not be neutral with in particular the fact that the cost of access to periphery might increase with the distance travelled in the case of a pricing of infrastructure proportional to the distance.

2.2.2 To shift the balance between modes

When looking to the past trends, as well as to trends projections, it is clear that rail transport is marginalized. In long distance and in particular for transport between continents air transport and maritime transport play a major role.

These evolutions have negative consequences for environment and congestion. Enlargement of Europe to the East and transition in CEEC countries give a new impulse to transport growth and to equipment of households with cars, which again play in favour of road.

Therefore the Commission would like to be active in favour of alternative modes to road for passengers and for freight.

For passengers it is important to stress that most of the volumes of transport are short distance: more than 80 % of the traffic is short distance, for distance lower than 50 km concerning regular trips, which are not only working trips but mostly short trips related to social life, shopping, education. Urban sprawl has certainly increased the average distance of such trips, which remains in the sphere of urban, and suburban spatial organisations. From this point of view there is no clear reason why economic growth should automatically imply transport growth since most of decisions to live in suburbs are related to the cheaper price of housing, with the price of land decreasing with the distance from the centres ; for passengers "decoupling" will probably find part of an answer in relevant local planning.

Concerning the modal shift for passengers, this will also be related to a good understanding of the relation between land-use planning and supply of public services. Until now supply of public services in areas with lower densities, in suburbs or rural zones remain costly solutions since light, flexible and more individual systems are not yet developed.

The orientation in favour of public services and transport closer to citizens is strongly reaffirmed in the White Paper but this domain is a privileged field of intervention of local authorities and any actions of the Commission are limited from the financial and regularity point of view.

For freight the proposals of the White paper intend certainly to go beyond declaration of principles, or specific actions of promotion ; a whole set of possible actions is reviewed:

- first to revitalise rail and promote intermodal transfer ;
- to promote short sea shipping and inland waterways.

2.2.2.1 To revitalise rail and promote intermodal transport

Revitalisation of rail requires first the creation of a genuine internal rail market.

So far rail markets have been mainly national markets with national, historical companies, but also national equipments, norms and operating systems. There is today a paradox, since one would expect rail to improve its modal share on longer distance market. The opening of economies should favour rail transport. But this is not the case because with longer international trips the number of border crossing increases with the necessity to change, most of the time, the driver, the locomotive to face new operating system for reservation of the slots, to adapt to new commercial practises and administrative procedures. These are "interoperability" problems rail has to solve in European transport, when interoperability problems for road can be overcome much more easily.

All these facets of interoperability, plus the aspects related to the principles of rail "open access" mentioned earlier are parts of the European strategy to revitalise a rail market. This revitalisation of rail goes in parallel with the production of "intermodal transport". Although formerly intermodal transport also includes some short sea shipping techniques we will limit ourselves in this chapter to rail/road techniques.

In order to well understand the problem of intermodality and its spatial dimension, it is important to proceed with the following distinction the White Paper has not clearly pointed out:

- The maritime container market for intercontinental trade

This traffic is distributed throughout Europe by sea ("feedering" which is one part of the European SSS market) or by land modes, intermodal land transport is the continental leg of an intercontinental maritime transport. This type of transport is a dynamic market for intermodal transport in particular for serving major European "hub" ports, when large container vessels stop. Block trains or shuttle trains of maritime containers penetrate along transport corridors the interior of Europe, to intermodal terminals where containers are distributed (or collected).

- The combined transport

The combined transport is a combination of rail and road modes with a transfer of a load unit: swap body or semi-trailer (piggy-back technique). These techniques are used for long distance (national and international traffics). Most of the international combined transport in Europe is for traffic across the Alps. Combined transport is a privileged technique for crossing "sensitive" areas and in particular mountain chains when long road tunnels might be difficult to build and operate, or might create important nuisances to the environment.

The use of intermodal techniques requires investments in maritime and inland terminals: the development of these techniques means also the development of a network of terminals in Europe as part of the infrastructure networks.

In the organisation of such transport chain, inland waterways can also be chosen as a mode to be combined with maritime or road transport: intermodal inland ports are also parts of intermodal network. The problem of development of "rolling road" is however somehow different: rolling road technique is the transport of a truck on a train including the tractor. It is generally not considered as an intermodal technique because the organisation of the transport chain is not changed ; the transfer is most of the time for a short distance link to cross a sensitive area where road link has no sufficient capacity or when road profile is not adapted to heavy transport. If one advantage of rolling road is often easy and fast transhipment, then one major disadvantage is the transport of "dead" weight (tractor and trailer), the payment of truck driver during rail transport (if the time is not accounted as resting time) so that rolling road services are limited to links where roads face very difficult conditions for operations (physical or restrictive administrative measures such as transit authorisation).

This segmentation of the intermodal transport indicates then the conditions and privileged places where they can develop in European space.

2.2.2.2 To promote short sea shipping and inland waterways

More recently, short sea shipping has been added to these intermodal techniques as an alternative mode to road including the feedering services mentioned earlier. Short sea shipping using containers for intra-European transport market also exists with container norms, which are not necessarily compatible with international ISO norms. However such services are so far limited to North Sea services and it is still early to say what success this technique will meet, and what progresses can be made for harmonisation of these container norms.

Therefore the privileged market segment for SSS within European trade market is certainly the transport of semi-trailer or swap bodies on the deck of ships (or on trailers): such techniques should be in direct competition with road transport, largely based on "RO-RO" techniques. However this market in Europe is not yet very much developed except in Baltic Sea, some relations on North Sea or in the Adriatic between Greece and Italy, keeping in mind that SSS is, with air, the sole mode to serve Islands.

In Mediterranean some experiences have been made in particular with ROPAX vessels and studies are made to investigate this potential market. In the White Paper several measures are envisaged to promote such intermodal techniques, to stimulate technologic development, to adapt administrative procedures in particular in ports, where transhipment still requires much time and where adapted equipments and infrastructure must be planned.

In this strategy of European Union, efforts will be made on demonstration cases, on the mobilisation of concerned actors and on subsidies to launch new services: following and extending the PACT programme, with a much larger amount of public funding, a Marco Polo Programme will be launched.

2.2.3 The implementation of TEN network

Implementation of TEN networks is also a major aspect of the European transport policy, which has a direct spatial impact on European space.

However the spatial dimension was not necessary the initial approach of the transport policy relative to TEN network, although it could not obviously be disconnected from the spatial dimension ; this is where transport policy takes a concrete spatial dimension and this is why it is useful to recall some steps of the TEN transport policy in order to better understand this articulation with spatial policies.

First, the trans-European network concept was first developed in transport policy before it was mentioned in Maastricht Treaty as an important aspect of the cohesion of European space. Two types of European network were prepared:

- a **HST[19] network** as a symbol of new services in Europe, linking major cities from different states with much shorter time than previous conventional rail, using new rail technologies ;
- a **combined transport network** with the objective to identify corridors where the volume of demand and the length of trips should be sufficient in order to promote a competitive service with road.

The Maastrich Treaty gave a new impulse to the concept of TEN network, which was also including energy, and telecommunication networks.

From the transport policy this gave rise to:

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[19] High-speed train

- different modal TEN European networks for road, rail, and inland waterways with the distinction for rail between a conventional rail network in addition to the HST network ;
- an effort to build an European intermodal network stressing intermodal solutions and including basic principles relative to efficient use of such a network from an economic but also an environmental point of view ;
- the definition of priority corridors in CEEC countries which should extend the TEN defined for the European Union ;
- and finally the definition in the TEN of priority projects (so called the Essen projects) with among them many major projects of interconnection between states in order to strengthen a European scope of such networks.

The recent White paper must then also be understood as a document in the process of definition of new guidelines for the TEN networks in 2002 in relation with the Parliament. The White Paper was completed by a document relative to this process of adaptation of the TEN and of their criteria for definition of priorities.

Among the objectives for priority the removal of bottlenecks is stressed including an improved management of infrastructures use.

For rail freight, the concept of “dedicated rail freight” network is proposed. This concept has been discussed in several countries with the objective to grant more priority for freight train in the slot allocation: the reason is that quality of service of freight trains is very poor because of the difficulty to get adequate slots along the train routes and that rail will never be competitive against road unless the situation changes and freight train can be better programmed.

The complementarities between HST and air are also stressed so that more flexibility can be introduced in the management of air capacity, developing new intermodal chain for passengers.

Concerning priority projects, new proposals have been made in addition to the Essen priorities including new lines for HST and freight in Italy, France, Germany and Spain as well as a project on the Danube and a new fixed link between Denmark and Germany ; improvement of satellite navigator and interoperability is also put highlighted. The question of funding these projects is certainly not solved but new perspectives are open as far as a possible increase in European contribution and possibility of cross financing, keeping in mind opportunities of private funding when possible.

Among the criteria to be promoted there is a criteria of accessibility but at this point it is also to give a different approach of the transport problem, the approach that privileged the spatial dimension from regional or European spatial development point of view.

2.3 The spatial approach of transport

The spatial approach was rarely presented as such at the European level.

At local level such approach has been existed for a long time and in particular in urban planning although a clear understanding between land use pattern and mobility is still not obvious. Nevertheless, progresses are made in this direction.

At national level, infrastructure schemes take into consideration problems of accessibility of regions or accessibility of remote areas, included islands. Through national master plans the national spatial policies are somehow "internalised" but there is no guarantee at all of an overall European consistency, from this point of view. Some master plans privilege uniform principles of accessibility, but others stress the criteria of financial or socio economic return making a clear separation between transport and regional development. In France for example there is a history of "Aménagement du territoire" which is not shared by many other European countries.

At European level an initial concern was regional development in order to reduce the gap between regions and to help regions with lower income to catching up. The structural funds policy were refined including redeployment of old industrial places and stimulation of trans-border cooperation. In all these actions transport projects take often an important place. The initiative of a "European Spatial Development Perspective" which was an informal perspective, proposed a more global approach, which is in line with an objective of bringing more cohesion in Europe. Transport networks have been considered as a way to reinforce cohesion and several important transport projects of peripheral countries have been partly financed by cohesion funds.

Therefore it is important to understand how transport has been included in the spatial approach of Europe so that the links between spatial and transport objectives can be strengthened.

2.3.1 European Spatial Development Perspectives and the polycentric development

The polycentric development concept is central in the ESDP. It is a more sophisticated understanding of the relationship between places as the simple core-periphery opposition. The guidelines of EU spatial development from the concept are:

- Development of a polycentric and balanced urban system and strengthening of the partnership between urban and rural areas ;
- Promotion of integrated transport and communication concepts, which support the polycentric development of the EU territory and are an important precondition for enabling European cities and regions to pursue their integration into EMU ;
- Development and conservation of the natural and cultural heritage through wise management.

Therefore the polycentric concept proceeds from an in depth analysis of functional interdependencies of urban areas within a region and across administrative boundaries ; this will include "local transport, waste management and the designation of shared residential or industrial areas".

Furthermore the relationship between urban and rural areas, as well as the way to access to EU territory and to world trade should be also stressed so that these metropolitan areas are also internationally accessible: the polycentric zone should be also a "global economy integration zone" pointing cities clusters and networks of smaller towns related to them to form viable markets with adequate economic services and institutions. From gateway cities or ports there is a distribution of functions, which take also into account a balanced development of rural and urban areas.

Such an approach will certainly imply the transport as a major component of polycentric development, but in the same time the diversity across Europe of such polycentric zones according to the historical development of cities and rural areas, and their location in European geography along major routes or close to a port, within densely populated areas or not, with more or less sensitive areas from ecological point of view (example of mountains areas).

The polycentric development can then be considered as a goal to be reached for spatial and transport policies, in an attempt to understand as deeply as possible the local context of development in relation with globalisation.

However the European spatial policy has been so far implemented with more global and uniform criteria within the framework of structural funds policies and cohesion policies.

2.3.2 Structural funds policies

Structural funds policies have developed progressively in a process of "deepening" the European policy, mainly after the accession of poorer Southern regions of Europe: first the South of Italy, then the integration of Spain, Portugal and Greece (not forgetting Ireland in the North with also a lower income per inhabitant).

The main objective was to help regions with lower income to catch up with European average: therefore indicators had to be set up with sector based policies for sectors which have specific market regulation problems (agriculture) or problems of redeployment.

Structural policies, sector based policies have then an obvious spatial impact which has to be taken into account.

In structural policies, transport investments have often been pointed out as important investments for catching up with the objective of improvement of local and regional transports considered from the local and regional point of view.

If in the beginning of the structural policy, the average income per inhabitant was the indicator chosen for access to such support (objective/mainly) then more specific interventions were possible to support local economic structure, face redeployment, unemployment or social specific problem. In doing so, most European countries for some well identified areas and specific purposes could also accede to structural funds even if the national or regional income average was higher than the European average. However these "second wave" funds for intervention were more limited than the funds granted for "convergence" purpose in terms of average income.

In a third phase "interregional" problems have been stressed and in particular across the borders, including across borders with countries which are not EU members. INTERREG interventions also included transport approaches since border crossing has been for a long time a major obstacle for the smooth functioning of a transport chain: lack of continuity and coordination of services provided, missing links, interoperability problems which prevent efficient public transports and often very heavy administrative procedures. Local services across administrative and natural boundaries were included for passenger traffic, facilitating trans-border communications, but also analysis of "Eurocorridors" across Europe.

Today INTERREG programme extends to a more comprehensive approach of large "Euroregions" and again, transport services including land and maritime transport services can provide adequate approach within such programme.

Since the opening to the East, structural funds policies have been extended making Germany a beneficiary of such policy after the integration of Eastern länder ; further East new INTERREG programmes were set up with candidate countries.

Concerning sector based policy the evolution must also be stressed because of their impact on space and on the understanding of interdependencies between different types of space: PAC policy for example is not only turned towards subsidies to product but also to rural area development.

2.3.3 The accessibility concept in spatial development

The objective of a general document on policy scope, is certainly not to discuss different accessibility indicators and the way to measure them: this would be done in a specific contribution on this topic. It is to stress different understandings of accessibility as regards the spatial equilibrium objective, which has been mentioned earlier.

One first difference to be made is certainly between local or regional accessibility and interregional or international accessibility.

In a regional or local accessibility short distance relations must be investigated which means the relations, which reflect the regional interdependencies and conditions of exchanges between rural and urban areas. However short distance relations can also be a terminal leg of a long distance transport chain. From that point of view it appears that cost and time of the terminal leg represent an important and growing percentage of the total cost of transport.

In this assessment distance is certainly a factor, which increases transport cost, but on the other hand time is also an important factor and time of transport is increasing in dense congested areas that often are central areas. The conclusion is that the traditional opposition between centre and periphery must be reviewed and certainly refined so that the concept of polycentrism can be properly introduced in an accessibility analysis, taking into account local accessibility and long distance accessibility as well as possible combination of transport "legs" which are parts of a door to door transport chain. For the final user it is the door to door performance of transport, which finally counts.

In the spatial analysis conducted in the ESDP as well as in the regional development policies, the importance of European transport network has been stressed. In the Maastricht Treaty transeuropean networks are considered as an important aspect of European cohesion and it has been seen that the TEN networks will extend to CEEC countries (ten priority corridors), to Balkans (Strategic network of the stability pact) or to Mediterranean region.

But in the same time, other distinctions must be made between dense areas facing congestion, remote or deadlocked regions with poor accessibility and peripheral regions.

Among the peripheral regions, many of them are maritime regions, and this is why it is also necessary to include maritime relations, not only for intercontinental trade but also for relations between European regions or between peripheries.

In conclusion the spatial development analysis had to adapt to this specific context and European diversity requires at the same time a more complex transport analysis in terms of multimodality and intermodal solutions. Infrastructures are not the unique answer to this problem of accessibility and availability of services, the quality of services must also be considered.

2.4 To bridge transport and spatial policies

Although the international organisation of institutions always introduces some rigidity in the decision system with on one side transport competence, and on the other side spatial policies at all decision levels whether they are national, regional or European, there has been progresses on both fronts towards a better understanding of the role of transport in spatial schemes.

When looking at the last White paper proposals, it is clear that there are opportunities for a more balanced spatial development ; concrete experimentation can be launched in close relation with regions. But in the same time the diffusion effect of these experimentations and the development of a spatial policy is also a problem of a good understanding of the role of the different actors in a long term planning process.

2.4.1 Opportunities of transport policies

Such opportunities have not been so far presented in terms of spatial planning process but more as propositions to solve transport problems that are related to congestion and impact on environment. Therefore alternative transport modes and transport chains are promoted bringing a wider range of potential services and therefore an opportunity to adapt to a diversity of regional contexts.

This is for example the case for the promotion of maritime transport, which can give a new impulse to peripheral maritime regions. Intermodal transport opens also the opportunity to combine performances of rail on long distance and performances of road on shorter distance. But these opportunities and a broader range of services call for more sophisticated transport solutions. Rail transport, intermodal transport, air transport require an organisation of concentration of traffics on nodal points as well the organisation of a distribution across regional space ; the result might certainly be more satisfying in terms of impact on environment or, possibly, costs of transport but the solution is obviously more complex than a straight road service, door to door, which is very flexible.

In other words there are new opportunities opened within a programme such as Marco Polo for maritime transport or intermodal transport, but this would rely on a good understanding of the role of decentralised units such as regions as well as the setting up of a long term decision making process.

2.4.2 A new role of regions and local institutions in transport organisation

When the transport supply is presented as a transport chain from door to door with the objective of development of alternative modes, the role of nodal points or concentration and distribution points becomes essential. In a world where the logistics policies of production and distribution sectors develop, such nodal points become important points of industrial strategies as well as important point of land use planning of regional authorities:

- From a logistic point of view they are privileged locations for warehouse and inventory ;
- For modes operators they are focal points for collection and distribution: rail transport, intermodal transport, maritime transport, air transport are competitive against road when a minimum volume of traffic can be transported from an origin to a destination ;
- For local authorities they are complementary investments to infrastructure links in order to obtain a better use of the infrastructures: for some cities, nodal points at regional level or metropolitan level will be entry points to urban transport when more stringent conditions might be imposed (regulation of transport problem, urban logistics).

In other words regional space is a space where the transport organisation takes place for long distance haul with

- intermodal centres for intermodal transport ;
- ports of short sea shipping on inland waterways ;
- airports served with public services on same time HST lines ;
- railways stations for HST networks or intercity networks.

For freight transport the regional space must often be considered as a whole because of the necessity to concentrate a sufficient volume of traffic for frequent freight services: the European network is more an interregional network.

For passenger transport the urban or suburban spaces are often the relevant ones to launch a high quality intermodal service, with HST or air transport.

2.4.3 A multilevel governance

The bridging of transport and spatial policies is obviously a long-term objective that calls for a new definition of long term decision process. This one takes now place in a context where different institutional actors must cooperate, at national, European and regional or local level. Consultation of associations and groups of citizens is also required which means more transparency and democracy in the process. Therefore it is important to define new tools according to these objectives and context.

This means in particular the definition of relevant criteria such as accessibility criteria mentioned before which must be integrated in the prioritisation of the projects. So far CBA techniques have been privileged for the choice of priorities. These techniques are able to take into account external efforts through monetarisation. But they are not well adapted to accessibility criteria ; multicriteria techniques can then be proposed but the problem of weighting the criteria will always lead to the setting up of an adequate dialogue process.

From the past experience several aspects must then be stressed so that each of the actors can better understand his role in the implementation of a more comprehensive policy:

- Importance of the definition of a common scenario of reference from which different policy options can be derived: this will concern socio-economic environment and transport projection associated to it ;
- A robust segmentation of the transport demand including a distinction between local, national, international and intercontinental traffics ;

- An analysis of the performances of the transport operating system, in complement of the analysis of the quality and capacity of existing infrastructures ;
- A specific description of intermodal transport chain including the location and performances of the nodal points so that terminal leg of transport can be associated to long haul transport ;
- And finally a good visualisation of the results with GIS tools so that dialogue and consensus can be obtained on solid, convincing grounds.

Such elements structure a database to support decision process, which must become a continuous process with regular evaluation of the progress, which in other words means the implementation of a monitoring system.

3 State of the art on transport indicators

This chapter provides a brief review on existing indicators for transport networks and services. It gives an overview on the state of the art of how to analyse transport services and networks in terms of methodologies and indicators. Specific attention is given to the approaches and methodologies applied later on in the empirical parts of the report.

It begins with the supply side of transport infrastructure and services. Subsequently, indicators for the actual use of transport infrastructure and services are summarised. After that, the concept of accessibility as a baseline for territorial indicators is introduced ; relevant accessibility models and their indicators are presented. Finally, a brief section is devoted to innovative mapping approaches. The purpose of the chapter is to serve as a kind of shopping list for the next phase in ESPON 1.2.1, namely the demonstration of existing indicators to the territory of EU27 plus Norway, Liechtenstein and Switzerland.

This part does not have for objective to be exhaustive but to present the main dimensions of transport indicators.

3.1 Supply of transport infrastructure and services

This section gives a very brief overview of which kind of supply indicators are used in relevant documents and studies. Indicators grouped in this section include the transport infrastructure supply as such, i.e. transport infrastructure endowment, capacity of infrastructure, indicators of transport services and indicators of network vulnerability. Indicators will be mainly presented in a list form.

3.1.1 Indicators of transport infrastructure supply

Transport infrastructure supply indicators can be grouped in two basic categories. Endowment indicators consider the transport infrastructure in an area expressed by such measures as total length of motorways or number of railway stations. Morphological indicators describe features of modal networks and are mainly derived from graph theory or fractal theory. Table 2.6 gives an overview on these types of indicators.

Table 6 Existing indicators of transport infrastructure supply

Indicator type	Sample indicator
Transport endowment	Length/density of roads by road category Length/density of railways by railway category Number of ports Number of airports
Network distance	Ratio Euclidean v. network distance (length, cost, time) Indicator of circuitry - curve of edges - detour of path
Graph theory	Degree of vertex Saturation (planar graph saturated) Vulnerability of graph Edge connected, K-connected
Fractal theory	Fractal dimension of network Fractal dimension of subgraph

3.1.2 Indicators of transport infrastructure capacity

Transport infrastructure capacity indicators can be grouped in two basic types, one describing capacities of links, the other capacities of terminals. Because there are many definitions of capacity that are not independent from the kind of service supplied, Existing indicators of transport infrastructure capacity.

Indicator type	Sample indicator
Link capacity	Capacity of road Capacity of railway track Capacity of ferry link
Node capacity	Capacity of road nodes (intersections, tollbooth) Capacity of airports by category Capacity of ports by category Capacity of intermodal terminals

3.1.3 Indicators of transport services

Existing indicators of transport services can be grouped in three basic indicator types: basic supply of nodes reflects the level of services available in nodes of rail, air and waterway networks ; travel time and travel cost indicators cover the disutility for the user of a certain link or a certain route and can be further differentiated (e.g. by type of vehicle and issues such as statutory rest periods of drivers, safety or traffic regulations in form of aircraft grounding or traffic banning during night time.

Table 7 Existing indicators of transport services

Indicator type	Sample indicator
Basic supply	Number of departing/arriving trains by category and destination Number of departing/arriving flights by destination Number of departing/arriving ferries by destination Number of passenger cars Number of public transport vehicles by type Number of goods vehicles by type
Travel time	Link travel time by transport mode or multimodal Origin-destination travel time by transport mode or multimodal
Travel cost	Link travel cost by transport mode or multimodal Origin-destination travel cost by transport mode or multimodal and type of traveller

3.1.4 Indicators of network vulnerability

The natural hazards Europe has faced during the last couple of years and in particular during this summer and the demolishing of transport infrastructure and services has given attention to indicators describing the exposure of transport infrastructure to potential damage. However, little more than nothing exists so far in this respect.

Table 8 Existing indicators of transport vulnerabilities

Indicator type	Sample indicator
Network vulnerability	Geographic structural vulnerability of corridors Climatic vulnerability of corridors

3.2 Use of transport networks and services

This section provides a brief overview of which kind of indicators for the actual use of transport networks and services are used in relevant documents and studies. A distinction is made between traffic indicators showing volumes on links or in nodes and flow indicators, which always include origin and destination of the flows.

3.2.1 Traffic volume indicators

Traffic indicators capture the actual use of the transport infrastructure networks and services. There are five types: transport quantities, traffic on links and traffic in terminals, and also indicators describing the environmental effects of traffic in terms of consumption of natural ressources and pollution as well as indicators describing transport safety.

Table 9 Existing traffic volume indicators

Indicator type	Samplers indicators
Transport quantities	km per person per mode by purpose km per ton by goods type per mode modal split (passenger and freight)
Link traffic	Traffic on roads by vehicle type Number of trains and passengers on rail links Number of passengers and freight, cars and lorries on ferries
Terminal traffic	Traffic volume (passenger and freight) of airports Traffic volume (passenger and freight) of ports Traffic volume (freight) in intermodal terminals
Energy consumption and pollution	Consumption of mineral oil products by link and by region Emission of green house gases by link and by region Emission by pollutant by link and by region
Transport safety	Number of persons killed by mode Number of persons injured by mode

3.2.2 Traffic flow indicators

Traffic flow indicators are different from traffic volume indicators as they always include origin and destination, i.e. the relationship between two different points in space.

Table 10 Existing traffic flow indicators

Indicator type	Sample indicator
Traffic flow	Passenger flows by user type, trip purpose Trade/goods flows by type of good

3.3 Accessibility indicators

In the context of spatial development, the quality of transport infrastructure in terms of capacity, connectivity, travel speeds etc. determines the quality of locations relative to other locations, i.e. the competitive advantage of locations which is usually measured as accessibility. Investment in transport infrastructure leads to changing location qualities and may induce changes in spatial development patterns.

There are numerous definitions and concepts of accessibility. A general definition is that "*accessibility indicators describe the location of an area with respect to opportunities, activities or assets existing in other areas and in the area itself, where 'area' may be a region, a city or a corridor*" (Wegener et al., 2002). Accessibility indicators can differ in complexity. More complex accessibility indicators take account of the connectivity of transport networks by distinguishing between the networks themselves and the activities or opportunities that can be reached by it. These indicators always include in their formulation a spatial impedance term that describes the ease of reaching other such destinations of interest. Impedance can be measured in terms of travel time, cost or inconvenience.

This sub-chapter first presents generic accessibility concepts and dimensions of accessibility. Subsequently, new accessibility models at the regional scale are briefly presented. Finally, pan-European accessibility models are reviewed in terms of their dimensions.

3.3.1 Accessibility concepts

In this section, accessibility indicators are addressed in which, in more general terms, accessibility is a construct of two functions, one representing the activities or opportunities to be reached and one representing the effort, time, distance or cost needed to reach them:

A_i is the accessibility of area *i*, W_j is the activity *W* to be reached in area *j*, and c_{ij} is the generalised cost of reaching area *j* from area *i*. The functions $g(W_{ij})$ and $f(c_{ij})$ are respectively called *activity functions* and *impedance functions*. They are associated multiplicatively, i.e. are weights to each other. Both are necessary elements of accessibility. A_i is the total of the activities reachable at *j* weighted by the ease of getting from *i* to *j*.

Subsequently, more complex accessibility indictors can be classified by their specification of the destination and the impedance functions (Schürmann et al., 1997, Wegener et al, 2002).

- **Travel cost indicators** measure the accumulated or average travel cost to a pre-defined set of destinations: for instance, the average travel time to all cities of more than 500,000 inhabitants.
- **Daily accessibility** is based on the notion of a fixed budget for travel in which a destination has to be reached to be of interest. The indicator is derived from the example of a business traveller who wishes to travel to a certain place in order to conduct business there and who wants to be back home in the evening (Törnqvist, 1970). Maximum travel times of between three and five hours one-way are commonly used for this indicator type.
- **Potential accessibility** is based on the assumption that the attraction of a destination increases with size, and declines with distance, travel time or cost. Destination size is usually represented by population or economic indicators such as GDP or income.

Table 11 Generic accessibility indicators.

Type of accessibility	Activity function $g(W_j)$	Impedance function $f(c_{ij})$
Travel cost Travel cost to a set of activities	$W_j \left\| \begin{array}{l} 1 \text{ if } W_j \geq W_{min} \\ 0 \text{ if } W_j < W_{min} \end{array} \right.$	c_{ij}
Daily accessibility Activities in a given travel time	W_j	$1 \text{ if } c_{ij} \leq c_{max}$ $0 \text{ if } c_{ij} > c_{max}$
Potential Activities weighted by a function of travel cost	W_j^{α}	$\exp(-\beta\, c_{ij})$

Each of the different accessibility types can be seen to have their own advantages and disadvantages. Travel time indicators and daily accessibility indicators are easy to understand and to communicate though they generally lack a theoretical foundation. Potential accessibility is founded on sound behavioural principles but contain parameters that need to be calibrated and their values cannot be expressed in familiar units. From the three basic accessibility indicators, an almost unlimited variety of derivative indicators can be developed (cf. Ruppert, 1975), the most important ones being multi-modal, inter-modal and interoperable accessibility. In all three cases the equations presented above remain valid ; what changes is the way in which transport costs are calculated.

Modal accessibility indicators are usually presented separately in order to demonstrate differences between modes. But they may be integrated into one indicator expressing the combined effect of alternative modes for a location. There are essentially two methods of integration. One is to select the fastest mode to each destination, which in general will be air for distant destinations and road or rail for shorter distances, and to ignore the remaining modes. Another way is to calculate an aggregate accessibility measure combining the information contained in the modal accessibility indicators by a 'composite' generalised travel cost. This is superior to average travel costs across modes because it makes sure that the removal of a mode with higher costs does not result in a – false – reduction in aggregate travel cost.

Inter-modal accessibility indicators take account of inter-modal trips involving two or more modes. Inter-modal accessibility indicators are potentially most relevant for logistic chains in freight traffic with different possible combinations of freight modes and terminals such as rail freight with feeder transport by lorry at either end. Inter-modal accessibility indicators in passenger travel involve mode combinations such as rail-and-fly or car access to railways.

Dimensions of accessibility indicators

Accessibility indicators may be sensitive to the following dimensions: origins, destinations, impedance, constraints, barriers, types of transport, modes, spatial scale, equity and dynamics (Wegener et al., 2000 ; 2002).

- ***Origins****:* Accessibility indicators may be calculated from the point of view of different population groups such as social or age groups, different occupations such as business travellers or tourists, or different economic actors such as industries or firms.
- ***Destinations****:* Accessibility indicators may measure the location of an area with respect to opportunities, activities and assets such as population, economic activities, universities or tourist attractions. The activity function may be rectangular (all activities beyond a certain size), linear (of size) or non-linear (to express agglomeration effects).
- ***Spatial impedance****:* The spatial impedance term may be a function of one or more attributes of the links between areas such as distance (Euclidean or network distance), travel time, travel cost, convenience, reliability or safety. The impedance function applied may be linear (mean impedance), rectangular (all destinations within a given impedance) or non-linear (e.g. negative exponential).
- ***Constraints****:* The use of the links between areas may be constrained by regulations (speed limits, access restrictions for certain vehicle types or maximum driving hours) or by capacity constraints (road gradients or congestion).
- ***Barriers****:* In addition to spatial impedance the non-spatial, e.g. political, economic, legal, cultural or linguistic barriers between areas or non-spatial linkages between areas such as complementary industrial composition may also be considered.
- ***Types of transport****:* Only personal travel or goods transport, or both, may be considered
- ***Modes****:* Accessibility indicators may be calculated for road, rail, inland waterways or air. Multi-modal accessibility indicators combine several modal accessibility indicators. Inter-modal accessibility indicators include trips by more than one mode.
- ***Spatial Scale****:* Accessibility indicators at the continental, transnational or regional scale may require data of different spatial

resolution both with respect to area size and network representation, intra-area access and intra-node terminal and transfer time.

- ***Equity**:* Accessibility indicators may be calculated for specific groups of areas in order to identify inequalities in accessibility between rich and poor, central and peripheral, urban and rural, nodal and interstitial areas.
- ***Dynamics**:* Accessibility indicators may be calculated for different points in time in order to show changes in accessibility induced by transport infrastructure investments or other transport policies, including their impacts.

3.3.2 New regional accessibility models

Since the detailed review of accessibility models done by the Working Group 'Geographical Position' of the Study Programme on European Spatial Planning – SPESP (Mathis, 2000; Wegener et al., 2000, 2002) some development of accessibility models has taken place. This section presents those new accessibility models that do cover only a region. The notion of region is very broad comprising one or more than one NUTS-2 regions, countries or INTERREG IIC/IIIB regions. New accessibility models covering the whole of Europe will be presented as part of the next section.

Menerault and Stransky (1999) proposed an approach of long distance accessibility based on intermodal connections between air and high-speed rail. They compared air only, rail only and air-rail journeys departing from Lille to a set of destinations in France. They showed that the high speed rail connection at the airport of Charles-de-Gaulle gives to the Lille passengers an improved accessibility, with an increase of the supply for most of the directly air connected cities, but also with a set of new possible destinations. The contribution demonstrates the new opportunities of high-speed rail and air connections in terms of transport service. It invites to question those indicators that are based only on infrastructure. For a city of a high level in the European hierarchy like Lille, what is the most important in terms of accessibility? Is it the possession of an international airport or is it the availability of a high-speed rail access to a major European hub ? This example shows that the combination of high-speed modes has to be considered in the study of accessibility at the European scale.

In a background study for the spatial development perspective VASAB of the Baltic Sea Region, **Spiekermann** developed a disaggregate accessibility model for that INTERREG IIC area (Hanell et al., 2000). Daily accessibility indicators for road, rail and air were calculated for raster cells of 10x10 km. The indicators were presented in three-dimensional accessibility surfaces showing the number of inhabitants that can be reached within five hours door-to-door travel time. Of relevance here are the spatial detail and the option to display difference maps of accessibility between transport modes or between different years.

L'Hostis and Decoupigny (2001) developed an assessment of the quality of service of public transport for supporting spatial planning principles at a regional scale. From a set of cities the authors analysed the relations corresponding to spatial patterns of the external relations, the hierarchical network, or city network. The assessment was done through analysing the possibility of doing a return journey between cities for complete working-day corresponding to a daily mobility pattern. The quality of the transport service is obtained if a "quick train at the right moment" is available in the morning, and after 9 hours spent in the destination city. This analysis of the daily accessibility indicator type shows the lack in the quality of service corresponding to the intercity relations to be developed if one wishes to support the spatial cohesion principles of hierarchical and city network.

Spiekermann et al. (2001) developed a NUTS-5 accessibility model for fourteen urban agglomerations in North-western Europe for the GEMACA II project. The indicator used was of the potential type and was calculated as European-wide road, rail and air accessibility of the municipalities. Results were presented in diagrams and maps, the latter showing accessibility of municipalities of the fourteen agglomerations standardised to the European average. The spatial detail led to the conclusion that accessibility within an urban region can be very different and depends on the location of municipalities with respect to the next nodes of high-level transport infrastructure, mainly with respect to high-speed rail stations and airports.

Geurs and Ritsema van Eck (2001) developed an accessibility model for the Netherlands for measuring job accessibility. A vast range of indicators was tested, including daily accessibility type indicators adjusted for commuters (45 and 60 minutes maximum travel time), potential type indicators as well as balancing factor or utility-based measures. Indicator values were calculated for Dutch municipalities, i.e. NUTS-5 regions. Transport modes were car and public transport. The model was used to analyse the effect of a set of land-use transport scenarii. Results were presented on maps showing the outcome of the different indicators and scenarii.

Luis (2002) applied temporal accessibility to the case of the Canary Islands archipelagos, and provided useful indications on two interesting directions with respect to the transport network issues. Firstly the accessibility indicators were applied to maritime passenger transport that belongs to the transport modes to be treated in ESPON 1.2.1. Secondly the method developed envisages an accessibility measure that allows assessing the service of transport. The measure is directly related to mobility needs through a door-to-door approach and is based on timetable information for ferries. The indicator of time available at destination, i.e. an indicator of the daily accessibility type, is used to assess the territorial cohesion of the archipelago.

3.3.3 Accessibility models for Europe

Over the last decades a vast number of accessibility studies addressing European core-periphery issues have been published. This sub-chapter will briefly review the most important European accessibility models ; the selection follows that in a number of more detailed reviews (Bruinsma and Rietveld, 1998; Wegener et al., 2000; 2002). Because the focus of the ESPON 2006 Programme is on territorial indicators for Europe, this section tries to give an overview on all European-wide accessibility models of the last decade and not only on the most recent (as it was done for the regional models in the previous section).

Most accessibility studies have a regional or national focus, but rarely a European dimension. However, there are a growing number of accessibility models that address European-wide accessibility and thus European peripherality. This section will briefly introduce European accessibility models developed in the last two decades and will try to classify and compare the accessibility indicators used by applying the dimensions of accessibility presented in the previous chapter. The order in which the models are presented is strictly chronological.

Keeble et al. (1982, 1988) were commissioned by DGXVI of the European Commission to analyse economic core-peripheral differences between the regions of the Community and to investigate whether any differences can be explained by relative location. For this purpose, they developed a gravity potential model with regional GDP as destination activity and road distance costs as impedance. The results are expressed as an Economic Potential Index and are presented on maps as contour lines.

The group of Törnqvist presented a more recent application of his method of daily accessibility developed in the early 1970s (Cederlund et al., 1991; Erlandsson and Törnqvist, 1993). The indicator is expressed in million inhabitants that can be reached from a city by a return trip during a work day with four hours minimum stay using the fastest available mode (outbound accessibility) or in million inhabitants that can reach a city by such a return trip (inbound accessibility). The important differentiation between in and outbound accessibility is possible due to the use of timetable information. Indicators are presented in numbers and map forms for more than 100 important cities in Europe.

Grasland (1991, 1999) developed accessibility indicators based on geographical or Euclidean distance between areas as spatial impedance. The spatial reference system is a grid of cells of 1° latitude and longitude. One indicator expresses the mean Euclidean distance to the population of Europe. Another uses the Euclidean distance in a potential analysis based on the Gaussian neighbourhood function. The indicator was used to illustrate the spatial integration taking place through the opening of the borders to Eastern Europe. The indicator is expressed as population potential and presented in map form as contour lines.

The *Bundesforschungsanstalt für Landeskunde und Raumordnung* (Lutter et al., 1992, 1993) in a study for DG Regio of the European Commission calculated the accessibility of NUTS-3 regions in the then twelve Member States of the European Community as average travel time by inter-modal transport (road, rail, air) to 194 economic centres in Europe. In the same study they also used other destinations such as the next three agglomerations, the next high-speed train stop or the next airport. In addition, they calculated a daily accessibility indicator as the number of people that can be reached in three hours using the fastest connection. Modes considered included road, rail and air with and without planned infrastructure investments (new motorways, high-speed rail lines and more frequent flight connections).

Bruinsma and Rietveld (1993) calculated potential accessibility of European cities with respect to population for road, rail, air and fast modes. Results are presented in tables and map forms in which the sizes of the circles indicate not population but accessibility of cities standardised to the maximum accessibility value. The resulting map for cities closely resembles the contour maps by Keeble et al and so demonstrates the spatial correlation between economic and population centres. Important is also the consideration of non-physical aspects of borders and their effect on accessibility.

MCRIT (1994; 1999) developed the ICON indicator, which evaluates the quality of access to the nearest nodes of long-distance transport networks weighted by importance and level of services. The indicator is a sophisticated transport infrastructure and service endowment indicator that calls attention to the fact that many accessibility indicators ignore the quality of local access to long-distance networks. The concept has been used in a number of regional and European-wide studies (Europe 2000, Europe 2000+

etc.) and is in process to be applied by the European Investment Bank to evaluate the cohesion interest of transport infrastructure projects. The ICON indicator may be presented in maps, which show the indicator values for small raster cells.

Spiekermann and Wegener (1994a; 1996; Vickerman et al., 1999) developed three-dimensional surfaces of daily and potential rail accessibility for Europe using raster-based GIS technology ; road and air accessibility were added later (Schürmann et al., 1997; Fürst et al., 2000). The quasi-homogenous accessibility surface was achieved by sub-dividing Europe into some 70,000 square raster cells of 10 km width and calculating accessibility indicators for each raster cell with respect to all other raster cells. The population of raster cells was estimated by allocating the population of NUTS-3 regions to raster cells with the help of a negative-exponential gradient of population density around population centres. Access travel time from each raster cell to the nearest network node was approximated using an average travel speed of 30 km/h.

In the UTS (Union Territorial Strategies) study, **Chatelus and Ulied (1995)** developed several accessibility indicators for the evaluation of trans-European networks at the level of NUTS-2 regions in the EU plus Norway. One of them, the FreR(M) indicator, measured the average cost to reach a market area of a certain population size by lorry. The impedance term is generalised road transport cost including the cost of the driver's time, the cost per kilometre and a fixed cost component. The CON(T) indicator accumulated population of NUTS-2 regions of EUR15 plus Norway and Switzerland reachable within a maximum travel time of three hours by any combination of car, rail and air, with transfer times between modes explicitly considered. The CON(T) index was used to assess transport infrastructure scenarios with respect to the criteria competitiveness, cohesion and sustainability. The FreR(T) index, a freight accessibility indicator expressing the size of the market that can be reached in a certain travel time accumulates the population that can be reached in one, two or three days by the fastest connection using road, rail or combined traffic with driving time restrictions for lorry drivers observed.

Gutiérrez et al. (1996) and Gutiérrez and Urbano (1996) calculated average travel time by road and rail from about 4,000 nodes of a multi-modal European transport network to 94 agglomerations with a population of more than 300,000 with and without planned infrastructure improvements. Road travel times included road and car ferry travel times modified by a link-type specific coefficient and a penalty for crossing nodes representing congested population centres. Rail travel times included time table travel time plus road access time and penalties for changes between road and rail (60 minutes), rail and ferry (180 minutes) and the change of rail gauge between Spain and France (30 minutes).

In studies for the Highlands and Islands European Partnership Programme and for DG Regio of the European Commission, **Copus (1997, 1999)** developed "peripherality indicators" for NUTS-2 and NUTS-3 regions based on road-based potential measures of the Keeble type. The model takes account of different average speeds for different classes of road, realistic ferry crossing and check-in times, EU border crossing delays and statutory drivers' rest breaks. Accessibility is presented as a peripherality index derived as the inverse standardised to the interval between zero (most central) and one hundred (most peripheral).

In a report of the Study Programme on European Spatial Planning for DG REGIO, **Wegener et al. (2000; 2002)** proposed reference indicators describing the geographical position of European NUTS 3 regions. Besides geographical, physical and cultural indicators, three accessibility indicators were proposed. The first two measure accessibility by road and rail to population, the last one, accessibility by air, to economic activity (expressed by gross domestic product, or GDP). Accessibility to population is seen as an indicator for the size of market areas for suppliers of goods and services; accessibility to GDP as an indicator of the size of market areas for suppliers of high-level business services. Accessibility is presented as index in which the average European accessibility serves as a reference.

Mathis (2000) developed accessibility indicators for Europe based on road travel times by car and lorry. The model is able to include European or national regulations in form of constraints, examples are statutory rest periods for lorry drivers and banning of lorry traffic during weekends in different countries. One of the advantages of the model is that not only travel times are calculated but the model keeps record of which links are used by minimum-paths. The outcome of this is an indication of transport corridors facing large transport demand. Results are shown in maps displaying travel time from the selected origin as well as the number of itineraries using the same link. Moreover, the model can take into account freight flows.

Schürmann and Talaat (2000) produced a background report for the latest Cohesion Report of the European Commission (2001) in which an index of peripherality of the potential type was implemented in a geographical information system. Potential type indicators are calculated for passenger or freight transport by road using GDP, population or labour force as destination activity. The indicators are calculated for NUTS 3 regions and for the equivalent regions of the candidate countries as well as for

Switzerland and Norway. Aggregation procedures for NUTS 2, 1 and 0 are supplied by the system. The peripherality index is presented in two ways: either standardised on as the European average (as in Wegener et al., 2000) or to an interval between 0 and 100 (as in Copus, 1997, 1999).

Baradaran (2001) developed a pan-European accessibility model to analyse the impact of different indicator types and different forms of the impedance function on the output. He analysed two groups of travel cost indicator types and two groups of the potential type and linked those with four different impedance functions. Accessibility indicators have been calculated for more than 4,500 European cities with a population greater than 10,000. Results of the different model implementations are statistically analysed, in addition accessibility surface maps were constructed with GIS-based interpolation techniques.

Most recently, **Spiekermann et al., (2002; Copus et al. (2002)** developed a multi-modal accessibility indicator, i.e. an indicator that aggregates over modes and is thus capable of integrating the contributions of different transport modes to the degree of centrality or peripherality. The indicator is a logsum accessibility potential aggregating over road, rail and air. Multi-modal indicators are considered to have much more explanatory power with respect to regional economic performance than any accessibility indicator based on a single mode only (Fürst et al., 2000). The indicator is presented for NUTS 3 regions with a focus on the differentiation of peripheral areas. In addition, a national peripherality index has been developed for which only national destinations were considered.

To sum up, t**he European accessibility models yield a wide range of approaches with respect to dimensions of accessibility. They differ in many respects, but there are also some similarities :**

- More than half of the models use a potential type indicator, the remaining ones use travel costs or daily accessibility indicators. A few models are able to calculate different types.
- Origins are usually NUTS-2 or NUTS-3 centroids, very few studies have a more detailed representation of space.
- The destination activities are usually population or GDP for the potential type models, and a pre-defined set of agglomerations for the travel cost indicators.
- Nearly all models use travel time as their impedance term, only a few apply travel costs.
- Models that consider freight transport use statutory drivers' rest breaks as constraints.

- Barriers are mainly in the form of border delays, only Keeble et al. use trade barriers.
- Nearly all models are based on personal travel, only a few consider freight transport.
- Half of the models consider one mode only, in most cases road. The other models have networks for different modes, however, only two use inter-modal travel times.

Table 12 Dimensions of European accessibility indicators

Authors	Generic Indicator type	Origins	Destinations	Impedance	Type of transport	Modes	Spatial scope
Keeble et al. (1982; 1988)	Potential	NUTS 2 centroids	GDP in NUTS 2 and in non-EU countries	Road distance	-	Road	EU9 EU12
Cederlund et al. (1991) Erlandsson and Törnqvist, (1993)	Daily	European cities (about 100)	European cities (about 100)	Travel time	Personal	Fastes mode	Pan-Europe
Grasland (1991; 1999)	Potential	1° raster cells	Population in 1° raster cells	Euclidian distance	-	-	pan-Europe
Lutter et al. (1992, 1993)	Travel cost Daily	NUTS 3 centroids	194 Centres next 3 agl. airports etc.	Travel time	Personal	Road rail air inter-modal	EU12
Bruinsma and Rietveld, 1993	Potential	European agglomeratio ns (42)	Population in 42 European agglomerations	Travel time	Personal	Road rail air fastest	EU 15 plus 8 countries
MCRIT (1994; 1999)	Travel cost	Raster cells	Next nodes of long-distance networks	Travel time	Personal	Road rail air multimodal	pan-Europe
Spiekermann and Wegener (1994a, 1996)	Daily potential	10 km raster cells	Population in 10 km raster cells	Travel time	Personal	Road rail air multimodal	pan-Europe
Chatelus and Ulied (1995)	Travel cost Daily	NUTS2 centroids	Population in NUTS 2	Travel cost	Personal freight	Road rail air inter-modal	EU15, Norway, Switzerland
Gutierrez and Urbano (1995, 1996)	Travel cost	4000 nodes	94 ag-glomerations	Travel time	Personal	Road rail	EU12
Copus (1997, 1999)	Potential	NUTS2 / NUTS 3 centroids	GDP, population, workforce in NUTS 2/3	Travel time	Personal	Road	EU15, candidate countries, Norway, Switzerland
Wegener et al., (2000, 2002)	Potential	NUTS 3 centroids	Population, GDP in 10 km raster cells	Travel time	Personal	Road rail air	EU15
Mathis (2000)	Travel cost	Selected origins	Network nodes and NUTS 2	Travel time	Personal freight	Road	EU27
Schürmann and Talaat (2000)	Potential	NUTS 3 centroids	GDP, population, workforce in NUTS 3	Travel time	Personal freight	Road	EU15, candidate countries
Baradaran (2001)	Travel cost potential	4500 European cities	Population in 4500 cities	Travel time	Personal	Road	pan-Europe
Spiekermann et al., (2002)	Potential	NUTS 3 centroids	Population in 10 km raster cells	Travel time	Personal	Multi-modal (road, rail, air logsum)	EU15

4 Methodologies to obtain transport indicators

The following pages deal with the general methods used in this report. They remain general, the specific methods being presented for each indicators presented in the other parts .

4.1 General overview

Transport time and costs for freight are basic indicators of European economic integration and regional accessibility. In many former studies either time or cost, or a combination of both, a "generalised" cost or time has been used to characterise differences in accessibility or to estimate a kind of "impedance" or "resistance" function between two zones.

Today the context has become more complex and it is often not relevant any more to use a single indicator between two zones, whatever is the degree of sophistication. Quality of service is also a factor which plays a more and more important role in the satisfaction of users, in their strategy of location for production "unit" or logistics centres which in turn influence in depth the pattern of flows in Europe: many recent studies have pointed the quality factors as well as state preference surveys (Intermodal Quality – IQ 2000, IV PCRD, MYSTIC survey IV PCRD…).

Furthermore the costs and time of transport also depend on the operating system chosen which in turn will be determined by the volume of traffic or the frequency of service required: rail transport gives a good example of such differences, with improved performances in time and costs when shuttle trains can be operated in good conditions as compared to wagon load units which must go through several marshalling yards from origin to destination thus increasing considerably both time and cost per units and deteriorating considerably the quality of service.

At a time when policy objectives for sustainable development focus on development of alternative modes (modes alternative to road), it is not possible to limit the question of transport accessibility to the sole road services for freight: availability of alternative services must also be considered making it much more complex to introduce relevant indicators. More elements have to be taken into account, characterised by a large number of operation variables in particular for rail, intermodal and short sea shipping transport.

In addition problems of congestion must also be taken into account for road as well as for alternative mode.

- For road this results in delays on certain routes although road freight transport has shown in the past a quite good aptitude to avoid peak hours in congested areas and to adapt accordingly the driving and resting hours ; but such flexibility encounters limits which become more constraining with increase of traffic.

- For rail this has led to the question of "priority for freight" because of the time lost to leave the right of the way to passenger trains and to the identification in Europe of a "priority freight" network, as recalled earlier to the policy context.

Therefore new methods must be developed for freight indicators taking into account in the best way possible this fundamental element for the availability of a freight service.

The method proposed in ESPON will be to differentiate major transport market segments which have their own specific requirements and to adapt consequently the modal (or intermodal) transport indicators ; these indicators will in turn determine the choice of routes, depending on infrastructure characteristics, including capacity problems.

For each step illustration will be given for specific markets, focusing on most sensitive part of the European network with for example the case of transit across the Alps and the Pyrenees or focusing on most important European regulation measures such as reinforcement of driving and working conditions. Illustration for modal split and production of alternative intermodal solution will be also produced.

4.1.1 The freight market segments

Several researches of the IVe Research framework programme have addressed this problem of relevant freight market segments because logistics requirements, transport needs and transport drivers differ considerably from one segment to another. Observed transport trends vary as a consequence so that it is more and more difficult to talk about global elasticities to GDP or revenues for freight and passengers. If global freight transport appears to increase more rapidly than global passenger transport over the past period, which was not the case 15 or 20 years ago, then this is the result of very contrasted segments evolution according to the distance of shipment whether it concerns international exchanges or not, high value added goods or not. The growth of passenger transport is the resulting combination of a slowing down in the motorised local transport trend and a continuous growth of longer distance trips.

For our purpose it is then necessary to take into account such structural evolution and changes in trends without introducing too much details in segmentation variables in order not to loose our

main objectives of spatial development of European space ; the definition of main segments to be considered in a common platform of understanding of transport needs and trends was precisely the topic addressed in Think Up thematic network for prospective analysis of transport and the differentiation proposed here is mainly based on these results.

4.1.1.1 A first level of segmentation

A first level of segmentation is clearly a distinction to be made between passengers and freight transport as well as a distinction between short distance and long distance.

For passenger it is fairly obvious although the distance threshold is sometimes difficult to identify precisely in terms of kilometres:

- *short distance trips* are most of the time regular trips among which working trip does not represent the majority: personal trips, shopping, school. represent a growing part of this segment and represent often, around 2/3 of short distance trips.
- *long distance trips* can be business trips or leisure trips including vacation trips, the frequency of such trip is increasing with shorter average time at destination.

For these two main segments and according to trip purposes it is clear that different types of transport services will be supplied whose characteristics will depend on the mode considered ; adaptation of technical constraints to demand requirements is also part of the problem of the segmentation of passengers transport market.

For freight the distinction between short and long distance can be less relevant except when specific cities logistics regulation are implemented for freight distribution and collection: in that case the implementation of a transhipment nodal points will be necessary in order to combine long haul transport with local transport. The important concept for freight is the well-known concept of transport chain, which takes all its significance for intermodal transport when transport units are transhipped from one mode to another. However transport chains are still most often organised within a single mode combining large trucks operations with small distribution trucks operations.

Therefore a more important dimension of the freight market will often be the type of logistic organisation with a major distinction between bulk transport, large shipment of general cargo and small shipments: shipment size is a very important determinant of transport organisation and of modal choice. Most of alternative modes do require indeed some consolidations or massification processes along the chain, which makes it more difficult for the appraisal of their performances. This is not the case for road which is more flexible and adapt more easily to different types of logistics organisation and to different types of shipment size: road is the most appropriate mode for diffuse flows which still gives to this mode an important role in the accessibility of remote regions.

4.1.1.2 A second level of segmentation: combining the demand and supply characteristics

The demand segmentation quickly suggests a supply segmentation in order to define more appropriate market segments so that a better understanding of possible contribution of is made possible. Today in the light of policy options it is not possible any more to talk about accessibility without differentiation of solutions between modes ; since the objective is to promote alternative mode for sustainable development, then the accessibility analysis must also point which solution can be provided with rail or sea mode, eventually in combination with road.

In this analyse of contribution of mode a fundamental factor pointed out is the size of shipment or the volume of traffic between two cities or regions. If no direct solutions can be implemented, a direct train or direct truck or direct ship then more sophisticated operating system with consolidation and deconsolidation points must be implemented.

The consequences of this is that the shortest "distance" route might not be the most appropriate and neither the shortest "time" route or the lower "general cost" route: indirect routing through nodal points of consolidation and deconsolidation might provide a solution with lower cost and may be lower time.

For truck organisation this problem can be more easily solved with implementation of central hubs in addition to regional consolidation points for small shipment distribution. But for rail the problem is in general much more difficult to solve ; and it has been pointed out that rail performances are very much depending on the operating system.

In recent transport studies segmentation is introduced more systematically for rail supply which in turn is adapted to transport demand characteristics.

4.1.2 The transport operating system

Once admitted that transport operating system has to be introduced in order to give a more accurate picture of the European situation for time and costs of transport, it is then necessary to go back to the different transport techniques available, including intermodal transport which will be considered here as an extension of rail and maritime techniques.

4.1.2.1 The road techniques

It is not necessary to tell much about road which is considered as the most flexible mode, adapted to short distance and long distance, small shipment size and large shipment size. However for very large shipment road meets sometimes technical problems and faces major congestion problems in the network for the years to come.

In big ports for example it becomes very difficult to use road mode when large container ships load and unload hundreds and sometimes one or two thousand of maritime containers ; this creates huge lines of trucks in area closed to very busy maritime container terminals, with few space and rail, inland waterways or feedering techniques (sea mode for terminal leg of the transport) are more adapted.

To face congestion in crossing dense area, not much can be said for road in the present situation except that a better information system, improvement of bypass and alternative routes close to large metropolis area might increase capacity use of network or postpone for a few years critical congestion problems.

However the question of the maximum load allowed for truck in Europe, top to 44 t, may be more in certain countries, is still not completely solved, and might also influence the level of traffic although in a rather marginal way, which again will be equivalent to postpone by a few years major critical congestion problems in the European networks.

So far the most efficient answer to congestion has probably been a more intensive use of the network by trucks off the peak hours of passenger traffic, thus levelling the use of network along day and night hours, so that average speed of trucks has not yet decreased very much although traffic has increased: the combination of such adaptations with new suburban infrastructures and completion of motorway networks probably explain the continuous performances of road in the nineties, but limit of these factors will probably be reached in the years ahead and motorway networks are now almost completed in most of European countries except CEEC countries.

A last point to be stressed is the question of harmonisation of driving and working hours in Europe, and the question of reinforcement of regulation including speed: it is a very important point on which this project will insist on the measure of time and cost performances for road as well as for the road assignment on network and modal split. Concerning working hours and driving hours an answer of road haulier has sometimes been the organisation of change of drivers along a given route as it is the case, in a very performing way between France and Portugal. For larger road companies this should not be forgotten and can maintain road performances with improved working conditions of drivers, remaining close to their living places. Another effect could also be the introduction of new techniques such as "rolling road" along most congested corridors: France is thinking about it for its two major corridors called the "Magistrale eco fret" in the Eastern part and the "Magistrale Atlantique" in the Western part of the country.

The rolling road technique exists already for crossing the Alps or crossing regions where road traffic is difficult or prohibited (no authorisation of transit): in this case the objective is quite different and the service would be proposed with rail shuttle on longer distance and easy transhipment, and may be attractive when considering that road drivers might be allowed to consider as resting time the time in the train.

Another aspect to mention for the future is the possible implementation on motorway of "chauffeur" technique. With this technique there is an automatic control of distance between trucks which allow much shorter distance between them and increase capacity: today it is still to early to say what will be the influence of such technique.

4.1.2.2 The rail operating techniques

The rail operating techniques are probably the ones that supply more diversity because of the constraints imposed by the infrastructure use: it is a "guided" transport.

The first consequence of this situation was the necessary multiplication of rules for the use of infrastructure concerning planning of route, slot allocation, signalling and so on. So that different definitions of such rules in the different European countries have created huge problems of "interoperability". Rail is still very much penalized when crossing border although it is a mode relevant for long distance and many European programmes try to improve this situation.

As a result border crossing time should decrease significantly: it varies from 30' up to 4 hours in average and often more than 10 hours for crossing border of a country like Spain when there are in addition gauge problems. But also border crossing cost should also decrease since drivers and locomotive have often to be changed, and these are two major factors of rail costs. Therefore interoperability progresses affect time and cost performances for rail.

Once this general question of interoperability that affects all the rail operating systems has been recalled the following distinction can be made between:

- direct train operations
- single wagon operations
- intermodal operations that again divide in direct train and wagon load services.

4.1.2.2.1 Direct train operations

These are the easiest ones for network assignment although trade off chain to be made between time and distance, time and costs. The question of priority and slots allocation is also an important problem for direct train that could benefit very much from the definition of a "priority freight network" or "dedicated freight network" in Europe. Simulation made shows that train time (and consequently costs because of better use of human resources and equipment) such a policy could significantly improve rail performances along major corridors.

It is clear that sometimes longer trips with low speed, for bulk products, can be used as rolling stock, and that time is not a strong constraint for certain products: but this is certainly not an efficient way of solving a storage problem and certainly not design for such a purpose, and end up with a costly solution for society.

From a commercial point of view the direct train often appear as the best solution if the volume of traffic is sufficient between an origin and destination: better performances for users and lower costs for operators. Some companies and new entrants try to promote direct trains along major corridors and this introduces a differentiation in European space as regard rail performances provisions to regions.

It has already been stressed that promotion of rail might benefit more to larger regions or dense O/D relations if rail services are not thought also in terms of consolidation techniques for more remote or smaller regions: the main reason is because direct trains are performing better and potential improvement on dense relations served with shuttle could reach decrease up to 30 % or even 50 % in cost and time.

4.1.2.2.2 Single wagon technique

Single wagon technique is probably the most difficult to operate because, in addition to the problem of interoperability and slots allocation, there is the question of train composition. Wagon have to be brought to some consolidation points with very expensive terminal operations, and along the trip the composition of trains changes, in general several times, in marshalling yards.

Some rail operators have developed single wagon market or have asked for extra charges to cover the extra costs, making often this technique not competitive against road. Today the debate still goes on about single wagon future which suffers from direct competition with road but also from some competitions with Intermodal technique, for which boxes are concentrated in intermodal terminals, and collected and distributed by road.

It is then difficult to say much about the future of this technique when solutions are too costly for terminal part of rail operations, being aware that there is not a clear cut in the market between full train and single wagons: sometimes solutions appear in part trains or wagon blocks of several units, which bring back rail in competition with road.

4.1.2.2.3 Intermodal technique

The intermodal technique is already well developed on certain market and corridors and should develop quickly on this privileged market giving again a fairly contrasted overview of European situation.

The problem of intermodal technique is to compensate transhipment costs of the transport unit by economies on rail haul so that it becomes competitive with road. It has been stressed already that maritime container market is a privileged market and quick expanding market of intermodal transport because transhipment from "mother" ship (large intercontinental container vessels) to land is in any case necessary conditions, which are more favourable for alternative mode.

Another privileged market is transalpine and trans-pyrenean markets since more freight has to be transferred to rail for the crossing of these mountains because of reduced capacity of road tunnels.

But within the intermodal market there is still a distinction to be made between direct services between terminals and "indirect" services according, again to the volume of traffic:

- direct service means operation of direct trains or block trains
- indirect service means recomposition of train along the route in rail intermodal hubs or terminals which are less and less often marshalling yards.

Again direct train will in general be less costly with a more reliable service with significant difference with indirect train.

Concerning the assignment on network of intermodal transport, there is a strong concentration of flows on few corridors and a major problem is the implementation of terminals so that a door to door services can be competitive.

So far implementation of terminals is available in European GIS for transport networks, but again the selection of points for composition of trains will affect the route choice.

4.1.2.3 Sea shipping operating techniques

In short sea shipping operations different segments must again be pointed out:

- the bulk segment

This is a classical short sea shipping market, which represent most of the SSS traffic in Europe between countries and within countries. Major products concerned are petroleum, fertilisers, building materials, basic chemical products, coal, wood.. are they often required specific logistics: major ports activities are related to these traffics which often do not go out the port area and are transformed in industries nearby.

- the feedering segment

Feedering is the European maritime distribution of intercontinental containers. Feedering lines develop in Europe with the increase of maritime container traffic ; in general the ships are dedicated to maritime containers and they serve the major ports in Europe or major hubs for maritime containers, which are transhipment places between large "mother" vessels and smaller "feeder" boats (Algesiras, Goia Tauro, Malta..).

The feedering segment is in general organised by large maritime operators when considering the mother ship operation and their market geographic distribution ; accessibility and regional development will not be in that case the major concern.

- the intermodal segment

This segment has been presented already in the former report as a segment more directly in competition with European road transport. RoRo technique, and possibly LoLo technique can be used ; freight vessels and Ropax (mix vessel for passenger and freight) can be appropriate according to the market.

For this technique possible maritime routes have to be investigated in detail pointing the road route in competition. So far this market is not much developed except in Baltic or North Sea region where maritime routes often benefit from a geographic advantages with road routes, which are much longer to serve the same O/D relations. This is not always the case for Atlantic and Mediterranean costs and researches are underway in order to develop assignment tools, which include both road assignment and maritime route assignment.

4.2 Travel times and cost: The graph theory

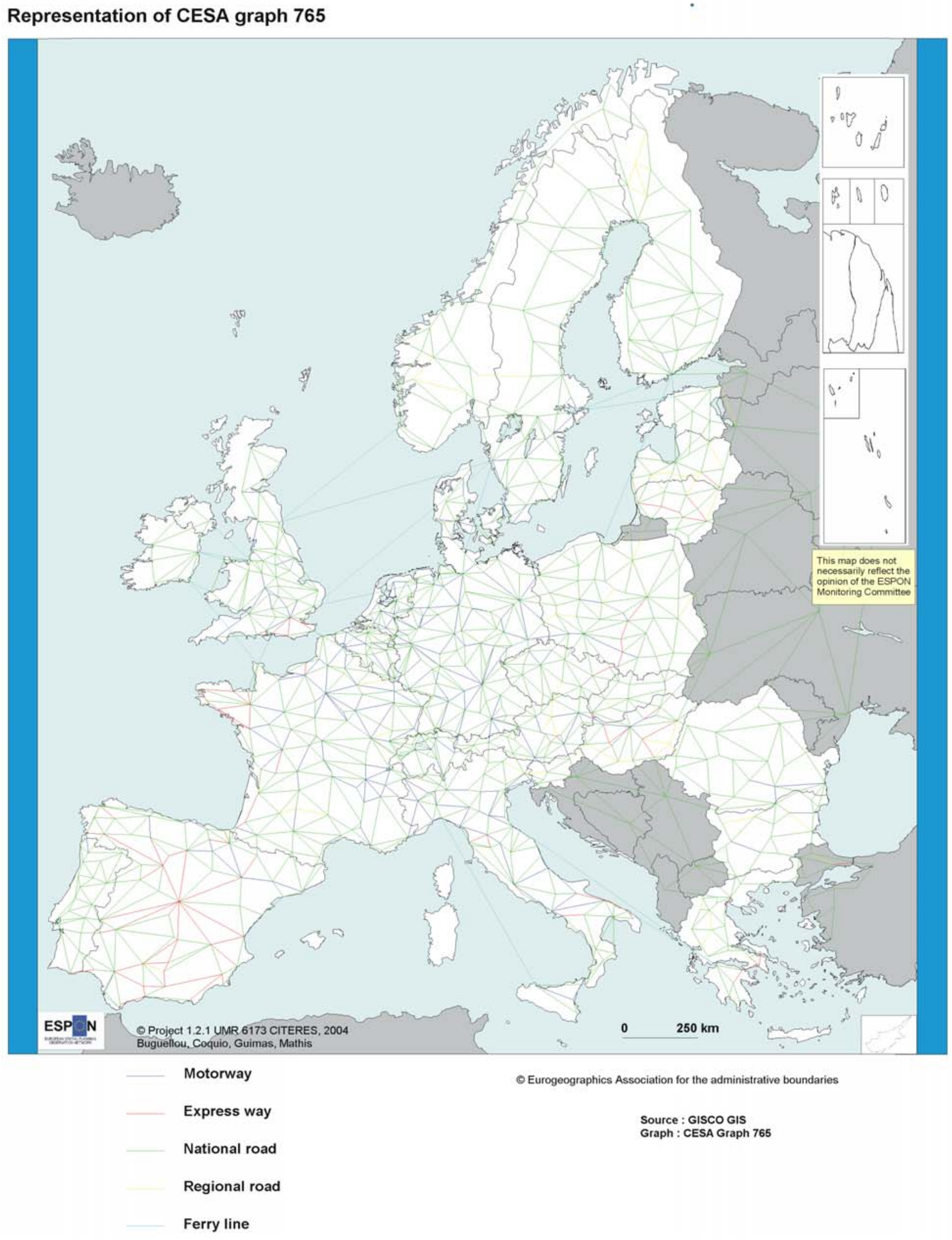
4.2.1 Rationale

In the domain of the transport, the numerous applications of **the graph theory** have shown its effectiveness to model a transport network and to develop indicators about accessibility, travel times, fractality, density[20]… Our work is based on the potentialities supplied by this theory.

That is why we have created **two different graphs**, each one representing a simplified picture of the European road and ferries' network.

The first one, that is the only one used in the different interim report, is composed **of 765 nodes and 2265 edges**, covering **the entire Europe of the 27 plus Switzerland and Norway allowing moreover the transit by Western Balkans, Russia, and Turkey**. In the rest of this report we will call it **C*ESA graph 765***. It is represented on the map 1 below:

[20] MATHIS (P.). – Graphes et réseaux : modélisation multiniveau. – HERMES Science: Paris, 2003



Map 1 Representation of CESA Graph 765

Since the beginning of our work this graph has been improved in a consequent way. It is now really more dense (**4172 nodes and 9350 edges**), allowing more precise and various calculations. To simplify the notation we will call it ***CESA graph 4172*** in all this report. By default, when we do not precise nothing in the choice of graph, it is the one that we will be used to calculate the different indicators described below.

Of course both of these graphs can be criticised for their imperfect representation of a really more complicated reality in terms of transport network. But, as in all model exercise we have had to make a **choice between precision and time and computing power** available (to represent but also to exploit this simplified representation). It is the pertinence of the choice determining this balance that consequently limits the possible interpretation of the results. Indeed, it is indispensable to always keep in mind that all the results produced in this report have to be taking into account with all the necessary precaution and modesty naturally linked to this kind of exercise. It is an orientated simplification under material constraints and not a perfect and total view of the situation.

Nevertheless, all our work has been concentrated in the goal of **minimizing the level of errors and imprecision**, inevitable by nature in this kind of exercise.

4.2.2 Method

4.2.2.1 Realisation

- Choice of nodes:

In the aforesaid optic, nodes have been chosen simultaneously taking into account three important kinds of criteria:

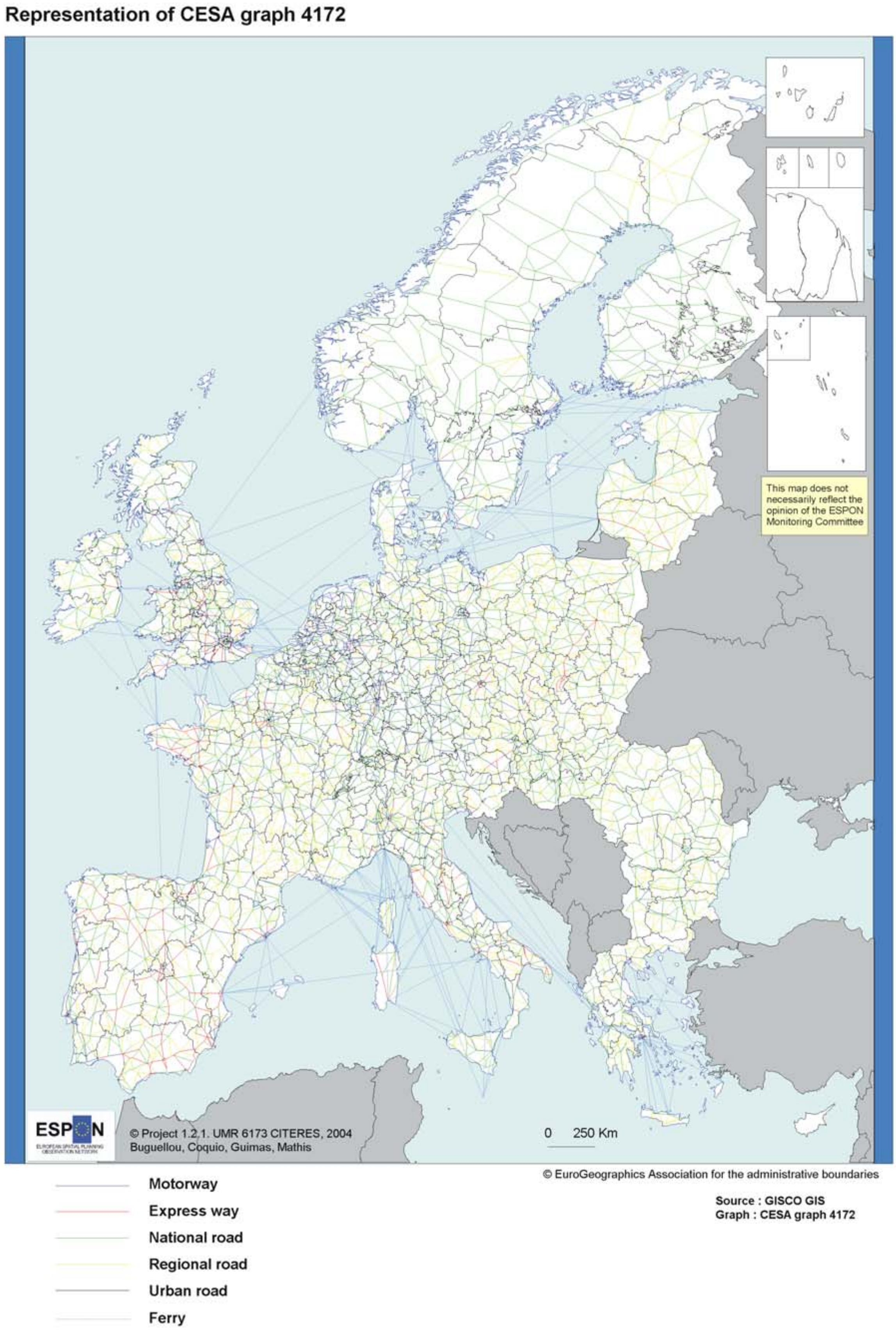
- the first one is relative to **the importance of the node in terms of potential emission and reception** of transport flows. Considering freight and passenger transportation, we have decided to represent the main European cities in terms of population (based on databases furnished by EUROSTAT), making the hypothesis that the level of flow is linked to this criterion. The choice of the minimal number of inhabitants used depends in a general manner on the level of this study and in a more local way of this relative level in each different country[21]. Of course the precision is not the same in the two produced graphs.

[21] All the cities included in the list of MEGAS furnished by the ESPON group 1.1.1 are represented by a node

- the second one depends on the nodes **importance in terms of** intercommunion into the transport's system. Each of these nodes constitutes an entrance in the transport network.

In an obvious way, this criterion is linked with the first one, because important cities are generally well connected to the transport network. But this second approach permits also to add nodes located for example in the ring road of cities, permitting to transit flow not to go through cities but to circumvent around them, like it is the case in the reality because of the saving of times it generally induces. With this method, we can approach **a quasi "door to door"** precision (at least with *the CESA graph 4172*).

Finally, to assure a minimum of homogeneity **in the whole Europe**, we have added few supplementary nodes to have at least one of them in each 280 NUTS2 for the *CESA graph 765.* For the CESA graph 4172, we have at least one node in each of the 1329 NUTS3, except in 145 of them, mainly located in Germany because of the very small size of these NUTS.



Map 2 Representation of CESA Graph 4172

Remark: According to Claude Berge, "the only thing important to know is how the nodes are linked"[22]. Even if that is totally right in the field of pure mathematics, that is not sufficient to use graph in the domain of transport modelling, not only to calculate existing relations between nodes, but also to represent the results obtained. In fact, you have to add to this necessary information a goal of "resemblance" between the graphical representation of graphs and the real territory, as on a classical map. In this goal, we have decided to complete our realisation by associating to each considered node its geographical position in a system of latitude/longitude projection.[23] In this way, we have a bijection between our representation of European transport networks and more classical maps, as Michelin's.

- Valuation of edges:

Concerning **edges**, we have decided, in the light of the wished precision, to distinguish 9 kind of infrastructure according to **maximal speed allowed** (depending on national regulation), **average speed** (observing in the reality) and **localisation** (between urban areas, into urban areas or into city centre).

Each edge is valuated with **a kilometric distance** and **a speed, function of the used vehicles** (in our case, truck, car or ferry). The table below shows the respective speed we have used:

[22] « Seul importe de savoir comment les sommets sont reliés » in [BERGE (C.). – Graphes. –Dunod : Paris, 1970]

[23] this system of projection appeared in the fact as one of the most adapted to consider the continental scale of this study.

Type of infrastructure	Type of vehicles	
	By individual cars	By trucks
Highway	110 km/h	75 km/h
Express lane	90 km/h	65 km/h
Urban artery	50 km/h	40 km/h
Urban express lane (ring road)	65 km/h	60 km/h
National road	70 km/h	55 km/h
Regional road	60 km/h	40 km/h
Local network	50 km/h	30 km/h
Urban network (streets)	25 km/h	15 km/h

Table 13 : Speed of vehicles according to the type of road infrastructure.

For *ferry lines*, we have considered an average speed of 37 km/h adapting the kilometric length to obtain a travel time coherent with whose given in timetables for ferries' lines.[24]

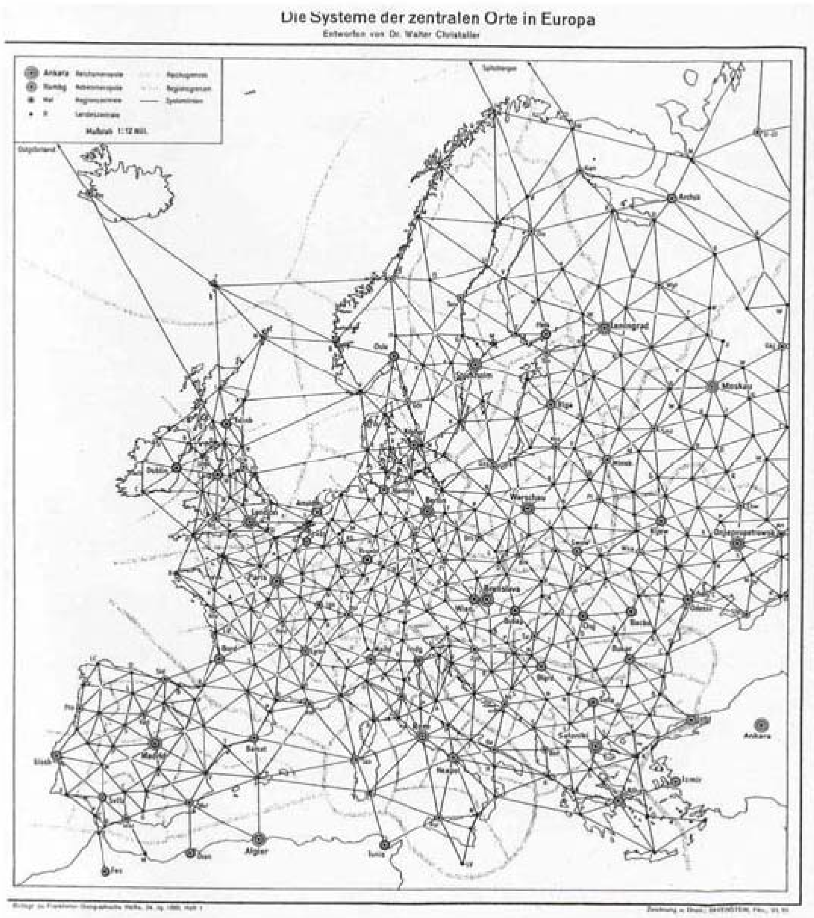
For a given edge, the combination of these two values permits to obtain the travel time necessary to go from the origin's node of this edge to the destination one. These values generalised to the whole graph give us the basis to calculate minimal path between each couple of nodes.

Remark: In term of representation each edge is represented by a segment of line. The sinuosity of real road infrastructure is not visually clarified but is taken into account its valuation in terms of kilometric distance. For the indicators requiring a more precise geographical representation of the network, we have used the GISCO's network produced by EUROSTAT.

- General remark:

Like the graph of transport network conceived by **Christaller**[25] in 1933 and his European map in 1954, our graph is a plan graph with essentially triangular grids but none planar nor saturated because few edges (mainly whose representing ferry lines) intersect themselves not on a node and, as a corollary, few faces are quadrangular.

[24] Source : Thomas Cook. - European timetable. – November 2003
[25] [CHRISTALLER (W.). – Die zentralen Orte in Sûddeutschland. – G. Fischer : Paris, 1933]



Map 3 Walter Christaller network, 1954

4.2.2.2 Distribution

- Population of nodes

To calculate the population affected to each node of the graph, we have taken **the population of cities in GISCO GIS** as an input. With a procedure written in Visual Basic language imput in the model RASTA developed at the CESA, we have determined for each city the node of our graph which was the nearest (there are generally superimposed because of our nodes' choice)[26]. Thus, the population of the cities of GISCO GIS has been affected to the nodes of our graph.

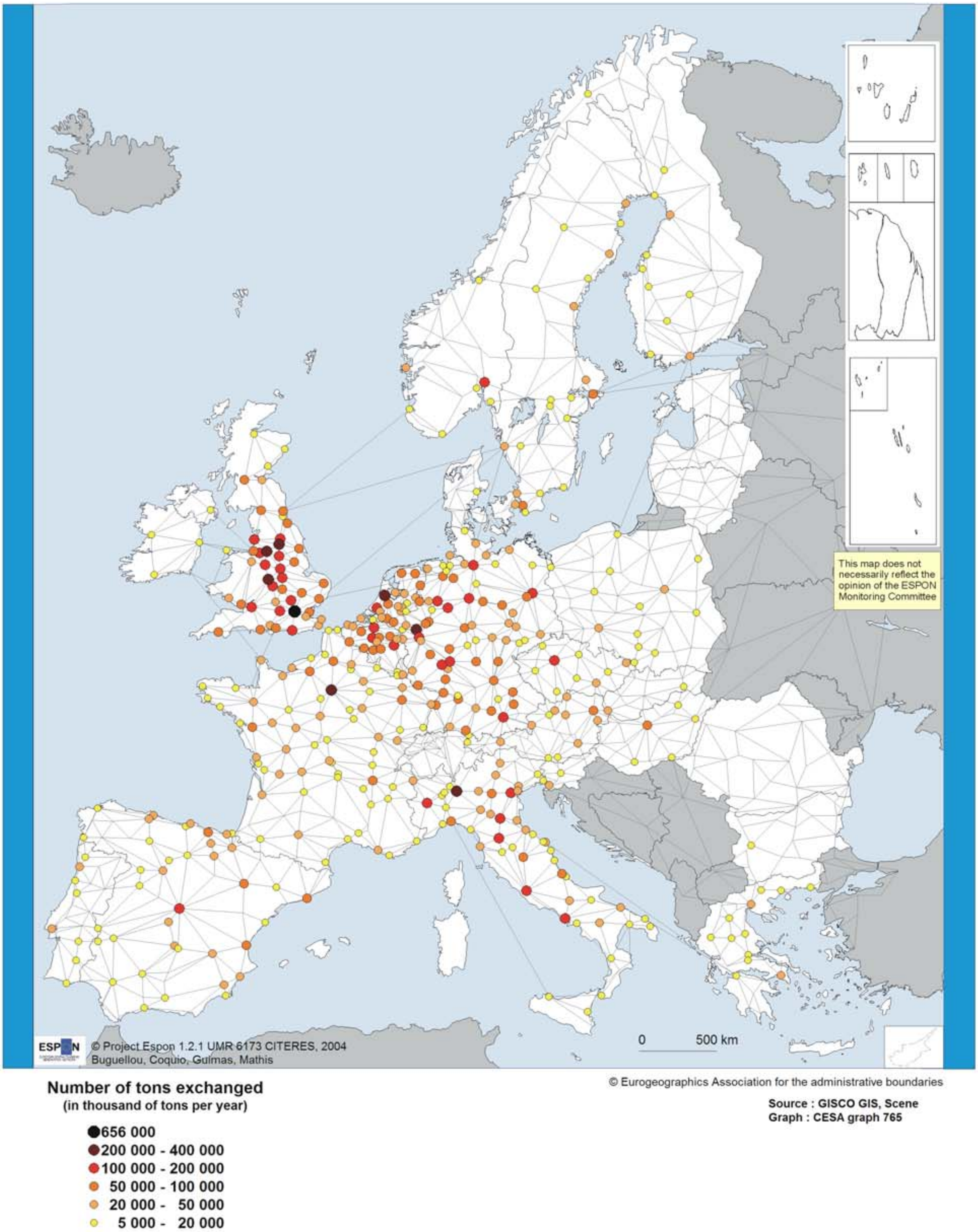
Subsequently, to respect the global population of each NUTS 2, we affected the rest of population of each NUTS to all the other nodes of the concerned NUTS.

[26] If, in a general manner, population taking into account is the population of urban areas, there are nevertheless some problems of coherence between the countries. Indeed the definition of urban areas seems not to be exactly the same all around Europe. But, because we have not got other sources that GISCO GIS, we are forced to use this data.

- Freight emission and reception:

We use the scene base which give an origin/destination matrix flow between each couple of NUTS2. Subsequently, for a given NUTS, we consider that the emission and the reception of each node of this NUTS is proportional to its relative population in the total population of the NUTS. The map below shows the result of this affectation on the *CESA graph 765*:

Number of tons exchanged by the main nodes of CESA graph765



Map 4 Number of tons exchanged by nodes

Remark: The information furnished by the reading of this map seems to be coherent with the reality. We can note the importance of metropolises and capitals of biggest European countries as Paris, London or Madrid. We have also to underline the low number of tons exchanged by nodes in the Eastern countries. This relative weakness is provoked by the low level of emission/reception in these countries, according to the used Scene Database for freight, single available source at this scale.

4.2.2.3 The Algorithms

- Calculation of minimal paths

Working on the more adapted graph according to the indicator applied, we used the model FARI written in language C++ and developed at the CESA, to calculate the minimal costs from each point to another one, **based on Floyd's algorithm**[27] and the logic of **minimal paths**: for each couple of nodes (*i, j*) this algorithm calculates the length of potential paths going through the node *k*, *k* representing successively each node of the graph.

This algorithm is polynomial and this complexity is O[N^3], that is to say if the number of nodes doubles, the computing time is multiplied by eight (2^3 = 2 x 2 x 2). Only the shorter one is stored into computer's memory. By a process based on iterations, we finally obtain two matrixes including all necessary data. The first one is the so-called *minimal path matrix* and gives minimal distance (travel time, kilometric distance or cost) necessary to go from a node of our graph to another one. For example in the CESA graph 4172, we have 17 401 412 different minimal paths between all our couples of nodes.

- Calculation of the route of minimal paths

The second table is the so called *matrix of precedents* that permits the description of minimal paths (i.e. the succession of nodes and edges) to go from a node to another one by simply giving for each couple of nodes the "previous", that is to say the last node before reaching the destination node[28]. This method supplies the opportunities to describe entirely the minimal paths with a simply square table, because the precedent of a couple

[27] As it is, in particular, described in [BARTNIK (G.), MINOUX (M.). – Graphe, algorithmes, logiciels. – Bordas : Paris, 1986]

[28] For more information, see [BAPTISTE (H.). – « Détermination des chemins optimaux dans un graphe temporisé ». – In Graphes et réseaux : modélisation multiniveau. – MATHIS (Ph.) (under the direction of). – HERMES Sciences : Paris, 2003]

is itself the destination of an other couple, and so on …. It is so a very elegant algorithm and compact procedure that uses minimal memory [29].

Different units can be used: classical metric distance, temporal distance, cost in monetary units, etc... Because metric distance is not pertinent for our specific work (necessary symmetric, heterogeneity of average speed,...) and because we have not got enough data to estimate with enough precision the monetary costs of a displacement, we have decided to use in the quasi-totality of this work **the travel times**. In the facts, this metric is the most adapted to developed transports 'indicators. Indeed, in the mind of carriers or individual travellers, is often the time unit that is considered as the discriminating criterion of paths' choices.

Even if we dispose of the technical possibility to taking into account time schedules[30] (for example for the ferries), the complexity of the data processing treatment, the lack of numerical data and the difficulties of general representation of the results (that depends on the hour of departure) have decided ourselves to not use this approach for this study.

We adopt the following notation for the rest of this report[31]:

N is the total number of nodes for a giving graph[32]

For a given node *i* such as $i \in [1, N]$

For a given node *j* such as $j \in [1, N]$

$T_{i,j}$ is the minimal travel time to go from the node *i* to the node *j*

Notes: By default, $T_{i,i}$ = 0 and, in our graph, the minimal path is single

In the case of **freight transportation** we have appended an additional time to take into account **the social laws and regulations** concerning the obligatory breaks[33]. The scheme below explains our approach.

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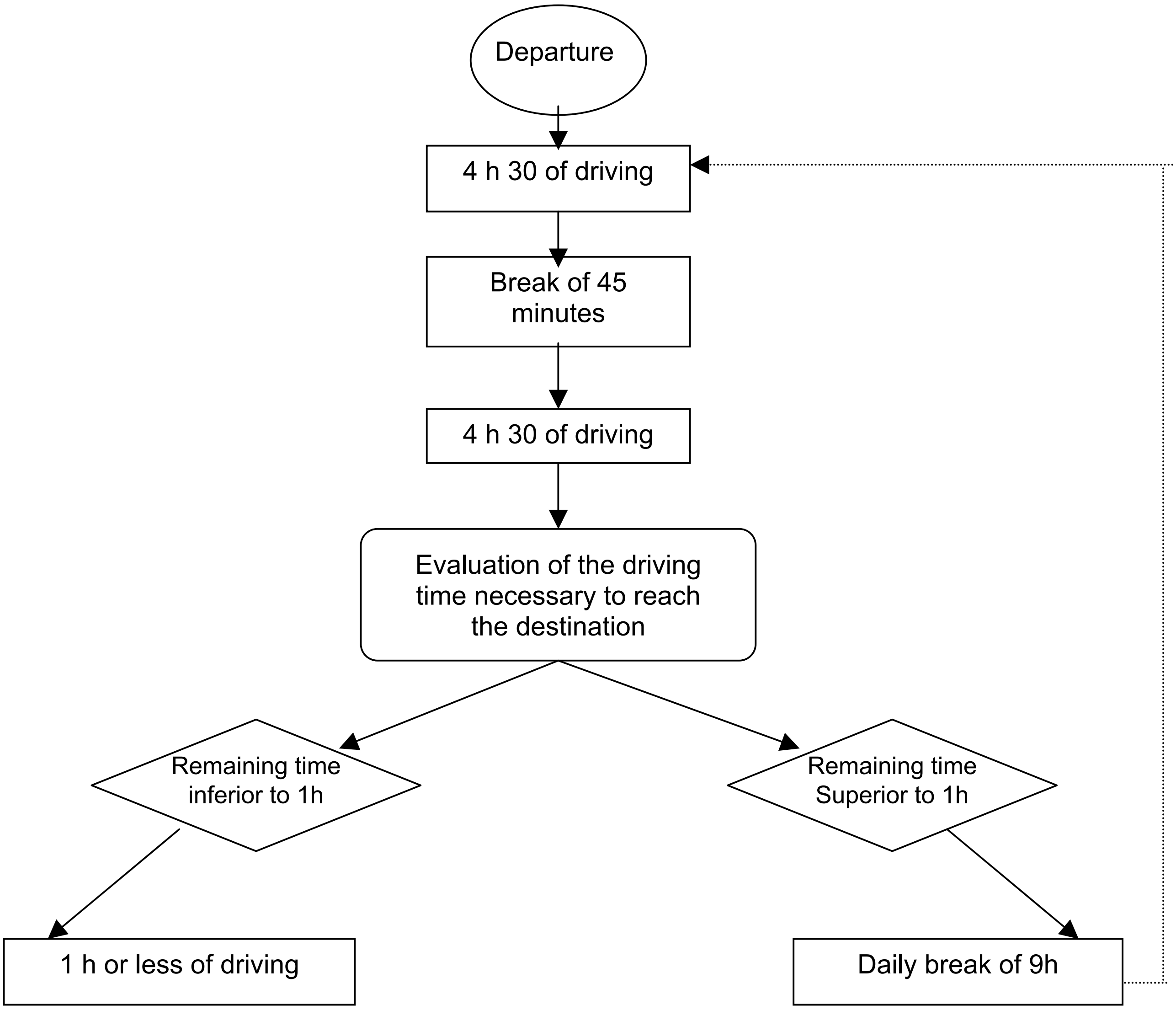
29 A minimal path between a couple of nodes can have several ten of edges and can be defined by the same number of node plus one. As we have just seen we have 17 401 412 minimal paths between the 4172 nodes. It is why the solution of *the matrix of precedents* is necessary to obtain our results considering the computing power available.

30 Ibid

31 For each indicators described below, we precise in the data requirement the type of transport considered : freight or passenger

32 For each indicators described below, we precise in the data requirement which of the two graphs presented above : *CESA graph 765* or *CESA graph 4172*

33 According to the European regulation 3820/85 of 12/20/1985



Moreover, we have also added also a **waiting time** (180 minutes when path included at least an edge representing **a ferry line)**.

Remark: we have decided to mainly base our calculation on freight transportation case because, taking into account the regulation about time of driving – that is respected by the majority of carriers – we obtain more realistic results than with individual travellers, for which frequencies and times of breaks are more heterogeneous. Nevertheless, for each indicator described below, we precise in the title and in the data requirement the type of transport considered: freight or passenger.

- Affectation on the network

We must consider by hypothesis that each travel (concerning passenger or freight) uses the minimal path in terms of travel times corresponding to the couple (origin, destination) nodes[34]. In this way, we suppose that **each driver has a perfect knowledge of the network** and that there are no problems of congestion[35]. We use the *matrix of precedents* for this exercise[36].

We adopt the following notation for the rest of this report[37]:

E is the total number of edges for a giving graph

For a given edge k such as $k \in [1, E]$

F_k is the total flow going through the edge k

All the F_k value are stocked in the *edges' values matrix.*

4.2.3 Data requirement

National road map (MICHELIN and/or IGN) of 2003

GISCO GIS (Precise localisation of the main road network, coordinates of cities, boundaries of NUTS 3, NUTS 2 and national frontiers)

GISCO Database (population of cities)

Internet web sites as www.iti.fr, www.viamichelin.fr and www.mappy.fr

Ferry lines timetables

4.3 ICON: Connectivity to transport terminals

This chapter presents the Connectivity Indicator (ICON). The indicator was an early attempt (the first application was carried out in the late eighties, (see Turró and Ulied, 1989; Turró 1990; Esquius 1991, Ulied 1995) to redefine some of the conventional assumptions of accessibility indicators. Basically, ICON proposes to define the concept of the "distance" between places in terms of their *relative connection of each one to the communication networks* instead of in terms of their geographical *remoteness.*

34 This hypothesis of total rationality is strong but necessary for our modelling work.

35 We have not be able to take into account the capacity of infrastructure because of the lack of European homogeneous data.

36 BARTNIK (G.), MINOUX (M.). – Graphe..., op. Cit.

37 For each indicators described below, we precise in the data requirement the type of transport considered : freight or passenger

ICON has been applied and tested in several studies, especially at European scale (EC/DG Regio –1993, 1994, 1995-, EC/DG TREN –1997-, European Investment Bank -1999) but also at national and regional levels (Ministerio de Fomento, 1993; Pla Territorial Metropolità de Barcelona, 1994; Ferrocarrils de la Generalitat 1997). ICON results were input for the firts discussions of the European Spatial Development Prospective (ESDP).

While the fundamental concepts of ICON have been validated by its successive applications, as well as for the technologic evolution of communication networks during the last decade, few aspects of the earlier mathematical formulation need to be reformulated, as is proposed in this paper.

ICON provides the value of the "connectivity" of any spatial location to the transport networks by measuring the access time (or cost) from the location to the closest connection node or terminal of the network, the utility that this closest node supplies to the average user, and the gap between the ideal utility sought and the actual utility obtained in the node (due to delays, congestion, service discontinuities, externalities...). The actual mathematics formulation of these measures was defined to be as simple, flexible and intuitive as possible in order to make it easily applicable even when data was scarce and understandable by decision-makers.

ICON does not aim at replacing more conventional accessibility indicators, but rather complement them in a wider and updated theoretical framework.

4.3.1 The connectivity approach

The conceptual basis of the connectivity methodology lies in the fact that the development of transportation systems as integrated networks at different scales is deeply changing their operation and the way they induce urban and regional development patterns.

According to many transportation analysts (e.g. Chisholm, 1992) one of the most common fallacies about transport costs is that they vary with location to the extent that geographical peripherality implies a substantial cost burden over more central locations. Empirical observations (e.g. Diamond and Spence, 1989, Plassard 1992) have verified the increasing insensitivity of most economic activities to transportation costs in developed areas. Places equally connected to transportation networks, independently of their geographical situation, show no significant differences in their transportation costs. These cost are, in general, less and less dependent on the total length of the trip.

As a result, the distance between two places (in time, cost or psychological perception), and the opportunity to establish relations between them, is increasingly dependent on *the kind of transport and communication networks to which they are connected rather than the physical distance between them* (Distler, 1986). And, as Milton Friedman pointed out, for developed economic activities it is now possible to produce a product anywhere, using resources from everywhere, by a company located anywhere if it is connected to the kind of networks of exchanges they need. Most authors even pointed out that the contemporary economic landscape could be represented by the superimposition of two increasingly independent geographies: *The geography of places and the geography of communication networks* (Beauchard, 1991), both with different logics.

These observations (already made in the late eighties) are to some extent contradictory with conventional transport and development theories. In the contemporary networked environment (the so-called *space of flows*; Castells, 1986), transport and communication will not influence location and mobility decisions only in terms of saving travel time to the most interesting destinations at a given moment (*which destinations?, at which moment?*), as conventional theories assume, but rather in terms of providing permanent maximum flexibility to reach any potential destination efficiently, under certain threshold values (for instance, the maximum travelling time allowed for daily commuting trips is estimated at around 35-40 minutes; the total budget devoted to transport is no more than 10-15% of the total revenue, the total daily travel time is, in average, about 1 hour).

In conclusion, there is a need to rethink the meaning of “distance”. The conventional definition of “distance between places” seems not sufficient nowadays. A connectivity approach, focused on measuring the “distance to the networks” is needed to measure how transportation networks influence location decisions and induce spatial development, in the context of current economic and technological changes.

4.3.2 Introducing the connectivity formulation

The connectivity of any place to a given network could be, in principle, simply defined as the *minimum time or cost (ta) required to reach the closest access node (or terminal) of the network* (e.g. the closest airport in relation to the airport system). Generically:

$$iCON = f(t_a)$$

This rather simple measure is already useful as indicator of transport infrastructure plans based on territorial goals such as fixing a maximum distance to a given network from selected points (e.g. administrative capitals) of the national territory. For instance, the so-called "Principle of Accessibility" proposed in the preparatory works for the trans-European road network (TERN) (SPREAD Report, 1994) stated that all conurbations above 100.000 inhabitants (350-400 towns) needed to be linked to the TERN and that all medium-sized towns, the definition of which varies from country to country (40.000 inhabitants, or less in countries such as Portugal, Ireland and Greece), should be, at most, thirty minutes from a TERN network access point.

A more realistic measure of the transport endowment is obtained however, if the actual services provided by terminals and their utility for the locations connected to them are considered. For instance, in the just mentioned SPREAD report it was also proposed that all high speed stations and ports handling more than 10 million tones of goods and all major ferry terminals, should also be connected to the TERN by high-quality access roads.

In general, the "utility" of a transport terminal depends on the number and characteristics of the services supplied and their relation with the specific mobility demands of each connected place. It can be intuitively understood as a "generalised waiting time" (tw).

Finally, it is likely that the expected utility do not reflect some identifiable problems in the node itself or in the network, due to systematic delays, network discontinuities, accidents, and more in general all kind of transport externalities (noise, pollution, etc.). This "utility reductions" should have to be included in a general ICON formulation, despite their obvious difficult and highly risky quantification. In fact, in all ICON applications carried out until now, this has been measured according to the specific characteristics and purposes of the exercise and no general formulation to calculate it has been developed yet.

In conclusion, for a given point, the generic expression of its connection to a given transport terminal or connection node is as follows:

$$iCON = f(t_a, t_w, t_g)$$

The partial measure of ICON for a given terminal has to be aggregated for all available terminals and all transport networks to give a synthetic measure of spatial connectivity to transport networks. Two options are possible in principle:

- One option would be first to aggregate first network by network (e.g. calculating the overall connectivity to airports, then to ports, railway stations etc.) and finally aggregate the partial values obtained for each network to get a final multimodal value.

- Another option could be to focus on the transport services instead of networks. Since passenger transport and freight transport services work almost independently, they can be treated independently. Then, instead of obtaining partial values of ICON for each network (as proposed in the first option), we would end up with two partial values of ICON one for intermodal passengers and the other for intermodal freight which would be somehow aggregated.

The actual choice between these options largely depends on the purpose of the study were ICON will be applied. For strategic and supply-oriented applications, where transport utility has to be measured in terms of infrastructure capacity, the first option seems more consistent with a long-term horizon and will give a more relevant measure of transport endowment. On the other hand, it requires less input data and can be implemented more easily (this option will be developed in the next section).

In fact, ICON, as accessibility indicator, is especially useful for strategic, supply-oriented and long-term studies focused on exploring the spatial implications of transport infrastructures. Next table proposes a comparison for the two traditional field of interest: traffic forecasting studies (evaluation of the network capacity to channel existing and forecast traffics) and accessibility studies (evaluation of the network's impact to induce spatial development).

	TRAFFIC FORECAST MODELS	**ACCESSIBILITY INDICATORS**
model results☐	Intensities of traffic in the links	spatial connection to the nodes
planning recommendation☐	Required capacity in the links	convenient location and utility of the nodes
policy goal☐	Maximizing network efficiency to satisfy traffic demand	Integrating transport networks in long-term territorial strategies

Needless to say, both approaches are interlinked. Within the classic 4-steps traffic forecasting models, accessibility changes play a critical role. In the Generation step, for instance, induced traffic demand results from accessibility improvements, and in the Distribution step Origin-Destination matrices result, among other elements, from assuming network impedances based on actual distances through the network. In integrated Land-Use and

Transport Models, accessibility use to be the key concept linking both submodels. The discussion of the implications of introducing the ICON connectivity approach in classic forecasting models goes beyond the aim of this paper, but is an extremely interesting research area.

4.3.3 ICON mathematics formulation

For each network (i=1...n) a value ($ICON_i$) is calculated. These partial values are then summed up in proportion to their relative contribution to transport endowment. Therefore, the aggregated value of ICON is:

$$iCON = \sum_{i=1}^{i=N} p_i \, iCON_i$$

The relative proportions (p_i) can be adjusted in relation to the economic value added of each transport sector or, in a first approach, estimated according to current modal split.

The main advantage of this formulation is the intuitive meaning of the ICON aggregated value, which is not an abstract index but a measure dimensionally equivalent to each partial ICON value ("weigthed access time to the networks", expressed in hours or minutes). On the other hand, the weighted addition is consistent with the strategic and long-term assessment aim of ICON, since it assumes independence between the contributions of each network to the regional endowment. Deficits in a given network (resulting in high values for the ICONi) reduce development opportunities.

By definition, it is assumed that the minimum value of ICONi in a point should be the access time to reach by road the closest transportation node in the network (tam_i). Accordingly, the maximum value of $ICON_i$ should be, by definition, the minimum access time (tax_i) necessary to reach by road the closest node with a service provision above a pre-determined quality level (Sx_i). (So_i) is the minimum service level acceptable for any node or terminal to be included in the network (i) (e.g. in an interregional application transport terminals that exclusively provide local services, or a marginal number of international services, should not be considered as connection alternatives).

Because of the previous definitions, all terminals and connection nodes (j=1...n) included in the network (i), having service (S_{ji}) and located at access time (taj_i) from the point where $ICON_i$ is calculated, must necessarily verify the following:

$$Sx_i \geq Sj_i \geq So_i \; j = 1 \ldots N$$

$$tax_i \geq ta_{j_i} \geq tam_i \, , j = 1 \ldots N$$

This means that alternative nodes are only considered when they provide better service conditions than a closer node. To be consistent with the ICON concept, the aggregated $ICON_i$ value for the network (i) must lie between tam_i (minimum time to the closest connection alternative with service above Soi) and tax_i (minimum time to the closest alternative providing the maximum service Sxi). Then, ICONi must be as follows:

$$ICONi = tam_i + \delta_i (tax_i - tam_i)$$

verifying:

$$1 \geq \delta_i \geq 0$$

δ_i, aggregates the contribution of all intermediate connections between tami and taxi. By definition, δ_i has to be formulated to tend to 1 the closer the alternative nodes are, and the higher the available service in each one is. δ_i could be understood as an aggregate measure of the "deficit of utility" not obtained, in relation to Sx, after considering all alternative connection nodes in between tami and taxi. It can take a conventional logistic formulation in order to reduce the importance of most extreme values:

$$\delta_i = \frac{1}{1 + a \cdot e^{-b \frac{U_i^{max} - U_i}{U_i - U_i^{min}}}}$$

where (a) and (b) are arbitrary parameters (always positive), and (U^{max}_i), (U^{min}_i) and (U_i) are the maximum and the minimum pre-defined levels for the network, and actual utility obtained by the point.

The "utility" of a connection node is based on the access time (taji) from the point where ICON is calculated, and the service provided (Sji). The utility captures the fact that this service is less and less useful with increasing distance. Utility is calculated using a diffusion function, in order to phase out the effect of the utility reduction with increasing distance.

$$U_{j,i} = S_{j,i} e^{-\beta_i (taj_i)}$$

where beta is a parameter to be fixed for each network (e.g. airports may have a lower beta than railway stations since air trips are much longer and the airport's density, is accordingly, also lower).

In order to adjust the values of (a) and (b), it is sufficient to realise than in a network (i), the minimum deficit of utility δ_i (δ_i = 0) should be obtained, by definition, when the closest connection node at (tami) provides the maximum service considered (Sx) and tami=0. Then,

$$U^{max}{}_i = Sx_i e^{-\beta(tam_i)} = Sx_i$$

And, on the other hand, the maximum deficit of utility δ_i (δ_i = 1) should obtained when the maximum service (Sxi) is only provided by the most distant node and there are no alternatives (so when tami=taxi). Then,

$$U^{min}{}_i = Sx_i e^{-\beta(tax_i)}$$

If all the services assigned to connection nodes are independent, it is easy to define the total utility obtained from a given point as the addition of the utilities provided by all its alternative connections located between tami and taxi.

$$U_i = \sum_{j=1} U_j = \sum_{j=1} S_{j,i} e^{-\beta(taj_i)}$$

However, the assignment of independent services to transport terminals is a relatively complex task and requires both very detailed information and the use of sophisticated algorithms. The indicator representing the level of service of a terminal can easily be affected by double counting (the same service can be considered in all terminals where there is a stop). In this case a good approximation is provided by the following expression:

$$U = U_1 + \sum_{j=2} \alpha_i \frac{U_j}{\sum_{l=1}^{j-1} P_l \cdot U_l} \bullet U_j$$

where U1 is the utility provided by the closest node (at tami) and Uj (j=2...) the utilities provided by the successive alternatives until the connection providing Sxi at taxi is reached.

Pl is the probability that some services in Ul had already been considered in closer connection nodes, and α_i should be fixed for the whole network, based on the likelyhood to find double countings in the network (e.g. in relation to the frequency of direct services between terminals, and services with intermediate stops).

4.3.4 Conclusion

In conclusion, ICONi can be calculated as the addition of the minimum access time by road to the closest connection node in the network plus an additional time which encapsulates a measure of the deficit of utility (in relation to a pre-defined quality level) not obtained from all available alternatives: This additional time can be called "generalised waiting time". To these two main components, another one should be added to take into account discontinuities in the network or special circumstances (e.g.

accidents, congestion, delays...) or more in general any externality which may reduce the contribution of transport endowment to development. This final additional time is called "gap" since it pretend to reflect the difference between the ideal transport contribution to economic development (measured by the first and second terms) and the real one. No specific formulation is proposed, however, and in most ICON applications this "gap" was evaluated based on expert rules and ad hoc criteria.

4.4 Specific and innovative approach

4.4.1 Cartogram

The aim of this indicator is to illustrate the deformation of transportation networks according to socio-economic data, so it is possible to carry out a different point of view putting forward the geographical disparities of the distribution of individuals, richness and transportation networks.

In order to carry out this deformation, we used a Geographical Information System (ArcView 3.x) and a script in Avenue language written by Andy Agena corresponding to a continuous cartogram. This one conserves the topology of the geographical areas. Indeed, the deformation of surfaces is realized according to the value of the selected attribute but it maintains the relative position of each geographical entity in order to facilitate the interpretation. This deformation is done through successive iterations. At the end of the tenth one, the surface of the objects corresponds to **97%** of the value of the attribute chosen. In our example, with a graph of **2265 edges** and the choice of the **NUTS 2 area** as a cartographic reference, each iteration is approximately made in 10 hours[38]. The time spent for each iteration is exponential function of the number of objects to deform.

The script only modifies surfaces. In order to deform the NUTS2 and the road network jointly, a grid of space has been carried out according to administrative limits and of road axes. The attribute (population or GDP) is then distributed in a homogeneous way on the whole NUTS2. That hypothesis can seem strong but it is the hypothesis of all maps that represents a NUTS value with a colour on the surface.

The transformation by the script is thus realized on each mesh according to the attribute value deforming in the same time the surface of the geographical objects and changing the distribution of road axes. We then

[38] So roughly 100 hours to obtain the final map, that explains why we have only done this work with the *CESA graph 765* and at NUTS 2.

developed a new method allowing us for the first time as far as we know to represent on a cartogram something other than the areas limits.

The software used is CARTOGRAM. It has the advantage of not modifying the general shape of the space too much, thus allowing then a relative recognition of the shape of the different Countries or NUTS1 areas.

The software uses Arcview 3.x. version. The calculation of the surfaces distortions is made with 10 iterations and from regions whose adopted attribute has the strongest local value.

4.4.2 Fractal dimension of networks

We develop a fractal analysis intended to underline the dual aspect of the density that is to say its discontinuities and its imbalances. The "fractal analysis " has been created by Benoit B. Mandelbrot[39] and developed by large authors in many fields[40] [41] [42] [43] [44]

The fractal is a discontinuous process based on the dual aspect of density, this last one always being based on the hypothesis of a continuous value in each zone. It is the reason of the potential great heterogeneity of the densities' values for different scales as, for example, NUTS1, NUTS2 or NUTS3 (Cf. part 3 chapter 1.3.1. "Network density of cities").

With the aim to show the possible imbalance between the local network configurations, the density is an inadequate mathematical operator because of its simultaneous linearity and continuity.

In reality, numerous spatial phenomena are non linear, polynomial or exponential, and/or discontinuous. The graphs "Average travel time by cars to reach the three nearest cities of more than 100 000 inhabitants" aggregated successively by country, NUTS2 and NUTS3 in the part 3 chapter 1.3.1 illustrate this non-linearity and the importance in the scale's choice.

The largest definition of fractal dimension is the ratio of full and empty space expressed in logarithms.

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[39] Benoit B. Mandelbrot. - The geometry of nature. - 1977, 1982, 1999 Library of Congress Cataloguing in Publication Data New York

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[41] S. Thibault. - Modélisation morpho fonctionnelle des réseaux d'assainissement urbains à l'aide du concept de dimension fractale urbains. - Doctorat d'Etat INSA Lyon 1987

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$$Ds = - Log N / Log R$$

With

Ds, the fractal dimension

N, the number of observed entities or elements

R, the increment or rate of increase

We can also note: $Log N + Ds. Log R = 0$

Ds, the fractal dimension of observed elements, here the edge of network, corresponds to Hausdorff's² dimension and it is always included in the interval [1 ; 2]. Ds = 1 corresponds to a line and Ds = 2 to a surface.

The essential property of fractal is self-similarity that is an internal self-similarity, that is to say there is a persistence of structures at each level or scale.

The aim is to know if the fractal dimension of each zone is the same or on the contrary different. If it they are different, we have an objective indicator of the distribution of network in the space.

4.4.2.1 The algorithm of square pattern

We use the Minkovski-Bouligand method[45]: we build a decreasing series of square pattern of η of side in the aim to entirely cover the studied surface.

The fractal dimension value is obtained with the computing of the total number of squares and the number $N\eta$ of squares containing an element of network, as follows:

$$Ds = \lim_{\eta \to 0} (Log [N\eta] / Log[1/\eta])$$

We work by successive iteration diminishing each time the size of squares[46].

[45] A. Le Méhauté. - Les géometries fractales. - Hermès, Paris 1990 p.50 and following

[46] from 5 km to 320 km in doubling the size of squares at each step

4.4.2.2 The algorithm of expansion or Minkovsky's algorithm

It consists in calculating the surface covered by a dilatation of networks given that the considered width is increased at each iteration.

It raises two problems:

- In the case of a mode whose access is limited to certain points of interfaces such as the train with stations, the plane with airports or even the highway with interchanges, this Minkovski evaluation can only be intermittent and not continuous, but the principle of calculation remains the same.
- In the case of the crossing of axes, there should not be double accounts.

4.4.3 The « radial analysis »

This is an improvement of the " radial analysis" that measures the length of the structure contained in a circle with a variable radius. To have a meaning, the circle centre must be a city. The subsequent computing of population included in the circle with NUTS4 or 5 (if possible) will be easy.

4.5 Vulnerability

We suppress the edges corresponding to the links we study.

In the case of a single link, we suppress just it, only authorizing local traffic (i.e. between the 2 two NUTS linked by the edge or into the NUTS including the edge) on small road existing (because of capacities problem). Then we recalculate the matrix of minimal path and affected the freight flow on this new network.

In the case of problems due to flood, we suppress all the links of which origin or destination nodes are located at less than 5 km of the river.

In the case of problems due to snow or ice, we suppress all the links of which origin or destination nodes are located at more than 750m of altitude.

We note *G* the original graph and *G'* the simplify graph after a suppression as described just above. E is the total number of edges for the graph *G*, E' this number for *G'.* In an obvious way E' < E.

We recalculate the matrix of minimal path and affect the freight flow on this new network.

We note:

$\forall k \in [1, E]$, F_k is the total flow going through the edge k in the graph *G*

$\forall k \in [1, E']$, F'_k is the total flow going through the edge k in the graph *G'*

We logically have E-E′ edges suppressed between G and G′. By simplification of writing, we consider that the suppressed edges are all the edges with $k \in]E',E]$

We add $\forall k \in]E',E]$ F'_k = 0 ; F'_k is yet define in $[1, E]$

Then we represent the transfer of flow, underline the decrease and the increase of number of tons going through each edges. We express the result in difference of number of tons between the reference (all links could be used) and the truncated network.

$\forall k \in [1, E]$ we call D_k this difference for the edge k[47]

$$\boxed{D_k = F'_k - F_k}$$

47 We recall that we do not take into account capacities of roads because of the unavailability of relative data.

PART 3: TRANSPORT INDICATORS AND MAPS

Part 3 forms the major part of the report. It contains the basic empirical results obtained in the project. The meta-approach is to describe different aspects of the transport system in form of indicators and maps with a focus on spatial issues, i.e. spatial distributions and variations of those aspects of the transport system. The presentation of each indicator follows the same structure: first the rationale is discussed, followed by methodological issues ; then data needs are listed, finally each indicator is applied to the ESPON Space and the spatial variation is discussed.

The indicators are **grouped into themes** following a logic. First, indicators and maps on **infrastructure endowment** are presented, i.e. it is analysed what is existing. Then, it is presented what is the infrastructure supplying in terms of travel times and what are the costs to reach certain points. Following that, the opportunities supplied by the transport system are presented in form of more **complex accessibility indicators**. First, daily accessibility is presented in different indicators, demonstrating what opportunities can be reached within a day-trip. Then, **potential accessibility indicators** are presented which allow a further differentiation of space in terms of market or economic potential of areas enabled by transport networks and services. After looking at potential, the real use of the infrastructure in terms of flows on the networks is modelled, i.e. it is analysed which parts of the European transport networks have to carry which traffic load. **Transport and mobility** has also a backside that is reflected in the following sections with indicators on **transport externalities**. Finally, certain risks related to our dependence on a functioning European transport system are reflected in a series of indicators and maps on **transport network vulnerability** and its consequences.

1 Transport Infrastructure Endowment

1.1 Motorway network evolution

Rationale

Roads are the oldest and most evenly distributed transport infrastructure. Every human settlement is connected by some road to the world. Roads serve a variety of transport modes, from walking and cycling to automobiles and lorries. However, with the advent of the automobile, a second layer of more specialised, faster roads was introduced. Motorway access today is a prerequisite for economic success of a region.

Method

The map shows all motorways and dual carriageways in the countries of the ESPON space, with the colour code indicating the evolution of the motorway network in the last decades.

Data requirements

The motorway network data presented on the map were extracted from the European network database compiled and maintained at the Institute of Spatial Planning of the University of Dortmund (IRPUD, 2003).

Application to ESPON Space

Motorways developed first in the most advanced industrialised countries of North-western Europe, and before and during World War II were extended partly for strategic military reasons. After World War II, motorways were built to facilitate and reinforce the rapid economic growth in the countries of the early European Union: France, Germany, Italy and the Benelux countries. With the first enlargement of the European Union, motorways were built to improve the integration of the Mediterranean 'cohesion' countries into the European Union. The same process is now in progress in the new EU member states through the TINA projects. Nevertheless, there remains a large gap in motorway provision between central and peripheral countries. And this gap continues to widen. In the 1990s, about 1,000 km of motorway per year were built in the member states of the European Union; the corresponding figure for all CEC countries together was 100 km.

Map 5 Evolution of the motorway network

1.2 Motorway density

Rationale and policy relevance

The indicators most frequently used to measure transport endowment are "density of infrastructure" (e.g. km of motorways or rail lines per surface or number of inhabitants). These indicators are able to somehow capture the capacity of the infrastructure. They are the simplest and more widely used in regional economics as indicator of the stock of social capital allocated to transport; therefore, most regional analysis based on Regional Productivity functions integrates these types of measures.

The services actually provided by transport carriers and their quality, and the utility they provide to fulfil the development opportunities of the region are not included in these types of endowment measures, nor the levels of congestion or externalities.

Method

The methodology to determine these indicators consist first on calculating the length of transport networks in each NUTS3. Once the length of each transport network is calculated the function to determine the density is as follows:

$$D_{ij} = \left(\sum_k L_{kji} \right) / P_i$$

where D_{ij} is the density of transport network *j* of territorial division *i*, L_{kji} is the length of links k in transport network *j* in territorial division *i*, and P_i is the population of territorial division *i*.

Data requirements

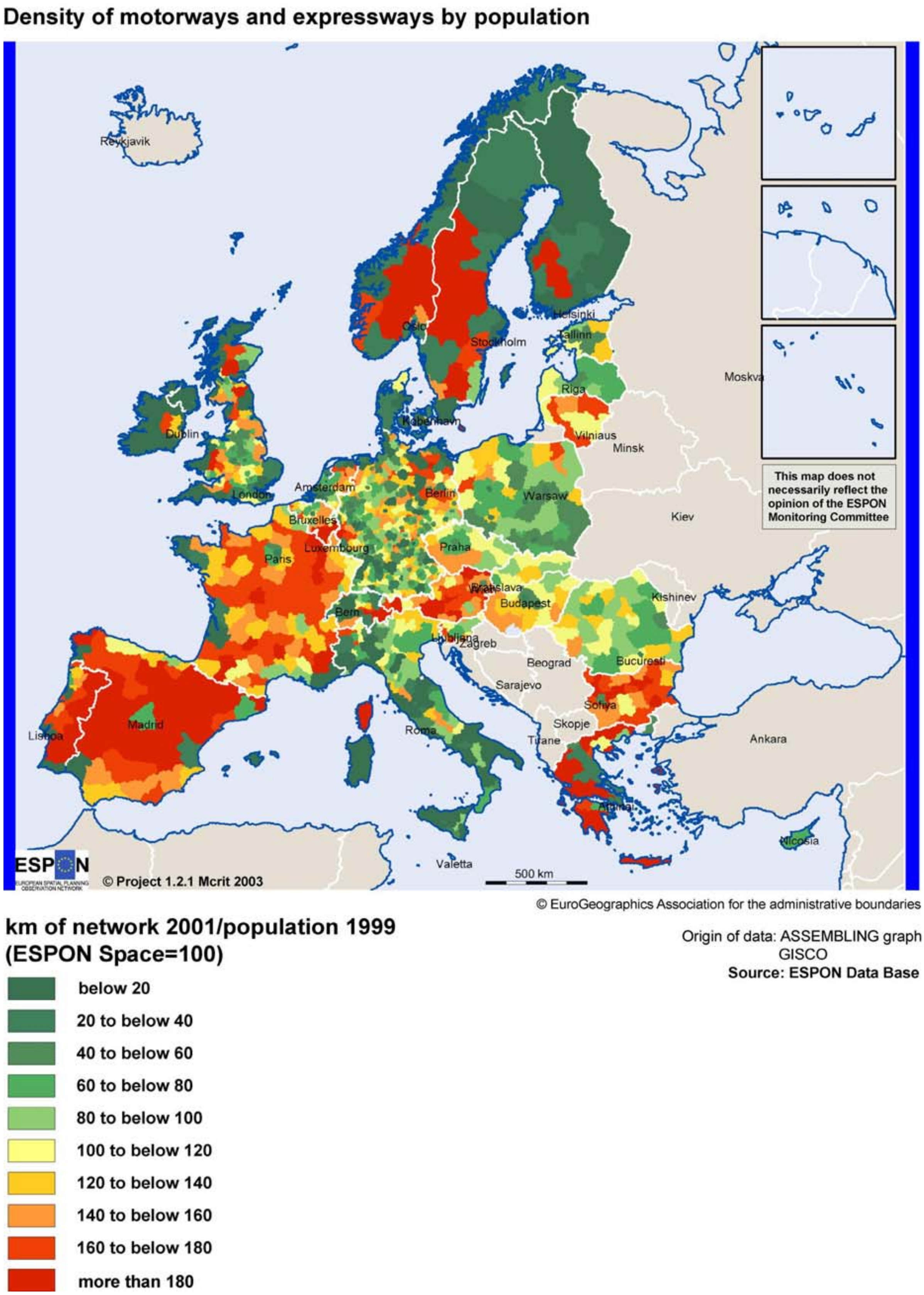
The basic data needed to calculate this type of indicator is a transport multimodal network at European level, with information concerning infrastructure characteristics.

The transport network used is from ASSEMBLING multimodal graphs, at 1:500.000 scale, reaching 1:50.000 for major cities. The graph covers EU and Eastern European countries including Russia, as well as North of Africa and Middle East. It contains Trans-European links (roads, rail, ports, airports, inland waterways), all existing high speed, upgraded, conventional and main rail lines, and existing motorways, expressways, main and regional road, local roads, streets, and roads connecting ports and airports to the rest of the network. The rail and road network database contains information on speed and TEN and TINA programmes. The regional data consists of the population (inhabitants 1999) of NUTS3, from Eurostat.

Application to ESPON Space

The density of motorways and expressways (with estimated speeds higher than 85 km/h) has been calculated for all NUTS 3 regions of the ESPON space. It has been mapped with relative values of this indicator with the average. Green coloured areas need to enlarge their motorway and expressway network and coincide mainly with NUTS3 with high-populated urban areas (most of NUTS3 containing country capitals and other main cities), and populated NUTS3 in Eastern countries in the ESPON space (Poland, Bulgaria, etc.). NUTS3 coloured in reds show sufficient motorway and expressway network infrastructure according to its inhabitants.

In most non-EU countries the international road network lies on a road system of a regional nature and design standard, which are not yet adequate to promote the qualities of urban areas. Note that the smaller size (and relative population) of German NUTSIII creates the false impression of a lower motorway density in some German areas.



Map 6 Density of motorways and expressways by population

1.3 Network density of cities

1.3.1 Average travel time by cars to reach the three nearest cities of more than 100 000 inhabitants

Rationale

This indicator gives an idea of the **city network and their relative distribution** all over Europe, while taking into account the travel time between these cities. It underlines the density of important cities according to the existing transport network.

Method

We calculate for each node the average travel time to reach the three nearest cities of more than 100 000 inhabitants.

We note $\{\mathbf{C}_{100000}\}$ the nodes' set of more than 100 000 inhabitants,

N the total number of nodes

$\forall\ i \in [1, N]$, $\mathbf{AT}_i$ the value of the indicators presented in this part for the i^{th} node

For a giving i such as $i \in [1, N]$

$A_i = \min(T_{i,j}$ with $j \in \{\mathbf{C}_{100000}\}$). We note $j1$ one of the number such as

$A_i = T_{i,j1}$

$B_i = \min(T_{i,j}$ with $j \in \{\{\mathbf{C}_{100000}\} - \{j1\}\}$). We note $j2$ one of the number such as $B_i = T_{i,j2}$

$C_i = \min(T_{i,j}$ with $j \in \{\{\mathbf{C}_{100000}\} - \{j1, j2\}\}$)

$$\mathbf{AT}_i = \frac{A_i + B_i + C_i}{3}$$

Note:

The choice of 100 000 inhabitants is based on the population criterion used by the INSEE[48] to define "medium city". Of course it is an arbitrary choice that can be criticized but, for our point of view, it is a significant level of population, inducing generally the existence of superior services in the concerned cities.

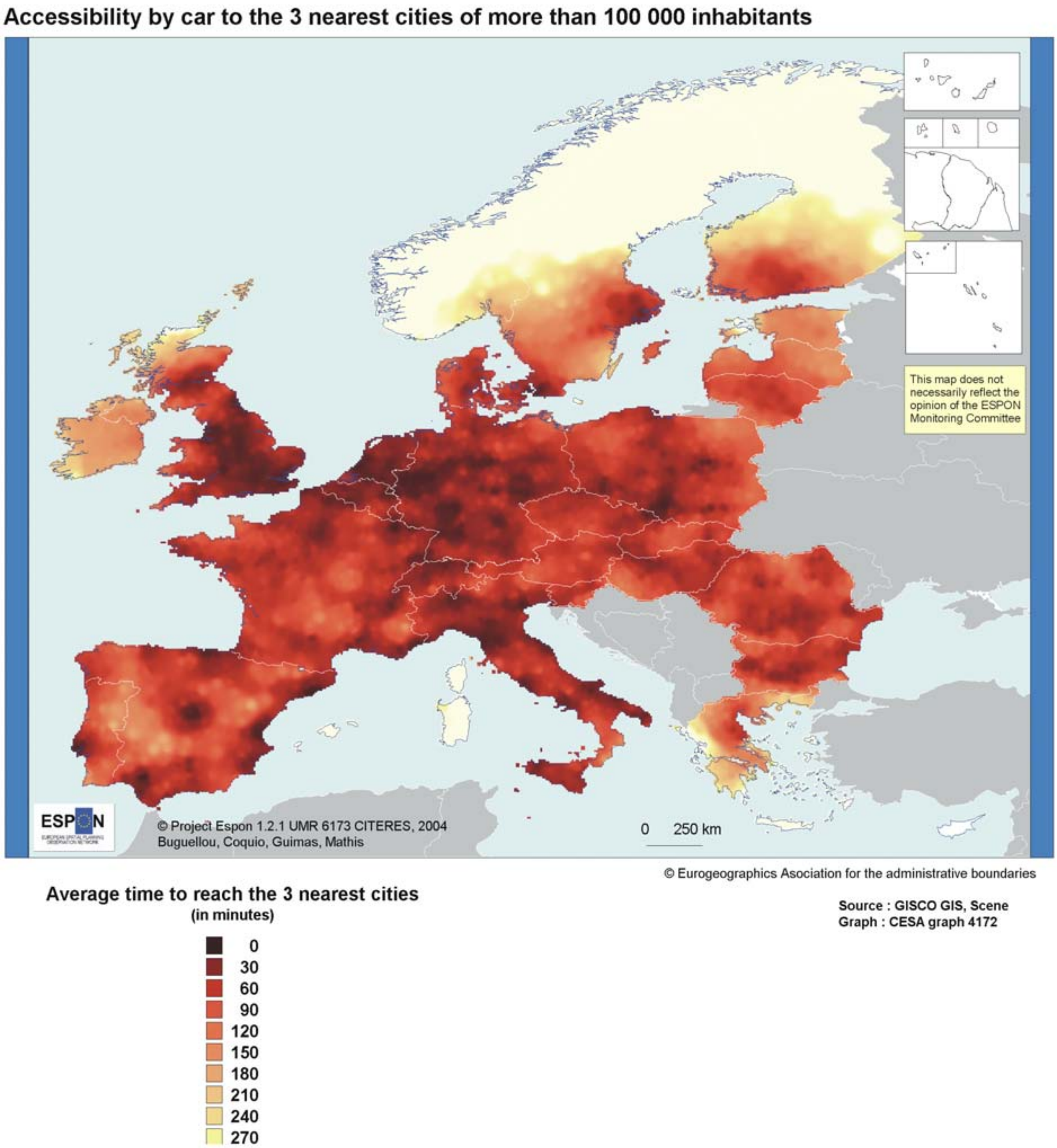
[48] The (French National) Institute of Statistics and Economic Studies

If the population of the node i *is superior to 100 000 inhabitants, we have* j*1 = i so* $T_{i,j1}$ = $T_{i,i}$ *= 0*

Data requirement

CESA graph 4172

Minimal path matrix for cars



Map 7 Accessibility by car to the 3 nearest cities of more than 100000 inhabitants

Application to ESPON Space

Let us begin reminding that, in an obvious way, this indicator depends on the studied network and of the selected minimal number of inhabitants.

Its main interest is to estimate in a quantitative way the degree of isolation of territories, taking simultaneously into account various **physical elements**, as geographical constraints (mountains, rivers,…) or **anthropogenic** as quality of transport network (because we deal with the travel time) and density of population. This indicator shows clearly the **imbalance between territories**.Various observations can be made, underlining different phenomena, more or less regular in the whole Europe.

The phenomenon of centre-periphery **clearly appears: the average travel times in Ireland, Greece, the Baltic States, Finland and Scandinavia are very high, materializing the important degree of isolation of the major part of these countries.**

The littoral effect is really more contrasted. If in some areas the littoral lands are far away from a city of more than 100 000 inhabitants, in others the localisation of many important cities is near or on the coast, as for example around the North Sea, the Western Mediterranean Sea, the South-East of Italy, etc…, and drive to a very low average time[49].

The third phenomenon concerns the important **isolation of certain internal areas**, mainly due to a particular geographical situation as for mountains in Spain, France, Italy and Austria or plain in Poland, Latvia and Estonia.

This indicator can also be aggregated at various scales to obtain an interesting way to **compare European areas**. The graphs below materialize the result of these work at the successive scale of country, NUTS2, and NUTS3.

On a national scale this indicator shows **three groups** of countries:

- **Nineteen** countries have a slow growth of this average travel time, always inferior to **2 hours**
- **Four** countries present an average value of roughly **3 hours**
- **Two** countries have a medium value superior to **5 hours**.

[49] That is coherent with the fact that, on a worldwide scale the human density on littoral areas is about 200 inhabitans/km² in the South and 130 in the North, 60% of global population living at less than 60 km of coasts.

We can note that all the **Scandinavian countries** and Finland are part of the two last groups, as a consequence of their low human density, to the low number of important settlements.

The fact that Greece belongs to the last group is probably due to its large number of islands. The necessity to take a ferry to reach major cities, and its slow speed, are the main cause of this apparent isolation.

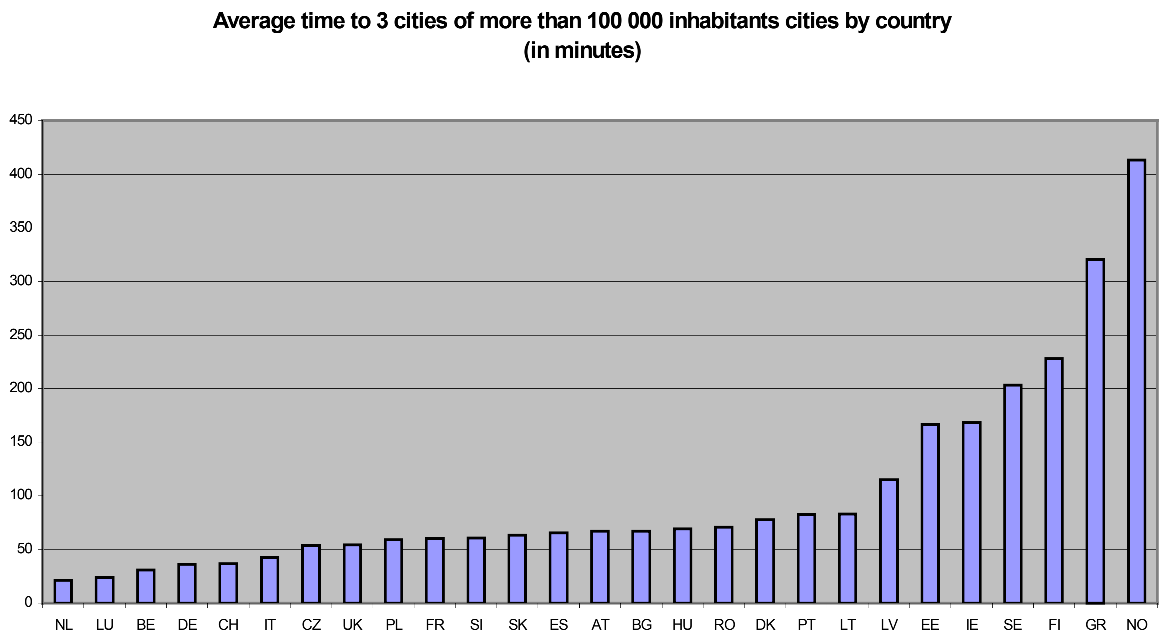


Figure 2 Average time to 3 cities of more than 100000 inhabitants cities by country

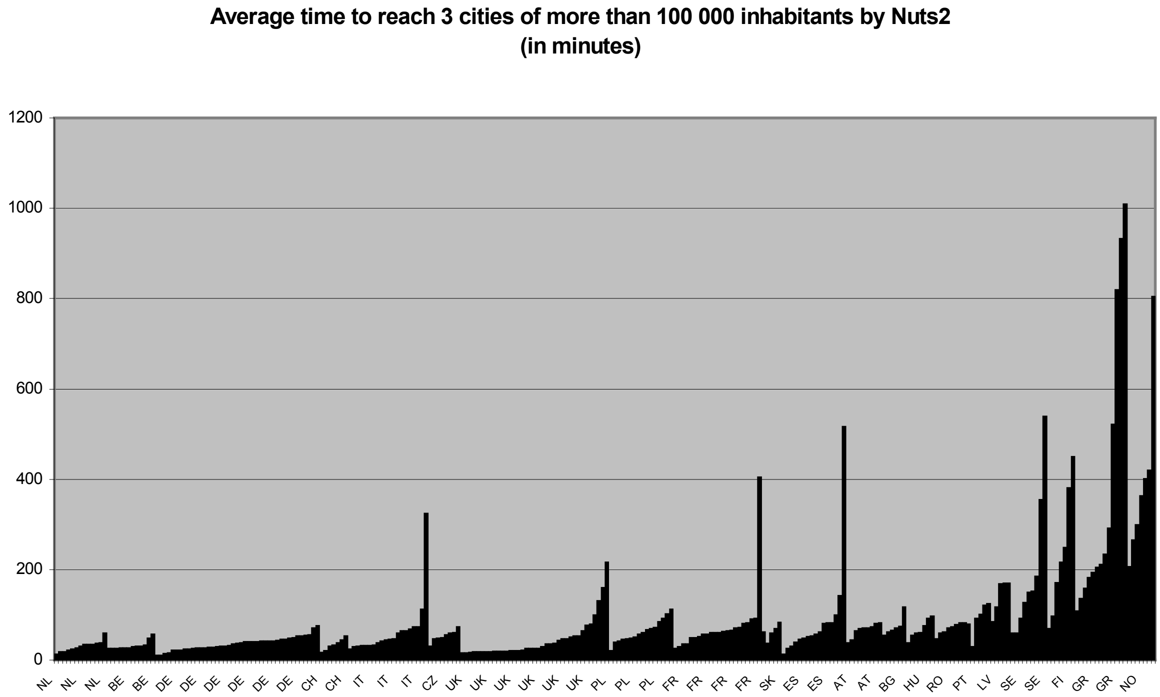


Figure 3 Average time to reach 3 cities of more than 100000 inhabitants by NUTS-2

The aggregation by NUTS2 shows internal differences, underlining the relative homogeneity/heterogeneity **inside the countries themselves**. The different peaks show the existence of **very isolated NUTS** in some dense countries. They generally concern specific areas **as islands**. (For example, the French peak represents the Corse). The great heterogeneity of Greece is coherent with its specific morphology as mentioned above.

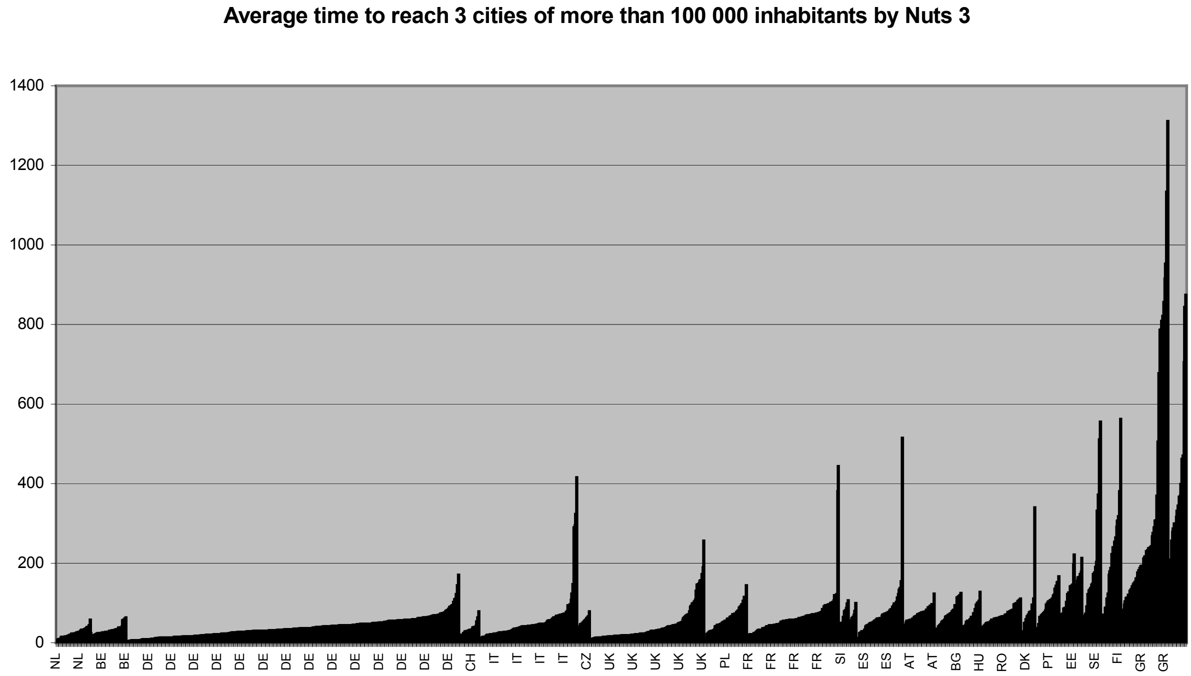


Figure 4 Average time to reach 3 cities of more than 100000 inhabitants by NUTS-3

At the greater scale of NUTS3, the amplitude of imbalance increases and the maximal values are clearly more important. The countries that still presented heterogeneous distribution at the scale of NUTS2, see their **internal imbalance accentuated** in an obvious way. This is the case for example of Norway, Sweden, Finland and Greece.

But, in spite of this scale's modification, some countries continue to be homogeneous. It is the case of Germany and of countries of the Benelux countries, probably because of the regular network of important cities and the good accessibility of each NUTS of these countries.

Logically, the greater the scale is the higher the values are underlining the importance of internal differences. It is possible to do many others computations or classifications modifying the size of aggregation, the minimal population of cities to reach or their number, depending on the phenomena to study.

1.3.2 Travel time by cars to reach the nearest city of a given minimal population.

Rationale

This indicator underlines the localisation in the road network of important European cities.

Method

Using the matrix of minimal path between each couple of nodes, we calculate the minimal travel time to reach the nearest city of a minimal given population.

We note {**C**x} the set of the nodes of more than x inhabitants,

N the total number of nodes

$\forall\ i \in [1, N]$, **TC***i* the value of the indicators presented in this part for the i[th] node

For a giving node *i* with $i \in [1, N]$, and a given population P

$$\mathbf{TC}_i = \min(T_{i,j} \text{ with } j \in \{\mathbf{Cp}\})$$

Data requirement

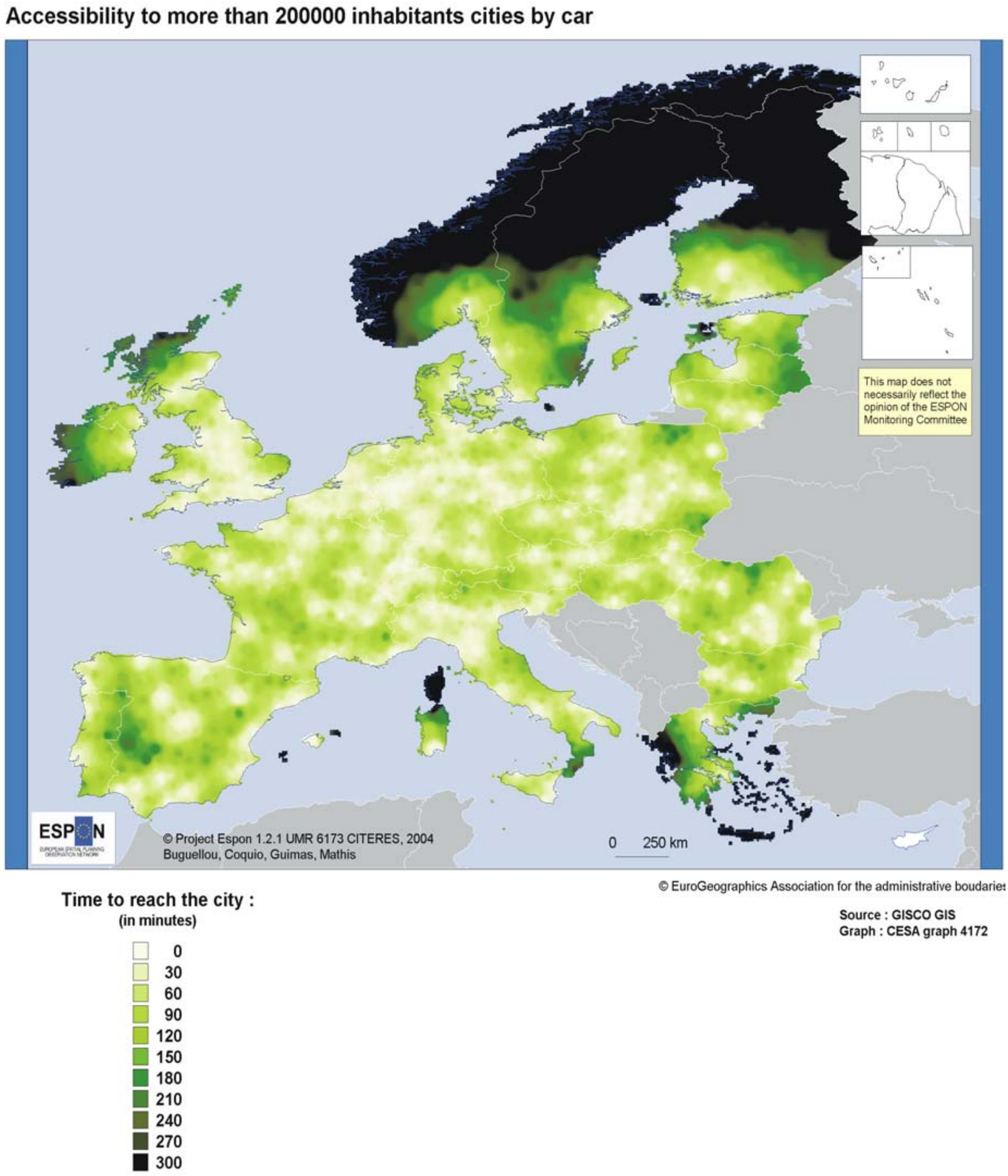
CESA graph 4172

Minimal path matrix for trucks

Application to ESPON Space

The map proposed here concern the result for cities of more than 200 000 inhabitants. Maps for 20 000, 50 000, 100 000 and 500 000 inhabitants are available in the annexes, each of them showing different phenomena.

As with the previous indicators, we can observe a great difference **between the core and the periphery of Europe**. A major part of Scandinavian countries and Finland, of Ireland but also of Greece are in the upper classes, that is to say there is an average travel time to reach the nearest city of more than 200 000 inhabitants superior of 6 hours.



Map 8 Accessibility to more than 200000 inhabitants cities by car

But this phenomenon of centre/periphery is also at an other scale. Indeed **inside some countries themselves** we observe the differentiation between these two areas. This is the case for example for France with a high value of the indicators for the regions of Limousin and near the Massif Central or on the boundaries between Spain and Portugal.

It is not the case in the “blue banana” where the indicators have a low and homogeneous value inferior to 1h30. We can formulate a similar observation around and inside the **mountainous areas** such as the Pyrenees, a part of the French Alps and the Austrian Alps.

The situation of **coastal areas** is different with, in a general manner, a greater accessibility than inside countries. It is the case in an obvious way for Spain, because of the presence of many big cities (that is to say, in our case, of more than 200 000 inhabitants) near the sea. It is coherent with the conclusions obtained with the previous indicators.

To say around the thematic of water, it is interesting to note we can nearly see **the bed of the main European rivers** as the Po, the Danube or the Rhine because of the pale colours around them, materializing the proximity in terms of travel time a metropolis.

1.3.3 Hierarchy of network

Rationale

This indicator has for goal to show the hierarchy of the transport network according to the potential relation between major European cities (in terms of population). It depends simultaneously on the global configuration of the network, of the relative localisation of these cities but also of their population. It is not directly function of the effective exchange (in goods or in travellers) but only on potential relation.

Method

From the *matrix of precedents* we determine all the edges included in each minimal path, that is to say for each couples of nodes of the graph. Then we class these edges in five categories, according to the number of inhabitants of the cities of departure/arrival of each path. When this edge is integrated in at least a path that link two cities of more than 1 000 000 inhabitants, it belongs to the first category. The second corresponds of 500 000 inhabitants, the third to 300 000 and the fifth to 100 000. The other edges are not represented on the final map.

Data requirement

CESA graph 4172

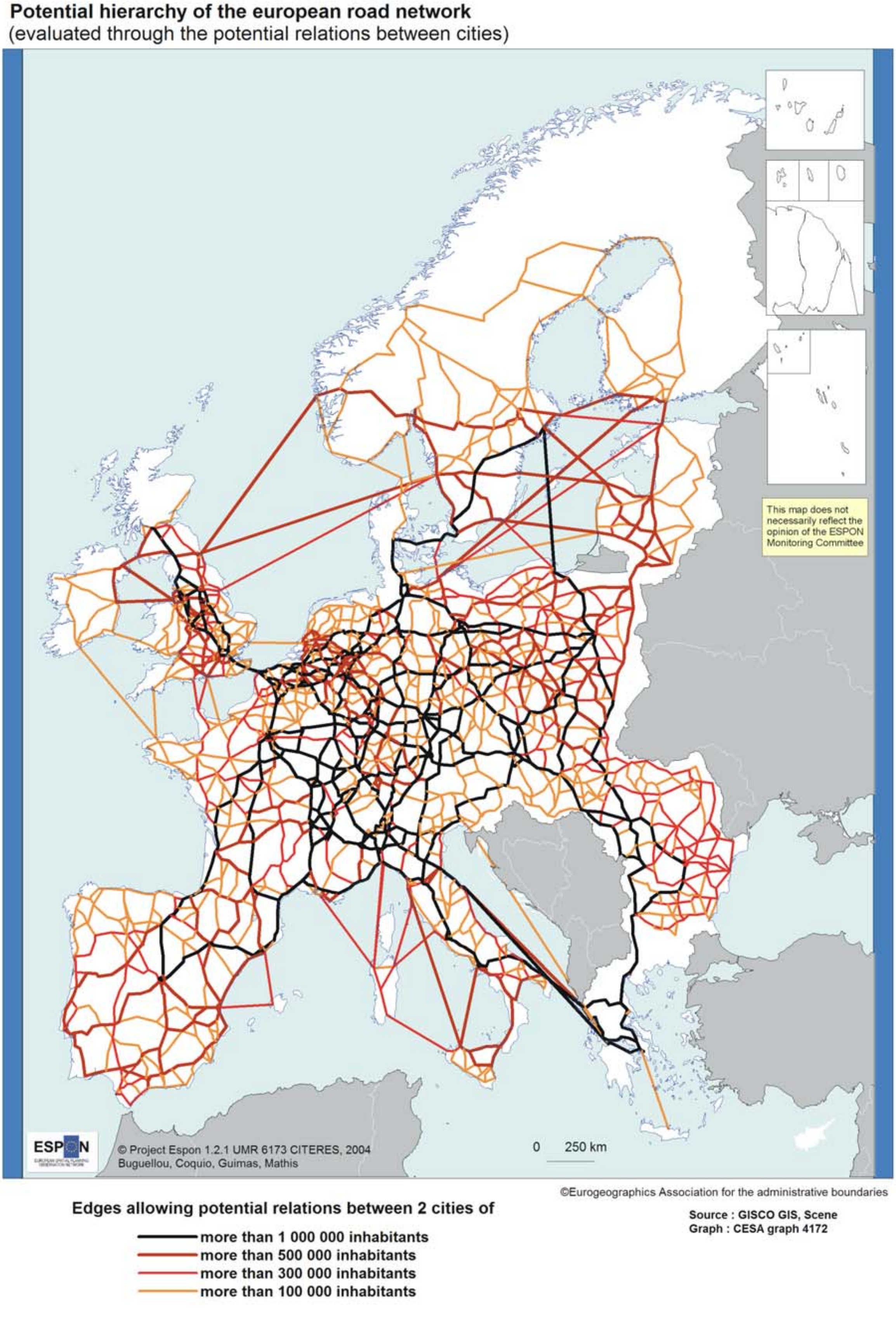
Matrix of precedents *for cars*[50]

[50] We work on individual cars because, in this case, we do not reason in terms of travel time but only on edges constituent of the minimal paths.

Application to ESPON Space

The observation of this map is coherent with the known urban distribution with a strong density of metropolises in the core of Europe.

The network is clearly hierarchical with four distinct levels (cf. graph above). This stratification is not recent. Indeed this actual structure finds its roots in the 15th century, with the will to link capitals of kingdoms to the others cities in province, and after to the maritime infrastructures. It is the same phenomenon, for example, with the present High Speed Train network in France, entirely centred around Paris.



Map 9 **Hierarchy of the European road network**

There is a obvious relation, at least for the two first level (1 000 000 and 500 000 inhabitants) between these results and the maps of the Trans-European corridors[51] (the TENS). The edge of higher values seems to correspond to the path used exchange between the main production's areas in the whole Europe, at least in a potential way for the Eastern countries. But it raises the problem of spatial equity in terms of accessibility. The superior network (two first classes) does not cover peripheral areas, where population is sometimes dense without be concentrated in big cities. It is the case for example of French Brittany, Ireland, Cornouailles, Wales, that inevitably ask the question of the specific situation of the Atlantic arc[52].

A new structure of transport network takes shape, not only concentrated in the West of Europe. Bratislava becomes a major crossroads for the exchange with Hungary, Bulgaria, and Romania and more generally all the European South-West least while the passage via the Balkans is really open and safe. The apparition of a triangle linking Warsaw, Berlin and Vienna is explained by the potential strong relations between these cities and, in corollary, the risk of the saturation of roads.

At a regional level, **ferries' line**s play an important role in territorial service. It is the case for the relation concerning cities around the Baltic and between Mediterranean islands (as the Sicily and the Sardinia) and the continent.

We can also see the apparent importance of **specific links**, as tunnel (in the Alps for example), bridges (as between Denmark and Sweden) and the Channel between France and Great Britain. This phenomenon may be interpret in terms of **vulnerability** of the global network in relation to the connectivity's role of these edge[53], that is to say, in the sense of the graph theory, that an eventual locking of these links will provoke a lost of modal connectivity of the network. Finally the roads infrastructures are dense and the problem concerns more the amelioration of certain part of it, notably in terms of capacity, rather than the creation ex-nihilo of new infrastructures, that is coherent with the low number of TEN-T project of European interest.

The graph below permits to complete this analysis. It is based on the same data, aggregated by countries according to the number of nodes

[51] Cf. Trans-European Transport network outline plan (2010 horizon). www.Europa.eu.int/comm/ten/transport/revision/maps_en.htm

[52] This specific situation will be more analysed in the part 4 chapter 3.2 of this report "Policy recommendations for macro-regions"

[53] This information will be reused in the part 3 chapter 7 of this report, dedicated to the Network vulnerability

extremities of edge of each category. The chosen colours are the same that on the map.

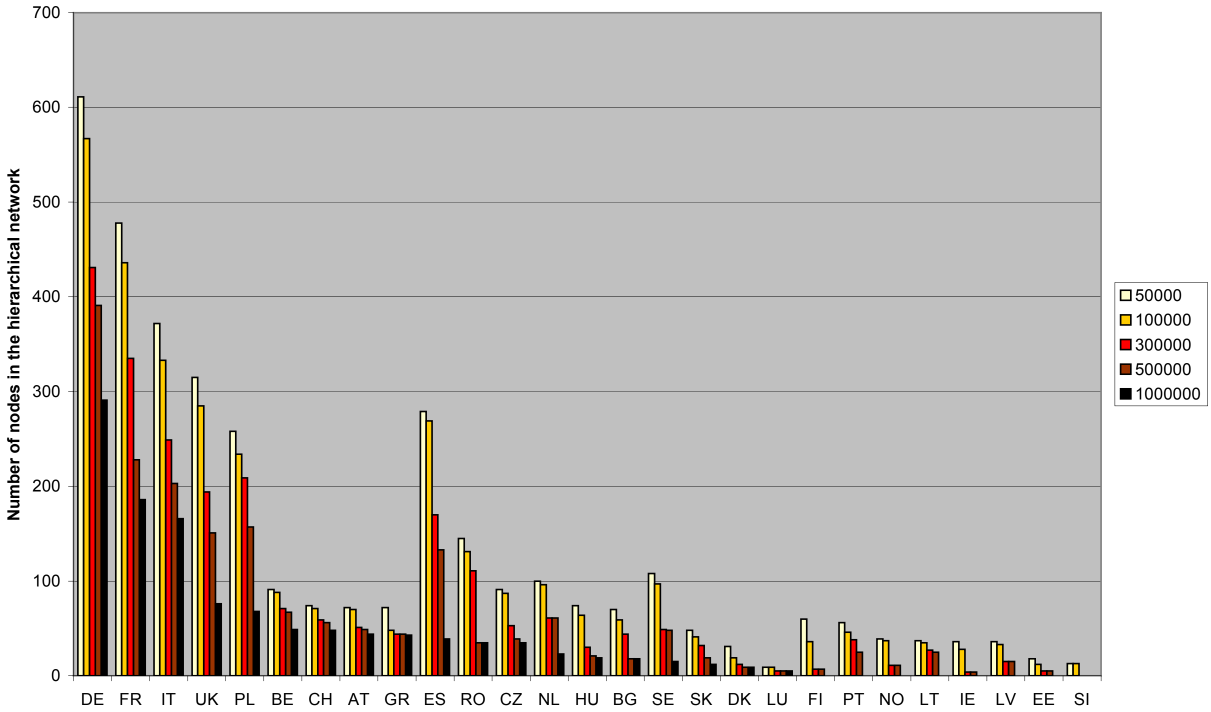


Figure 5 Number of nodes in the hierarchical network

We can distinguish four groups on it:

- the first is composed of Germany, France, Italy, the United Kingdom and the Poland. In these five countries there is a regular decrease between the different levels of network, according to our typology. They are characterized by high level in each category, with a big of nodes belonging to the higher level of the network. The **presence of many cities of more than 1 000 000 inhabitants** and the important role in term of **transit between this kind of cities** explain this observation
- The second containing Belgium, Switzerland, Austria and Greece show countries with a relatively homogeneous distribution of the nodes between the different classes. This situation is induced for a part by the presence of major metropolises in these countries (Athens in Greece or Brussels in Belgium) and for an other part by their role in terms of potential transit.
- The third is composed of eleven countries, from Spain to Luxembourg. The situation of Spain is a bit particular because of the

strong number of nodes relative to low level of infrastructure but a weak number in the first level. **The Spain is not a country of transit between major cities, at least in potential terms and for road mode**. The size of the other countries (Luxembourg or the Netherlands for example) and their specific location (as Sweden or Denmark) in peripheral areas permits to explain this situation.

- The fourth level, containing six countries, from Finland to Slovenia, regroups countries that do not have any nodes of the first category. There are **small and/or remote countries** (relatively to the core of Europe).

But all these data only concern **potential relation by trucks or car** and may be considered in consequences.

1.4 Railway network

Rationale

Europe has the densest railway network in the world. Starting from England in the second half of the 18th century, railways quickly spread across the continent together with industrial development. Railways made the extension of cities beyond their medieval fortifications possible, and railways displaced inland waterways as the dominant mode of freight transport and so freed industry from water locations. Today the importance of railways as a location factor for industry has been reduced. However, since the 1970s, starting from France, a new network of high-speed railways is spreading across the continent, and to be connected to the new network is becoming an important location factor for high-level services.

Method

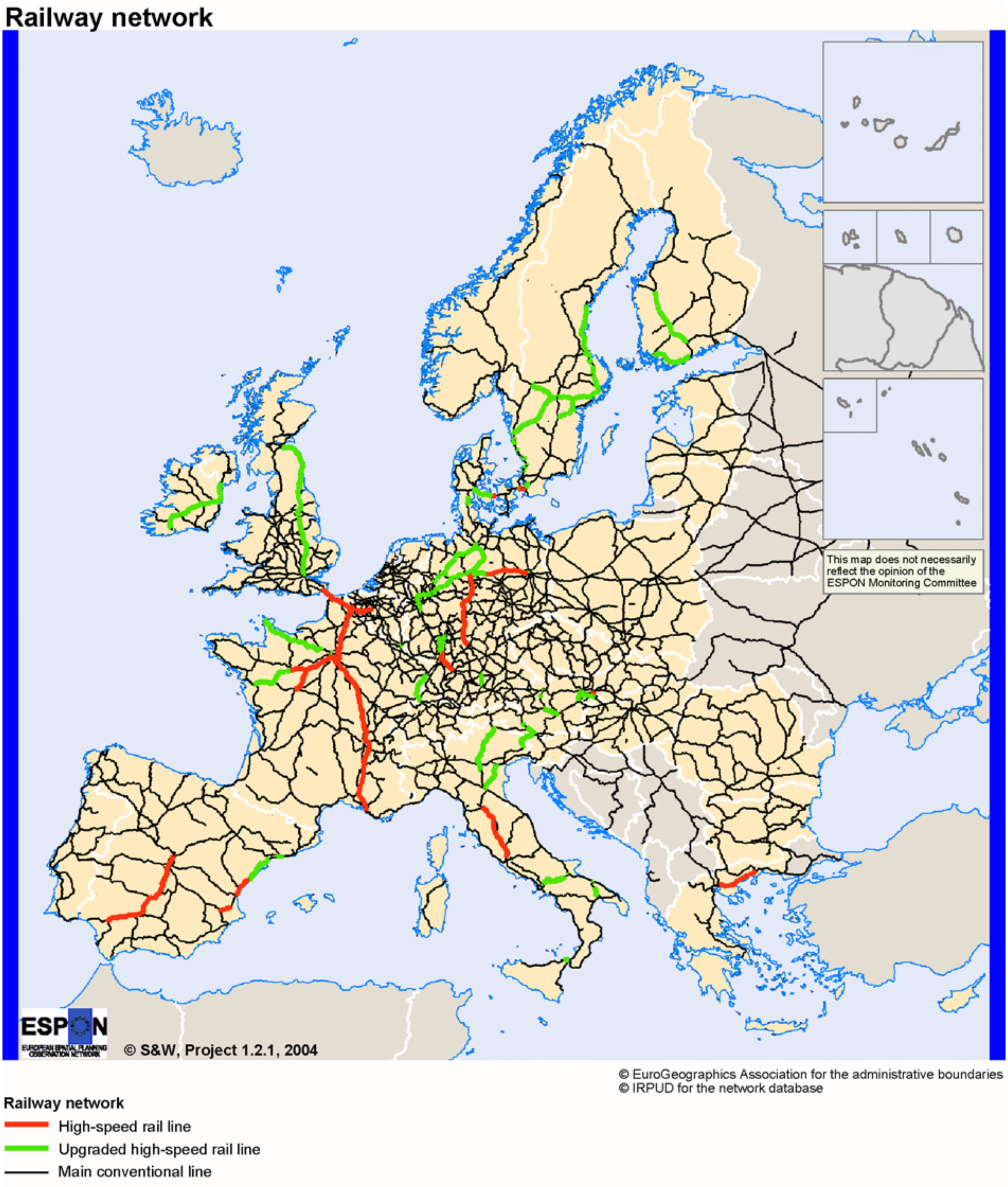
The map shows the 'strategic' rail network consisting of the most important railway corridors in the countries of the ESPON space, with the colour code indicating whether the link is a high-speed rail line, an upgraded high-speed line or a conventional line.

Data requirements

The rail network data presented on the map were extracted from the European network database complied and maintained at the Institute of Spatial Planning of the University of Dortmund (IRPUD, 2003).

Application to ESPON Space

For historical reasons, the European railway network is most developed in the countries of Northwestern Europe. However, in these countries many rail lines in rural areas have been closed down because of the competition of the automobile and the truck. As this has not yet started in the accession countries in Eastern Europe, the CEC countries have an over-proportional share of rail and inland waterway infrastructure: whereas the CEC countries account for about 21 percent of the population of the ESPON space, they have 29 percent of all railway kilometres on their territory (Eurostat, 2002). However, high-speed rail lines are still concentrated in Western Europe, i.e. in France, Germany, Spain, the United Kingdom and Sweden.



Map 10 Main railway network

1.5 Rail density

Rationale and policy relevance

Density of rail lines follows the same rationale and policy relevance as the density of motorways and expressways explained in the previous section. In this case, a caution related to the non-consideration of quality of service in the indicator is specially needed when reading the resulting maps.

Method

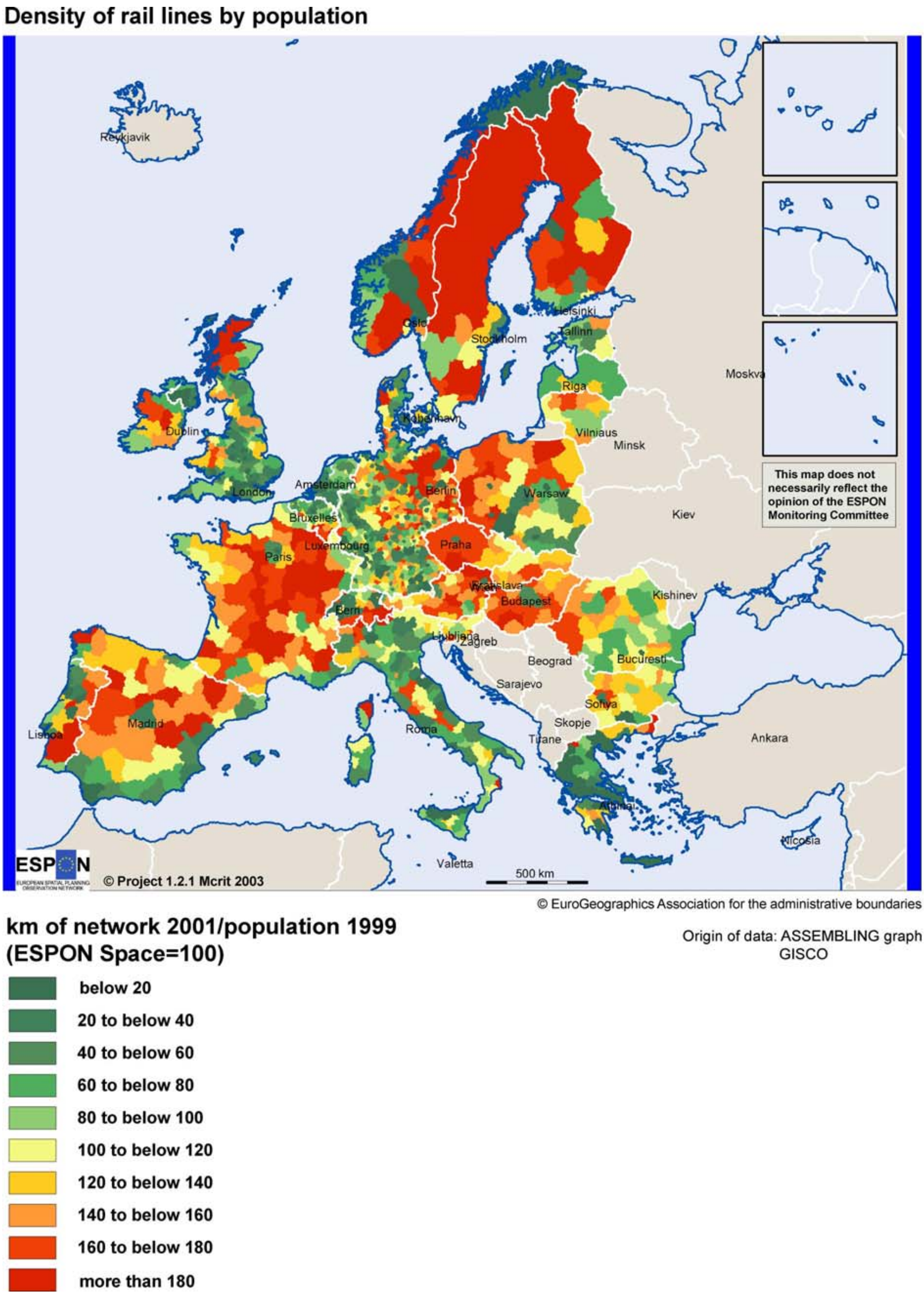
The methodology used is the same explained in the Section 1.2 with the difference that the transport network considered is the rail network in ESPON space.

Data requirements

The basic data is the same as explained in Section 1.2.

Application to ESPON Space

The density of rail lines has been calculated for all NUTS 3 regions of the ESPON space. It has been mapped with relative values of this indicator with the average value for all NUTS3 in ESPON space. Green coloured areas represent regions without rail network or regions with an existing rail network that needs to be enlarged to reach the existing level in other areas. These are mainly regions with high-populated urban areas (most of NUTS3 containing country capitals and other main cities), and populated NUTS3 in Eastern countries in the ESPON space (Poland, Bulgaria, etc.). NUTS3 coloured in reds show sufficient rail network according to its inhabitants. Note that high levels of this indicator does not necessarily mean good performance of the rail network; many areas in East Europe may have high density and also a relative low endowment due to lack of maintenance. This is also the case of the Baltic countries, where all the main cities are linked to the international railways network, but the overall quality of the railway services is insufficient in the majority of the transition countries.



Map 11 Density of rail lines by population

1.6 Inland waterways

Rationale

Rivers and canals were the first infrastructure for transporting large volumes of freight over land. The location of early industries depended on the availability of rivers and canals to link industrial sites to seaports and large cities. The importance of inland waterways was dramatically reduced by the advent of the railway. Today inland waterways are the most environment-friendly mode for freight transport.

Method

The map shows all inland waterways in the countries of the ESPON space, with the colour code indicating the inland waterway classes I to VII.

Data requirements

The inland waterway network data presented on the map were extracted from the European network database compiled and maintained at the Institute of Spatial Planning of the University of Dortmund (IRPUD, 2003).

Application to ESPON Space

The first inland waterways were rivers, but already in the Middle Ages the Netherlands had a highly developed system of shipping canals. In the 18th century industrialisation brought a rapid growth of inland shipping canals for transporting coal, raw materials and manufactured goods between mines, factories and cities. The highest density of shipping canals is therefore found in the countries which industrialised first: Belgium, Northern France and the Western part of Germany. Early industrialisation in England also depended on a dense network of canals; however these early narrow canals are no longer used for shipping and are therefore not visible on the map. The inland waterway network in the accession countries is highly developed, in fact the CEC country, which together account for 21 percent of the population of the ESPON space, have about 23 percent of all inland waterway kilometres in their territory (Eurostat, 2002).

Map 12 Inland waterway network

1.7 Seaports

Rationale and policy relevance

Maritime transport dominates most of long-distance freight transport and for most regions it supposes a relative competitive advantage. The availability of maritime terminals is historically linked to the geographic conditions of each region, and the road and rail connections of each port with its hinterland. More recently, new logistics demands have developed “freight villages” or intermodal road-rail terminals connected to ports but far away from the sea.

Method

The methodology used is similar to the one explained in the previous sections. For each region the traffic volume of all the seaports has been aggregated.

Data requirements

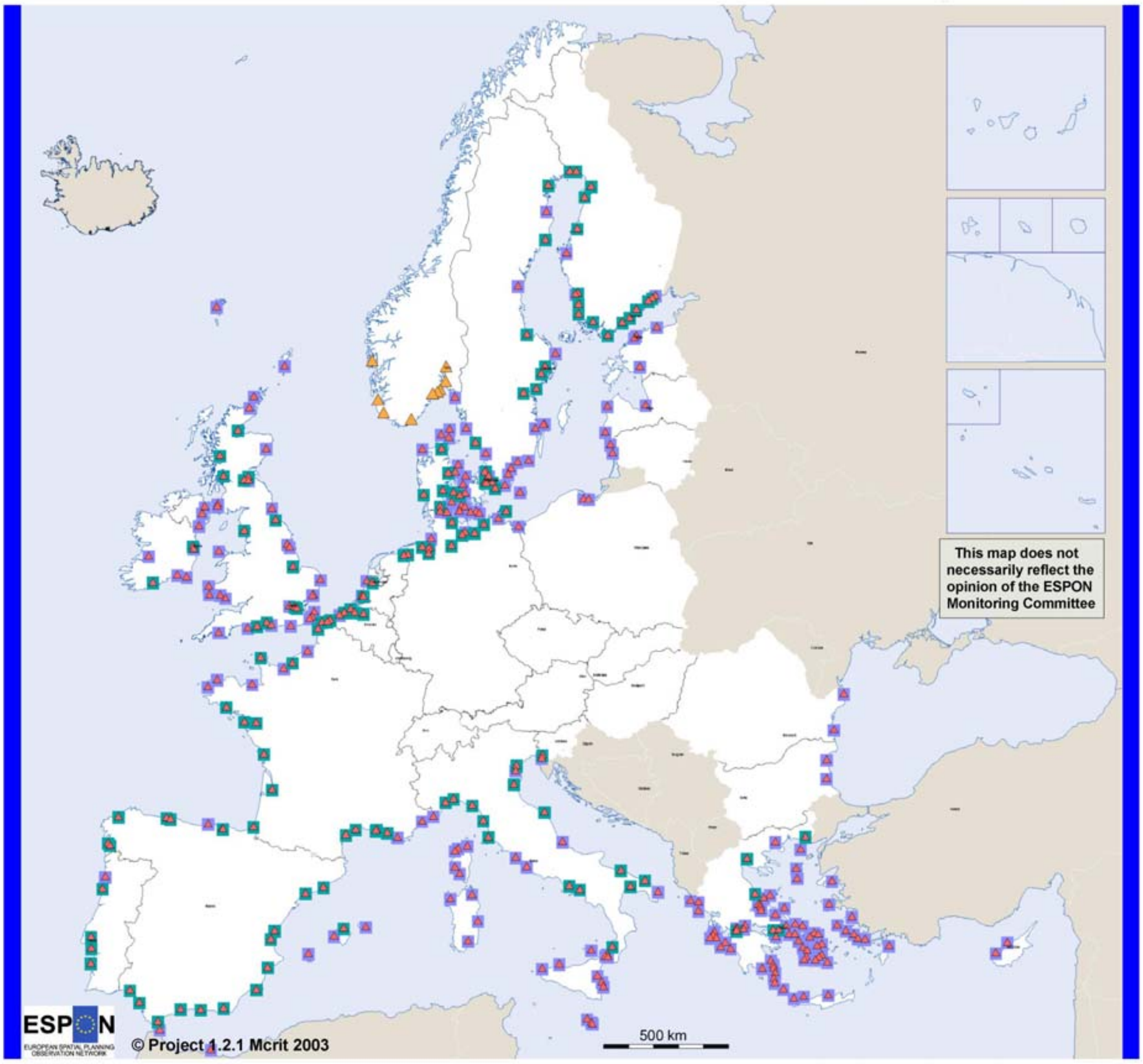
The data requirements are the ASSEMBLING graph and the EC seaports classification.

Application to ESPON Space

The commercial seaports infrastructure has been mappified for all NUTS 3 regions of the ESPON space. Islands and some peripheral regions, like the ones from the Scandinavian countries and Greece, are dependent on maritime transport, and therefore they have a higher absolute number of seaports in comparison to other countries with a great coastline, like Spain of France.

Other alternative measures such as traffic in terms of containers may also provide for useful indications.

Ports



© EuroGeographics Association for the administrative boundaries

Origin of data: European Comission

Source: ESPON Data Base

Ports classification

- ▲ **TEN/TINA ports**
- ▲ **Other ports**
- ■ **Sea ports**
- ■ **Sea-inland waterway ports**

Map 13 Ports

1.8 Commercial airports infrastructure

Rationale and policy relevance

Commercial airports infrastructure follows the same rationale as the previous section. Airports' network, in a more liberalised and globalised market of air services follow and intensive reorganisation, as maritime ports, leading to hub-and-spoke configurations, with airports of different levels playing different roles according both the commercial strategies of the different groups of private air companies and the national or local interest. The indicator calculated here provides just for the first approach to the geography of European airports.

Method

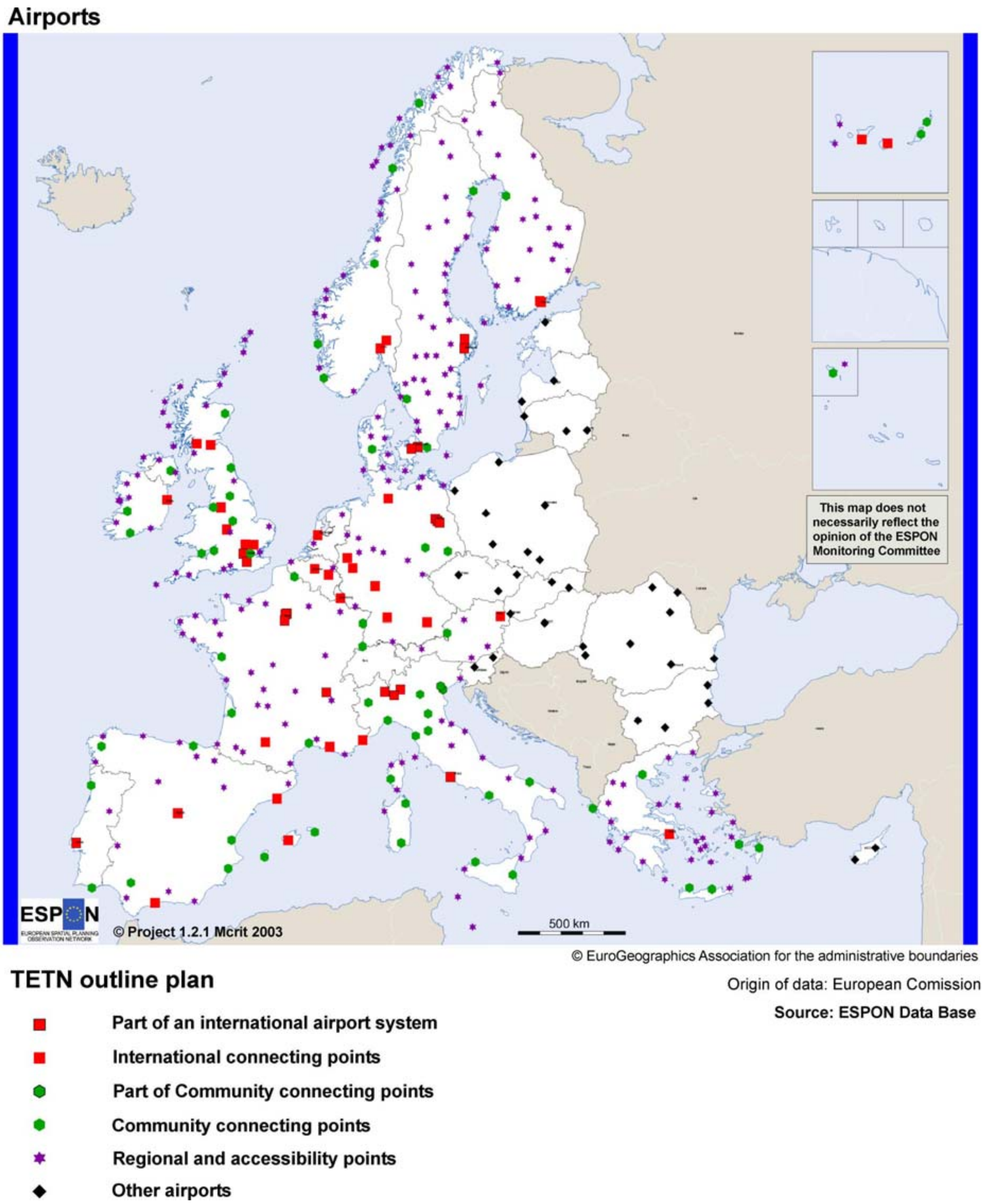
The methodology used is the same as the one explained in the previous section. For each region the commercial airports infrastructure has been aggregated.

Data requirements

The data requirements are the ASSEMBLING graph.

Application and results

The commercial airports infrastructure has been mapped for all NUTS 3 regions of the ESPON space. Following the TETN categories, airports which are part of an international system and international airports are located in EU15 countries and macro-regional capitals like London, Paris, Frankfurt and Milan, Madrid, etc. . It has to be noted that in EU countries there is a complete hierarchy of all airports, weather in most of the accession countries this is still to be completed (only main airports in new EU countries have been mapped). Scandinavian countries and Finland have a significant number of regional airports in comparison with community and international ones, due to the their size. Countries with a lot of islands, like Greece, have also a bigger proportion of regional airports due to the dependence of islands of this kind if infrastructure.



Map 14 Airports

1.9 Fractal dimension of networks

Rationale

The **morphology of transport networks** reveals the structure of a space from a geographic, economic and political perspective. It is a construct of the inheritance of the past: for example, if France and Spain have a centralized network and Germany a meshed one, it is not by chance.

However the morphology of networks also, at least partially, determines the future evolution of a territory and a certain number of its potentialities.

In that section, we will develop a fractal analysis intended to underline the dual aspect of the density that is to say its discontinuities and its imbalances.

The "fractal analysis " has been initiated by **Benoit B. Mandelbrot**[54] and developed by numerous authors in many fields[55] [56] [57] [58] [59]

The fractal is a discontinuous process based on the dual aspect of density, this last one always being based on the hypothesis of a continuous value in each zone. It is the reason of the potential great heterogeneity of the densities' values for different scales as, for example, NUTS1, NUTS2 or NUTS3 (see the part 3 chapter 1.3. "Network density of cities").

With the aim to show the possible imbalance between the local network configurations, the density is an inadequate mathematical operator because of its simultaneous linearity and continuity.

In reality, numerous spatial phenomena are **non linear, polynomial or exponential, and/or discontinuous**. The graphs "Average travel time by cars to reach the three nearest cities of more than 100 000 inhabitants" aggregated successively by country, NUTS2 and NUTS3 in the part 3 chapter 1.3 illustrate this non-linearity and the importance in the choice of the scale.

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[54] Benoit B. Mandelbrot. - The geometry of nature. - 1977, 1982, 1999 Library of Congress Cataloguing in Publication Data New York

[55] A. Le Méhauté. – Les géométries fractales. - Hermes, Paris 1990.

[56] S. Thibault. - Modélisation morpho fonctionnelle des réseaux d'assainissement urbains à l'aide du concept de dimension fractale urbains. - Doctorat d'Etat INSA Lyon 1987

[57] P. Frankhauser. - La fractalité des structures urbaines. - Anthropos Paris 1994

[58] C. Genre Grandpierre. - Forme et fonctionnement des réseaux de transport : approche fractale et réflexions sur l'aménagement des villes. - Thèse de Doctorat Besançon 2000.

[59] Ph. Mathis s/dir . - Graphes et réseaux. - Hermes-Lavoisier Paris 2003

The largest definition of fractal dimension is the ratio of full and empty space expressed in logarithms.

$$Ds = - \text{Log } N / \text{Log } R$$

With

Ds, the fractal dimension

N, the number of observed entities or elements

R, the increment or rate of increase

We can also note: $\text{Log } N + Ds \cdot \text{Log } R = 0$

Ds, the fractal dimension of observed elements, here the edges of network, corresponds to Hausdorff's² dimension and is always included in the interval [1 ; 2]. Ds = 1 corresponds to a line and Ds = 2 to a surface.

The essential characteristic of fractal is self-similarity that is an internal similarity (in its mathematical definition), that is to say there is a persistence of structures at each level or scale.

It is possible to compute the fractal dimension at different levels (NUTS1, NUTS2 or NUTS3). But the surface of some NUTS3 is too small for the GISCO network definition, even if the random auto similarity is observed on the hierarchy of European network (see part 3 chapter 1.3.3)

The aim is to compare the fractal dimension of each area. So, we have an objective indicator of the distribution of network in the space.

1.9.1 The algorithm of square pattern

Rationale

With the " square pattern " algorithm, we calculate the fractal dimension of the considered networks, which characterizes it in a general manner and by country.

Method

We use the Minkowski-Bouligand method[60]: we build a **decreasing series of square pattern** of η of side in the aim **to entirely cover the studied surface**.

The fractal dimension value is obtained with the computing of the total number of squares and the number $N\eta$ of squares containing an element of network, as follows:

---

[60] A. Le Méhauté. - Les géometries fractales. - Hermès, Paris 1990 p.50 and following

$$D_s = \lim_{\eta \to 0} \left(\text{Log}\,[N\eta] \,/\, \text{Log}[1/\eta] \right)$$

We work by successive iterations diminishing each time the size of squares[61].

Data requirement

GISCO graph

Limits of national boundaries (GISCO GIS)

Application to ESPON Space

As we have seen, if Ds = 1 we have a line and if Ds=2 we have a surface. In the practice, the nearer to 2 the fractal dimension is, the denser the network is.

On the map below, the dimension fractal has been computed independently for each country.

The graph below complete our point of view. We can distinguish **three groups**:

First: Countries with a network fractal dimension *DF < 1.2*

Second: Countries with a network fractal dimension *1.2< DF<1.35*

Third: Countries with a network fractal dimension *1.35< DF*

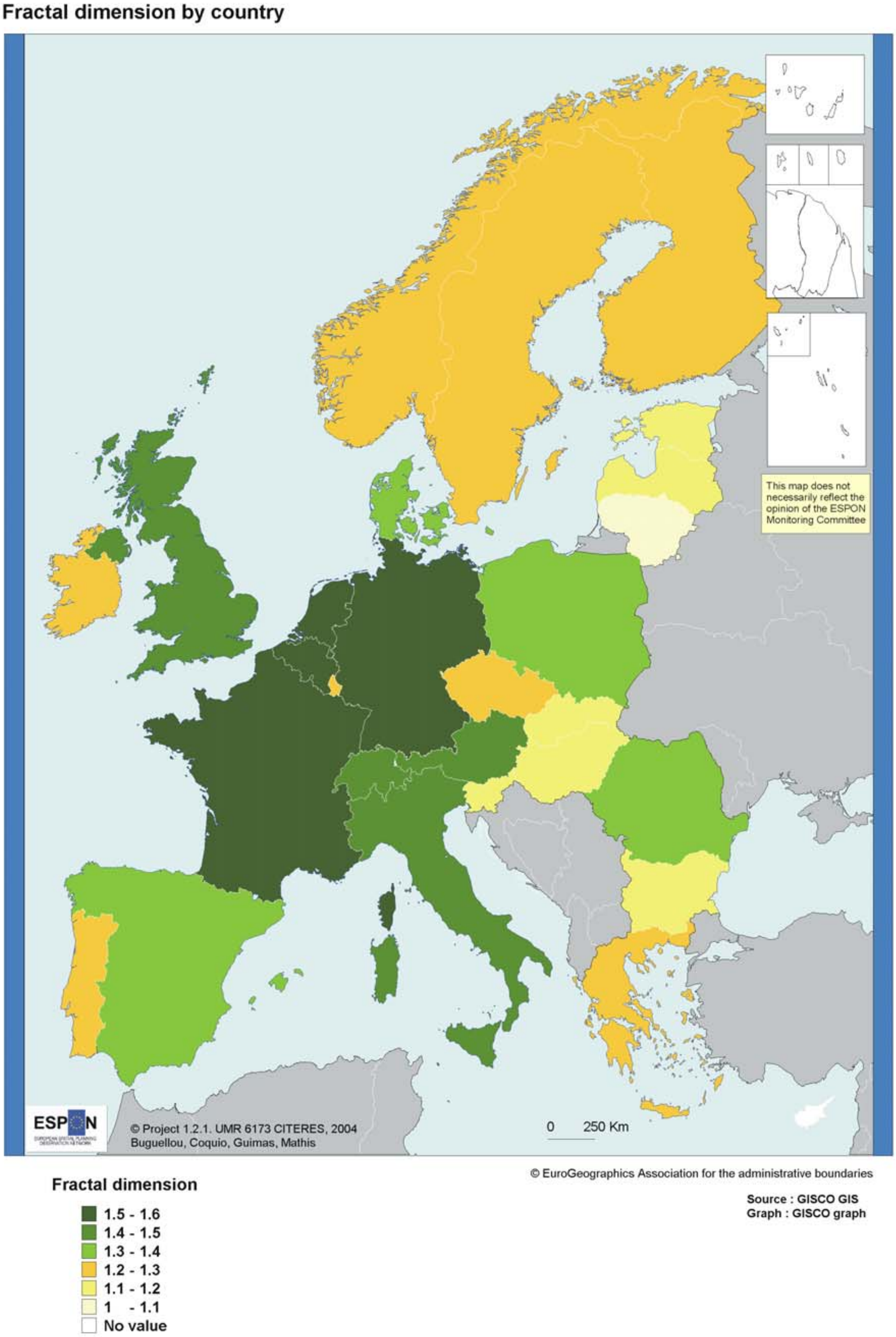
The first group contains the old countries of European Community (excepted Luxembourg which presents a particular morphology of its network because of its very weak surface), plus the United Kingdom and Switzerland.

The Scandinavian countries and Finland are in the second one because the networks are not very developed owing to their weak density of population.

We must note that this indicator takes into account the number of considered elements (here the edges of graph) but not the structure of the network. Moreover, this analysis does not integrate the population or the GDP but only the surface.

It is possible to extend this analysis and to take into account the population or the GDP with the cartogram (part 3 chapter 1.10).

[61] from 5 km to 320 km in doubling the size of squares at each step



Map 15 Fractal dimension by country

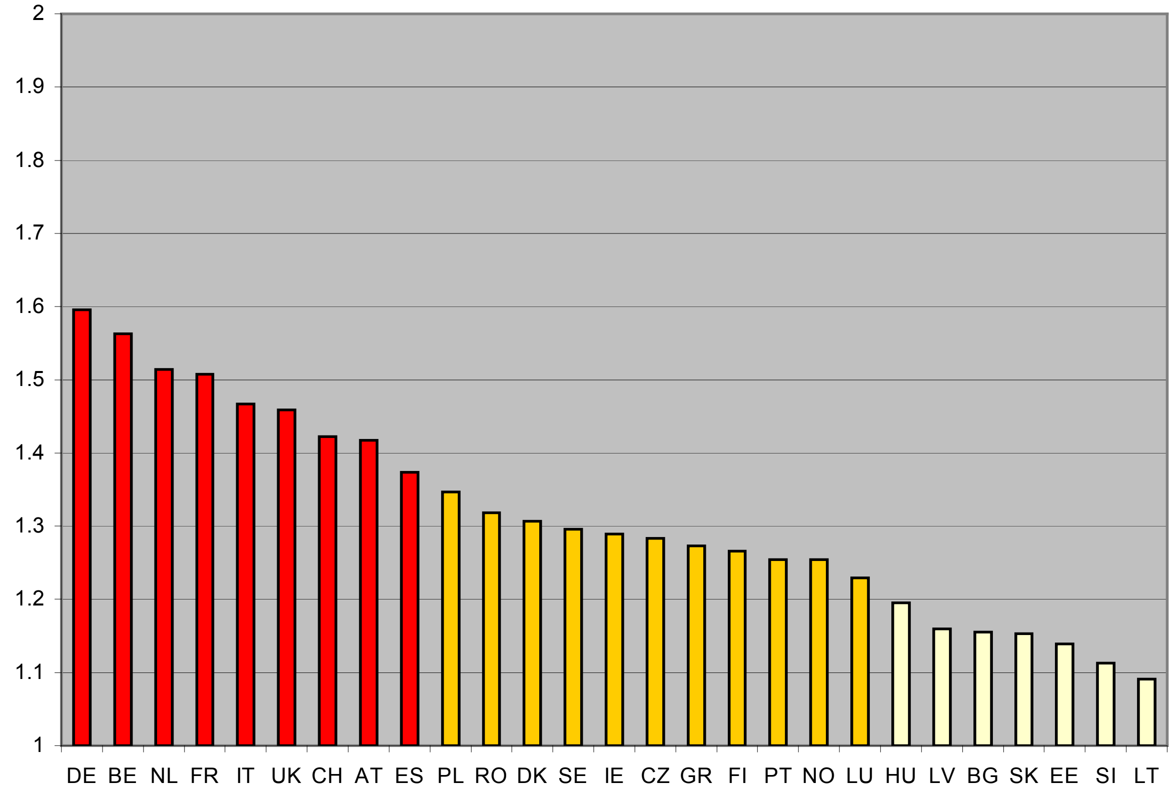


Figure 6 The fractal dimension of each country

1.9.2 The algorithm of expansion or Minkowski's algorithm

Rationale

Using the **"expansion algorithm" of Minkowski,** we study the relative proximity of the whole territory to road network. In this goal we work on buffer areas around this network with a variable buffer size of x km.

This analysis permits to underline the unbalanced between NUTS and complete the fractal analysis of national level as seen in the previous chapter above.

The Minkowski indicator consists in calculating the proportion of surfaces at less than x km from one or several networks relatively to the total surface of the studied territory.

Thus, we have an indicator **of network coverage** in the sense of proximity of the specific network to each studied area. It could characterize areas in a more precise way than a simple calculation of classical density. In fact, this fractal indicator allows to calculate the non-covered surface of every zone and, thus, to give an initial valuation of the distribution, (or, in other words, of the local concentration) of networks by comparing this value with a classic indicator of density.

This indicator can be calculated for **variable size of buffers**, until the threshold for which all the territory is covered.

This analysis does not depend on the speed of the networks: **it is purely geometrical**. We must qualify the results that depend on data: the difference in size NUTS between Germany and Sweden for example, nature and choice of network….

The data for each country are readable in the annex of this report

Method

It consists in calculating the surface covered consequently to a dilatation of the considered network, with a variable width, increased at each iteration. In practice we work at NUTS3 level in two steps:

First we make **buffer zone around network of x km of width**, x taking successively the value of 750 m, 1, 1.25, 1.5, 2, 2.5, 5, 7.5, 10, 12.5, 15, 20, 25, 40, 50, 75, 80 and 100 km. The map on the next page summarizes this successive iteration.

Secondly, we quantify this result by dividing for each NUTS3, **the surface covers by a given buffer by the total surface of the NUTS3.**

Remarks:

It raises two problems:

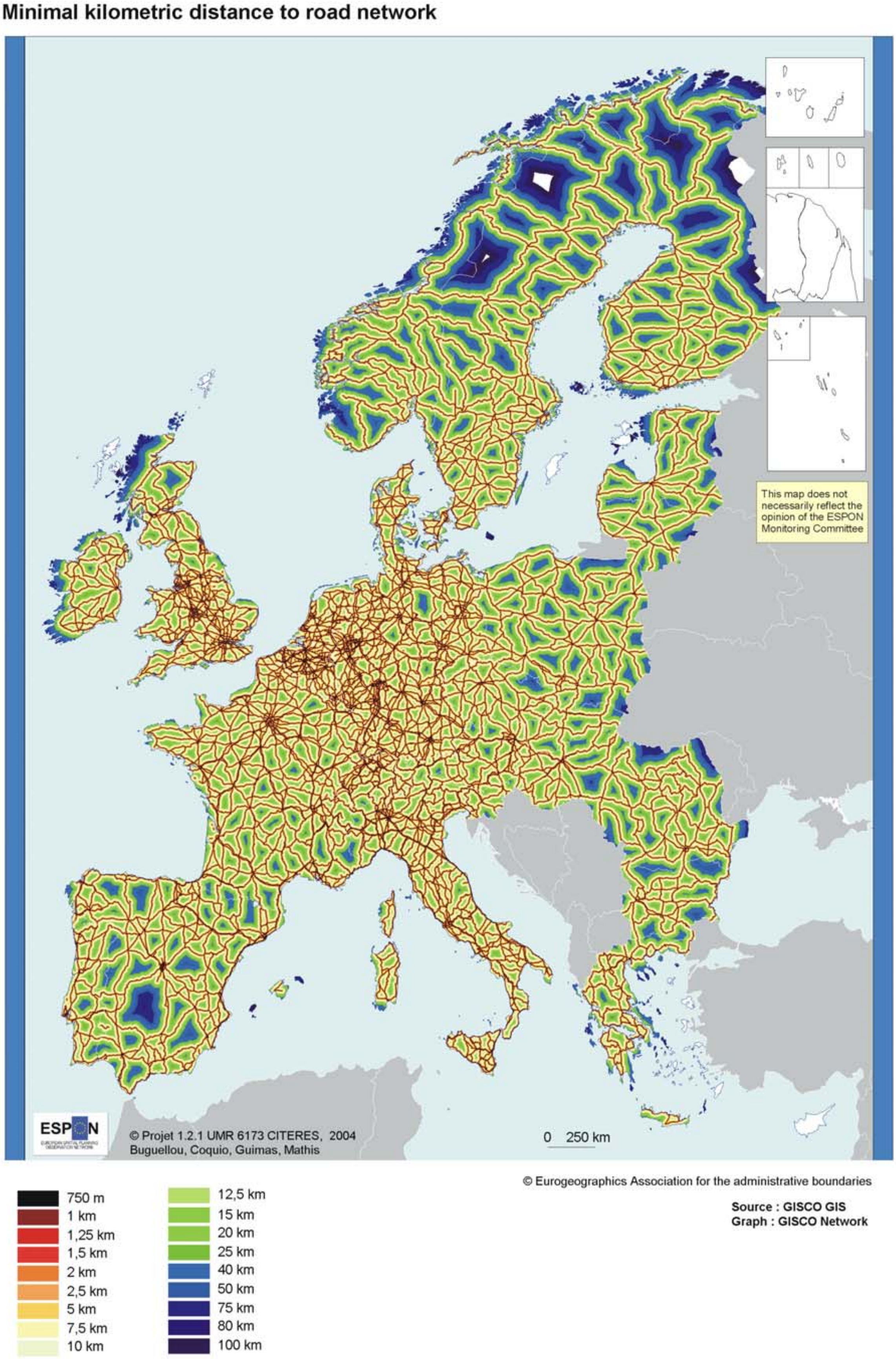
In the case of a mode whose access is limited to certain points of interfaces such as trains with stations, planes with airports or cars with the interchanges' highway, this Minkowski evaluation can only be punctual and not continuous, but the principle of calculation remains the same. We can then compare the spatial influence of the various networks according to this criterion and determine the non-covered areas which does not permit the usual calculation of the densities

In the case of road crossroads, there should not be double accounts.

Data requirement

GISCO Network

GISCO GIS (for boundaries of NUTS3)



Map 16 Minimal kilometric distance to road network

Application to ESPON Space

The observation of this map reinforces the conclusion make about the hierarchical network (see part 3 chapter 1.3.3) and the concentration of roads in the centre of Europe, even if the hierarchic aspect is not visible.

Here, **the real question is not the network itself but its faces**. We will characterise the importance of theses surfaces and the imbalance of the space cover i.e. the easiness of moves for the population.

The map shows that the European space is heterogeneous. The different regions are in unequal situation.

But, if this map is clear and **the inequalities are obvious** it is necessary to measure and have a numeral and precise indicator.

As seen in the general method presented above, the calculation are realized at NUTS3 level, in the goal to show the imbalance between the different countries and inside the various counties themselves.

The graphs below show our result for two values of expansion: 2.5 and 10 km.

To facilitate the reading of graphs, we have materialized the separation between each country by representing with a line the first (and higher because of our system of classification) value for each of them. This line is red for the case of 2.5 km and white for 10 km.

For 10 km, it is a kind of negative of the situation that is represented, with a white line between countries.

If the first graph 2,5 km shows the give the prominence to the better covered zones, on the last graph we can see the NUTS disadvantaged.

It is possible to note the imbalance in a same country and the form of it: the decrease of values is more or less rapid. For example the German values are more homogeneous than the French one and in their evolution for the United Kingdom is relatively regular. All these values are available in the annexes. The effect of the NUTS size is very important and with these differences the comparison with NUTS is difficult.

For buffer of 10 km of widths, we see that in Germany and United Kingdom some NUTS are entirely covered.

A last map, presented below, aggregates these data by NUTS2.

In the aim to take in account the surface effect, we have realised a **little typology with the surface of NUTS and the gradient of curves**. We have computing the relation between surface and the expansion by NUTS2 to obtain a global surfaced indicator.

The correlation coefficients of the curves are goods: 0,9766 < R^2 < 0.9987

We can see clearly the effect of NUTS size: Belgium, Holland, Germany and a part of Austria, England and roman Switzerland, very developed countries but with little Nuts are the same colour: an homogeneous zone. The Spain is characteristic country with very important settlement on the littoral and in Madrid region. The Eastern Europe with the new adherents is also characteristic.

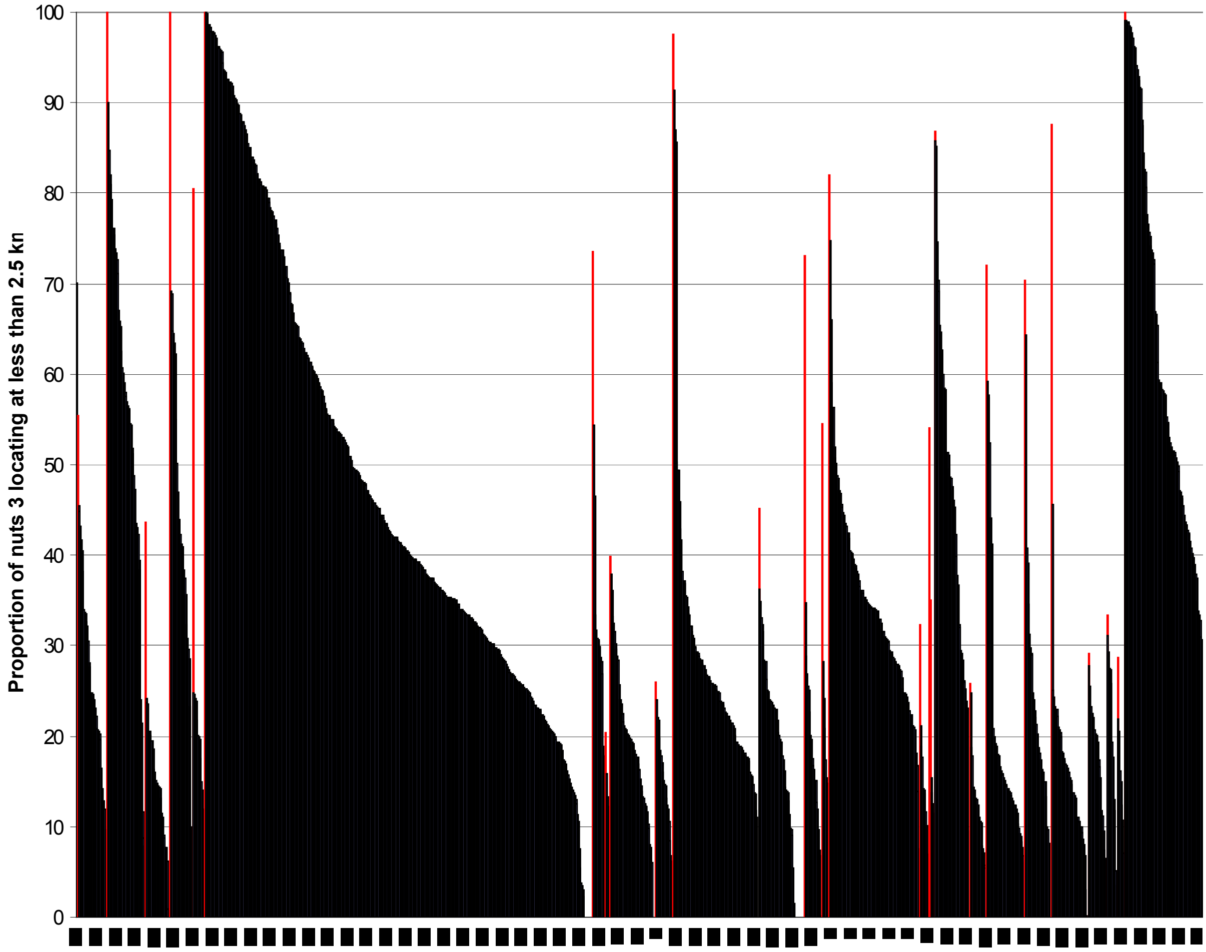


Figure 7 Proportion of NUTS-3 locating at less than 2.5 km

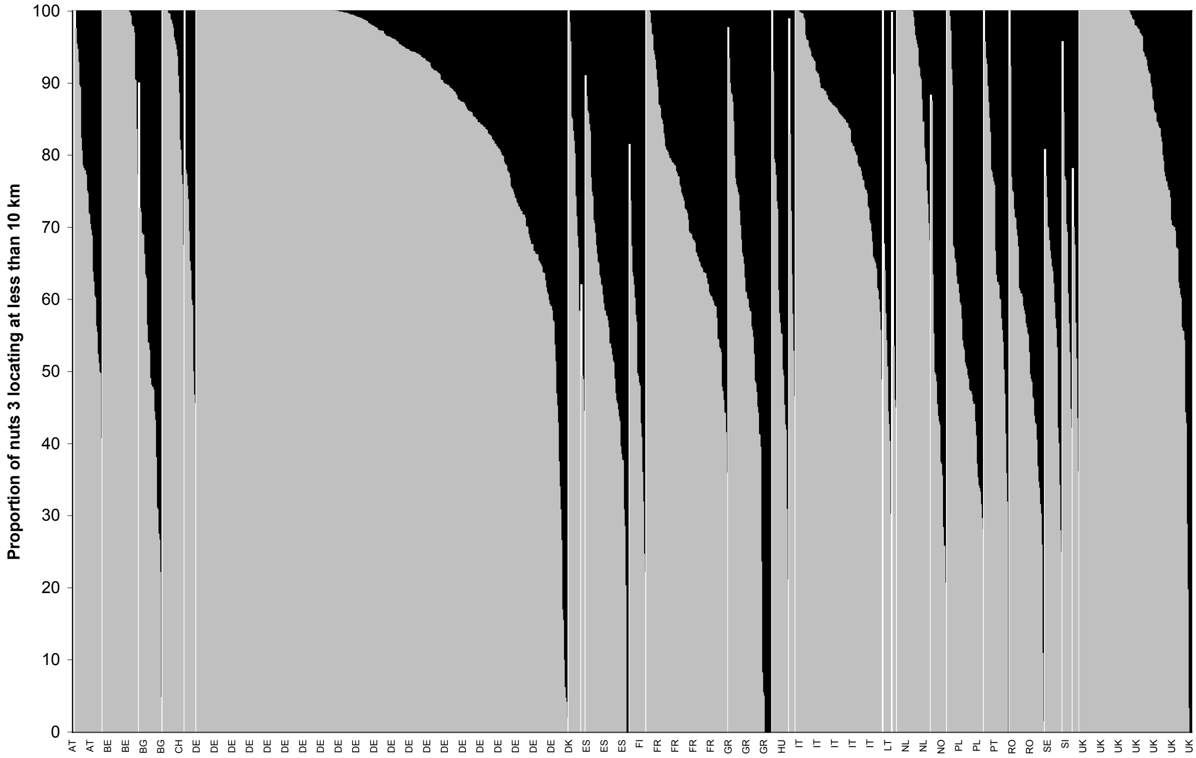
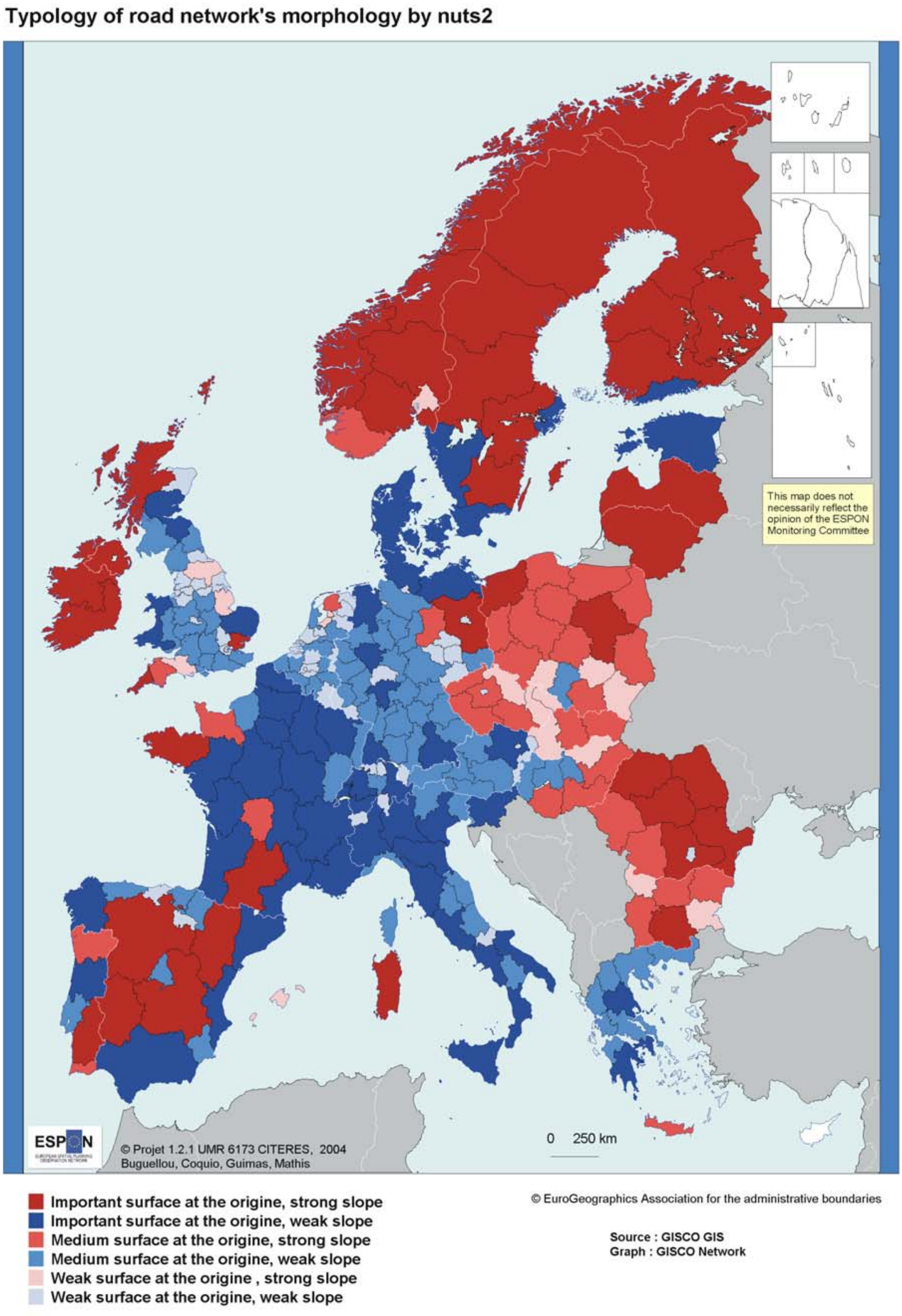


Figure 8 Proportion of NUTS-3 locating at less than 10 km



Map 17 Typology of road network's morphology by NUTS-2

1.9.3 The « radial analysis »

Rationale

We propose an example of radial analysis allowing us to approach the same phenomenon as studied above, but **from nodes**. This indicator also permits to analyse the spreading and the **local polarization of the road network**.

This is an improvement of the " radial analysis" that measures the length of the structure contained in a circle with a variable radius. To have a meaning, the circle centre must be a city.

In this way we study the length of road in a buffer around the city of x km and the evolution when radius of circles increases.

These lengths vary with the network geometry and the density of cities

Method

We process in two steps:

First we draw numerous circle centred on each European cities of more than 100 000 inhabitants. The radiuses of circle successively take the value of 5, 7.5, 10, 12.5, 15, 12.5, 20, 25, 30, 35, 40, 50, 60, 70, 80 and 100 km.

The map on the next page shows the result of this step for 10, 25, 50 and kilometres

Subsequently, we calculate the total length of road network included in each circle. Thus, we obtain 16 values for each considered cities.

The whole data are available in the annexes.

Data requirement

GISCO Network

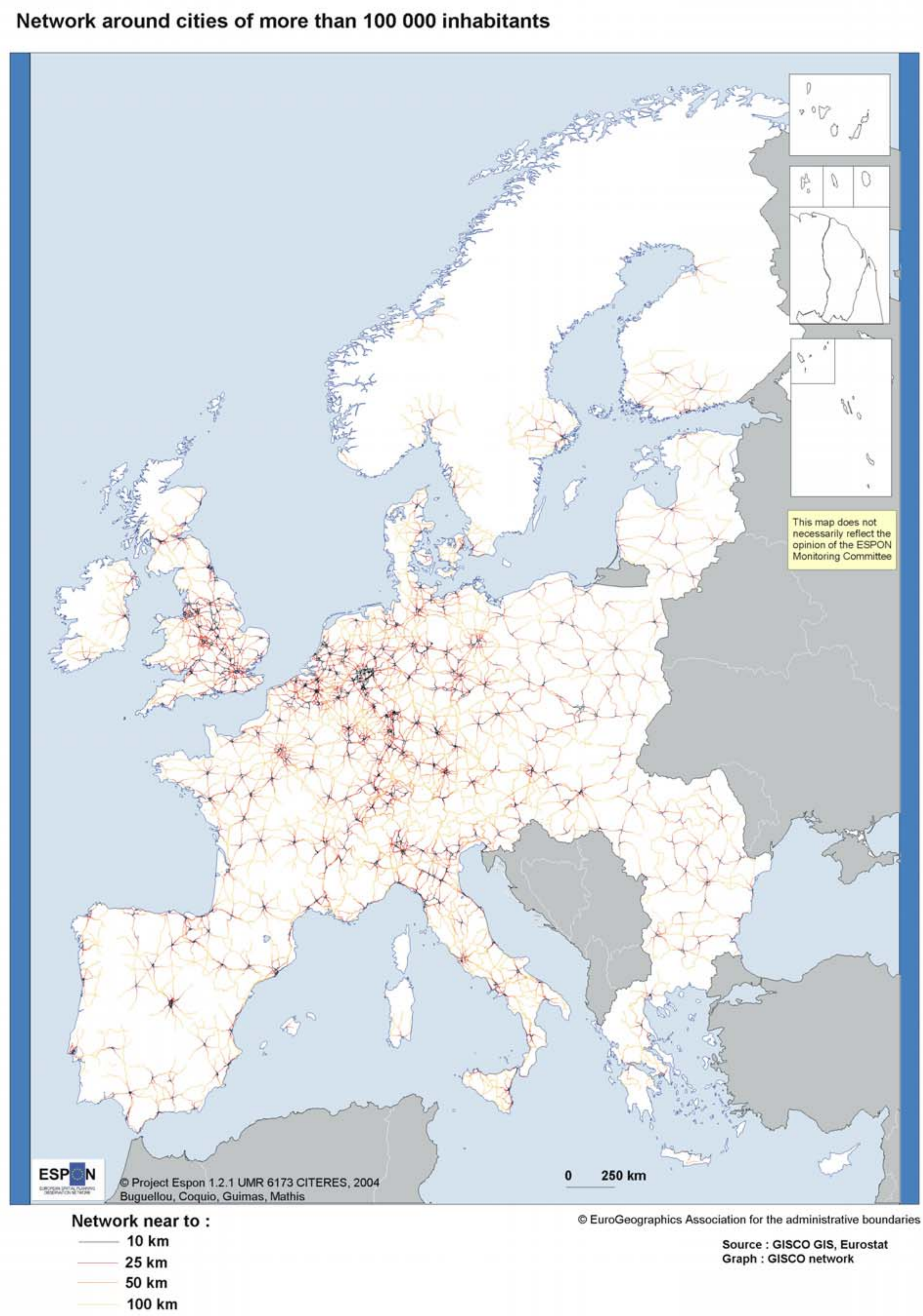
GISCO database (inhabitants per cities)

Application to ESPON Spate

This map is not dependent on the NUTS' surfaces.

We can see the "density" of cities but no yet the including population. An other perspective is shown by the number of accessible cities in less of so many kilometres.

It permits us to see the "continuum" of cities, an aspect developed in depth in part 4 chapter 2 and 3 with the notion of polycentrism.



Map 18 Network around cities of more than 100000 inhabitants

But the radial analysis shows also the specificities of each county. The graph below described this heterogeneity. They link radius of circle and length of network included in it. The indicator is specific of each node or city and it is possible to draw plan curves and calculate these characteristics and especially the gradient. The coefficients of correlation are very good and significant: 0,9172 < r² < 0,9995 and only 11 cities have a value inferior to 0,95.

We have choice four examples of curves two for great countries (in terms of surface) and two for the little ones.

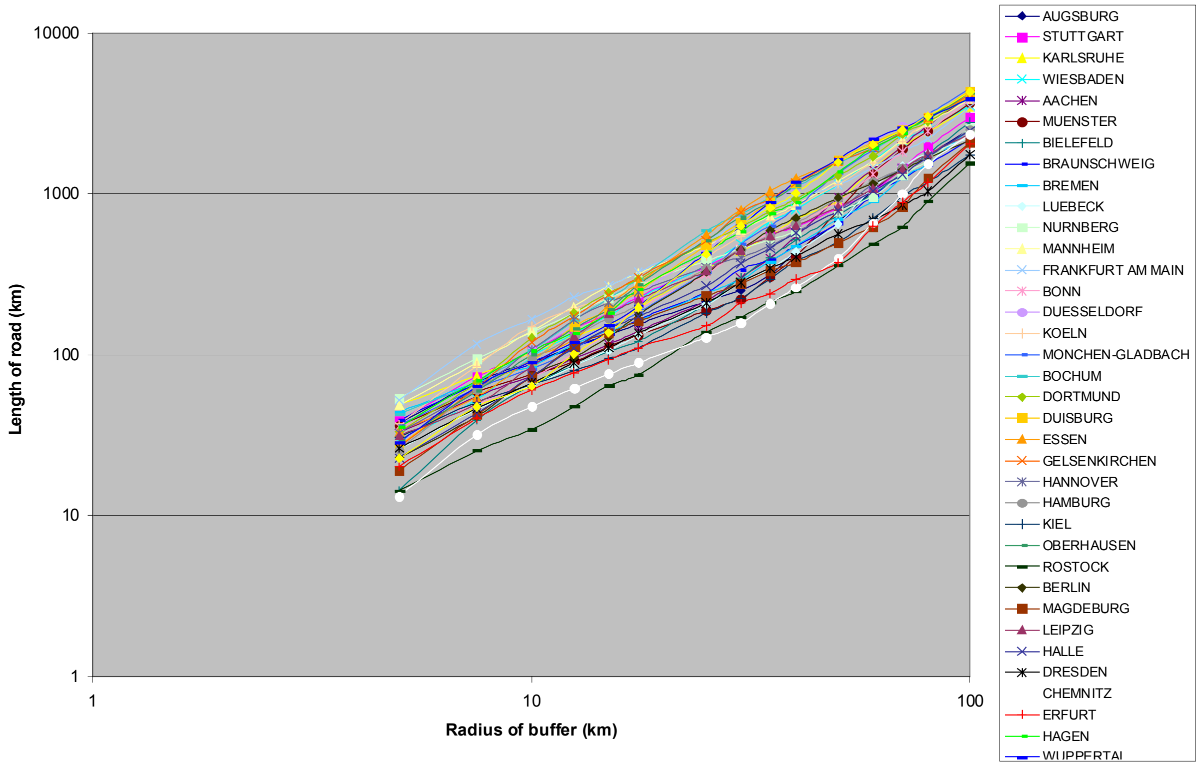


Figure 9 **Kilometres of roads included in a circular buffer around German cities**

This first example is about **Germany** (that is o say we have only considered German cities of more than 100 000 inhabitants). We can note **the homogeneity of the structure**. Globally the gradient is the same, curves are parallel and the gap at the origin depend on the cities density, because many cities can be situated in a given circle, accentuated logically the increase of the network's length.

The second example is about Spain. We note that the situation is different than for Germany less homogeneous. We can distinguish for example **the specific situation of Madrid** that is isolated in the centre of territory and of **Palma de Mallorca** that is an island. Locally, the geographic constraints change the phenomenon.

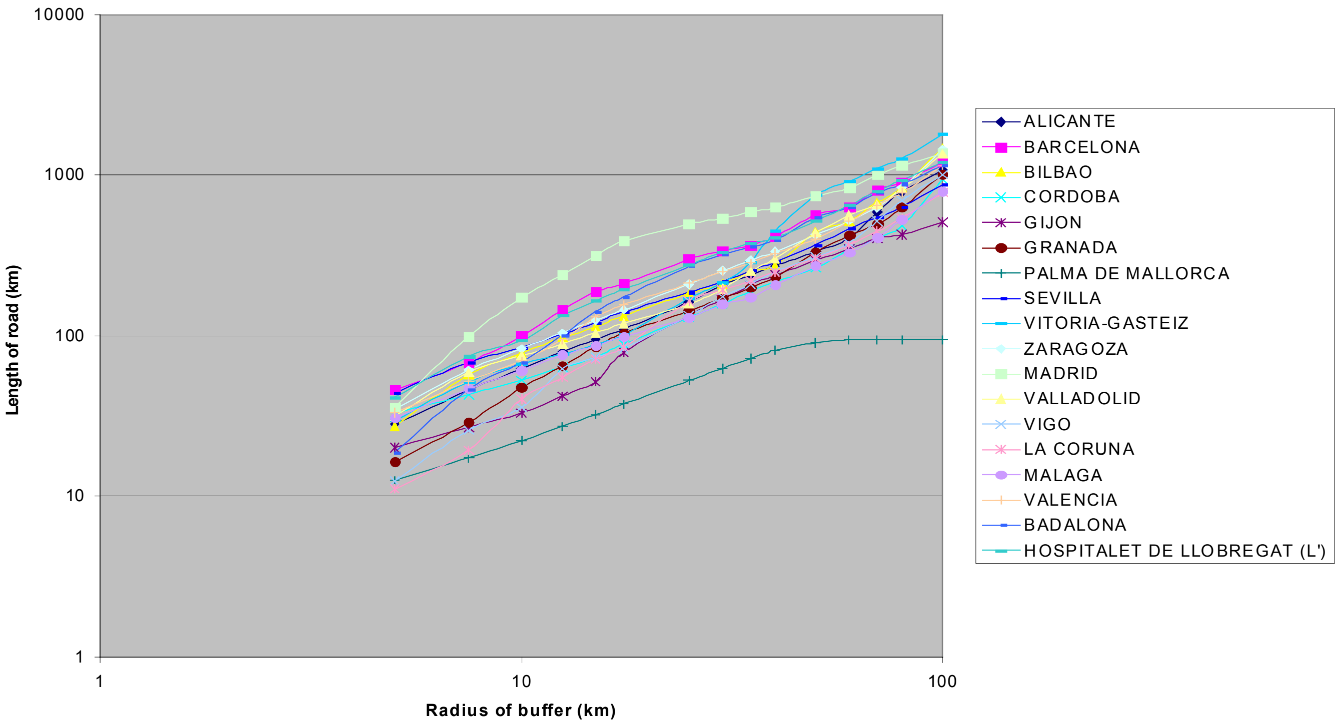


Figure 10 Kilometres of roads included in a circular buffer around Spanish cities

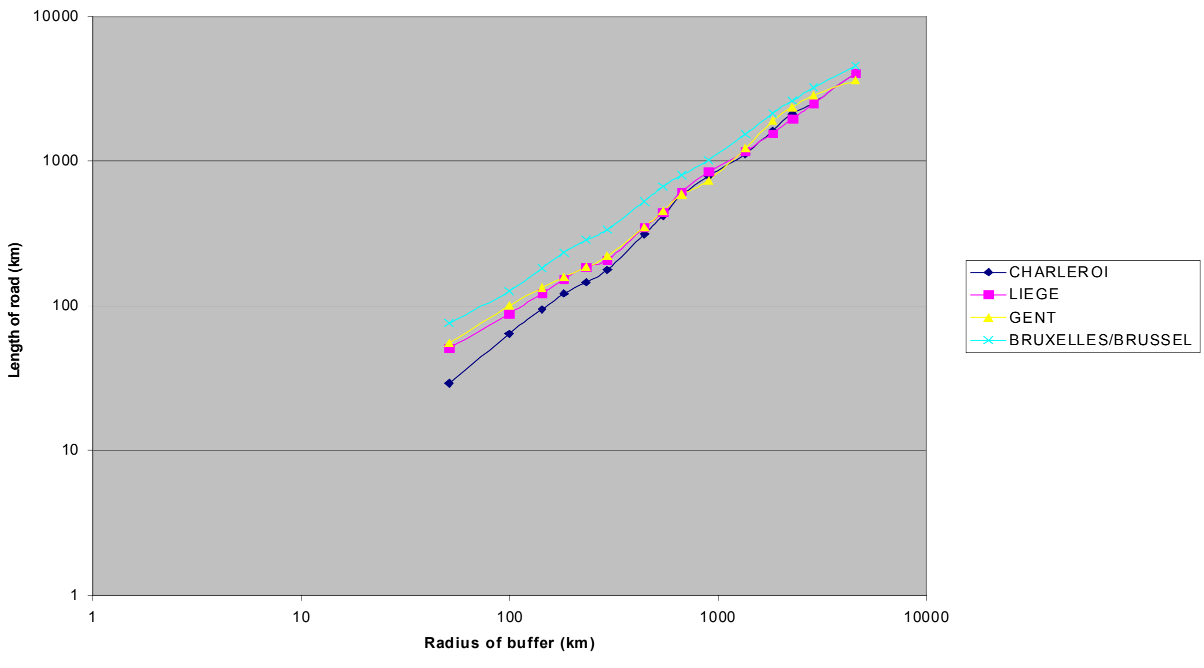


Figure 11 Kilometres of roads included in a circular buffer around Belgian cities

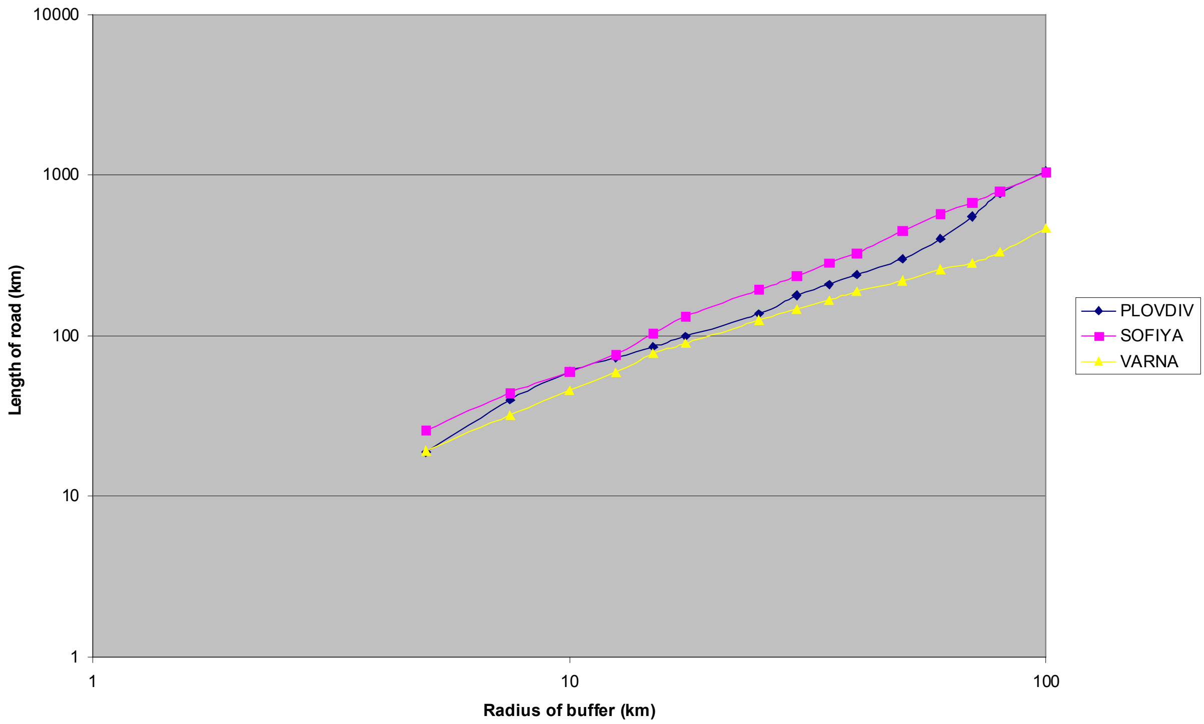


Figure 12 Kilometres of roads included in a circular buffer around Bulgarian cities

The two graphs above are about the case of Belgium and Bulgaria, two countries of little surfaces. If the first examples shows relatively homogeneous situation, exception done of some very precise example, **we have here two types of curves** with the Belgium and Bulgaria. Belgium is in the blue banana and this network growth is faster than in Bulgaria, less dense and developed in terms of transport network.

1.10 Cartogram

Rationale

The aim of this indicator is to illustrate **the deformation of transportation networks according to socio-economic data** and in parallel to exceed the limits of indicators such as road infrastructures densities for example. The cartograms allow the transformation of geographical surface objects by changing the surface of the areas according to an attribute, data attached to them. It permits, for example, to show the distribution of the road network according to the local population in a different and complementary way of classical densities' maps. Thus, cartograms make it possible to carry out a **different point of view putting forward the geographical disparities of the distribution of individuals, richness and transportation networks**.

Method

In order to carry out this deformation, we used a Geographical Information System (ArcView 3.x) and a script in Avenue language written by Andy Agena corresponding to a continuous cartogram. This one conserves the topology of the geographical areas. Indeed, the deformation of surfaces is realized according to the value of the selected attribute but it maintains the relative position of each geographical entity in order to facilitate the interpretation. This deformation is done through successive iterations. At the end of the tenth one, the surface of the objects corresponds to **97%** of the value of the attribute chosen. In our example, with a graph of **2265 edges** and the choice of the **NUTS 2 area** as a cartographic reference, each iteration is approximately made in 10 hours[62]. The time spent for each iteration is exponential function of the number of objects to deform.

The **script only modifies surfaces**. In order to deform the NUTS2 and the road network jointly, a grid of space has been carried out according to administrative limits and of road axes. The attribute (population or GDP) is then distributed in a homogeneous way on the whole NUTS2.

That hypothesis can seem strong but it is the hypothesis of all maps that represents a NUTS value with a colour on the surface.

The transformation by the script is thus realized on each mesh according to the attribute value deforming in the same time the surface of the geographical objects and changing the distribution of road axes.

62 So roughly 100 hours to obtain the final map, that explains why we have only done this work with the CESA graph 765 and at NUTS 2.

The software used is CARTOGRAM. It has the advantage of not modifying the general shape of the space too much, thus allowing then a relative recognition of the shape of the different Countries or NUTS1 areas.

The software uses Arcview 3.x. version. The calculation of the surfaces distortions is made with 10 iterations and from regions whose adopted attribute has the strongest local value.

Development of the method

In the case of the 1.2.1. project, the aim is a bit different: we want to show the network according to the population and to the GDP by giving a visual representation of the importance of the selected attribute. However, any classic map, even with lively colours and chosen areas would not allowed us to understand well the logic of networks clearly.

We then developed a new method allowing us for the first time as far as we know to represent on a cartogram something other than the areas limits.

Data requirement

Population by NUTS(Gisco Database)

CESA graph 765

Boundaries of NUTS2 (Gisco GIS)

The NUTS2 level and the CESA network have been chosen

The advantage of the CESA network with regard to the GISCO network is that **it is nodal, centred on the main European cities** (among 765), it is practically a subset of the whole ESPON 1.1.1. list.

The choice of the GISCO network NUTS3 level was rejected because the polylines points have no clear connection (nor are they easy to establish) with cities. Moreover, the number of the necessary areas to use with our method would have implied **15 days of calculation** by map which was impossible, when it is already takes three days with the *CESA Graph 765*.

Application to ESPON Space

But these results are classic even if **they are not usually used in representation** at the ESPON level or at the Commission DG REGIO. They supply the advantage to propose another aspect of the present situation, even if it can be considered as rough or more exactly disturbing.

The result of each iteration is available in the annexes, showing the process of cartogram algorithm. The distortion is strongly accelerate at the beginning then there is convergence of the process

We present **three final maps** obtained by this method.

The first is realised according to the GDP by NUTS2.

The second depends on the number of inhabitants by NUTS2.

The third is based on the result obtained for level of population, adding a typology of colours to represents in more the density of network.

The first map, above, allows us to show the importance of the adopted factor, in this case **the GDP by NUTS2**. A huge imbalance appears clearly inside the European Union. The GDP cartogram is surprising but the GDP also: the picture, in that case, the map, is stronger that the number in terms of readability.

GDP ratios appear in a really **significant visual way**. It is difficult to read the information without habit.

The network is not plainly distinguishable in the East of Europe.

The distortion of countries surface is very important for Scandinavia and Finland but their populations are small even if the standard of living is very height.

Concerning this GDP cartogram, the most stringent phenomenon is the **great contraction of the Eastern countries, Scandinavian countries and Finland**, in a weaker way. Once again, the areas undergoing the bigger increasing of their surface can be found in the capitals, in the West of Germany, in Benelux.

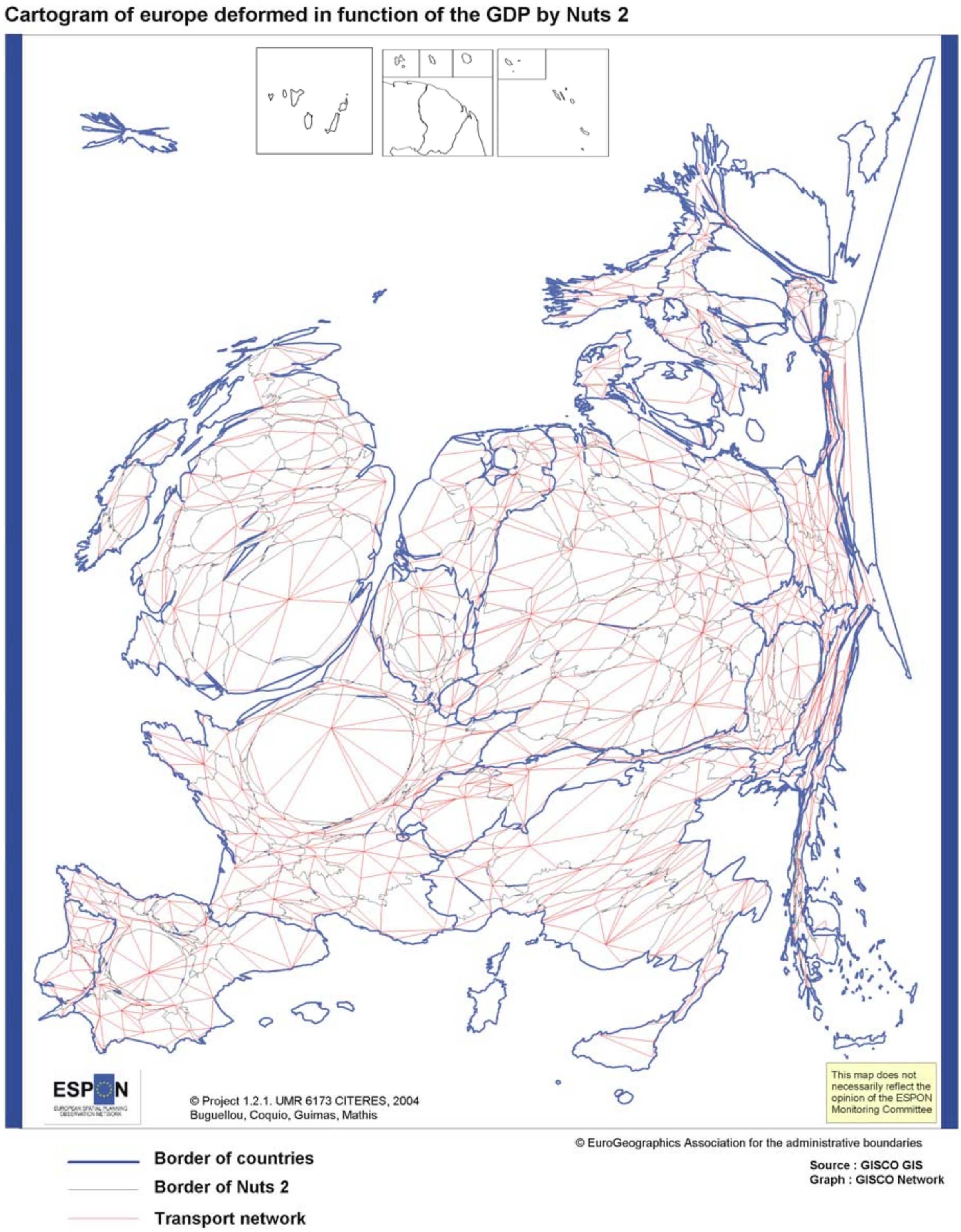
An interesting phenomenon concerns Italia: we can see the difference between the North and the South of the country, due to the uneven distribution of the GDP.

Concerning the distortion of the network the distortions are so important that the "new density" of network is not equally distributed as for the cartogram population.

The second map, presented below, is realized according to **the population in each NUTS2**.

The distortion of population cartogram is very important for the **Scandinavian countries** and Finland because of their low density of population. Furthermore, we can see the **disparities of the distribution of population all over Europe**. Indeed, some areas grow in an important way (Paris, London, Madrid, Athens, Benelux, West of

Germany) whereas other ones undergo a great contraction (Scandinavian countries, Finland, Ireland, areas around main capitals).



Map 19 Cartogram of Europe deformed in function of the GDP by NUTS2

But beyond the distortion linked to the population of areas, the transportation network (here the *CESA graph 765*) has also been deformed and therefore gives to us very interesting visual information. Indeed, the network distribution seems to be highly correlated with the number of population in each area. In other terms, we can observe **a homogeneous distribution of the network** on this map, which is not the case in the original map[63].

The NUTS2 surfaces are function of the population, and the main road corridors are shown on the cartogram. The transformation of surfaces is less strong that with the GDP. The imbalance is more readable, even if the Scandinavian countries and Finland appear very scaled-down because of their low number of inhabitants.

It is clear on the map that the **road corridors connect the regions with a very high population**.

And the main network is more homogeneous on the cartogram than on the geographical map.

Once the distortions have been made, it is possible to add other data on the maps. It is then possible to produce a lot of different maps showing various phenomena. The aim is to produce maps to show data in a different way that usually to underline **the disparities by a stronger visual impact**. We have chosen to produce maps presenting "the density of motorways by surfaces of NUTS2 in Europe" which is very close of the work done for part 3 chapter 1.2. It is why we do not make many comments, but nevertheless presents this map because, in our opinion, it is in very important to have **different ways of representing the same phenomenon**.

This other cartogram represents simultaneously the **length of motorways and highways (km) per NUTS2 areas (km²) and the population of NUTS2** (readable through the observation of the new surface of NUTS2) ; It is another perspective than in the classical maps.

The length motorway and highway length by km² is high in the NUTS with many people. It is logic because these infrastructures are making as a priority for the great cities. For the others networks, the roads in the rural NUTS the accuracy of database is not sufficient, the results are too heterogeneous.

At the first side, this cartogram can be choking and politically incorrect but it shows the importance of our implicit point of view of **our habit of geographical system of reference**. But it is the interest and the goal of that method to show clearly the imbalance.

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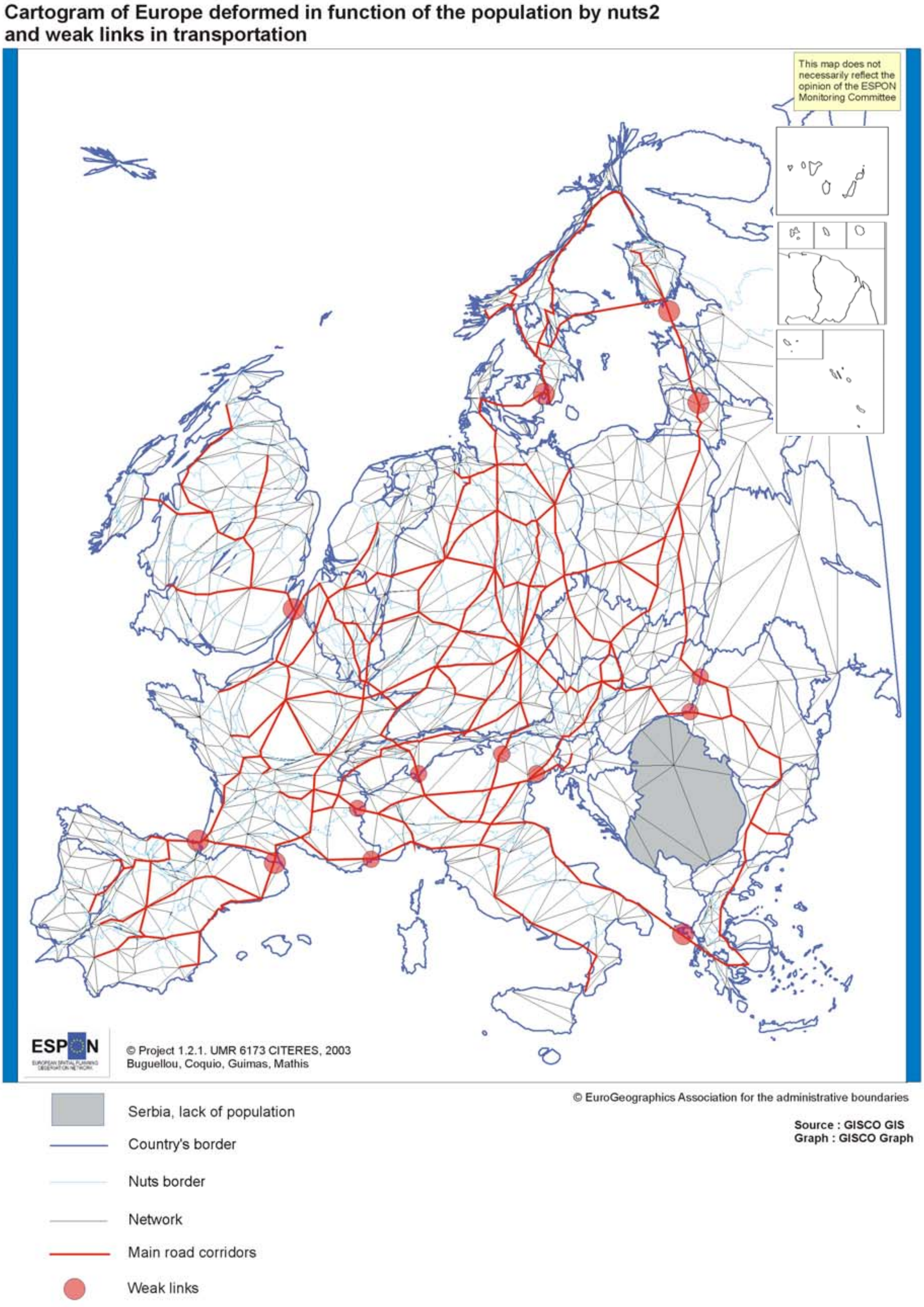
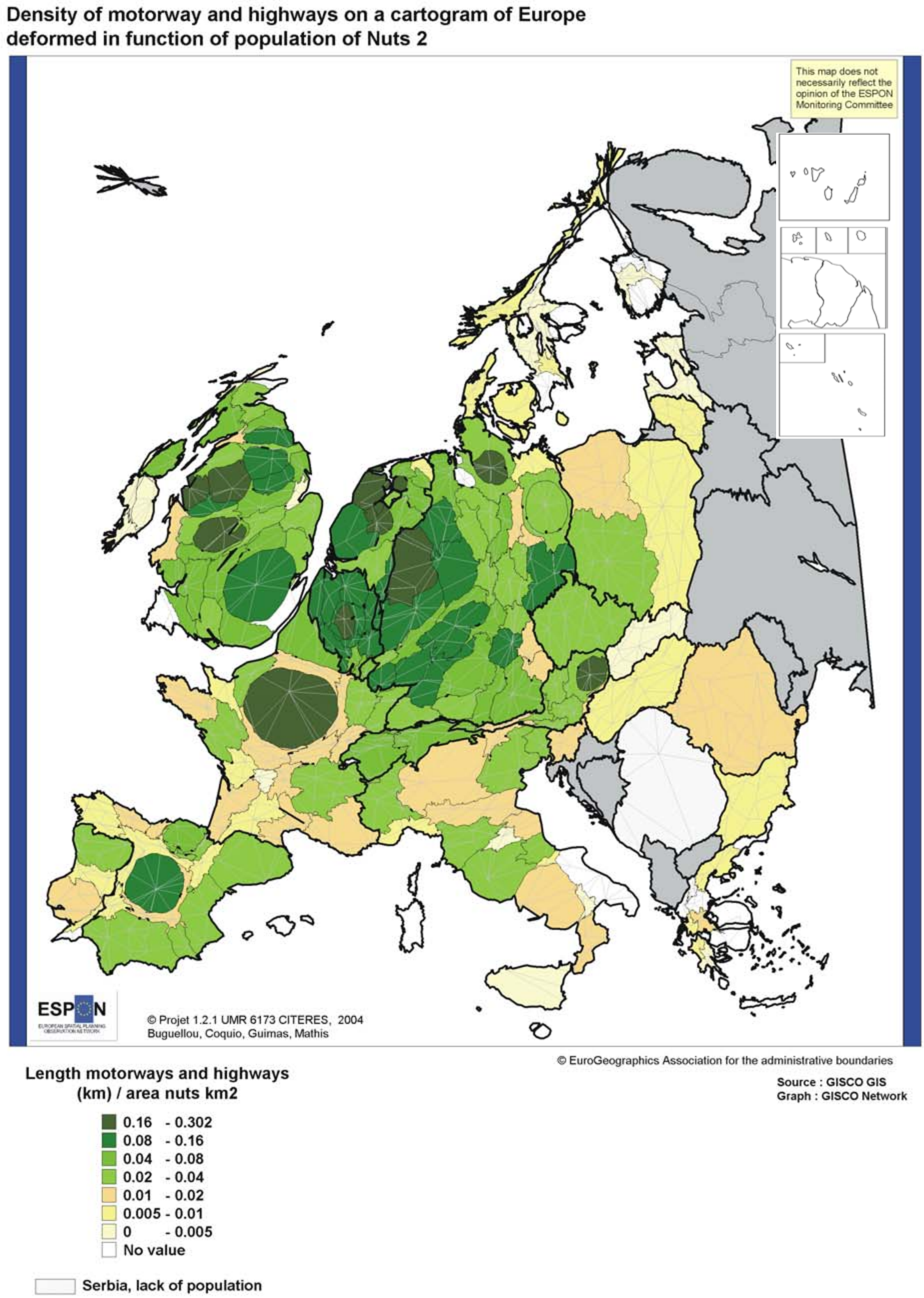
[63] See part 2 chapter 4.2



Map 20 Cartogram of Europe deformed in function of the population by NUTS2 and weak links in transportation



Map 21 Density of motorways and highways on a cartogram of Europe deformed in function of population by NUTS2

2 Travel times and costs

2.1 Connectivity to basic transport networks

Rationale and policy relevance

The ICON (Index of Connectivity to basic transport networks) is defined for a given location as the minimum access time by road to the closest nodes taking into account the utility that these nodes provide in terms of service (facility to access all possible destinations). It was applied in European studies since 1989 several times both for regional and transport strategic analysis.

ICON proposes a new approach in which more emphasis is given to spatial aspects such as the location and connection conditions of transportation nodes: The location of the transportation nodes, their hierarchy in the network to which they belong, and their connectivity with other scales and modes of transportation, constitute the key issues to analyse the coherence of the transport system as a network, and the new geography of proximity, so to speak, it creates. These aspects are the more relevant ones creating urban and regional development opportunities and, furthermore, inducing specific patterns of urbanisation. Therefore, there is a correlation between urbanisation and connectivity: zones with high ICON values use to be urbanised and zones with low ICON use to be rural; in between, zones can be classified as suburban, periurban or rururban.

Method

ICON, in a point, is evaluated as an aggregation of the values (ICONi) obtained independently for each considered transportation network (i=1...N). These modal values (ICONi) are aggregated in proportion to their relative contribution to regional transportation endowment. The relative weight of every transport mode (pi) can be evaluated according to a measure of their impact on economic development (See part 2 Chapter 4.3 for the detailed formulation).

$$iCON = \sum_{i=1}^{i=N} p_i \; iCON_i$$

For each transport mode (i), ICON (i) is a time value which lies between the road access time to the closest transport network (road entrances, rail stations, commercial airports and seaports) with a minimum acceptable level of service (So) and the road access time to a transport network providing an adequate level of service (Sx). If the closest transport network provides a service Si≥Sx, ICON (i) is the time to reach it. If this is not the case, ICON (i) will be a weighted average of the times to reach the next transport networks (providing S>Si), until one with the adequate service level is reached.

The model used to calculate the ICON (Bridges/NIS) uses centroids of NUTS3 as origins and transport terminals (road access, rail stations, commercial airports and seaports) as destinations. It calculates the time to reach the transport network with a minim and a maximum service already defined as a parameter (see Table no. 3.2) using the road network. Once the indicator is calculated for each node (the value reaches a maximum value of 3 hours), it has been diffused according to the speed of the road links in a grid covering all ESPON space of 2 x 2 km cells.

Transport networks	So	Sx	Pi
Road network	85 km/h	100 km/h	55
Rail network	75 trains/day	100 trains/day	15
Commercial airports	0,5 Mpass/year	15 Mpass/year	20
Commercial Seaports	0,5 Mtonnes/year	10 Mtonnes/year	10

Source: ESPON Project 1.2.1, Mcrit

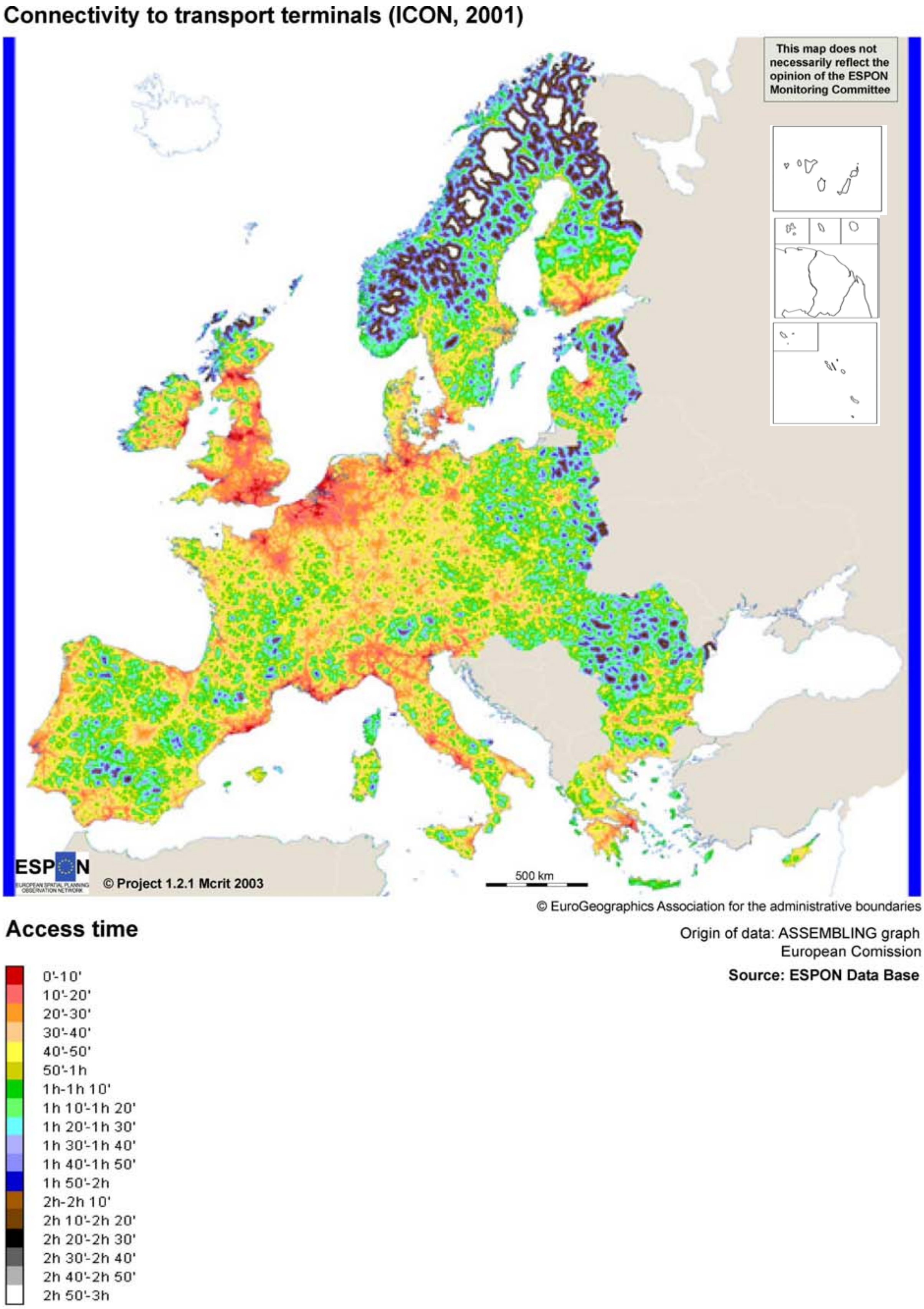
Table 14 Services and weights

Data requirements

The basic data needed to calculate this type of indicator is a transport multimodal network at European level. The transport network used is from ASSEMBLING road graph (explained in part 3 chapter 1.2) with all transport terminals represented as nodes and connected to city nodes by specific road and rail connectors. The airport database contains millions of passengers per year, the port database contains millions of tonnes per year, road intersections contains the maximum speed of the road links that intersect in it and rail stations database contains the number of trains per day.

Application and results

The connectivity to basic transport networks has been calculated for all NUTS 3 centroids of the ESPON space using road transport network in 2001. The highest connectivity is to be found in the more dense urban areas and their metropolitan regions. Coastal regions with good serviced ports show a higher connectivity than some important inland urban areas, as this increases the global utility of the network (ex: Madrid and Barcelona). Finland and Sweden show the lowest connectivity in the EU15 countries (except from the metropolitan areas of their capitals) due to the isolation of their NUTS3 centroids.



Map 22 Connectivity to transport terminals

2.2 Access to motorway entrances

Rationale and policy relevance

As connectivity to transport terminals, the cost to motorway entrances follows the same rationale as described in the previous section. Roads, and specially motorways and expressways, are the basic providers of accessibility and in most developed and populated regions they constitute the basic transport network. In some countries in EU, the geographical distribution of motorways is linked to population and wealth, with policies to provide the whole territory with a certain level of access to motorway network in order to support long-distance traffic and to allow better integration between the regions.

Method

The variable represented is the minimum value to reach a road entrance that gives a service equivalent of a 100 km/h speed by car, which is the maximum level adopted for road entrances services.

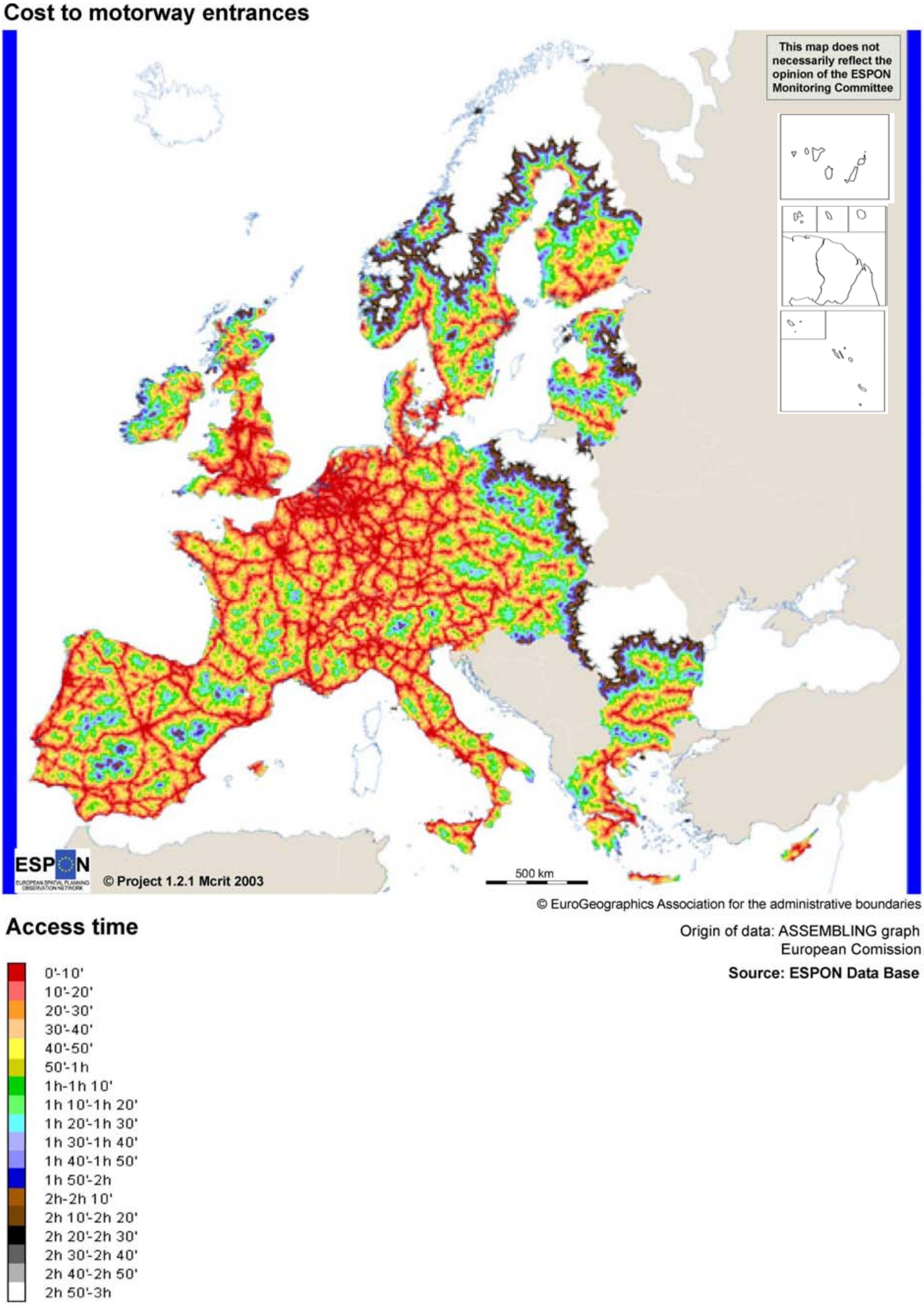
Data requirements

The data requirements are the same to the previous requirements, but only considering as transport nodes the road entrances. The services of each road entrance depends on the maximum speed of the road links available from it.

Application and results

The access to motorway access has been calculated for all NUTS3 regions of the ESPON space and it gives an overview of the location of road entrances of roads with at least a speed of 100 km/h, as well as the regions with lack of this type of road infrastructure. There is a clear distinction between eastern countries and EU countries, especially those in the EU centre (The Netherlands, Belgium and the west of Germany) that is served by a dense motorway network.

It has to be noted that nearly all country capitals in the EU are linked with a motorway network. This does not happen in certain isolated areas, particularly on the EU periphery and on the EU borders with the accession countries, and even between these countries (Poland, Romania and Bulgaria), where some missing links still have to be filled in.



Map 23 Cost to motorway entrances

2.3 Access to rail stations

Rationale and policy relevance

As connectivity to transport terminals, the connectivity to rail stations follows the same rationale as described in the first section of this chapter.

Method

Following the connectivity to transport terminal method, to calculate the connectivity to rail stations, the same method in the first section of this chapter has been applied here.

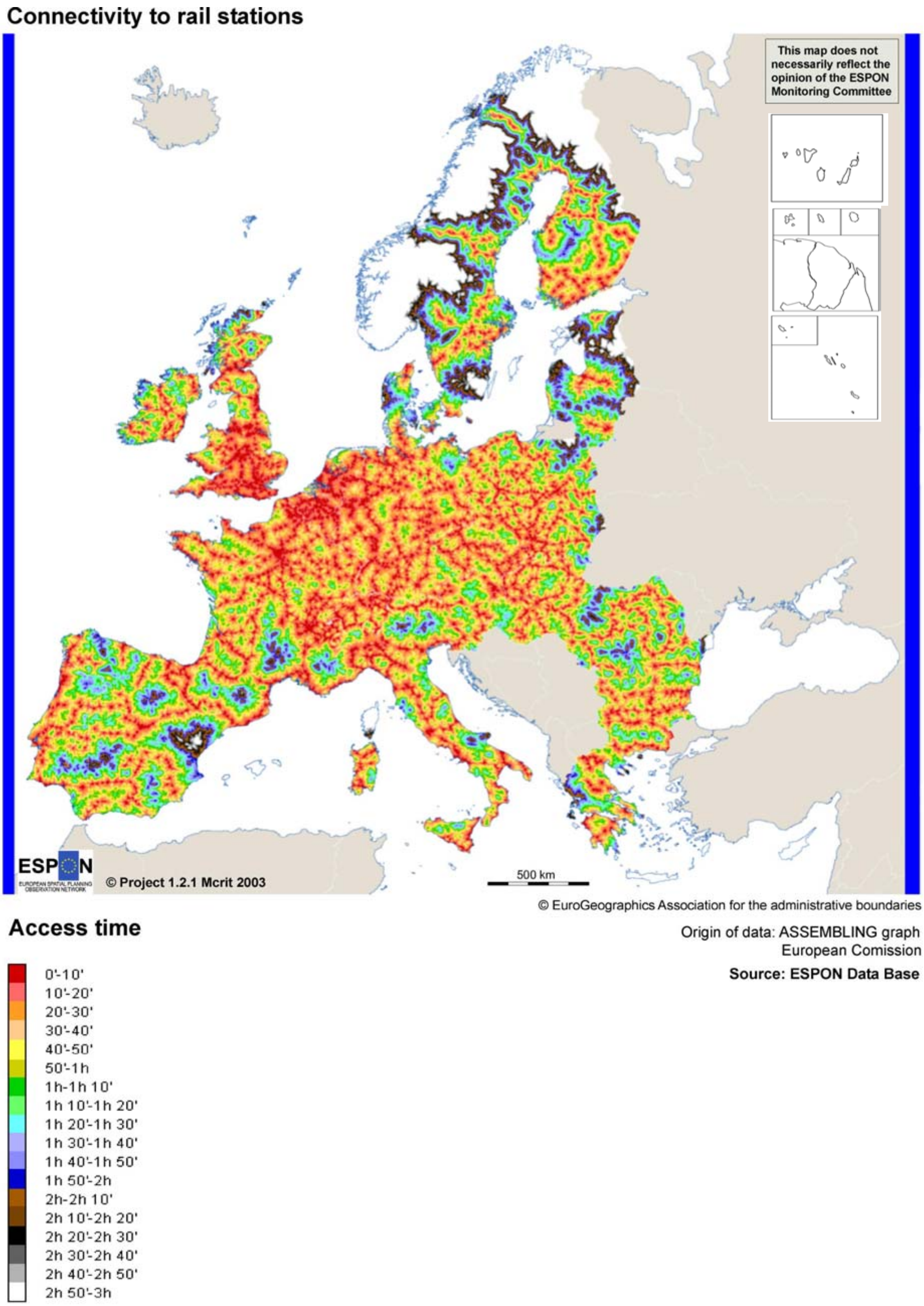
ICON (rail) is a time value which lies between the road access time to the closest rail station with a minimum acceptable level of service (So) and the road access time to a rail station providing an adequate level of service (Sx). If the closest station provides a service Si≥Sx, ICON (rail) is the time to reach it. If this is not the case, ICON (rail) will be a weighted average of the times to reach the next stations (providing S>Si), until one with the adequate service level is reached. The service of a rail station is considered in terms of interregional trains that depart from it.

Data requirements

The data requirements are the same to the previous requirements, focused only in railway stations.

Application and results

The connectivity to rail stations has been calculated for all NUTS3 regions of the ESPON space. Unlike the access time to road motorways, Eastern countries have a similar connectivity to rail stations with at least 75 interregional trains departing per day than that of some EU15 countries.



Map 24 Connectivity to rail stations

2.4 Access to seaports

Rationale and policy relevance

As connectivity to transport terminals, the connectivity to commercial seaports follows the same rationale as described in the first section of this chapter. Ports and their hinterlands are strongly connected. Big vessels calling at ports stimulate the development of the hinterland's railways, roads and inland waterways. This also works the other way, when a well-developed hinterland will attract the big vessel to their ports.

Method

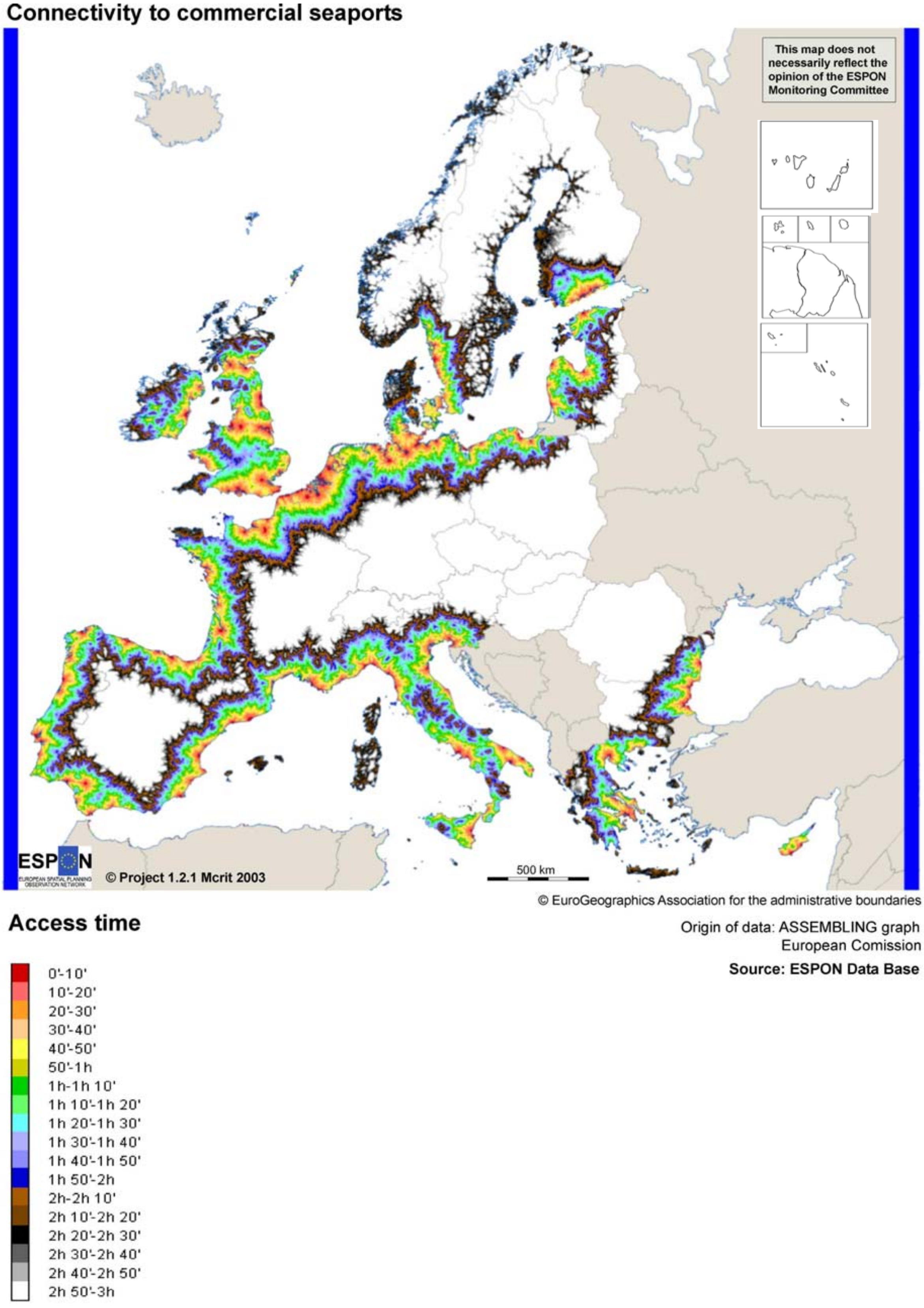
Following the connectivity to transport terminal method, to calculate cost to commercial seaports, the same method in the previous section has been applied here.

Data requirements

The data requirements are the same to the previous requirements, but only considering commercial seaports and its services.

Application and results

The cost, in hours, to commercial seaports has been calculated for all NUTS3 regions of the ESPON. The map represents the hinterlands of each seaport in 1 hour (red and yellow coloured cells) and up to 3 hours (green to black coloured regions). Nearly most of coastal regions, except Scandinavian ones (with small fishing seaports), have good seaport infrastructure, although the hinterland changes depending on the road network to access to it.



Map 25 Connectivity to commercial seaports

2.5 Cost to commercial seaports by truck

Rationale and policy relevance

Cost to commercial seaports by truck is a basic indicator of economic integration and regional accessibility. It is an indicator of the potentiality of a region to produce intermodal transport, in parallel to rail, to drive freight to the nearest port. Road freight transport has the advantage in front of rail that it has less interoperability problems for long-distance trips when crossing borders.

It also regards the regions where the location of inland terminals could be viable in order to practice combined transport (road combined with an alternative transport modal solution, like rail, then to the port).

Method

The model used to calculate this indicator uses centroids of NUTS3 as origins (the capital if identified and the geometric centre if not) and commercial seaports with a minimum of 0,5 Mtonnes/year in ESPON space as destinations. It calculates the minimum time to reach the nearest seaport and using the road network in 2001. The speeds linked to the road network are speeds by car without capacity constraints reduced into 80% its value if the free speed by car is higher or equal than 85 km/h and to 70% if it's lower than this value (see table no. 3.1). The maximum time that a truck driver can drive and the rest time have not been considered.

Type of road	Speed by car (km/h)	Speed by truck (km/h)
Local road	50	35
Regional road	50	35
Main road	70	49
Express-road	85	68
Motorway	110	88

Source: ESPON Project 1.2.1, Mcrit

Table 1 Speed by car and truck in road links

Data requirements

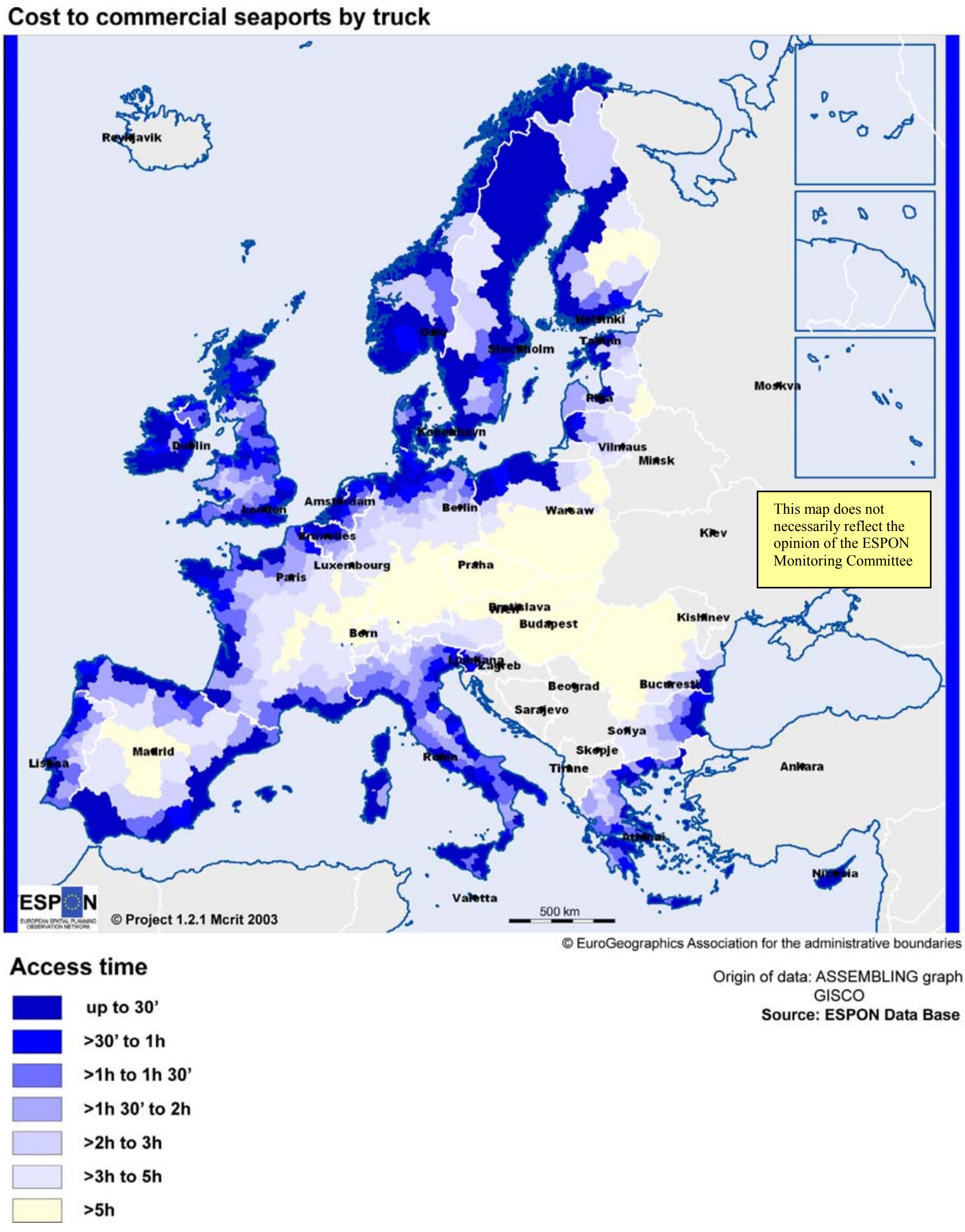
The data requirements are the same to the first section of this chapter.

Application and results

The cost, in minutes, to commercial seaports has been calculated for all NUTS3 regions of the ESPON.

Coastal regions and islands have a good connectivity to seaports. As seen in part 3 chapter 7. There are ports nearly everywhere in the coast. Compared to the figure in the previous chapter, the hinterland of 3 hours by car of the seaports is larger because here the capacity of the seaports is not considered. For example, most of Scandinavian regions, and Corsega and Sardinia, except from the ones with the respective capitals, have a more than three hours connectivity to a seaport with a good service. Instead these regions have a seaport nearby, independently from its characteristics.

Some regions near hub ports in non-European countries, like eastern regions in Leetonia to the Riga port, have a high cost to port due to the lack of motorways and expressways network.



Map 26 Cost to commercial seaports by truck

2.6 Access to airports

Rationale and policy relevance

Connectivity to airports follows the same rationale as connectivity to seaports.

Method

Following the connectivity to transport terminal method, to calculate the connectivity to commercial airports, the same method in the first section of this chapter has been applied here.

Data requirements

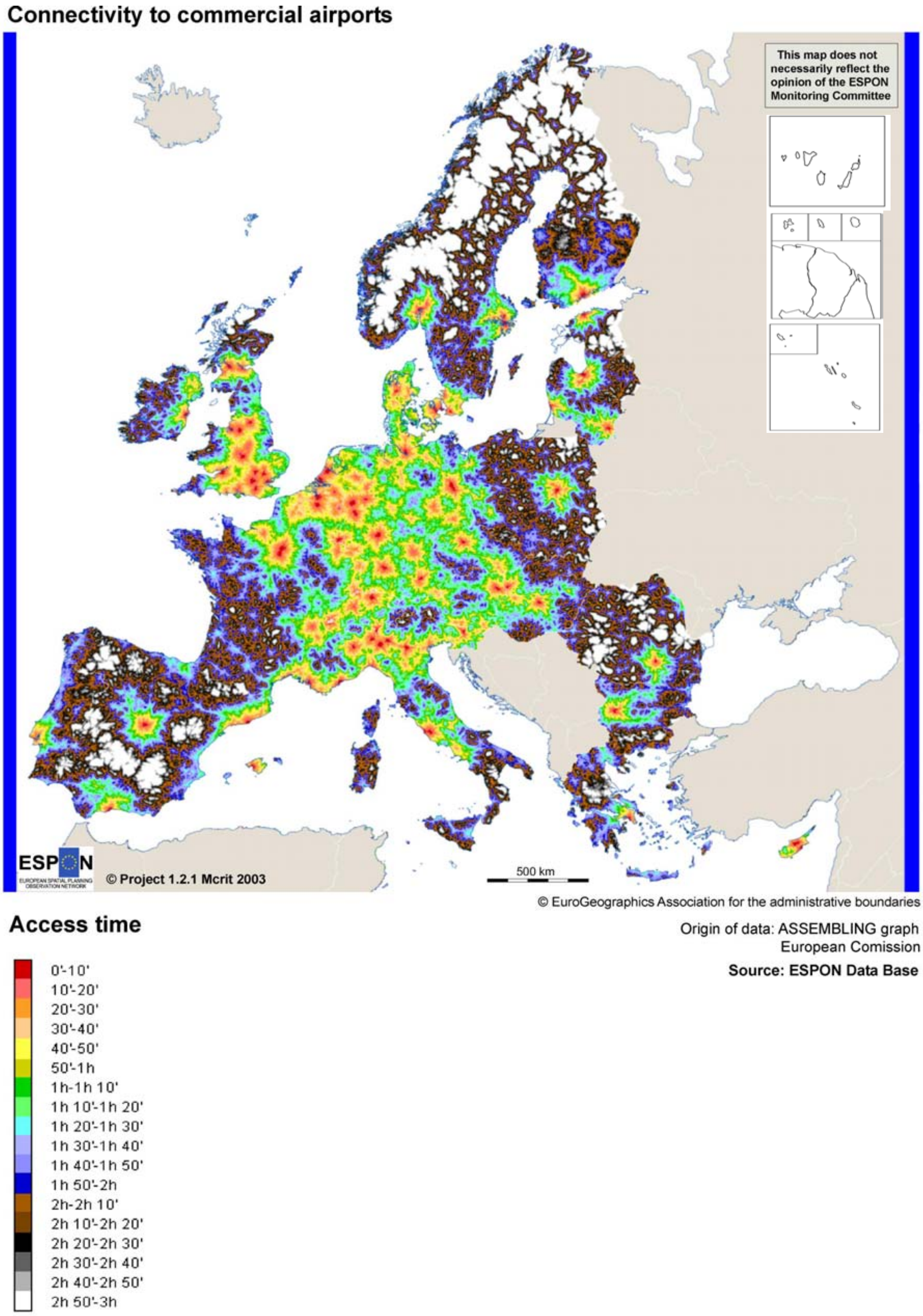
The data requirements are the same to the first section of this chapter, but only considering commercial airports.

Application and results

The cost, in hours, to commercial airports has been calculated for all NUTS3 regions of the ESPON space.

The map represents the hinterlands of each airport in 1 hour (red and yellow coloured cells) and up to 3 hours (green to black coloured regions). In EU centre countries, major airports with good services are spread through all the territory. This is not the case of the peripheral EU countries like Spain, Sweden and Finland, and either to the accession countries, where the hinterlands are small and are surrounded by inefficient connected regions. An extreme case happens to the Scandinavian countries where only the metropolitan areas of each capital are well connected to good-serviced airports; the rest of the territory is hardly connected.

It seems as if in accession countries main airports do not act as hubs of secondary hubs spread around the rest of the territory.



Map 27 Connectivity to commercial airports

2.7 Time for road freight transport

For road freight transport the constraint of time does not only arrive from driving time. European regulations about driving time and resting time must be taken into account. These regulations have been harmonised in Europe and the strengthening of their application, the use of electronic speed recorder on board are among European policy priorities not only for social reasons and harmonisation of social conditions but also for safety which has become a major topic of national and European policies.

Method

One calculates times of paths for heavy truck from point to point on the network. These times correspond in minimal paths in minutes. One considers that the average speeds depend on the quality of the infrastructure and the relief (altitude or slope). The speeds retained are the following:

- motorway: =75 km/h,
- dual carriage: 70 km/h,
- main other road: 60 km/h,
- other road (secondary network): 40 km/h.

These speeds can be reduced according to the slope (when data are specified) or according to the altitude of roads.

Besides, the relations with the ferries are raised on average of 6 hours in a first time, we will introduce a time of waiting proportional at the frequency for every relations.

We also take account the time of waiting border cross, notably between countries candidates and the other countries of the East. This time is on average of 24 hours for the trucks, nevertheless this time varies meaningfully according to borders. Later, this time of waiting will be value according to the countries.

We integrate for the minimal paths the legislation on times of truck driver. The European regulation 3820/85 of 12/20/1985 concern times of driving and rest. The following diagram exposes this times.

Cycle of driving:

Time of driving 4h30	Time of stop	Time of driving 4h30	Time of rest 9 h	Time of driving 4h30	Time of stop 45 min	Time of driving 4h30

This cycle is completed by a specific disposition that concerns the definition of the time in ferries or trains. It specifies that the time of rest can be interrupted one time if:

- A part of rest is taken before or after boarding ;
- The time of interruption does not exceed 1 hour;
- The driver has a bed on the train or the ferry;

If these conditions are respected then the time of rest is increased of 2 hours.

Data requirements

We have need to value the average speed by link, the slopes or the altitudes. Besides the quality of the road network is very different between countries notably for candidates. Two roads of similar quality in Gisco can present a reality very different in term of speed. It is why we have need of more detail on the real quality of roads.

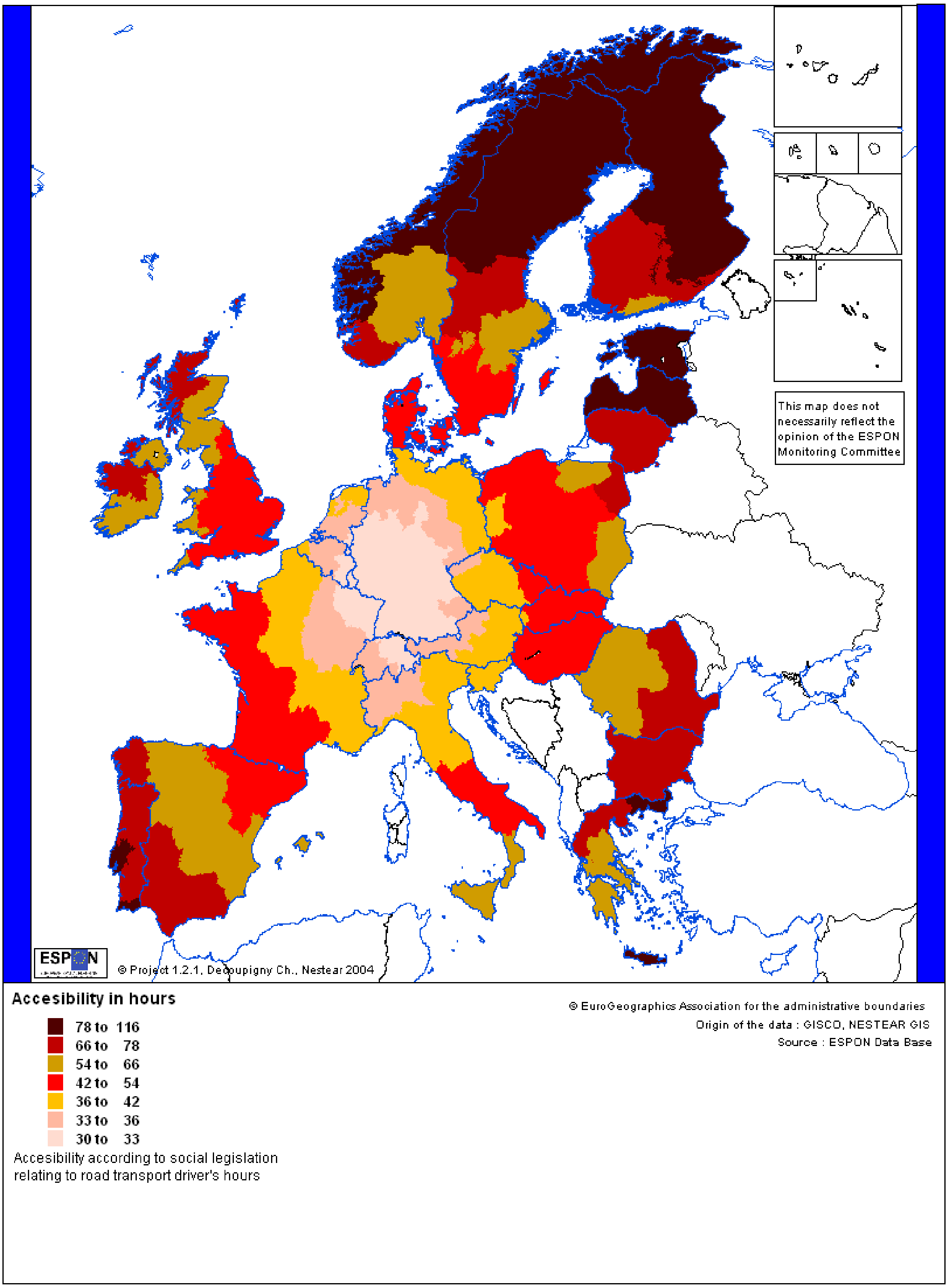
Demonstrations example.

The following maps show the accessibility door to door by truck according to social legislation relating to road transport driver's hours. The accessibility take into account the Ro-Ro services in Europe. The results are aggregated by NUTS level 3 and we consider that the European legislation is the same for all countries (members and candidates).

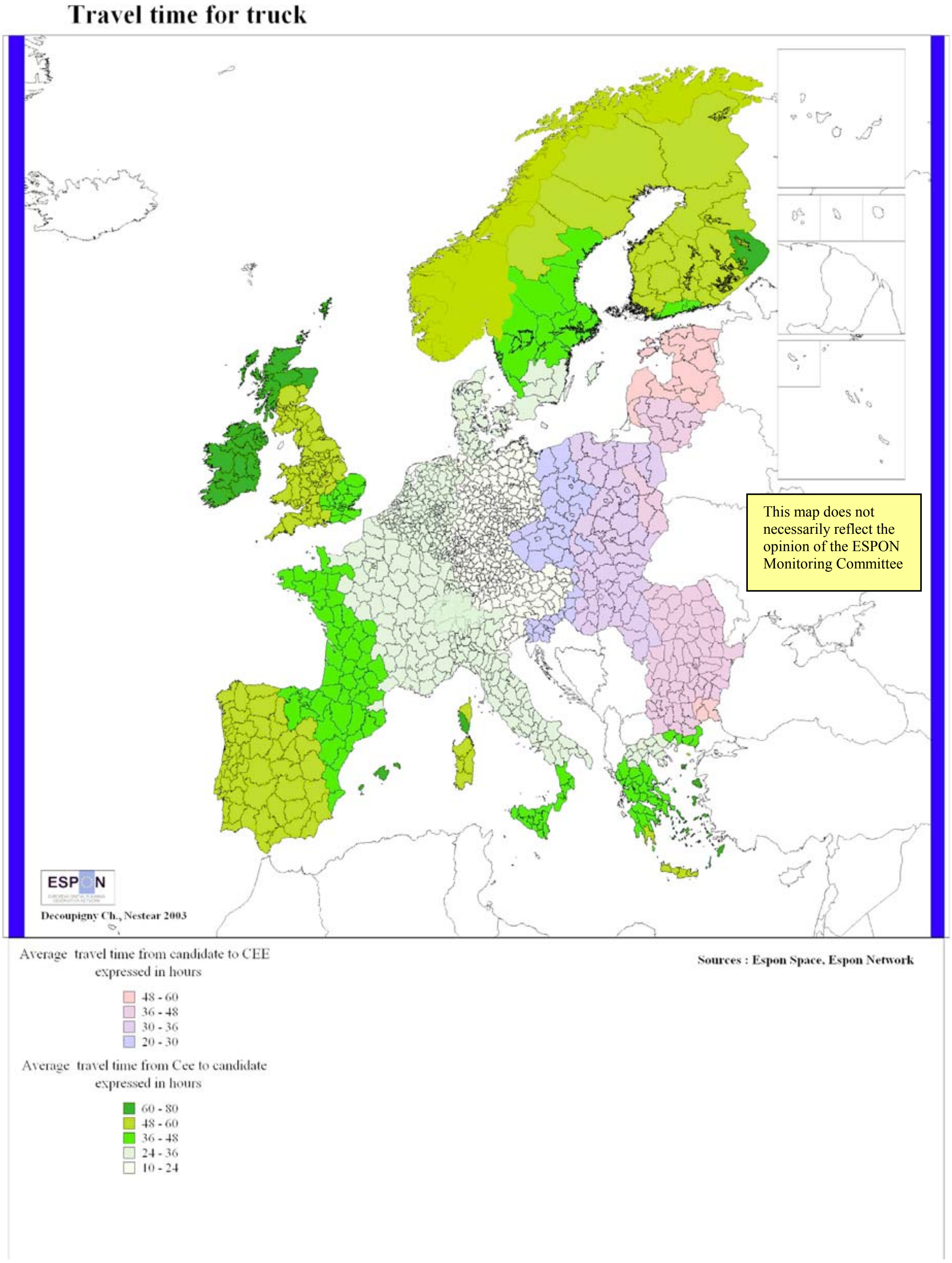
The first map shows the average accessibility, the second shows the average travel time for trucks from candidates to members and from members to candidates.

We can to observe (in relation to the CEE) that the peripheries as the Greece, the Finland or Suede seems less distant to this space to 27 countries whereas Portugal and Eire are more and more distant

Average accesibility by truck



Map 28 Average accessibility by truck



Map 29 Travel time for truck

2.8 Cost for freight road transport

Method

We use costs established by the Road National Committee (CNR) on the basis of investigations done every year that corresponds to conditions of average exploitation for different types of vehicle. We refer to the vehicle of 40 tons, doing transportation to long distance.

To calculate costs of exploitation of reference of these trucks, the CNR keeps three terms corresponding to the conditions of average exploitation:

- Euro by kilomèter: Ek ;
- Euro by hour of conduct done by the driver: Et;
- Euro by day of exploitation: Ej.

With times of journey (calculated in travel time) and of the minimal paths (used for the assignment), we know the distance Dp, the total time Tt put by a heavy truck to join two points (that understands times of rest and times of conduct Tc). The cost C becomes:

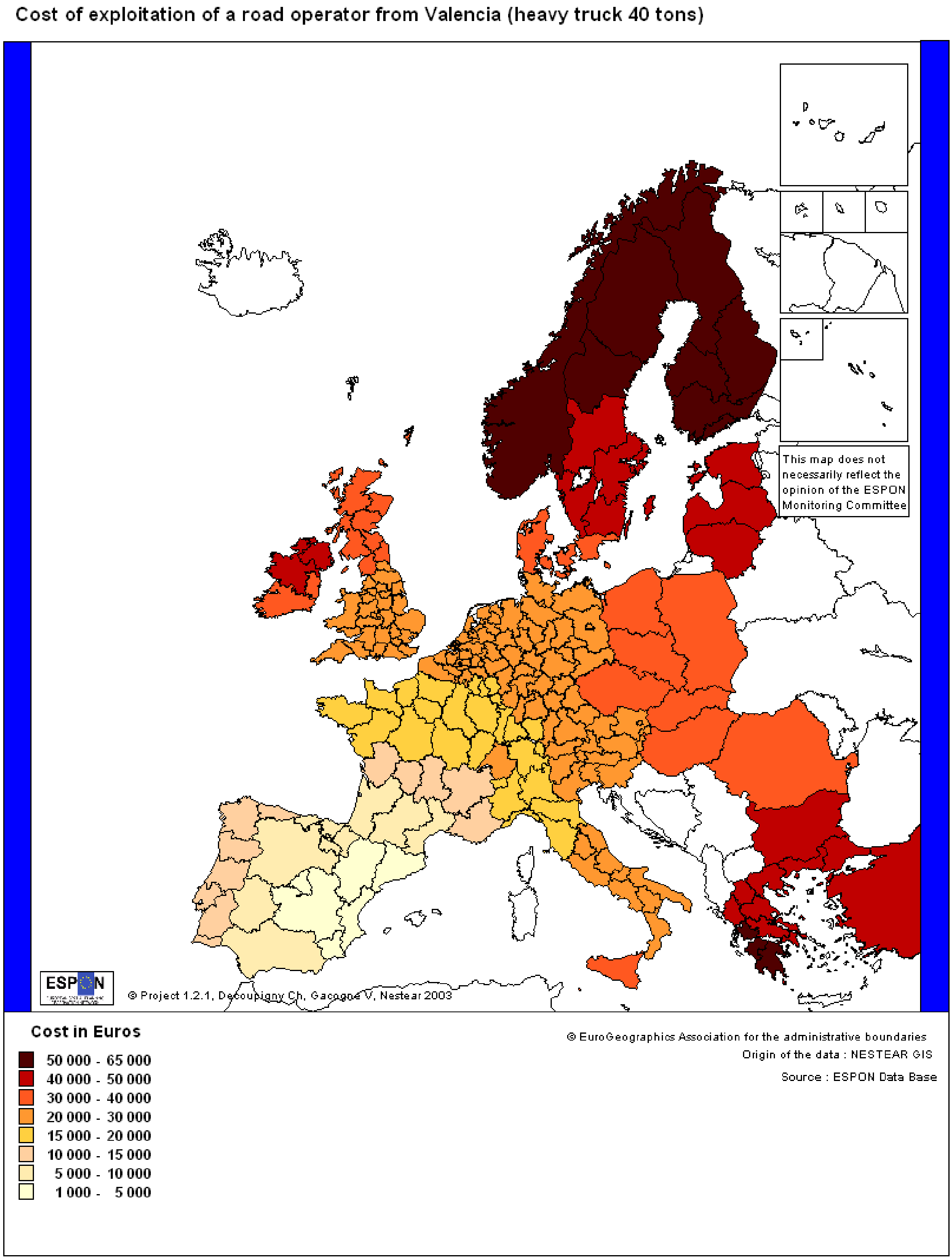
$$\text{C in Euros} = Ek * Dp + Et * Tc + Ej * Tt$$

Data requirements

The data requirements are similar to the previous requirements. Besides we need the toll definition for motorway section.

Demonstration example

The following map shows an example of cost in euros for the use of a truck from Valencia to the other countries. The cost is given in this example by region NUTS2. It is a representation of the cost of the truck travel time.



Map 30 Cost of exploitation of a road operator from Valence (for a heavy truck of 40 tons)

2.9 Travel times by air or rail between MEGAs

Rationale

What form of transport could support the development of 'city networks', and what form of accessibility indicators could help to evaluate the performance of the transport systems in terms of the policy objective of polycentrism?

The use of nodal indicators is necessary to guarantee a global level of accessibility in each centre of the polycentric pattern. But the links in the city networks also have to be assessed specifically, beyond the isotropic approach of the nodal indicator. The functioning of a city network supposes the activation of a limited set of links in which each city is at least connected to its closest neighbours.

Method

At the continental scale, two systems of mobility can be identified: firstly the sphere of daily mobility articulated around the trips between homes and workplaces and strongly constrained by individual time budgets, and secondly the sphere of occasional mobility for business purposes, operating at longer distance than the previous one. For a satisfying functioning of a city network at the European scale one can wish to specially support and develop this second level of mobility.

In a first approach we will consider the relations in one hour or less by plane as a necessary level of quality to support the polycentric city network. This criterion can be used to define a minimum service provision for the functioning of city networks and applies on the links in the network.

We need a definition of the European urban network to assess the quality of the relations inside this spatial network. The definition of this network is based on the work done in the ESPON theme 111 on polycentrism, but including modifications in the list. In reference to the CRPM studies it is possible to propose a modified list of MEGAs that would allow a better geographical coverage of the ESPON space.

We propose to reduce the number of MEGAs in the core of Europe, when the proximity of cities makes it hardly possible to distinguish them at the European scale. On the other hand we propose to add new cities, based on the CRPM analysis, with a particular focus on the peripheries.

Reduction of the number of MEGAs:

- Malmoe associated to Kobenhavn
- Rotterdam associated to Amsterdam
- Anvers associated to Bruxells
- Duesseldorf associated to Koeln

MEGAs introduced according to CRPM analysis:

- Bilbao
- Nantes
- Belfast
- Bristol
- Nottingham
- Leeds
- Newcastle
- Thessaloniki
- Genève
- Lodz
- Palermo
- Venezia
- Firenze

Data requirements

The data sources on the minimum flight time between the MEGAs is provided through a search on the major transport websites such as Amadeus[64] and the Deutsch Bahn website[65].

The data sources on the collective transport systems services reside in the information available on the major transport internet sites in Europe: Deutsche Bahn and Amadeus air transport database. The data collection is made through an automatised search on the websites. Extra data is used to connect transport nodes to cities, in order to attain a door-to-door approach.

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64 http://www.amadeus.net

65 http://www.bahn.de

Application to ESPON space

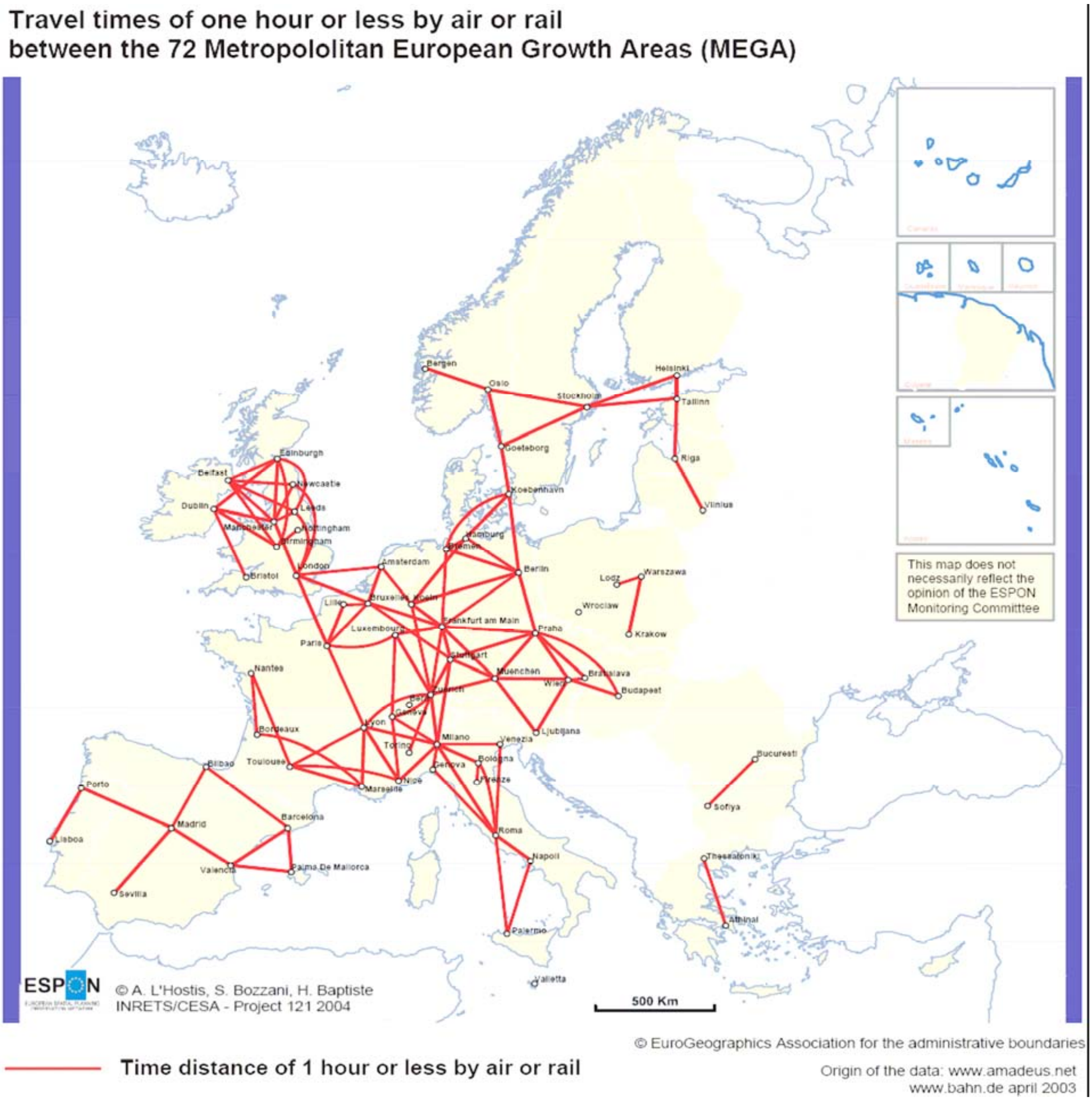
The map figures the existence of a minimum time flight or rail trip of one hour or less between the 71 MEGAs mixing the set of the 111 ESPON group and the CRPM set.

It must be stressed that the indicator is based on actual transport services: this means that the existence of a one hour relation is not only due to the strict time distance but also to the availability of a transport service. Consequently, cities quite close one another like Geneva and Lyon or Bruxells and Koeln display a lack of one hour relation when the rail relation is dominant, but takes more than one hour, or when no direct flight is available which greatly increase the trip duration. The indicator shows relations where direct flights exist or where high-speed connections in one hour or less are available like between Lille and Paris for instance.

The modification of the MEGAs list proposes a development of the one hour relations: the Italian network is improved especially with the introduction of Palermo and Venezia; the Iberic cities network is developed by the introduction of Bilbao but remains unconnected to France; connections in the British and Irish space are strongly developed by the addition of 5 MEGAs; the adding of Thessalonica allows to identify a one hour relation in the Greek territory.

This map expresses a factor of integration of the European territory. The connexity of the system of relations allows the continuity of one hour relations in the core of the continent from Rome to Edinburgh and from Bordeaux to Helsinki. The Baltic states are linked to the Union through relations between Tallinn and Helsinki and Stockholm.

According to that criterion, Poland, Romania, Bulgaria and Greece are poorly connected to the centre and poorly connected one to another. Furthermore, the Iberic peninsula has no one hour connection with the rest of Europe.



Map 31 Travel times of one hour or less by air or rail between 71 MEGAs in 2003

2.10 Travel time to MEGAs

2.10.1 Time to reach the nearest MEGA by trucks

Rationale

This indicator concerns the localisation of nodes relatively to the nearest European MEGA. It allows to determine the proximity (in time) to an important city at the European scale.

Method

Using the matrix of minimal paths between each couple of nodes, we calculate the travel time to reach the nearest MEGAS.

If we note {*ME*} the set of the nodes representing MEGAS,

N the total number of nodes

$\forall\ i \in [1, N]$, **MM***i* the value of the indicators presented in this part for the i^th^ node

for a giving *i* such as $i \in [1, N]$, we have

$$\mathbf{MM}_i = \min(T_{i,j}, j \in ME)$$

Data requirement

CESA graph 4172

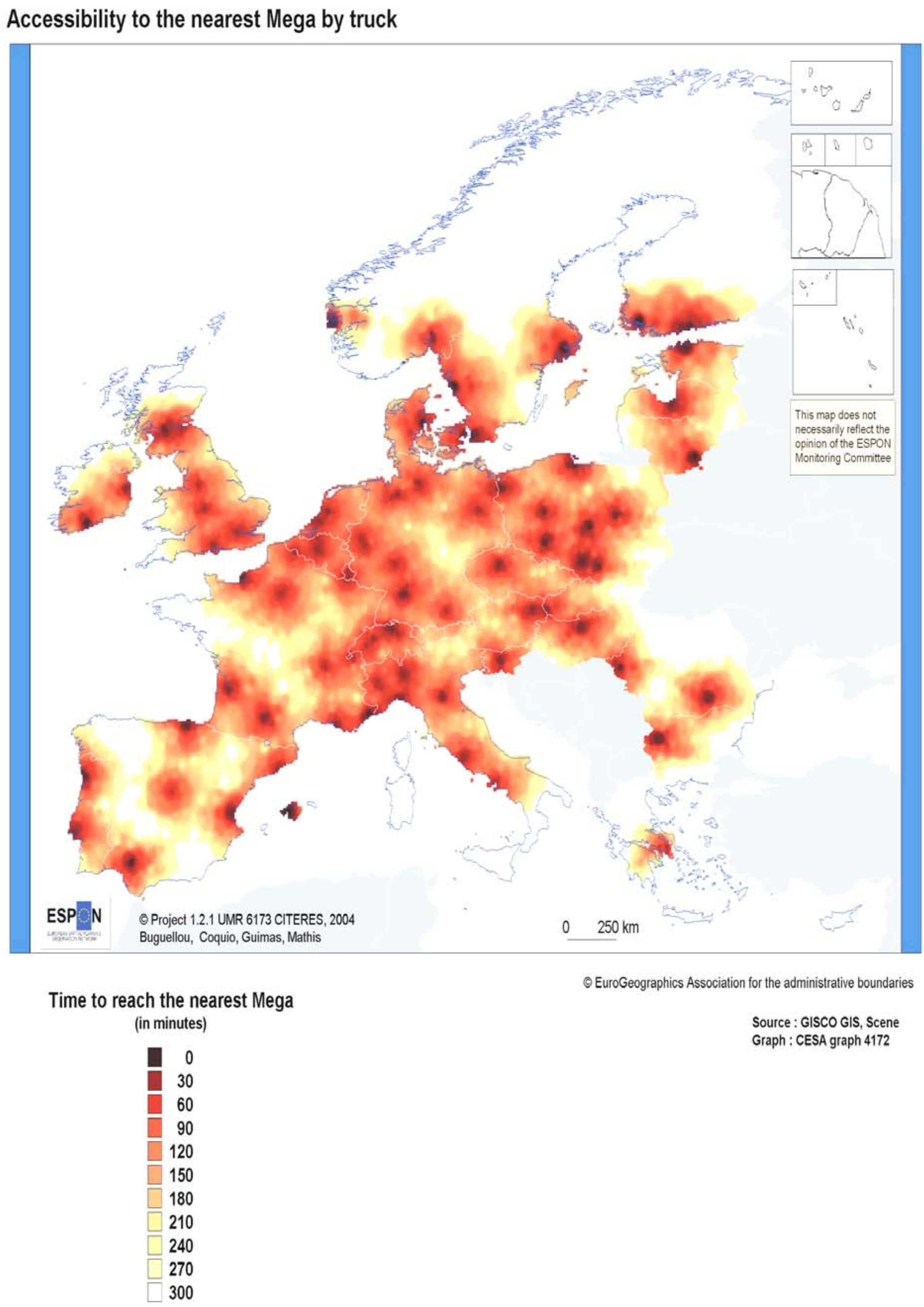
Minimal path matrix for trucks

List of European MEGAS furnished by the ESPON Group1.1.1

Application to ESPON Space

First of all, let us remind that the list of MEGAs depends on choices made by the Espon Group 1.1.1 and consequently, the results proposed here are highly linked to these choices. Indeed, the map would have shown a really different aspect if such cities as Nantes (in the West of France), Iasi (in the North of Romania), Thessalonica (in Greece) and Palermo (in Sicily) had been in the list.

Nevertheless, being aware of these considerations, some remarks can be made by the observation of the map.



Map 32 Accessibility to the nearest MEGA by truck

First of all, we can note that **some regions seem to be weakly accessible** to these MEGAs. The North of Scandinavia and Finland, the West of France, the boundary between Spain and Portugal, the Mediterranean islands, the North West of Greece, and the North of Romania present very high values concerning their travel time to the nearest MEGA. We can note that all these regions are located in **peripheral parts of Europe** where the network of important cities is less important than in the core of Europe. This phenomenon is probably a direct consequence of the unbalanced spatial distribution of MEGAs all around the European territory.

Secondly, we can nearly see the **"Blue banana"** going from Milan to London and presenting a high number of MEGAs (Milan, Stuttgart, Zurich, Brussels...). But if we look more precisely, we can observe that this dark area (according to the chosen typology of colours) does not exactly have the classical form of the "banana". It is a bit deformed, with **an extension to South and West** up to cities such as Marseille and Nice in the South-East of France.

Thirdly, we can note the difference between **West and East Germany**, linked to the former partition of this country.

Finally, let us note the high accessibility to MEGAs of the main part of Poland, which presents values nearly as high as the core of Europe.

2.10.2 Average time to reach all the MEGAS

Rationale

This indicator concerns the localisation of nodes relatively to European MEGAs.

Method

Using the matrix of minimal paths between each couple of nodes, we calculate the average travel time to reach all the MEGAS.

If we note {*ME*} the set of the nodes representing MEGAS,

N the total number of nodes

M the total number of MEGAS

$\forall\ i \in [1, N]$, AM_i the value of the indicators presented in this part for the i^{th} node

For a giving *i* such as $i \in [1, N]$, we have

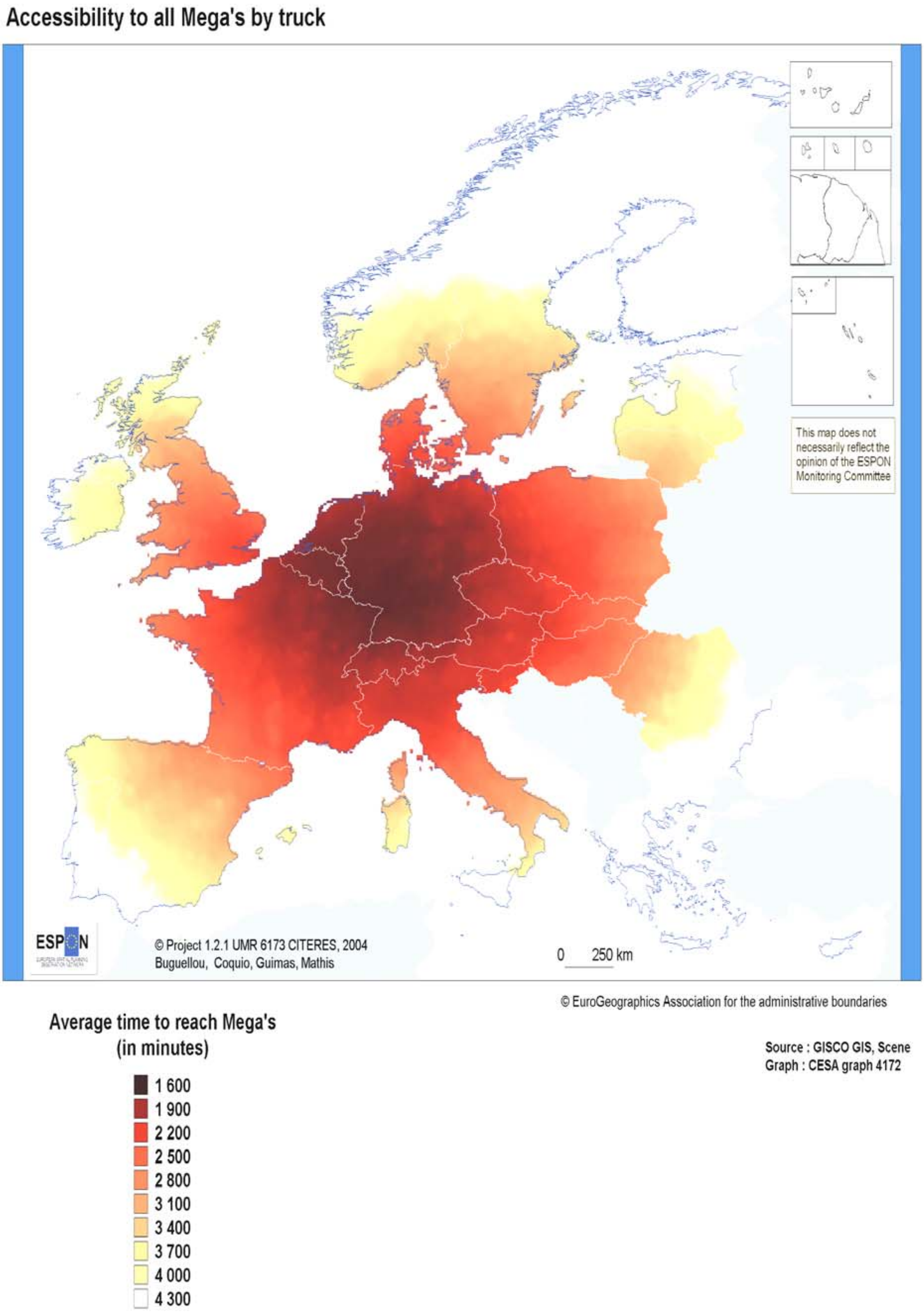
$$\mathbf{AM}_i = \frac{\sum_{j \in \{ME\}} T_{i,j}}{M}$$

Data requirement

CESA graph 4172

Minimal path matrix for trucks

List of European MEGAS furnished by the ESPON Group 1.1.1



Map 33 Accessibility to all MEGAs by truck

Application to ESPON Space

The map realized after the calculation of this indicator clearly shows **the importance of the geographical situation** of nodes for their accessibility when considering surface means of transport. Indeed, contrary to passengers who can in a certain way minimize the influence of their peripheral situation by taking air modes, the goods are highly dependent on roads and ferry lines[66] and so on, the accessibility of territories for their goods exchanges is dependent of their geographical position.

As a consequence, the various regions of Europe show very various levels of accessibility for this indicator. **The most accessible** parts of Europe are **Benelux, Germany and the East of France**. But this last region leads us to moderate our remarks about the geographical position. Indeed, the East of France presents its high degree of accessibility thanks to its proximity to the "the blue banana". So, the degree of accessibility here is also linked **to the distribution of the MEGAs** all over Europe. The geographical position of peripheral parts (mainly North Scandinavia and Finland, Greece) added to the lack of MEGAs leads to very high average times.

This map is coherent with the one presented in the part 5.5.1 "Potential accessibility by road" that seems to reinforce **the importance of MEGAs in terms of attractivity** and argument in favour of the validity of our method. The little difference between these two maps can be explained, by, in our case, the exhaustive consideration of all the MEGAs.

Finally, it is interesting to nuance these results. Indeed, if all the MEGAs have been taken into account, we have only considered them. Now, in an obvious way, they are not the single sources of emission/reception of goods. That is only a partial approach and be considered as it. The map about "Potential freight corridors from European maritime gateways" in the part 3 chapter 5.8.3 **completes this data**, adding the maritime port as strong areas of emission/reception for freight transportation. In this way **the importance of maritime transport** is taken into account, increasing the role of areas as the Eastern Spanish coast (including the major ports of Barcelona) or the South of Italy (with the ports of Taranto and Naples for example).

[66] We can add that the importance of geographical position is not minimized when considering inland waterways, which are not taken into account here. Nevertheless we can remind of the consideration of maritime ferry lines in all our calculation

2.11 Number of cities of more than 100 000 inhabitants accessible by cars by step of time

Rationale

This indicator gives an idea of the relative proximity (in terms of time accessibility) of European cities underline the network of cities.

Method

Using the matrix of minimal path between each couple of nodes, we calculate the number of cities reachable in a given time. Then we recalculate the result by step of 60 minutes.

We note {$\mathbf{C}_{100000}$} the set of the nodes of more than 100 000 inhabitants,

N the total number of nodes

$\forall\ i \in [1, N]$, $\mathbf{NC}_i$ the value of the indicators presented in this part for the i^{th} node

For a giving node *i* with $i \in [1, N]$, and a given duration t

$$\mathbf{NC}_i = \text{card } \{j \in [1, N] \text{ with } T_{i,j} \leq t\}$$

Note: card is the function cardinal that, for a given set gives the number of elements contained in this set.

Data requirement

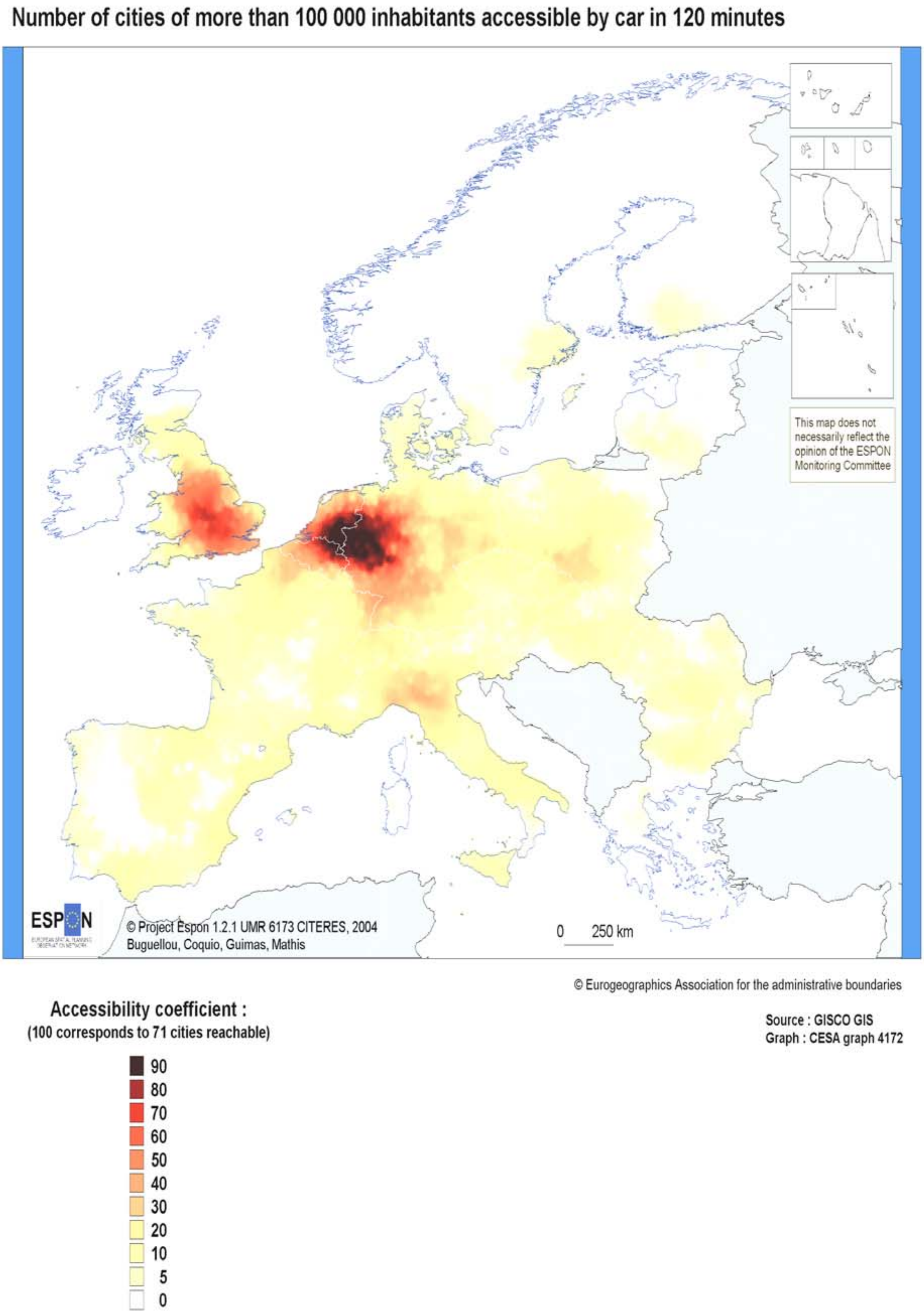
CESA graph 4172

Minimal path matrix for cars

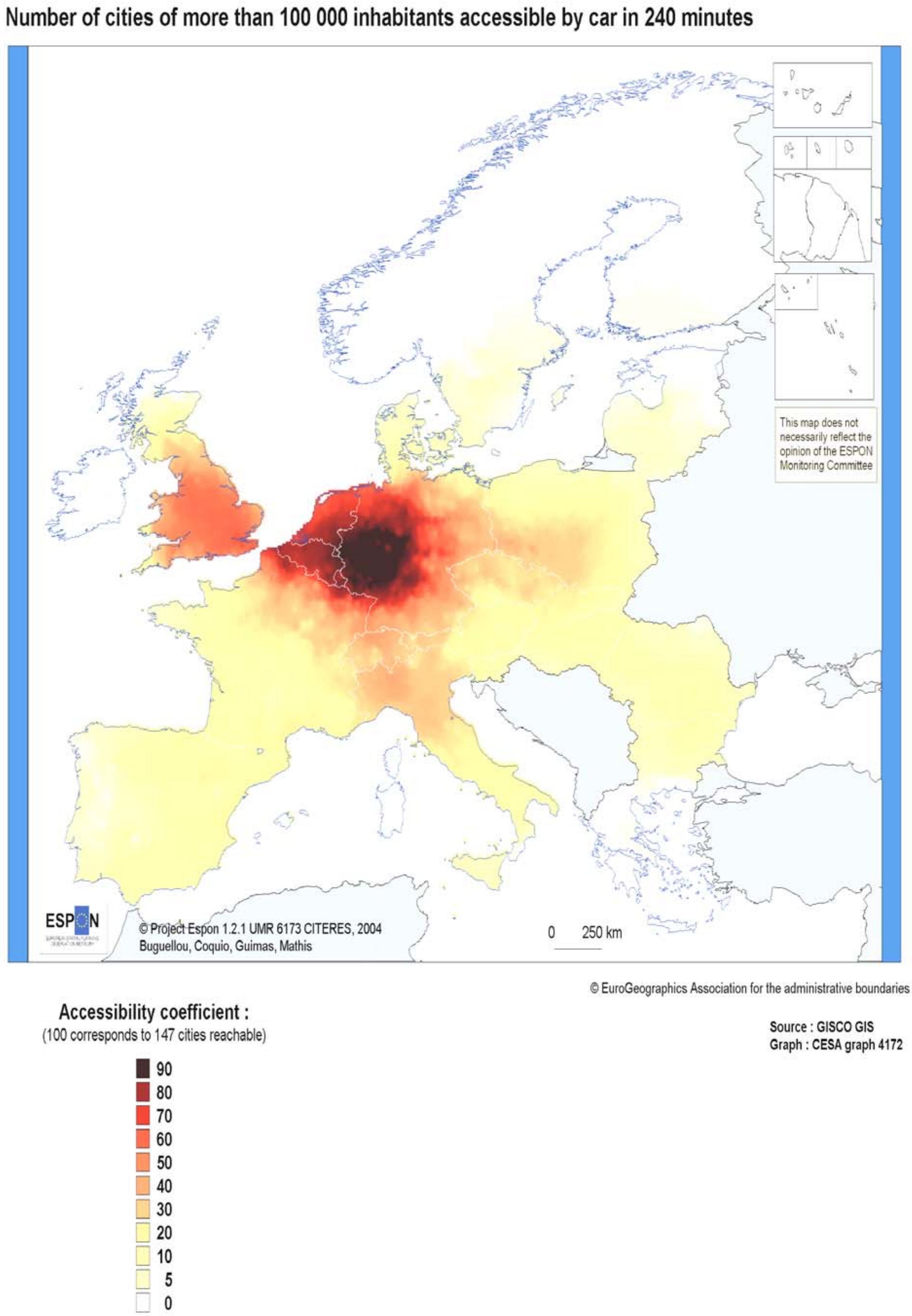
Application to ESPON Space

Accessibility by road seems to be characterised by a strong phenomenon **of distinction between centre and periphery**. **The core of Europe** appears in an obvious way on the maps in dark colours and grows little by little when the time considered increases, materializing the high level of accessibility of this area. The peripheral areas, such as Scandinavian countries, Finland, Greece, Portugal, Ireland Scotland or Southern Italy, are represented in pale because of the weak number of cities of more than 100 000 inhabitants. This phenomenon is readable whatever is the chosen time.

We present below the results for 120 minutes and 240 minutes. The other maps are available in the annexes.



Map 34 Number of cities of more than 100000 inhabitants accessible by car in 120 minutes



Map 35 Number of cities of more than 100000 inhabitants accessible by car in 240 minutes

Two explanations can be formulated:

First of all the differences between areas of the “blue banana” and other areas in terms of **spatial density of big cities** (without taking into account the transport and temporal aspect) mechanically drives the opportunity to reach more of these cities in a restricted area of diffusion. This explains for a part the level of this indicator for Great Britain, isolated in terms of transport because of its insularity, but with a high network of cities and a great density in the whole country.

Secondly, this distinction between centre and periphery is reinforced by **the local density of road infrastructures**, higher in the core of Europe This specific configuration of the network permits to go farer in a same period of time.

The conjugation of these two realities justifies our result, showing in an obvious and scientific way the existing unbalance between centre and periphery. Nevertheless, these results do not take into account the problems of reaching city centres, the congestion[67] and so, the high values for the core of Europe would have been moderated if these parameters could have been implemented in the model. What we can say is that the more the time considered increases, the more liable the results are.

Finally**, at a more precise scale**, the **specific geographical conditions** seem to play a major role. For example, the mountainous areas like the Massif Central, the Alps in Austria or the Carpates have a low accessibility, by contrast with river basins as in the Northern Italy with the Pô. The case of coastal areas is more contrasted, according to local particularities.

[67] The data for capacity problems are not avalailable and CESA graph 4172, though the important number of nodes, is not enough dense to allow a complete door-to-door analysis.

2.12 Time-space maps

Rationale

Time-space maps represent the time space. The elements of a time-space map are organised in such a way that the distances between them are not proportional to their physical distance as in topographical maps, but proportional to the travel times between them. Short travel times between two points result in their presentation close together on the map; points separated by long travel times appear distant on the map. The scale of the map is no longer in spatial but in temporal units. The change of map scale results in distortions of the map compared to physical maps if the travel speed is different in different parts of the network.

If one assumes equal speed for all parts of the network, the result is the familiar physical map. Time-space maps with equal speeds can be used as reference for the interpretation of other time-space maps.

Method

Time-space maps are created by transforming physical coordinates of a physical map into time-space coordinates. The transformation is calibrated in a manner that the distance between two points on the time-space map is in as close agreement as possible with the time distance between them. Because there are different speeds in the network, it is not possible to exactly reproduce the time distances of a time-space map in two dimensions. This would require a coordinate space with more dimensions. Time-space maps therefore can only be approximate.

Usually the technique of multidimensional scaling (MDS) is used for generating time-space maps. If the differences between a set of phenomena in one dimension (in metric or non-metric units) are known, the MDS technique generates a spatial configuration in multidimensional coordinate space of additional attributes of the phenomena such that the distances between the items are as close as possible to the known distances. MDS was developed in psychometrics in order to analyse, for instance, similar or different reactions of persons on multiple stimuli through visualisation in multidimensional space. Time-space mapping is an example of applying metrical MDS.

The calibration points may represent cities or other places, but they do not represent a complete map. Other map elements such as coastlines or borders have to be added. The time-space coordinates of the additional elements are not generated by MDS but by interpolation. The transformation of physical into time-space coordinates can be represented by displacement vectors or offsets in X- and Y-direction. These vectors indicate for each calibration node the transformation from physical to time-space coordinates. Offsets of additional map elements can be calculated by interpolation between the offsets of adjacent calibration nodes.

There are several problems associated with time-space maps. Technical problems include the possibility that the topology of the map is destroyed. For instance, if from a certain origin node a more distant node can be reached faster than a node closer by, the map will be 'warped'. Several modifications of the original method have been proposed to overcome that difficulty (Spiekermann and Wegener, 1994b). Conceptual problems are related to the fact that time-space maps show travel time reductions only for the most accessible nodes of the networks. What they do not show, or even hide, are the much smaller travel time reductions or even travel time increases in the areas *between* the nodes.

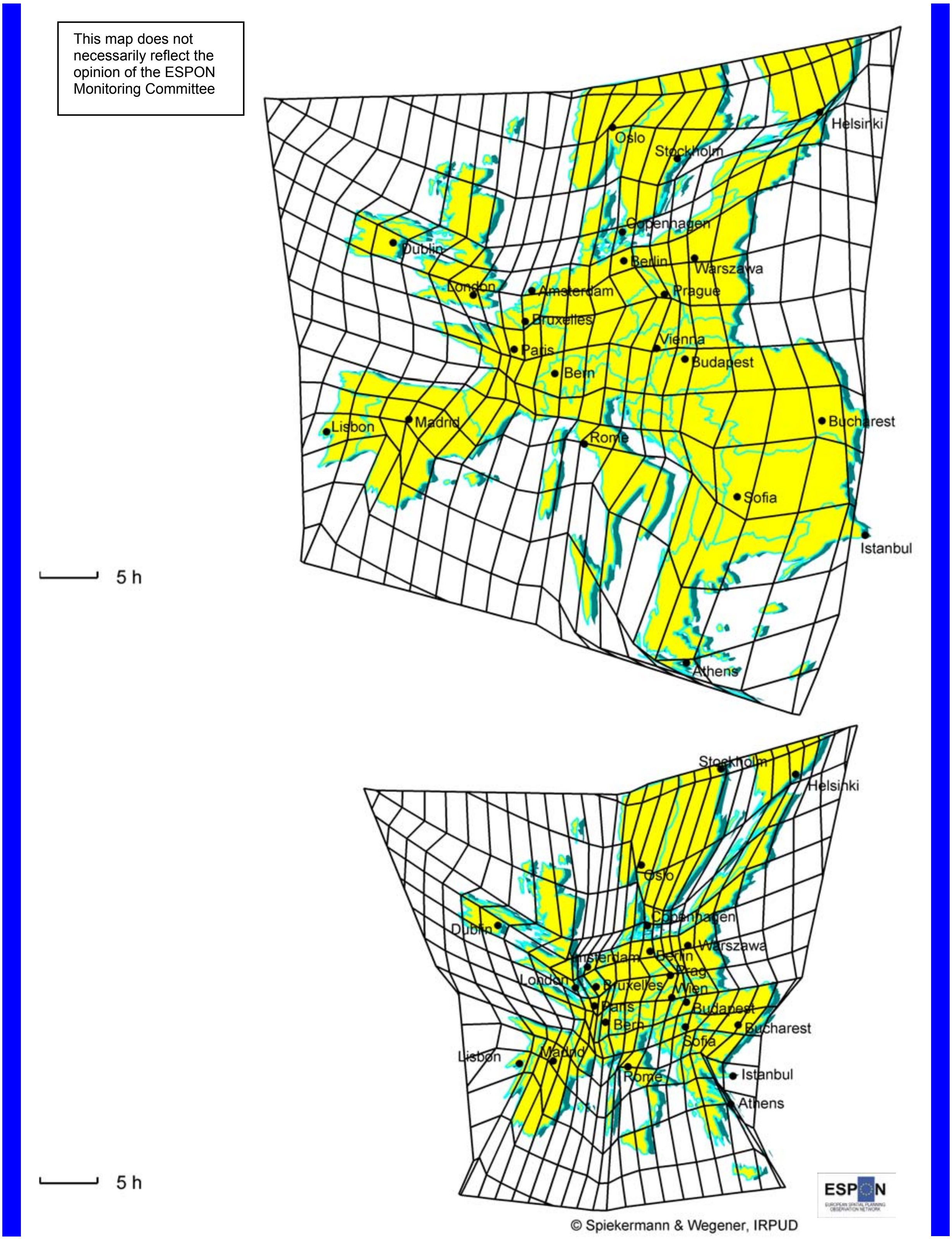
Data Requirements

To construct a time-space map requires two sets of data, usually maintained in a geographical information system (GIS): *network data* and *map data*.

- *Network data* consist of a set of calibration nodes with their geographical coordinates and the travel times between them over the calibration network. Travel time data can be current, historic or future travel times if the effects of network improvements on the time space are to be investigated.
- *Map data* consist of GIS data of other map elements besides the calibration network, such as locations of cities, coast lines or regions, i.e. all map features that are to be visible on the time-space map.

Application to ESPON Space

The map (top) shows a time-space map of the rail network in Europe in 1993. It can be seen that countries in which already high-speed rail systems were in operation, are contracted compared to their familiar shape, whereas countries in Eastern Europe appear larger than usual because their rail systems were still underdeveloped. The bottom part of the figure shows how the same map will look in 2020 if the present TEN-T outline plan will be implemented. The full 'space-eating' effect of high-speed rail becomes visible with the implementation of the trans-European rail network. In 2020 the continent will have dramatically shrunk in time space, yet its shape will have become more similar to the familiar physical map.



Map 36 Time-space maps of rail travel times 1993 (top) and 2020 (bottom)

2.13 European transport corridors in relief

Rationale

The idea of the transport corridor relief is that, between two locations, an intensely used corridor corresponds to the idea of easy communications whilst a weak link in terms of use corresponds to the idea of uneasy connection. Using **the metaphor of the terrestrial usual relief** an easy relation will take the shape of a wide and open valley, whilst a difficult relation will be figured through a high mountain to be crossed. It is an interesting **new point of view** of the potential level of use of the different edge, more visual than on classical maps.

Method

The principle of the relief transport corridor map is very similar to that of the **crumpled time-space maps**. The easiest links, that is to say the most heavily used, are drawn in the plane of the cities. The other links are drawn above this plane to form an elevation proportional to the relative level of use.

Data requirements

CESA graph 765

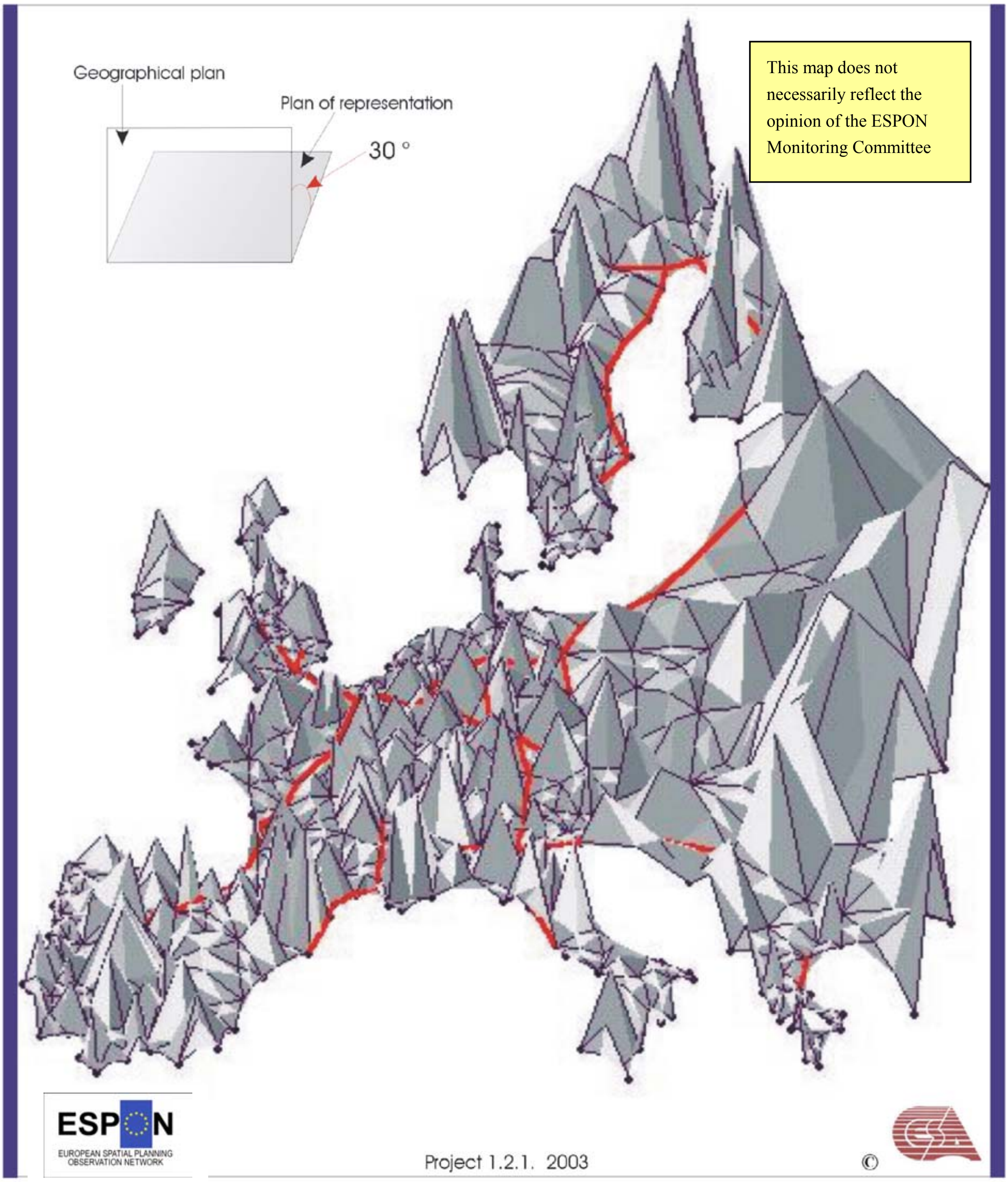
Matrix of minimal paths

Matrix of precedents

Application to ESPON Space

The data presented in this example comes from simulation of computed minimal paths through the European road network. The European corridors appear under the form of wide and deep valleys with high mountains on each side. This relief representation can be understood as goods transport accessibility mapping: to reach a location, **a good will be preferably be transported through large valleys**, avoiding high mountains, that is to say it will tend follow the main transport corridors.

The main corridors of European freight transportation appear in red in the Valley. They are essentially **corridors for trans-European transit**. For example this map underlines the importance of the Channel, of the valley of Rhone, the axe Milan-Zurich by the Saint-Gothard, and the French A10.



Most used transportation corridors

Authors : BUGUELLOU J.B., GUIMAS L., MATHIS Ph.

Geographical base : European road graph of CESA

Map 37 Relief map of the main European transport corridors

3 Daily accessibility

3.1 Daily accessibility by car

3.1.1 Daily population accessible by car

Rationale

Daily round trips opportunities is the most relevant accessibility measure to indicate the transport system effectiveness serving the most demanding trips, those more closely related to development opportunities for most economic sectors. The indicators used to be adapted to specific segments of transport demand, such as "number of efficient opportunities for daily round trips to key destinations" for business travellers, or "market area achievable at a given time or cost" (in terms of total population, accumulated GDP...) for industries moving goods.

Method

The methodology followed has been to calculate the hinterland of 3 hours by car of each NUTS3, considering each NUTS3 as its capital of each NUTS3 if identified and the geometric centre if not. The population accessible from each NUTS3 is the sum of the population of all NUTS3 accessible within this time adding the population of the NUTS3 origin, so that at least, a NUTS3 reaches its own population.

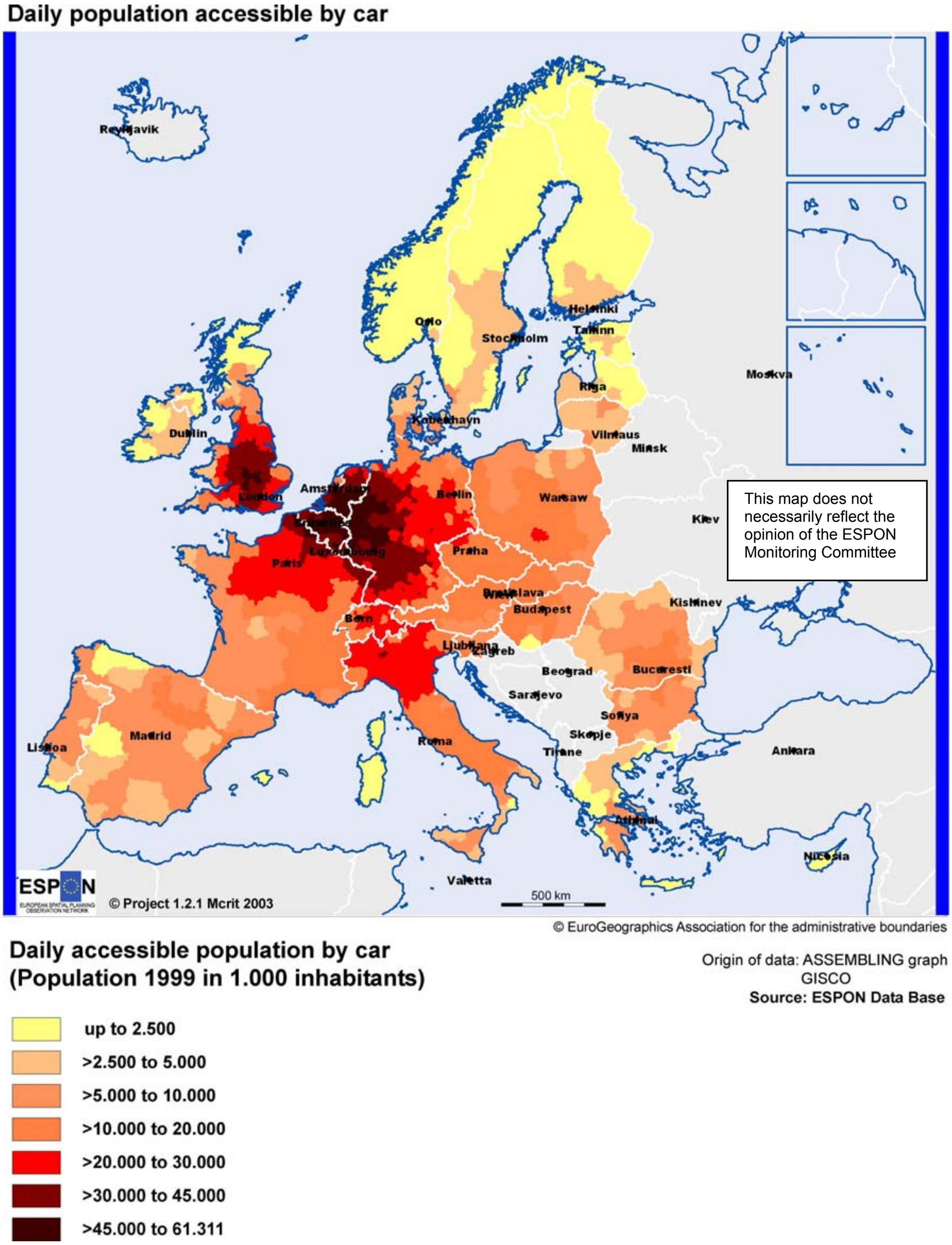
Data requirements

The basic data needed to calculate this indicator is the road network in all ESPON space, precise enough in terms of connections, with information concerning infrastructure characteristics. The road network used is from ASSEMBLING multimodal graph. The regional data consists of population data (inhabitants*1000, 1999), from Eurostat.

Application to ESPON Space

The daily population accessible by car has been calculated from all NUTS3 for all ESPON space. The highest indicators are to be found in the regions with high population density and high motorway and expressways road network (see Figure 5.1.1). The islands and the regions in the Scandinavian countries and Finland have the lowest daily population accessible due to its geographical isolation and in this last case, also to its low population density.

Note that for these type of indicators the size and shape of the area considered changes the result of each place (because of the European extension towards East, the zones along the Rhine river become more central; the centre of gravity of Europe shifts towards East).



Map 38 Daily population accessible by car

3.1.2 Daily market accessible by car

Rationale and policy relevance

Daily market accessible by car follows the same rationale as daily population accessible, explained in the first section.

Method

The methodology used is the same as the one in the previous section. The value aggregated in this case is the GDP of all NUTS3 reachable from a NUTS3 origin at the same time.

Data requirements

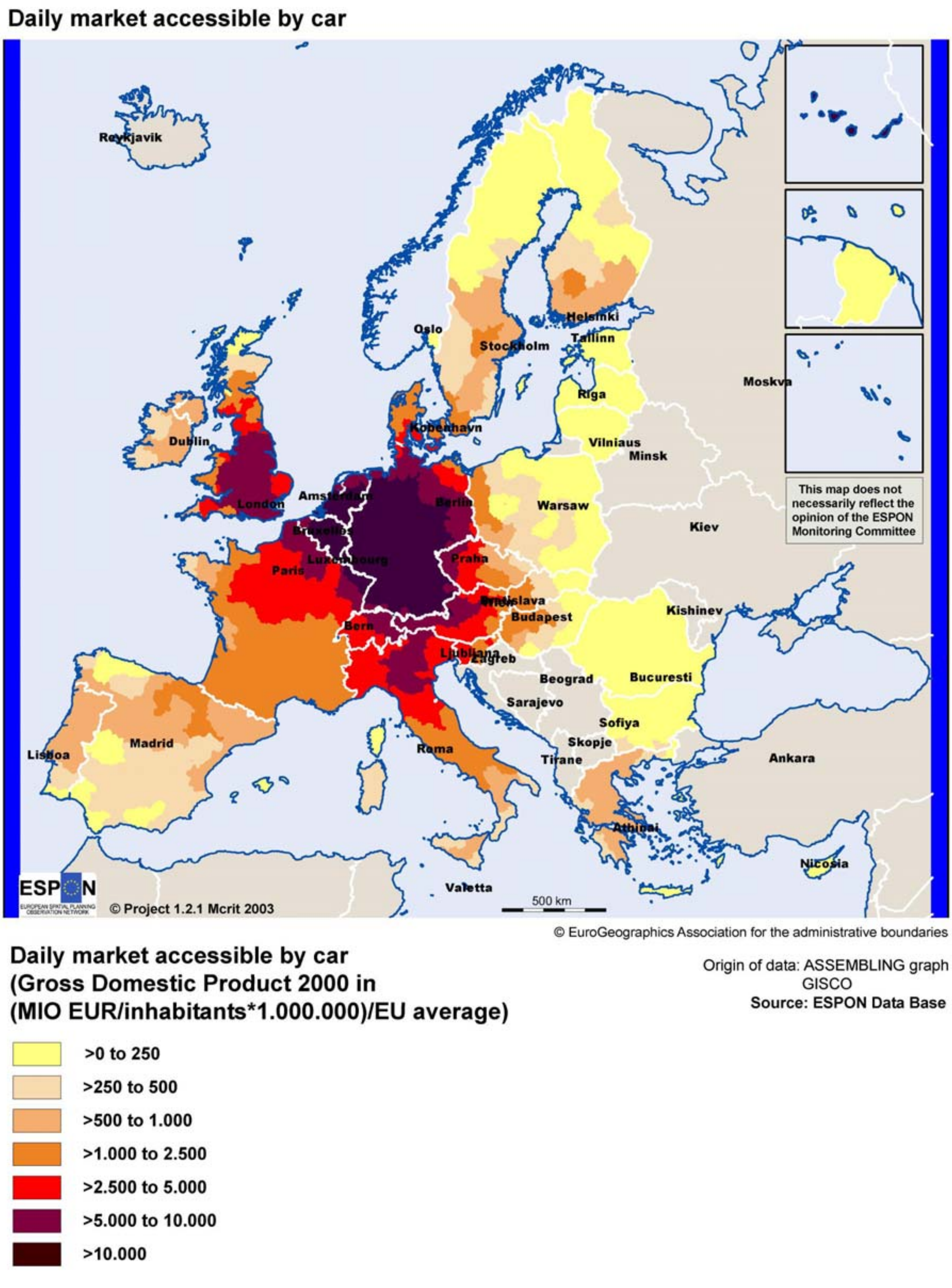
The basic data is the same as the previous section. In this case, the regional data used is the GDP in 2000 (MIO EUR/inhabitants*1.000.000), from Eurostat.

Note that there is not data of NUTS3 in Norway and Switzerland.

Application to ESPON Space

The daily market accessible by car has been calculated from all NUTS3 for all ESPON space. There is a clear distinction between EU15 countries and accession countries, due to the lower GDP. This distinction is not visible in the previous indicator. Norway and Switzerland are totally or partially covered because although there is not data of their GDP, they can reach other NUTS3 in 3 hours.

Comparing with the previous indicator, the recentralisation of European geography in Germany becomes clearer.



Map 39 Daily market accessible by car

3.2 Daily accessibility by rail

3.2.1 Daily population accessible by rail

Rationale

Follows the same rationale explained in the previous sections.

Method

The hinterland of 3 hours using rail network without capacity constraints has been calculated for each NUTS3 in the ESPON space, considering each NUTS3 as its capital of each NUTS3 if identified and the geometric centre if not. The calculation has been done considering the rail network with commercial speeds depending on the type of rail infrastructure without considering rail services, and therefore, without considering waiting times. The population of each NUTS3 reachable in this time has been aggregated for each NUTS3 origin, adding also its own population.

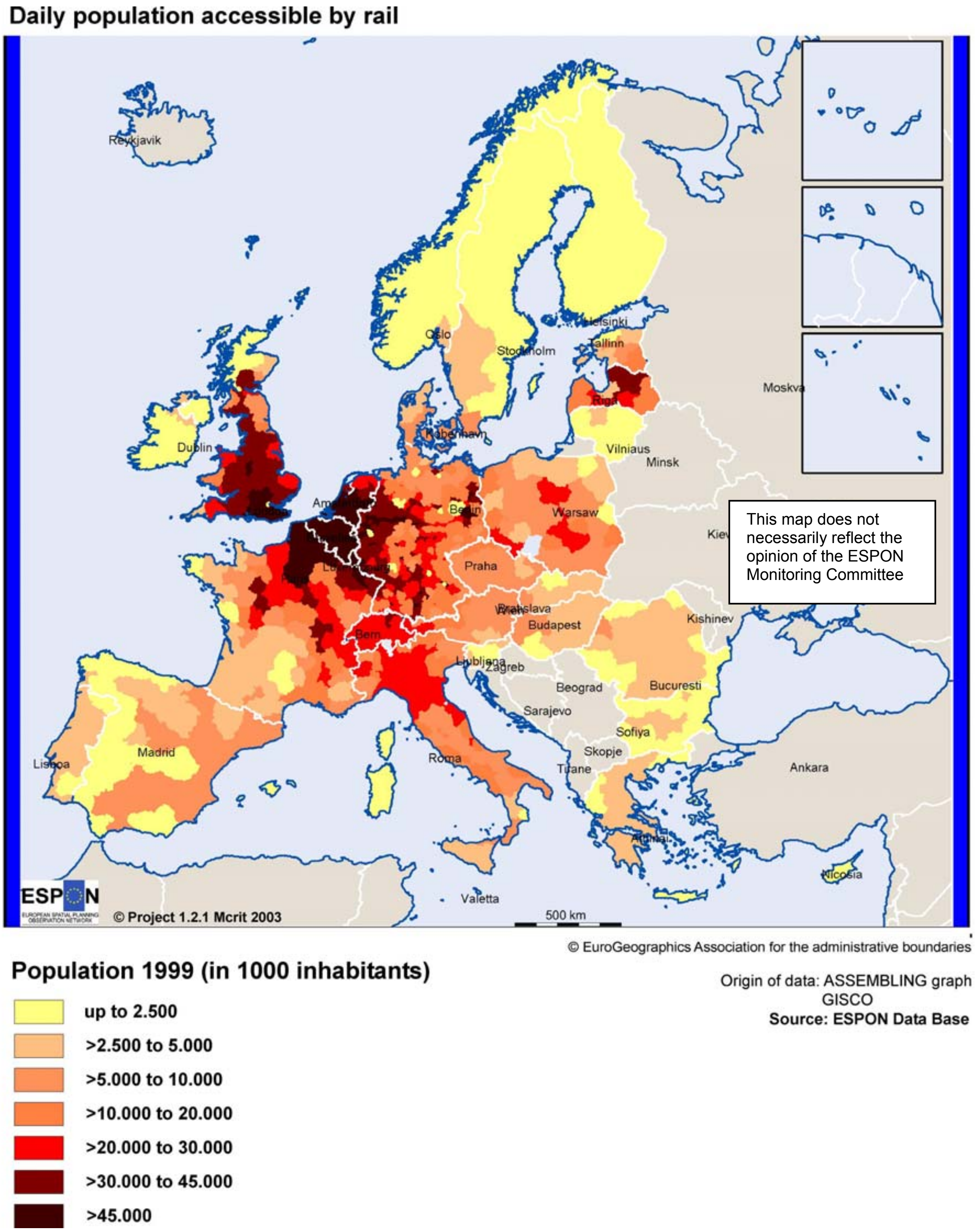
Data requirements

The basic data needed to calculate this indicator is the rail network in all ESPON space, precise enough in terms of connections, with information concerning infrastructure characteristics. The rail network used is from ASSEMBLING multimodal graph. The regional data consists of population data (inhabitants*1000, 1999), from Eurostat.

Application to ESPON Space

The daily population accessible by rail has been calculated from all NUTS3 for all ESPON space. The highest indicators are to be found in the regions with high population density and high-speed and upgraded high-speed rail network (see chapter 5.1 and 5.2). Like in chapter 5.4.1, the islands and the regions in the Scandinavian countries and Finland have the lowest daily population accessible due to its geographical isolation, also to its low population density and in some cases because of the inexistence of rail network.

In most of the regions this indicator has a higher value then the daily population accessible by car, as it has been calculated without considering the transport services between cities and therefore without adding any waiting time, which would certainly penalize this value in respect to the previous indicator.



Map 40 Daily population accessible by rail

3.2.2 Daily market accessible by rail

Rationale

Daily market accessible by rail follows the same rationale as daily population accessible, explained in the previous sections.

Method

The methodology used is the same as the one in the previous section. The value aggregated in this case is the GDP of all NUTS3 reachable from a NUTS3 origin at the same time, adding also the GDP of the NUTS3 origin.

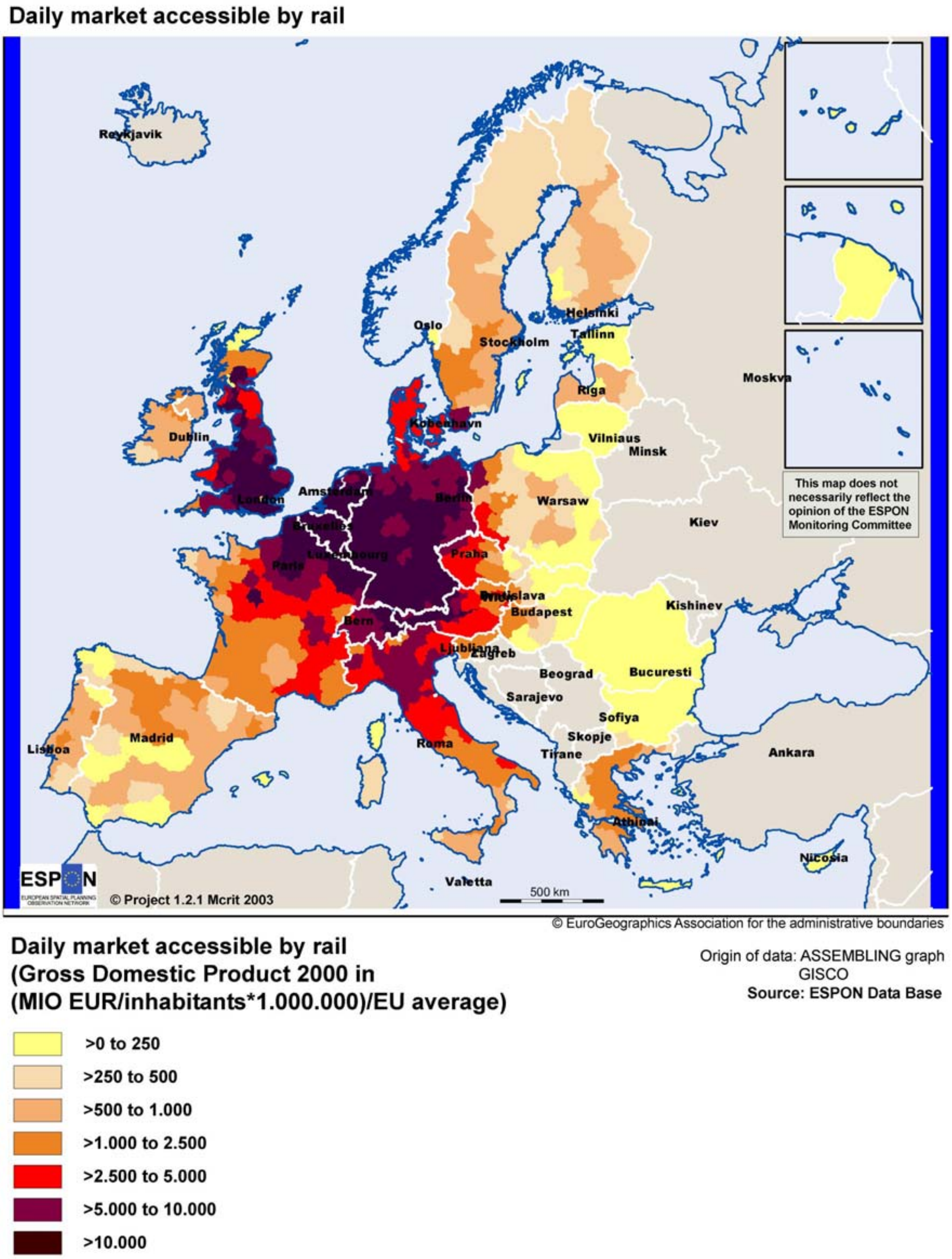
Data requirements

The basic data is the same as the previous section. In this case, the regional data used is the GDP in 2000 (MIO EUR/inhabitants*1.000.000), from Eurostat.

Note that there is not data of NUTS3 in Norway and Switzerland.

Application and results

The daily market accessible by rail has been calculated from all NUTS3 for all ESPON space. While in central EU countries both daily accessible population and market have high values, in Eastern countries this indicators have different ranges as the population density is very high and GDP is low. In Scandinavian countries and Finland, indicators have also different values for both indicators but in the opposite sense as population is lower in respect to GDP values. Norway and Switzerland are totally or partially covered because although there is not data of their GDP, they can reach other NUTS3 in 3 hours.



Map 41 Daily market accessible by rail

3.3 Daily accessibility by air between MEGAs

Rationale

The minimum time approach of the indicator (see part 3 chapter 2.9) assumes that the one hour minimum times are a condition sufficient to guarantee a good level of the transport system. Nevertheless, this method does not fully take into account the frequencies or the adequacy of the transport supply to mobility needs.

According to the time-geography theoretical framework initiated by Hagerstrand, the quality of the link between two poles can be assessed through the possibility to go from the pole A to the pole B, to have enough time for an activity related to work, education or other purposes, and to come back to pole A in a single day.

Method

Consequently we propose to evaluate the possibility of single day business trip with 6 hours available at destination and within the time window 6h-22h, in a door-to-door approach and detailed as follows.

This criterion can be used to define a minimum service provision for the functioning of city networks and applies on the links in the network.

The definition of the cities network is the same as the one developed in the section (see part 3 chapter 2.9) with an original list of 71 MEGAs distinct from the one developed in the 111 ESPON group.

Data requirements

This family of indicators deals with intermodality by allowing to compare modal accessibilities (rail, air, road), and intermodal accessibility (air-rail), but also by taking into account the initial and terminal parts of the trips.

Concerning the collective transport systems –rail and air– the main data considered is the timetable information. The assumption is made that short travel times and high frequencies are necessary but not sufficient to guarantee the daily accessibility level, and that an adequacy of timetables to mobility rhythms must be tested.

The data sources on the collective transport systems services reside in the information available on the major transport Internet sites in Europe: Deutsche Bahn and Amadeus air transport database. The data collection is made through an automatised interrogation of the websites. Extra data is used to connect transport nodes –station and airports– to cities, in order to attain a door-to-door approach.

Application to ESPON space

The map presented shows the possibility to do daily business trips between 71 MEGAs. Firstly the pentagon is clearly visible on the map with high levels of connection in the core region extended to Rome. Secondly, the cities of the Eastern and accessing countries show a relatively much lower level of accessibility, with the exception of Praha.

The coherence of the Nordic network appears clearly with the role of gateway of Kobenhavn. The Baltic States are clearly related to the Nordic triangle, even if the connections could be improved as for example from Stockholm to the Baltic States capitals. Indeed, the connections between the Baltic States and continental Europe according to this indicator are inexistent.

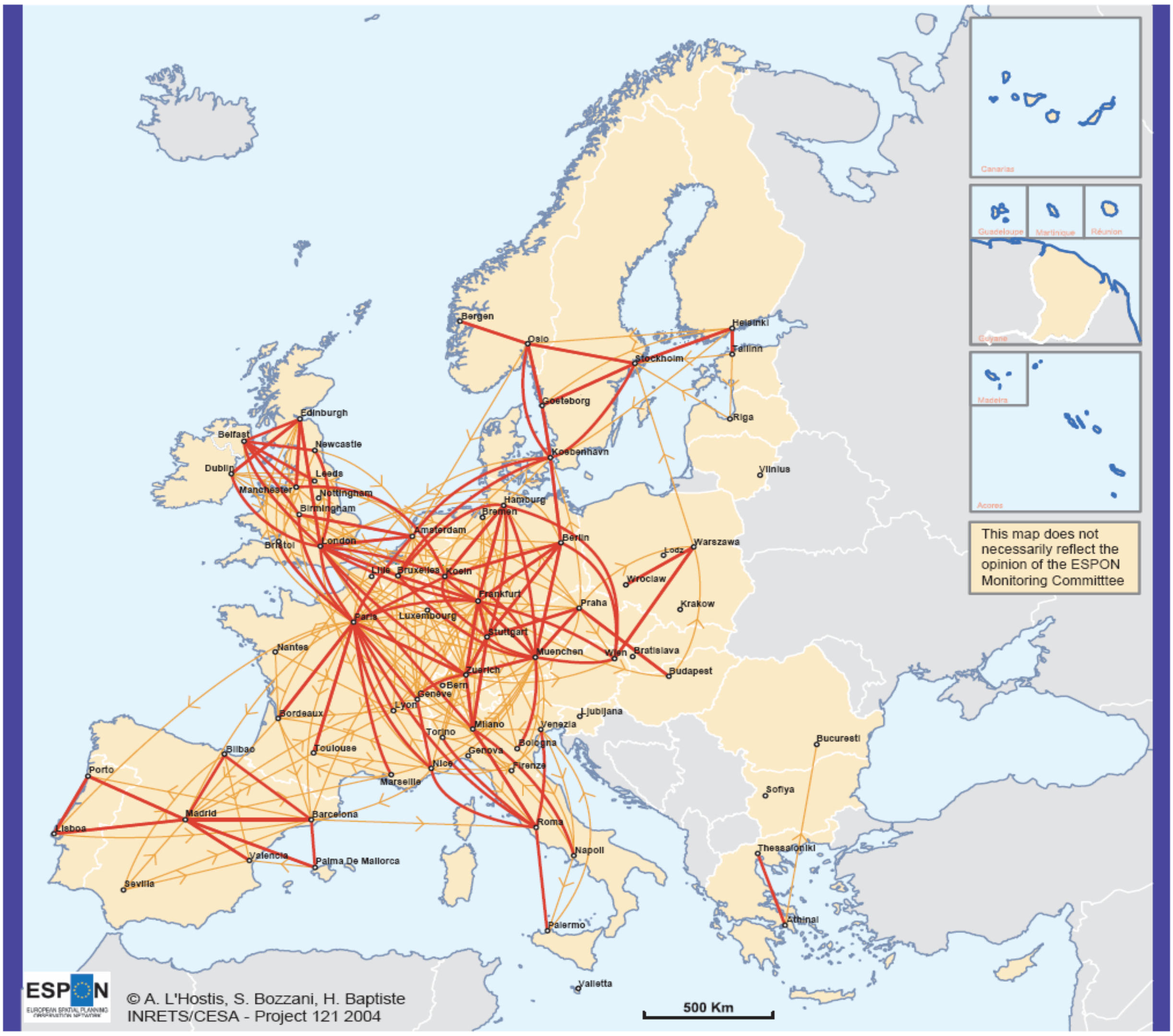
In the Iberic Peninsula, a high level of integration is reached between Madrid and the major Spanish and Portuguese cities, but the gap with continental Europe is here, confirming the findings of the travel times indicator (see part 3 chapter 2.9).

The accessibility levels with 13 added MEGAs as compared to the initial list of 62 cities provided by the 1.1.1 group can be seen on the map. Improvements in the spatial cohesion can be observed with apparition of a bilateral relation in Greece between Thessalonica and Athens. The Iberic network is reinforced by the inclusion of Bilbao, even if this addition does not allow to create a bilateral link with continental Europe. The improvements of linkages are strong in the British Isles and Ireland with new internal relations such as Belfast-Leeds. The Italian network of relations is greatly improved with bilateral links to Sicily.

To summarise, from the point of view of a city network daily accessibility indicator, this modified list of MEGAs shows a more integrated European territory than the initial list of 62 cities. The geographical coverage of the distribution of cities is better, especially in the peripheries, allowing to better illustrate the existing links between the periphery and the core, and also to identify the weak relations, as between the Iberic Peninsula and the rest of the continent.

It must be stressed that the indicator is based only on air relations. In the cases where air relations are poor but distances are short, as in the Swiss urban system for instance, the rail mode will fill in the gaps revealed by the air indicator. For some other specific cases, the high-speed rail can also replace the air mode in inter-MEGAs relations as in the typical example of the Lille-Paris relation.

City network daily accessibility by air
between 72 Metropololitan European Growth Areas (MEGA)



© EuroGeographics Association for the administrative boundaries
Origin of the data: www.amadeus.net april 2003

A —— B **Return trips possible in both directions**

A —> B **Return trip possible only from A to B**

Structure of the return trips:

Map 42 Daily accessibility by air between 71 MEGAs in 2003

3.4 Daily accessibility surfaces

Rationale

It was noted in the section on time-space maps that time-space maps only show the accessibility of nodes of the networks analysed. What they do not show are the 'grey zones' of lower accessibility between the nodes. Time-space maps therefore tend to highlight the positive effects of high-speed network improvements on the nodal centres, which are already highly accessible and hide the possibly negative effects on the areas in between.

To overcome this problem, Spiekermann and Wegener developed spatially disaggregate accessibility indicators using raster-based GIS techniques (Spiekermann and Wegener, 1994a; 1996, Schürmann et al., 1997; Vickerman et al., 1997). In this method a raster structure is used to represent a quasi-continuous activity surface of Europe.

Method

To calculate high-resolution accessibility indices the European territory is disaggregated into some 70,000 raster cells of 10 kilometres width. As no raster data for Europe are available, synthetic raster data are generated by allocating the population of each region to the raster cells belonging to it. For each region first the population of large cities is allocated to raster cells at and close to their geographical location. The number of cells for each city and the population allocated to each raster cell is determined as a function of total population of the city using the model of urban density gradients by Clark (1951). After the distribution of the population of large cities, the remaining population of each region is evenly distributed across the rest of the region, i.e. a homogenous density of the population living in smaller settlements is assumed. The method leads to a plausible intraregional distribution of population taking account of population centres and meeting the constraint that the sum of the population of all raster cells is equal to the regional population total.

Accessibility indicators are calculated by using each raster cell both as origin and destination, i.e. by generating a 70,000 by 70,000 origin-destination travel time matrix. The access time from each raster cell to the nearest node of the network is calculated by assuming an airline travel speed of 30 km/h. The total travel time between two cells therefore consists of three parts: the access time from the origin cell to the nearest network node, the travel time on the network, and the terminal time to the destination cell from the node nearest to it. If the direct airline travel time between two cells is shorter than travel over the network, the shorter direct travel time is used. With this travel time matrix, different types of accessibility indicators can be calculated. The results are accessibility indicators for each raster cell.

Data Requirements

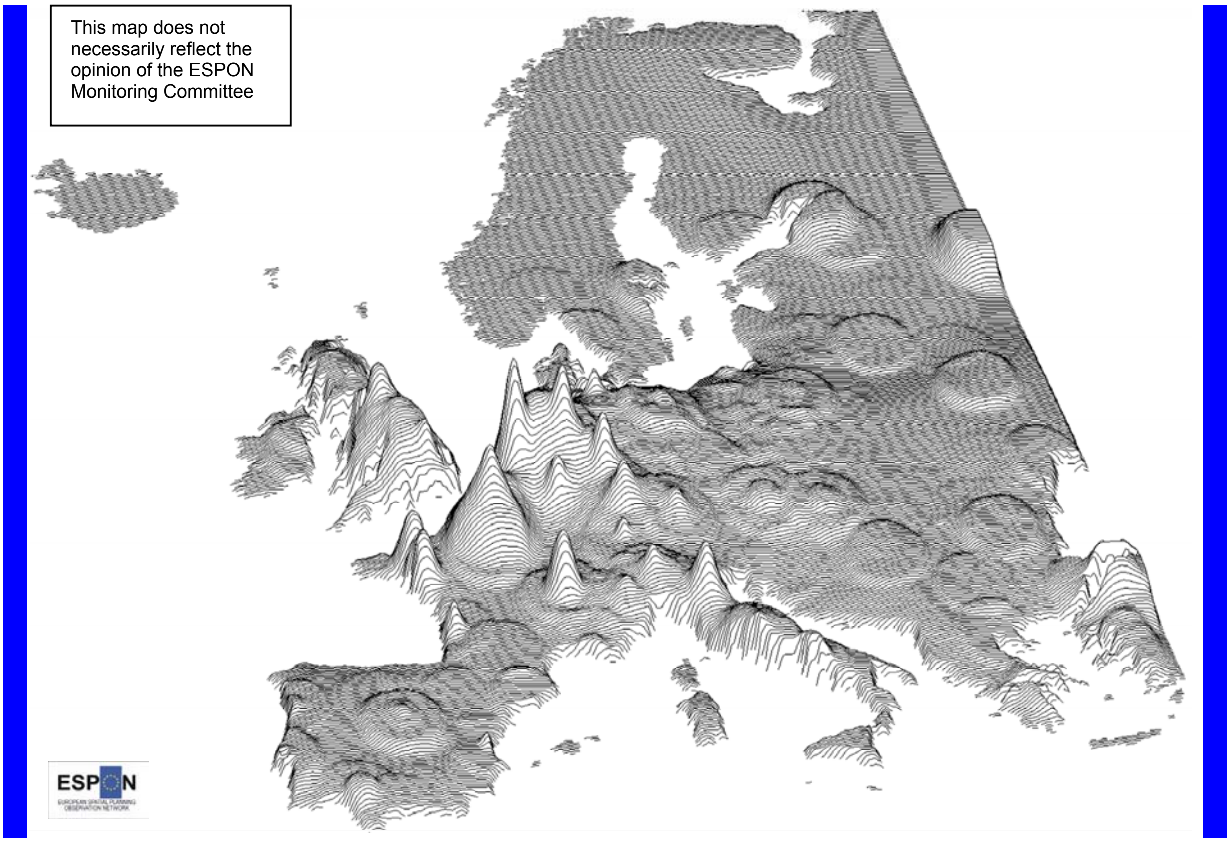
A raster-based visualisation of accessibility indices requires three sets of data usually maintained in a GIS: *region data*, *city data* and *network data*.

- *Region data*: a file with the boundaries of the regions of the study area and their population and economic activity (GDP),
- *City data*: a file with geographical coordinates of major cities in the study area and their population,
- *Network data*: a file with the geographical coordinates of the nodes of the network investigated and the travel times between them.

Population, economic activity and travel times may be current or may represent assumptions about future or historical developments or scenarios.

Application to ESPON Space

The raster-based accessibility indicators so calculated can be visualised in raster-based accessibility maps or three-dimensional accessibility surfaces. The map shows daily accessibility to population by rail in 1993. Daily accessibility was calculated on the basis of 70,000 raster cells of 10 x 10 km width. Daily accessibility indicators were calculated as the total number of population of all destination cells that can be reached from the origin cell within a certain number of hours weighted equally regardless of travel time; for all other raster cells the weight is zero. Five hours is assumed to be the maximum one-way door-to-door travel time for a one-day return trip. The elevation of the accessibility surfaces is proportional to the population that can be reached within five hours. Large differences in accessibility become visible. Urban regions have the highest and rural areas the lowest accessibility. Accessibility decreases from the city centres to the rural areas. Moreover, the areas in central parts of Europe, both urban and rural, have a higher accessibility than regions at the European periphery. With a little imagination the 'Blue Banana', the European megalopolis stretching from London along the Rhine corridor to Northern Italy, can be recognised. Locations in Eastern Europe have rather low accessibility values because of their poor connection to the international networks. This is even true for large agglomerations such as Moscow, St. Petersburg or Istanbul, which are only visible because of their large population base.



Map 43 Daily accessibility surface for rail 1993

4 Potential accessibility

This section contains a series of potential accessibility indicators based on the theoretical concepts explained in Chapter 4. It starts with potential accessibility by mode, followed by multimodal potential accessibility.

4.1 Potential accessibility by road

Rationale

Potential accessibility by mode has been proposed by the Working Group "Geographical Position" of the Study Programme on European Spatial Planning – SPESP as reference indicator concept (Wegener et al., 2000). Accessibility potential is one of the most common and most extensively tested accessibility indicators.

Potential accessibility is based on the assumption that the attraction of a destination increases with size, and declines with distance, travel time or cost. Destination size is usually represented by population or economic indicators such as GDP or income. Accessibility to population is seen as an indicator for the size of market areas for suppliers of goods and services; accessibility to GDP an indicator of the size of market areas for suppliers of high-level business services. Potential accessibility is founded on sound behavioural principles but contains parameters that need to be calibrated and their values cannot be expressed in familiar units.

Method

Potential accessibility is a construct of two functions, the *activity function* representing the activities or opportunities to be reached and the *impedance function* representing the effort, time, distance or cost needed to reach them (impedance function) (Wegener et al., 2002). For potential accessibility the two functions are combined multiplicatively, i.e. are

$$A_i = \sum_j W_j^a \exp(-\beta c_{ij})$$

weights to each other and both are necessary elements of accessibility:

where A_i is the accessibility of area *i*, W_j is the activity *W* to be reached in area *j*, and c_{ij} is the generalised cost of reaching area *j* from area *i*. A_i is the total of the activities reachable at *j* weighted by the ease of getting from *i* to *j*. The interpretation is that the greater the number of attractive destinations in areas *j* is and the more accessible areas *j* are from area *i*, the greater is the accessibility of area *i*.

Occasionally the attraction term W_j is weighted by an exponent α greater than one to take account of agglomeration effects. The impedance function is nonlinear. Generally a negative exponential function is used in which a large parameter β indicates that nearby destinations are given greater weight than remote ones.

The accessibility model used here (based on Spiekermann and Wegener, 1996) uses centroids of NUTS 3 regions as origins and destinations. The accessibility model calculates the minimum paths for the road network, i.e. minimum travel times between the centroids of the NUTS 3 regions. For each NUTS 3 region the value of the potential accessibility indicator is calculated by summing up the population in all other regions including those outside ESPON space weighted by the travel time to go there.

Data requirements

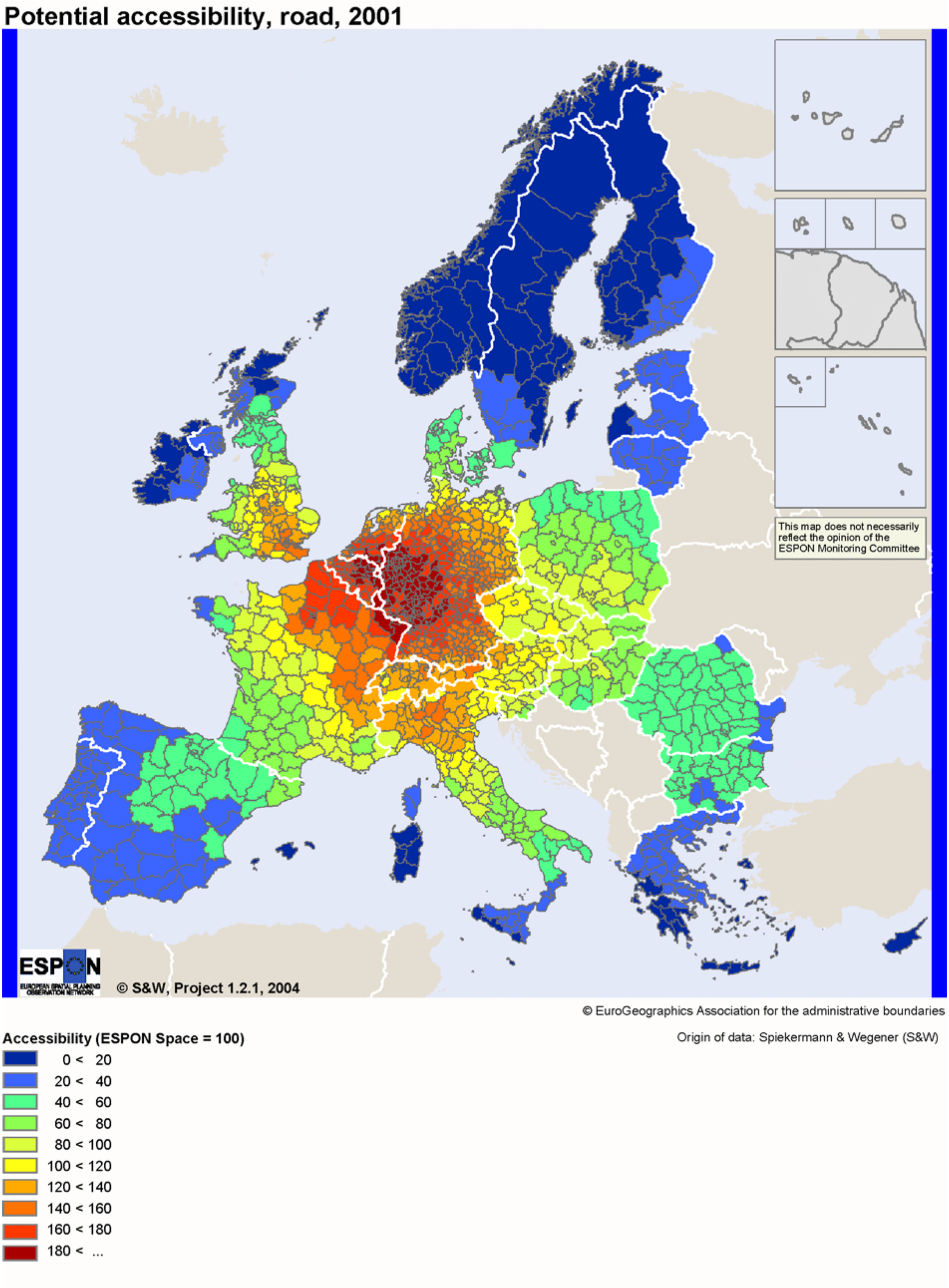
For the calculation of potential accessibility by road two different types of data are requested: road network data and regional data:

- The road network used contains all existing motorways, dual-carriageway roads and other expressways, E-roads and the most important national roads as well as car ferries and the Eurotunnel. It contains information on the type of road, national speed limits and border delays. The network part provides link travel time by taking account of average speeds in relation to different link-type speed limits in different countries. The road network used is part of the pan-European network database developed by the Institute of Spatial Planning of the University of Dortmund (IRPUD, 2003).
- The regional data consists of population data used as destination activity.

Application to ESPON Space

The potential accessibility by road indicator has been calculated for all NUTS 3 regions of the ESPON space (see map). Because the accessibility indicators are in non-familiar units accessibility has been standardised to the average accessibility of the ESPON space. Regions coloured in green have a below-average potential accessibility by road, regions in yellow and red an above average accessibility.

Accessibility by road is characterised by a clear distinction of centre and periphery. Accessibility by road is the only modal accessibility indicator that reproduces the 'Blue Banana', the central area nowadays called the European pentagon. All other accessibility indicators demonstrated below in this section provide different results.



Map 44 Potential accessibility by road, 2001

4.2 Potential accessibility by rail

Rationale

As potential accessibility by rail follows the same concept as potential accessibility by road the same rationale as described in the previous sections applies here.

Method

The same method as described in the previous section has been applied here.

Data requirements

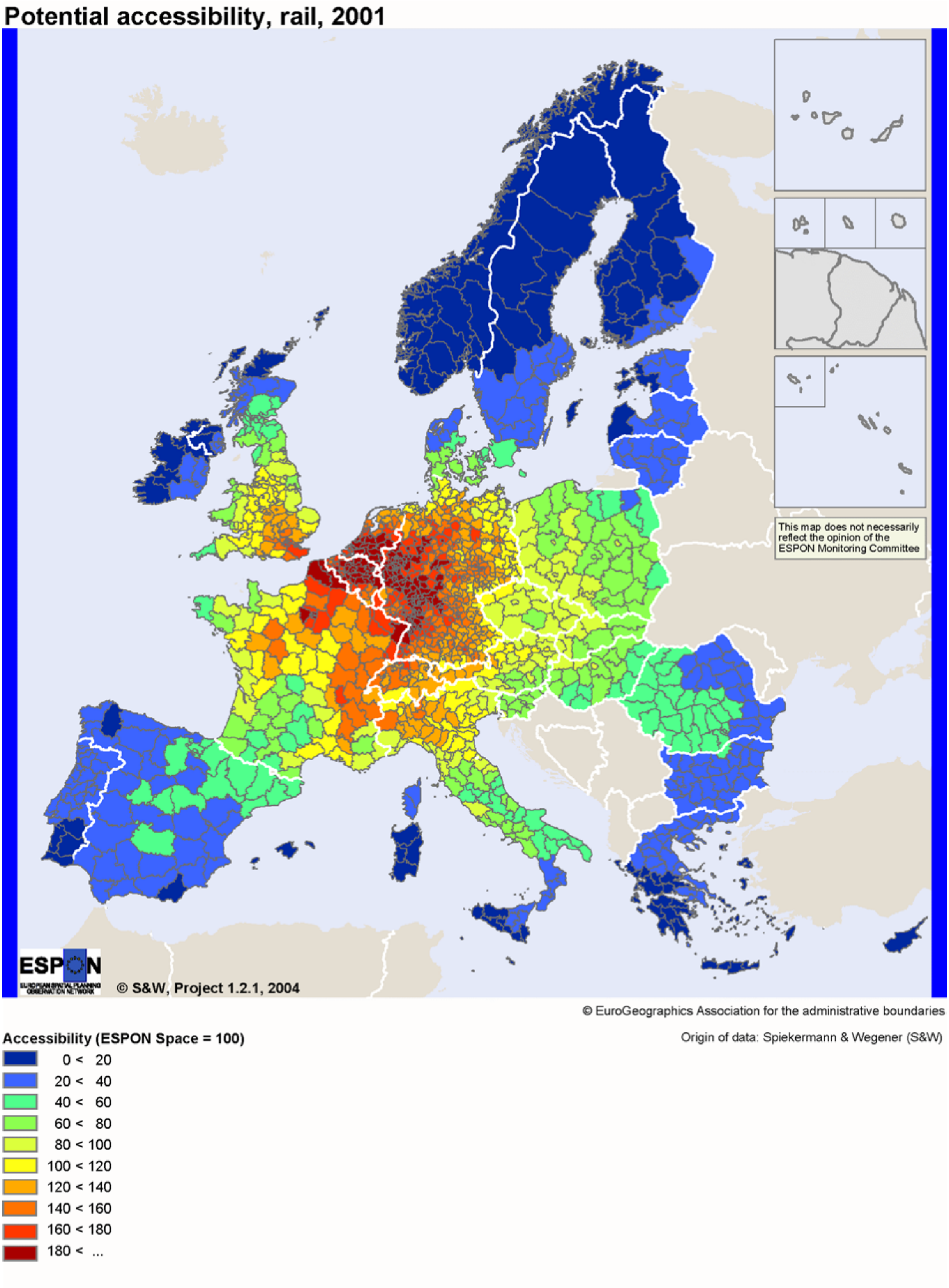
The data requirements are similar to the previous requirements. The only change is that a rail network replaces the road network.

The rail network used contains all existing and planned high-speed rail lines, upgraded high-speed rail lines and the most important conventional lines as well as some rail ferry and other secondary rail lines to guarantee connectivity of the NUTS 3 regions. The rail network database contains information on the link category, length inclusion in the TEN and TINA programmes and travel times derived from rail timetables. The rail network used is part of the pan-European network database developed by the Institute of Spatial Planning of the University of Dortmund (IRPUD, 2003).

Application to ESPON Space

The potential accessibility by rail indicator has been calculated for all NUTS 3 regions of the ESPON space (see map). Again, accessibility has been standardised to the average accessibility of the ESPON space. Regions coloured in green have a below-average potential accessibility by rail, regions in yellow and red an above average accessibility.

Potential accessibility by rail provides also a core-periphery pattern in Europe. However, there are two important distinctions from the accessibility by road. The first is that highest accessibility is much more concentrated in the central areas and is visible primarily in the cities serving as main nodes in the high-speed rail networks and along the major rail corridors. Second, it becomes apparent that investments in high-speed rail links and networks can enlarge the corridors of higher potential accessibility by road. This is mainly visible in France where the TGV lines towards the Mediterranean Sea and the Atlantic Ocean lead to corridors of clearly above European average accessibilities.



Map 45 Potential accessibility by rail, 2001

4.3 Potential accessibility by air

Rationale

As potential accessibility by air follows the same concept as potential accessibility by road and rail the same rationale as before applies here.

Method

The method as described in the previous sections has been applied here.

Data requirements

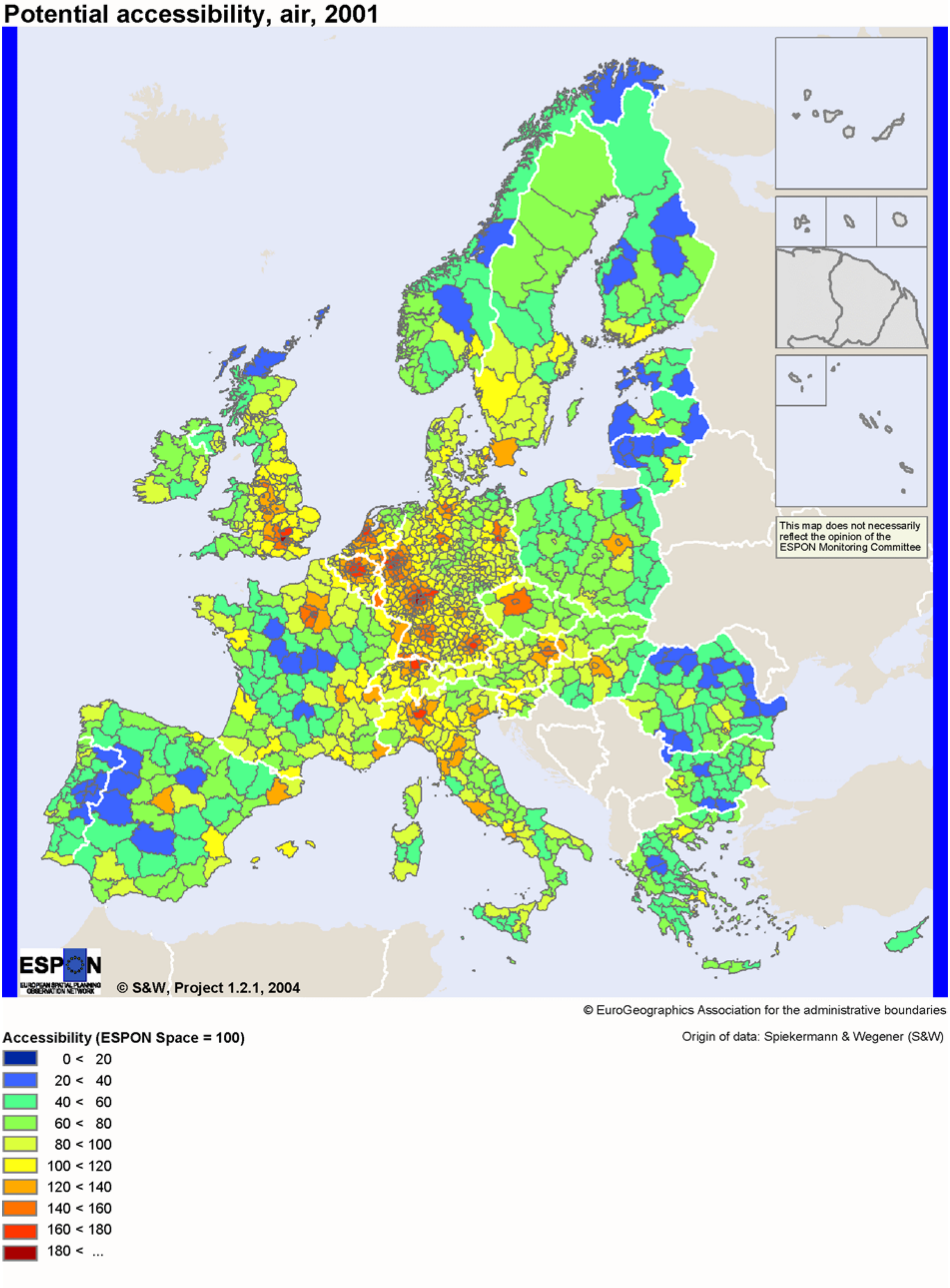
The data requirements are similar to the previous requirements. The only change is that now an air network is introduced in the accessibility model. The airports of the air network are all airports contained in the TEN and TINA programme. In addition, important airports in Eastern Europe and in other non-EU countries were included to guarantee connectivity of these regions. The air network contains non-stop relations between two airports. Only scheduled flights are taken into consideration, i.e. maper flights and other non-regular flights are not included. For each relation, the average flight time based on flight timetable information and the frequency of flights is available. The frequency is used for time penalties for those relations that have less than several flights per day.

Application to ESPON Space

The potential accessibility by air indicator has been calculated for all NUTS 3 regions of the ESPON space (see map). Again, accessibility has been standardised to the average accessibility of the ESPON space. Regions coloured in green have a below-average potential accessibility by air, regions in yellow and red an above average accessibility.

The areas of highest potential accessibility by air are strongly concentrated around major airports, yet as these are dispersed across Europe. Nevertheless, airport regions in the central EU areas have higher values than airport regions in other parts. The hinterland of the airports is very narrow; visible by a steep decline in accessibility when moving away from the airport.

Potential accessibility by air yields a completely different picture than the two accessibilities based on surface transport. The map of Europe is converted into a patchwork of regions with high accessibility surrounded by regions with low accessibility. Low accessibility is however no longer a concern solely for those in the 'traditional' European periphery, but now also is an issue for regions located in the European core.



Map 46 Potential accessibility by air, 2001

4.4 Potential accessibility, multimodal

Rationale

In general, multimodal potential accessibility follows the same rationale as described previously. However, the basic difference to the modal accessibility indicators is that multimodal accessibility integrates the modal indicators into one indicator expressing the combined effect of alternative modes for a location. The aggregation over modes is a major advantage over single mode indicators. If a single indicator is required to assess the European territory in terms of accessibility and peripherality, multimodal or intermodal accessibility should be chosen.

Method

Basically, the same method as described in the previous sections has been applied here. The aggregation over modes is introduced in the impedance function of the accessibility model by combining the information contained in the modal accessibility indicators by replacing the generalised cost c_{ij} by the 'composite' generalised cost

$$\bar{c}_{ij} = -\frac{1}{\lambda} \ln \sum_m \exp(-\lambda c_{ijm})$$

where c_{ijm} is the generalised cost of travel by mode *m* between *i* and *j* and λ is a parameter indicating the sensitivity to travel cost. This formulation of composite travel cost is superior to average travel cost because it makes sure that the removal of a mode with higher cost (i.e. closure of a rail line) does not result in a - false - reduction in aggregate travel cost.

Data requirements

The data requirements are similar to the previous requirements. But now, all three networks (road, rail, air) are processed at the same time.

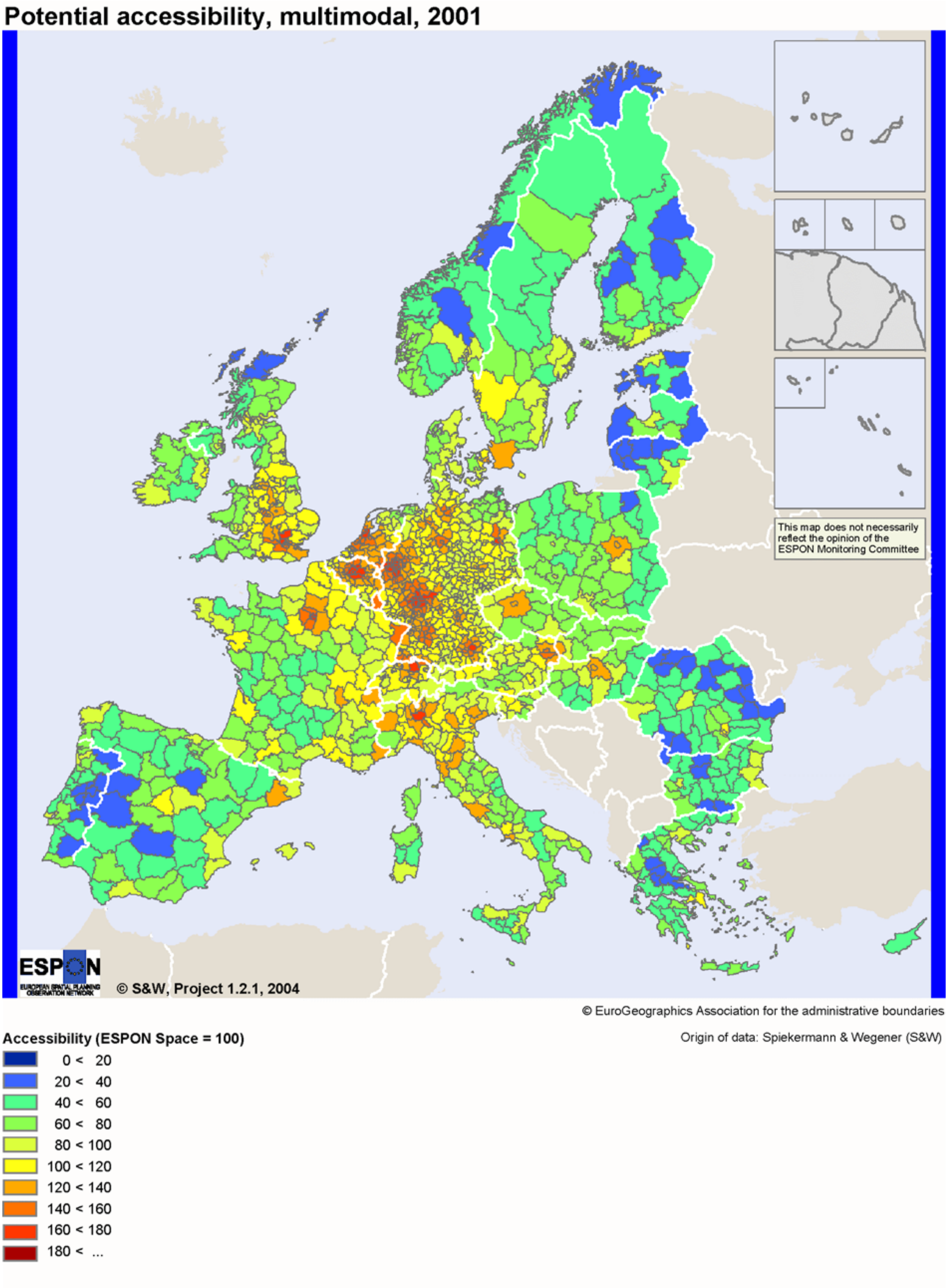
Application to ESPON Space

The multimodal potential accessibility indicator has been calculated for all NUTS 3 regions of the ESPON space (see map). Again, accessibility has been standardised to the average accessibility of the ESPON space. Regions coloured in green have a below-average multimodal potential accessibility, regions in yellow and red an above average accessibility.

Regions with clearly above average accessibility are mainly located in an arc stretching from Liverpool and London via Paris, Lyon, and the Benelux regions, along the Rhine in Germany to Northern Italy. However some agglomerations in more remote areas such as Madrid, Barcelona, Dublin, Glasgow, Copenhagen, Malmö, Göteborg, Oslo, Rome, Naples Thessalonica and Athens are also classified as being central or at least intermediate because their international airports improve their accessibility.

At the same time the European periphery begins in regions that are usually considered as being central. Several regions in Germany, Austria and France have below average accessibility values, some of them are even extremely peripheral. Many regions in Portugal, Spain, Ireland, Scotland, Wales, Norway, Sweden, Finland, Southern Italy and Greece have very low accessibility values. Those regions do not have good access to international flight services.

Nearly all regions of the candidate countries do have below average accessibilities. The only exceptions are the capital cities and partly their surrounding regions because of international airports and important connections. For all other regions the combined effect of low quality surface transport infrastructure and lack of air accessibility leads to the low performance in terms of accessibility. In general, the enlargement of the European Union leads to a decrease in average accessibility.



Map 47 Multimodal potential accessibility, 2001

5 Traffic volumes and flows

5.6.1 Trips generated

Rationale and policy relevance

Trip generation stage is the first step in the classical Four steps transport model aiming at predicting the total number of trips generated in the study area. This has usually considered as the problem of answering a question such as: how many trips (Oi) originate at each zone?

Methodology

Because there are many different types of trips (according to the purpose: business, leisure..., to the frequency: daily, weekly..., to the length: short-distance, long-distance... made by travellers with different revenue and social characteristics...) predictions may indeed be too complicated and a level of simplification is unavoidable in any kind of modelling exercise. It has been used a model able to generate flows between regions (NUTS2) based on basic socio-economic data and urban structures. KTEN ("Know trans-European Networks") is a passenger's traffic forecast model developed to facilitate a strategic analysis of the trans-European Transport Networks in a wider pan-European and Mediterranean scale. KTEN is a sequential Four-steps model, with combined modal split and assignment on multimodal networks (1 complete run of KTEN takes 150 minutes; KTEN is 40 Mb large in total). KTEN uses STREAMS results, WTO and EUROSTAT Air Traffic OD databases, as benchmark and/or references for result’s validation.

Figure 5.6.1.1: KTEN: Main interface of the Trip generation module

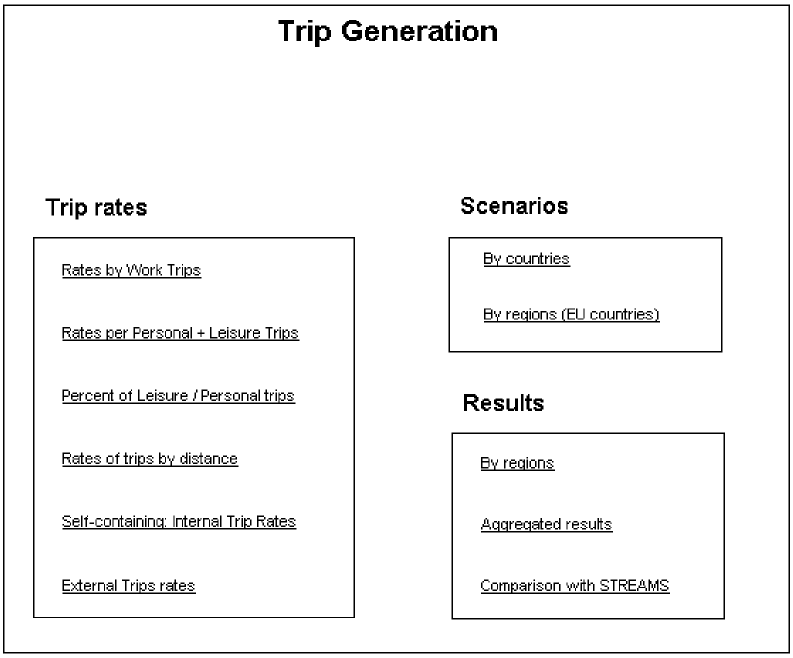
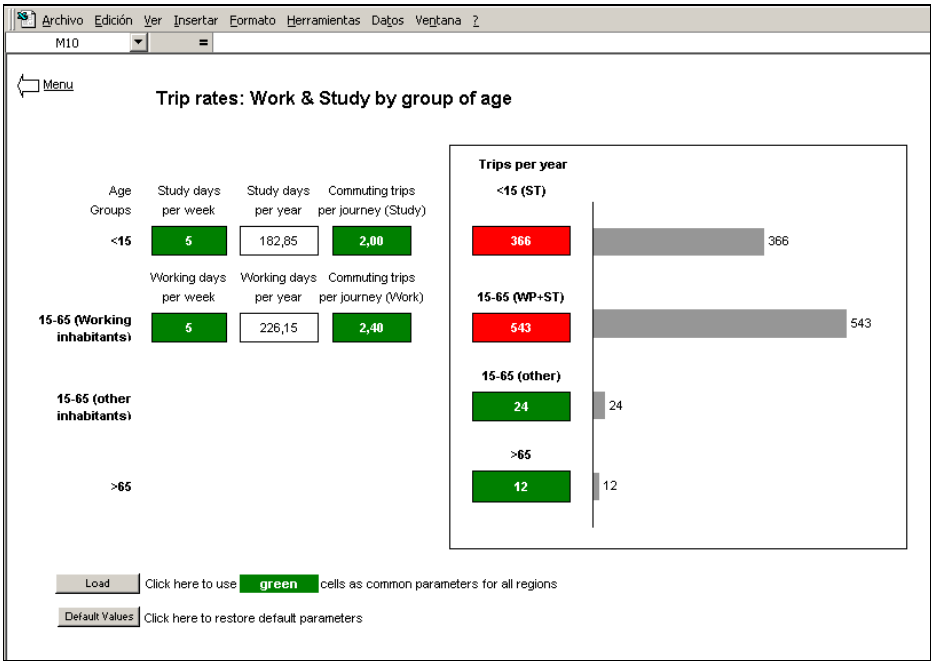


Figure no. 5.6.1.2: KTEN: Trip rates interface of the Trip generation module



To calculate trip generation KTEN considers zone-based ratios (by NUTS 2 or equivalent) and the trip purposes are business, leisure and visit (personal). Business trips generated depend on the work and study trips rates by group of age, internal trip rates to define the self containing trips, and the external trip rates.

To determine both leisure and personal trips first a maximum and minimum annual trip asymptotes, as well as annual commuting trips, per inhabitant. Leisure and personal annual trips depending on the GDP are calculated following a logistic function:

$$f(x) = A_i + \frac{1}{\frac{1}{A_s - A_i} + ab^x}$$

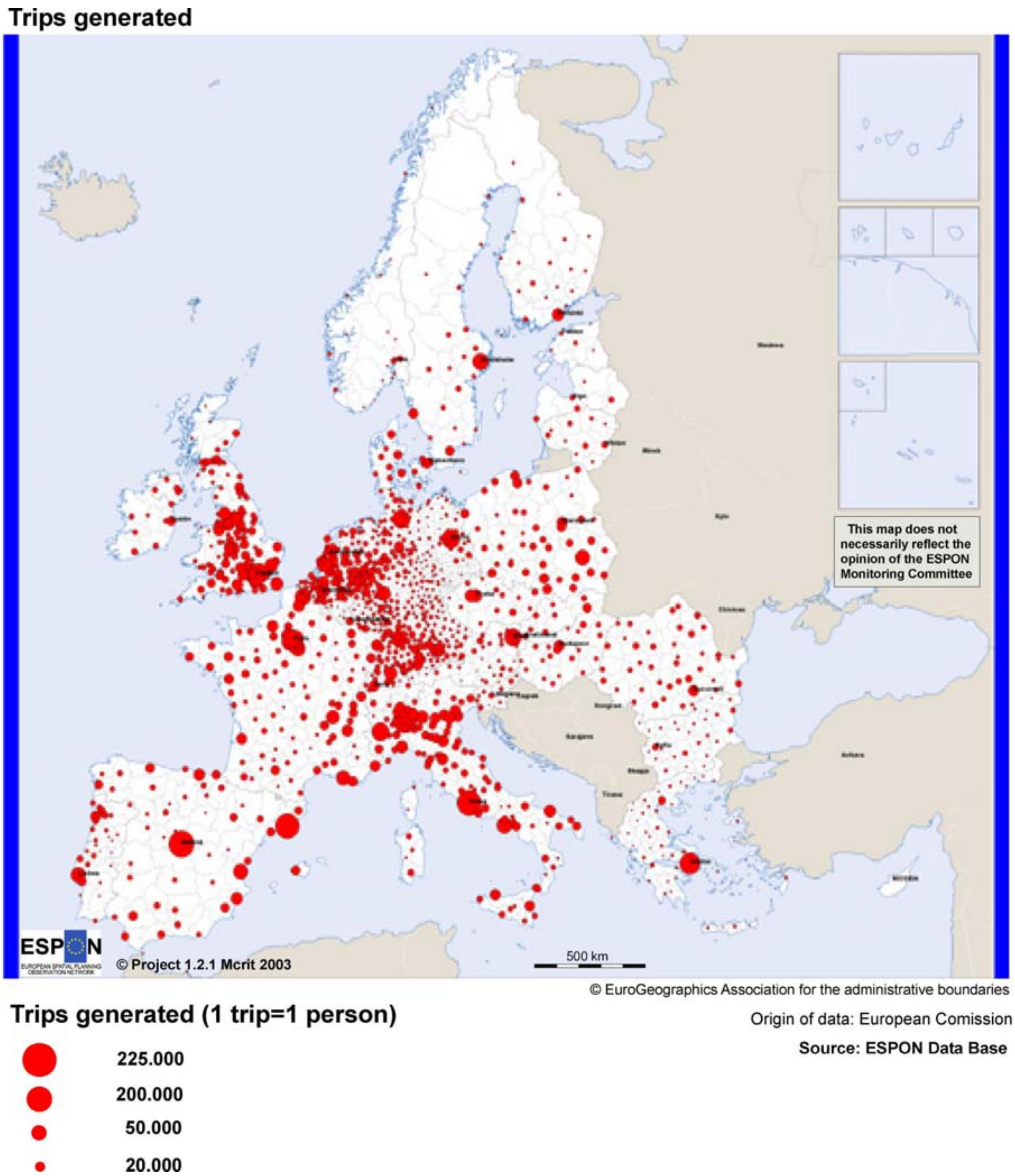
where A_s and A_i are the superior and inferior asynptotes of leisure and personal anual trips, a and b are parameters and x is the GDP per capita.

Data requirements

The regional data needed is the population and the active population of each NUTS2 to determine the work and study rates. For leisure and personal trips, the data are the GDP per capita of each NUTS2 (from Eurostat), and Spatial Indicators (SPESP).

Application and results

Trips generated for all purposes by a zone (i) have been calculated for all NUTS2 in ESPON space. NUTS2 with higher generation are those with high population between 15 and 65 years, with high GDP and with a high external trip rate. Therefore, NUTS2 with higher generation of trips are those containing country and macro-region EU15 capitals. As an exception, Poland and Romania generate more trips than the rest of the accession countries due to their high population. Scandinavian countries and Finland generate less trips that regions of EU15 countries because of their low population density.



Map 48 Trips generated

5.1 Personal trips attracted

5.1.1 Trips attracted

Rationale and policy relevance

Generations provide an idea of the level of trip making in a study area but this is often not enough for modelling and decision making. What is needed is a better idea of the pattern of trip making, from where to where do trips take place, the modes of transport chosen and, the routes taken.

Methodology

To calculate trip distribution, KTEN considers the type of trip; for business trips, it uses the following expression:

$$V_{i,j} = O_i \cdot A_i \cdot K_{i,j}^{\alpha} \cdot Cap_j^{\ \beta} \cdot Pop_j^{\ \gamma} \cdot Gdp_j^{\ \delta} \cdot C_{i,j}^{\rho}$$

where,

$V_{i,j}$ trips between zone (i) and zone (j)

O_i the origins from zone (i)

A_i calibration parameter to reach the Origins condition

$K_{i,j}^{\alpha}$ relationship between the countries containing the zones (i) and (j)

Cap_j^{β} capitatility index (4 for European Capitality ,2 for capital of country and 1 for others)

Pop_j^{α} population of zone (j)

Gdp_j^{δ} gross domestic product of zone (j)

$C_{i,j}^{\rho}$ cost to travel from zone (i) to zone (j)

And for leisure and visit trips the expression is as follows:

$$V_{i,j} = O_i \cdot A_i \cdot Cap_j^{\ \beta} \cdot Pop_j^{\ \gamma} \cdot Tp_j^{\ \delta} \cdot C_{i,j}^{\rho}$$

where,

$V_{i,j}$ the trips between zone (i) and zone (j)

O_i the origins from zone (i)

A_i calibration parameter to reach the Origins condition

Cap_j^{β} capitatility index (4 for European Capitality,2 for capital of country and 1 for others)

Pop_j^{α} population of zone (j)

Tp_j^{δ} Tourist pressure on site of zone (j)

$C_{i,j}^{\rho}$ cost to travel from zone (i) to zone (j)

The trips attracted by zone (j) are all the trips with origin zone (i) to destination zone (j). The expression is as follows:

$$V_j = \sum_i V_{i,j}$$

where,

V_j trips attracted by zone (j)

$V_{i,j}$ trips between zone (i) and zone (j)

Data requirements

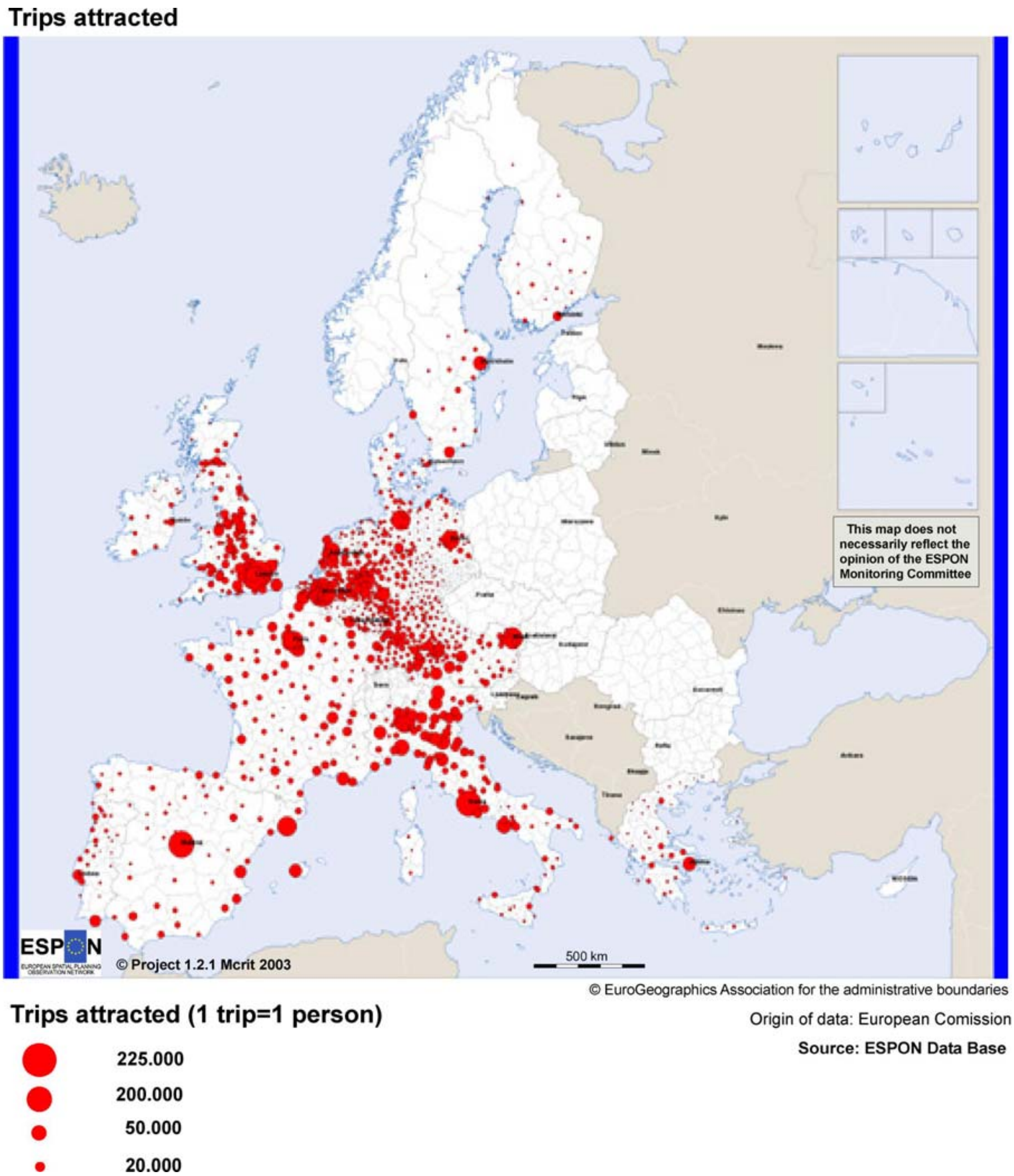
The transport network used to calculate the cost to travel between to zones is from ASSEMBLING multimodal graph, which is explained in chapter 5.1.1. In this case the cost is the minimum time using road network in 2001 without capacity constraints.

The regional data needed is the population (1999) and tourism pressure from Eurostat.

Application and results

Trips attracted by a zone (j) have been calculated for all NUTS2 in ESPON space. NUTS2 with higher attractiveness are those allocating country and macro-region capitals (in general very populated), especially if from EU15, and accessible from all points of the territory. This is the case of Paris, London, Milano, Köln and Berlin in Europe, and Warsaw in the accession countries. Some periphery regions have a high attractiveness due to the tourism pressure (like Spanish Western and Southern coast).

Note that due to the lack of data of tourist pressure for the new EU countries no leisure and visit trips have been calculated for them, and therefore the total number of trips attracted is much more lower than those of EU15 countries.



Map 49 Trips attracted

5.2 Car km generated

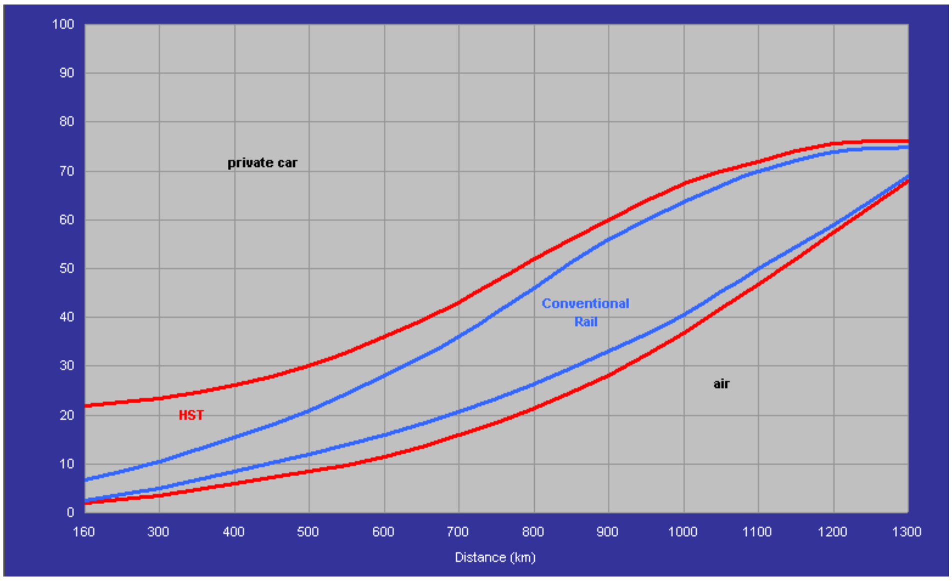
5.2.1 km per person in generated by car / Purpose: business

Rationale and policy relevance

The issue of the mode choice is provably the single most important element in transport planning and policy making. It affects the general efficiency with which we can travel in urban areas, the amount of urban areas devoted to transport functions, and whether a range of choices is available to travellers. This issue is important in urban and inter-urban transport, as rail modes can provide a more efficient mode of transport (in terms of resources consumes, including space), but there is also a trend to increase travel by road.

Method

The modal split has been calculated considering the following percentages for every mode (see Figure no 3.14). The distance in km is from zone (i) to zone (j) using road network and ferry lines.



Source: ESPON Project 1.2.1, Mcrit

Figure 13 Modal split for interregional trips

The average length of business trips by car from zone (i) is calculated with the expression:

$$K_{ijk} = \left(\sum_n L_{ijn} * N_{ijkn} \right) / \sum_n N_{ijkn}$$

Where

L_{ijn} cost (in km) from NUTS2$_i$ to NUTS2$_n$ using the mode *j*

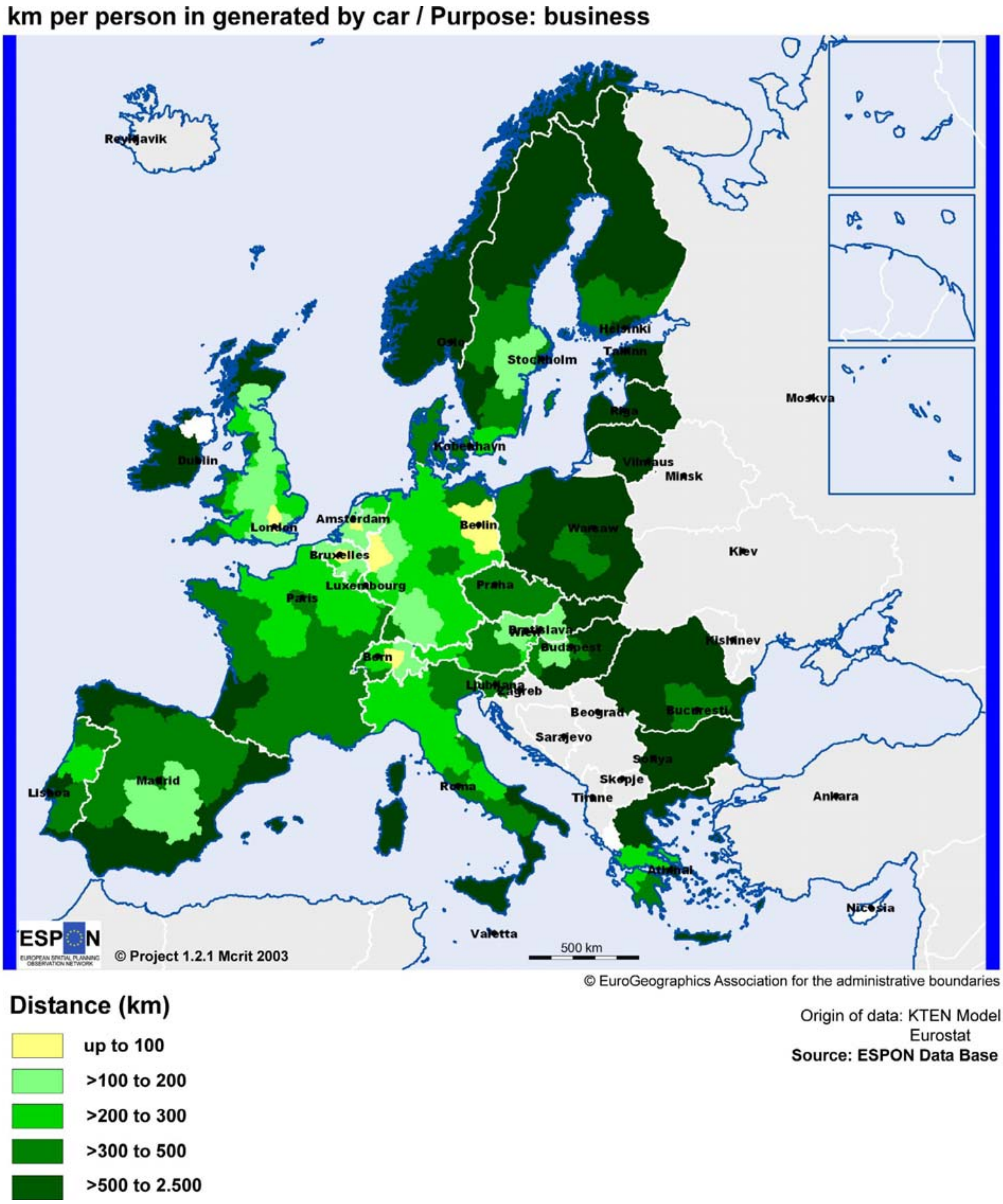
N_{ijkn} number of trips from NUTS2$_i$ to NUTS2$_n$ using the mode *j* by purpose *k*.

Data requirements

The data needed is the origin and destination matrix of business trips (see part 3 chapter 5.5) and the transport network to calculate distance between NUTS2. The transport network used is from ASSEMBLING multimodal graph, which is explained in in part 3 chapter 1.2.

Application and results

The number of km per person per road by obligated (business) trips has been calculated for all NUTS2 of the ESPON space. Regions coloured in dark greens are the ones corresponding to the periphery of the ESPON space, and so the distances to their destinations are generally higher than the ones the regions situated in the centre of this space.



Map 50 Km per person in generated by car for business purpose

5.2.2 km per person in generated by car / Purpose: leisure and visits

Rationale and policy relevance

Km per person by car in leisure and personal trips follows the same rationale as the previous section.

Methodology

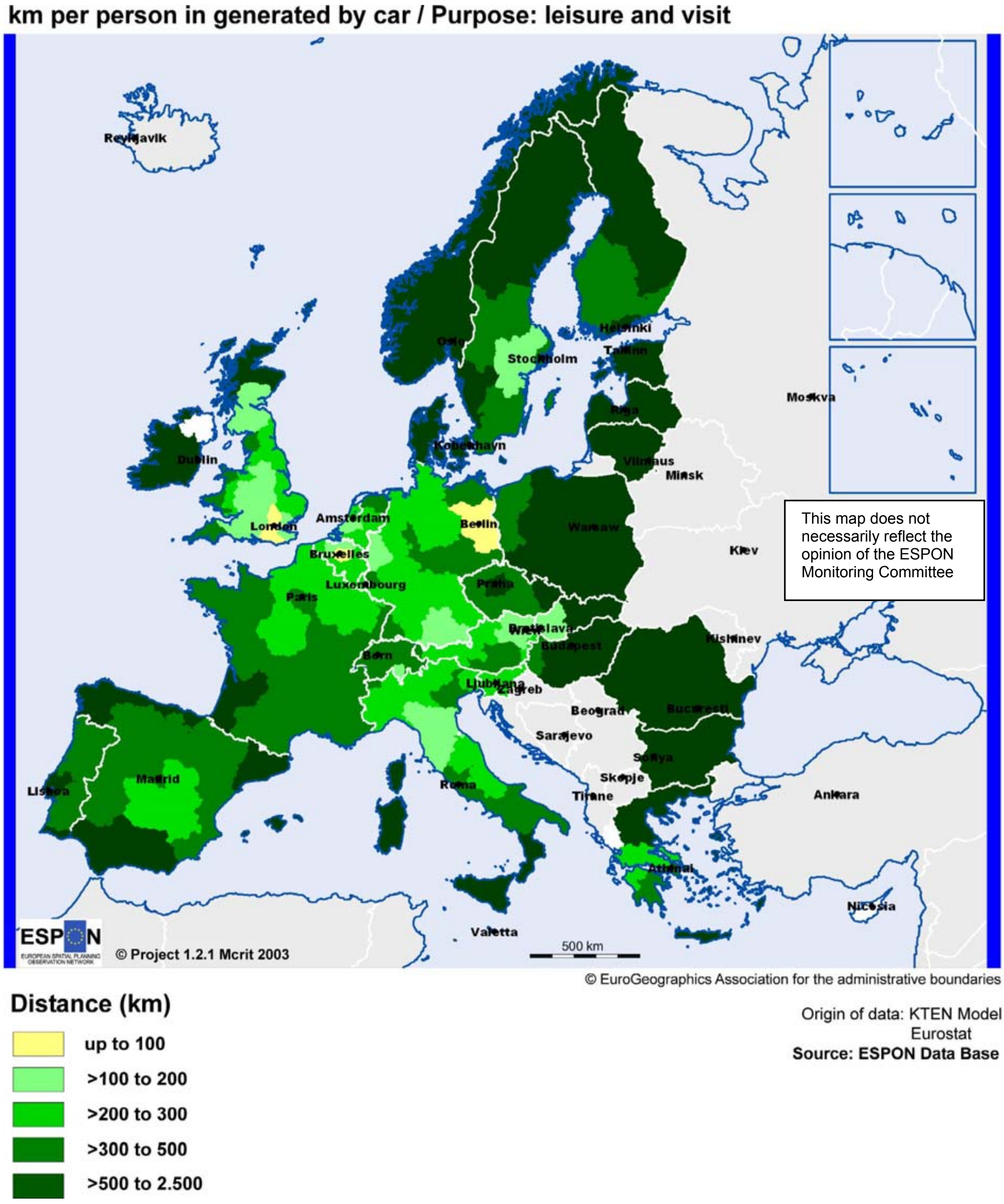
The method is explained in the previous section

Data requirements

The same data as the previous section has been needed.

Application and results

The number of km per person per road by leisure and visit trips has been calculated for all NUTS2 of the ESPON space. Like in the previous chapter, the regions situated in periphery of the ESPON space have a higher average distance in their trips. Because some of the most tourist attractive regions are also in the periphery (like Mediterranean coast) some regions in the centre of ESPON space with short business trips have longer trips for business or visit trips.



Map 51 km per person in generated by car for leisure and visit purpose

5.3 Freight volume generated

In the first point of this document the influence of transport operating system on transport costs and time, and consequently on accessibility has been stressed, showing that operations constraints and performances do introduce more spatial differentiations.

This introduction of operating system will also affect the choice of route and the assignment on network.

Concerning traffics volumes it is first necessary to stress that information at European level is fairly poor mainly for passenger traffic; this mean is particular that there is no O/D statistics at regional level (NUTS2 level or NUTS 3 level).

For freight transport the major data source is the COMEXT data base which gives information on trade between countries, per mode, at a detailed level concerning the type of product in NSTR and SH nomenclature, in tons and Euro.

For O/D flows between regions only national sources are available, expressed in NSTR nomenclature from regions (country of national source) to countries, being aware that most of the time this information is not very easy to obtain and to introduce in mere global data base because of lack of harmonization of presentation.

Among the existing sources one must however mention specific surveys realised for the Alpine and Pyrenees crossing in coordination between countries concerned (France, Italy and Switzerland): it is the CAFT multimodal survey for year 1993/1994 and 1999/2000 with support of the Commission ; this survey provides O/D flow information per mode in combination with Alpine and Pyrenees crossing routes.

The Commission and many experts in transport are well aware of this lacks of information which is very important at a time when TEN-T are implemented.

This topic has been several times pointed out in research program for transport during the IV and V framework program and is still a priority in present research in the ETIS (European Transport Information System) projects.

This means that flows must be often estimated using models and compared with existing information when it exists.

To obtain such reference, at NUTS2 level, two major types of tools have been used.

- a gravity model developed by NEA at NUTS2 level, per mode for ten categories of product, as well as a NESTEAR model based on 13 types of products: the 13 types of product have been defined as that bulk, general cargo and unitised cargo can be better differentiated on the basis of 2 digit NSTR nomenclature, following the regroupment proposed in SCENES project which follow; also an Eufranet exercise must be mentioned which is in fact based on the NEAC data base.

- an input output model developed in SCENES and STREAMS project (MEP) which estimate trade flows between region and the transport flows in tons on the basis mentioned above of 13 products.

For the first exercises attempted on this report the SCENES database has been used for road assignment. For rail the example given is taken a work developed, using Gisco network and O/D data estimated by NESTEAR.

Rationale

The quantity of freight is a classic indicator but important. These data are organized according to the mode of transport, and will be used for assignment on the network according to the mode, of the type of product and matrix O/D.

Method

We have several data bases for the goods, Scenes, Caft, Commext…who provide quantities of goods transported from region to region (NUTS2 or NUTS3 according to cases) or from country to country, by type of product (13 to the total) and by mode.

Table 2 Standard Goods Classification for Transport modified

Groups of goods	NST/R groups	Type of handling
1 – agricultural products and cereals	00 01 04 05 06 09 17 18	general Goods
2 – Foodstuffs	02 11 12 13 16	unit
3 – Foodstuffs conditioned	03 14	unit
4 – coal and iron ore	21 22 23 41 45 46	solid bulk
5 – Petroleum products	32 33 34	liquid bulk
6 – Metal products	51 52 53 54 55 56	general Goods
7 – Cement, lime, manufactured building materials	64 69	unit
8 – Crude and manufactured minerals	61 62 63 65	solid bulk
9 – chemicals of basis	81 83	solid bulk
10 – Natural and chemical fertilizers, plastic matters and other chemicals	71 72 82 84 89	general Goods
11 – Transport equipment, machinery, apparatus, engines, whether or not assembled, and parts thereof	91 92 93	general Goods
12 – goods of equipment	931	unit
13 – various product manufactured	94 95 96 97 99	unit

The following picture shows the structure of a basis (in this case the Scenes data base).

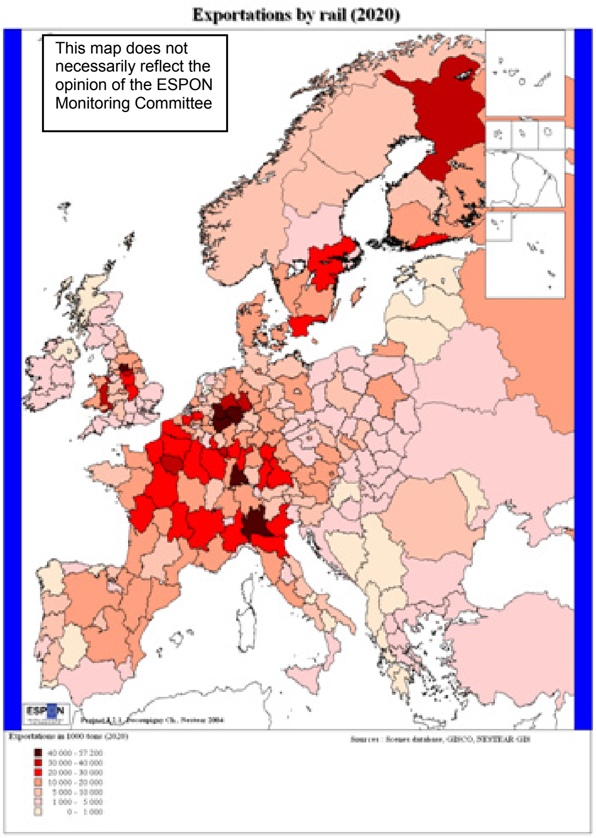
Origine	Destination	Groups of goods	Mode	Volume
AT11	AT12	13	6	1,1

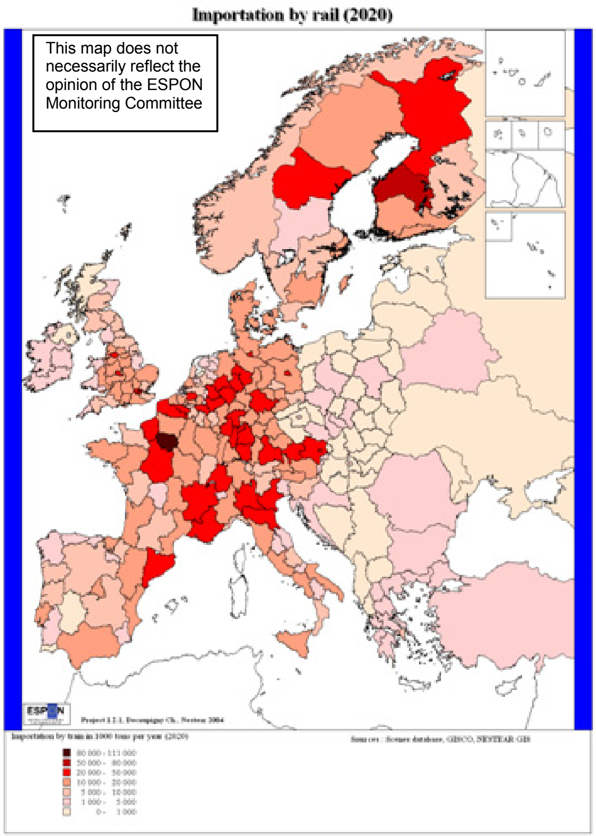
It is about the transport by road (mode 5, 6) by year of various products manufactured (Groups of goods number 13) between two Austrian regions.

Knowing accessibilities region / region, we calculate the quantities in tons kilometres for each region by mode and by groups of goods.

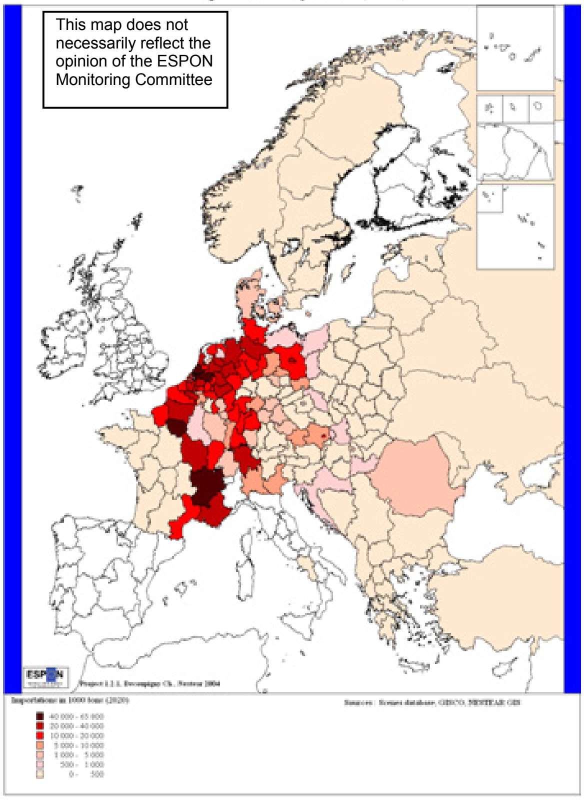
Demonstration example

The following maps give examples of use of these databases.

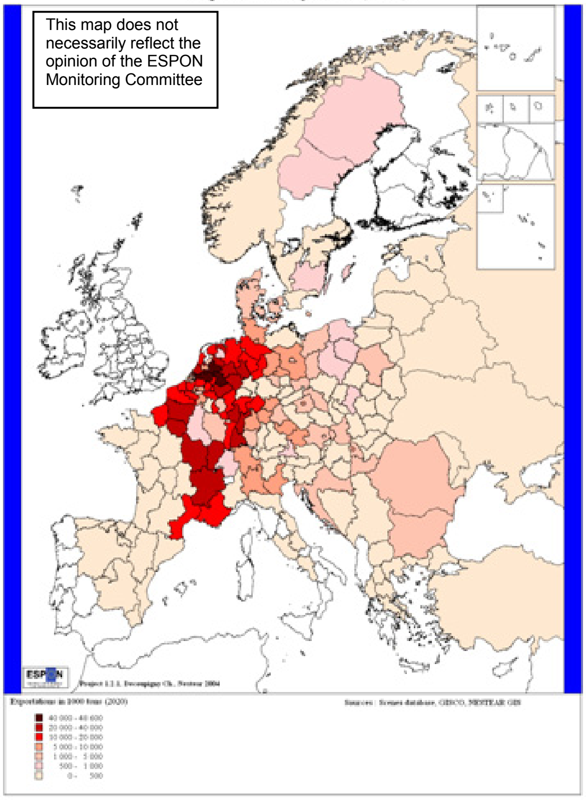




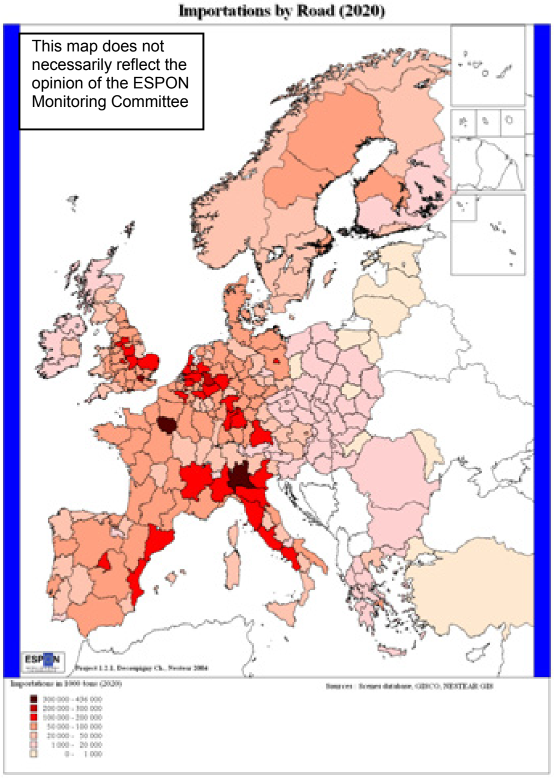
Importations by IWW (2020)



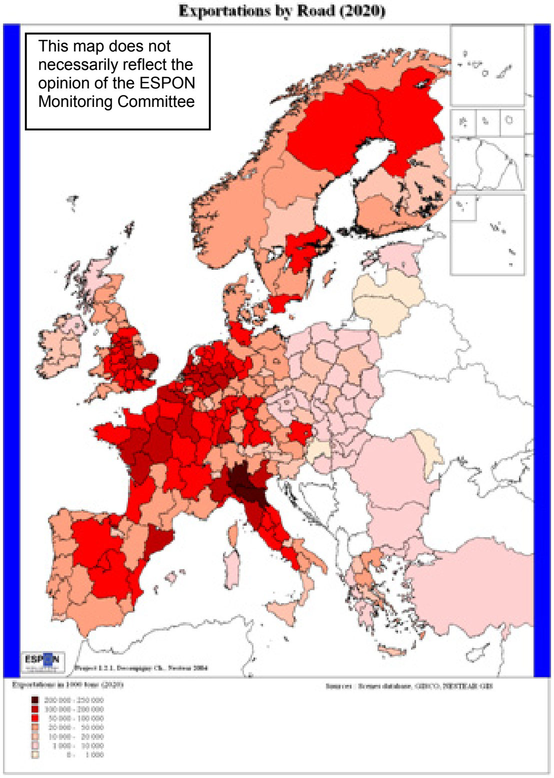
Exportations by IWW (2020)



Importations by Road (2020)

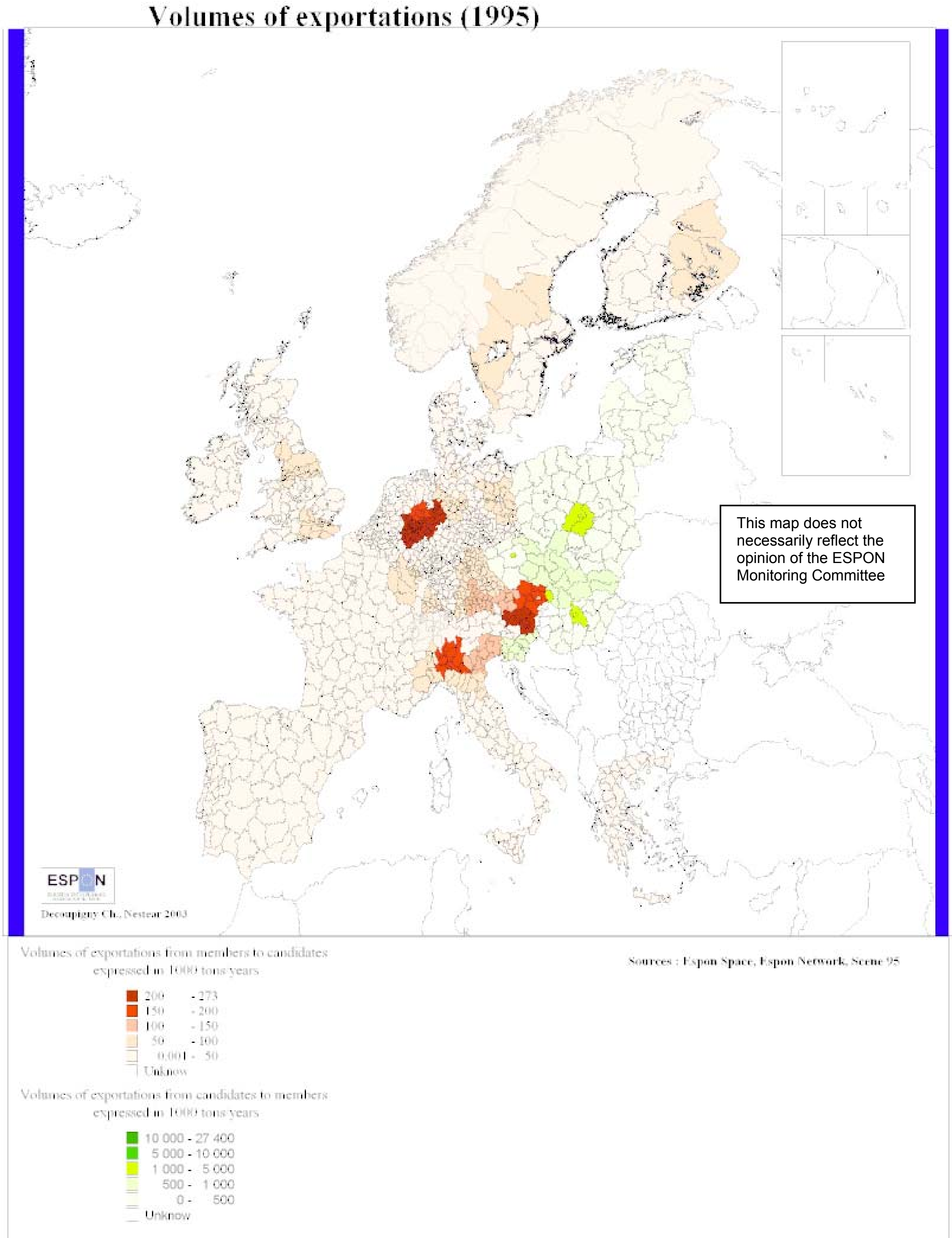


Exportations by Road (2020)



Map 52 Demonstration examples of Scene database for freight

The following map corresponds to exports of goods (in thousand of tons) from countries of the CEE to destinations of countries candidates and vice versa by road (all goods mixed). Data are assignment at the NUTS2 level without Bulgaria and Romania.



Map 53 Volumes of goods exportations

5.4 Car traffic on road / Purpose business

Rationale and policy relevance

Assignment is the last step of a transport demand model, and deals with the equilibrium between the demand and the supply side of transport. The demand side is made up of the number of trips by O-D pairs and mode, and the supply side is made up of a road network represented with links that have their own characteristics (length, free-flow speed, etc.). The equilibrium can be taken at several levels; in road network the travellers look for routes to minimise their travel costs, which depend on a number of factors like journey time, distance, monetary cost, type of road, etc. These allocations of routes define link flows that theoretically should be in equilibrium when travellers could not find better routes to their destinations. This resulting flow may affect choice of mode, destination and time of day for travel.

Assignment allows the identification of most congested links, which helps to identify areas subject to high traffic pressure, and therefore the option to try to reduce negative effects derived from this traffic by strengthening environmentally compatible means of transport, levying road tolls and internalising external costs.

Methodology

The matrix of business trips by car is taken from the KTEN distribution step for business trips. The business trips assigned are the ones made by car. The assignation is All-or-Nothing and time is the only variable is user’s generalised cost function to choose the route (since we are modelling long-distance interregional trips in a relative dense and precise network, this only time-based method, being the easier one, provides good enough estimates relative to more sophisticated assignments by Stochastic user equilibrium or Deterministic user equilibrium methods).

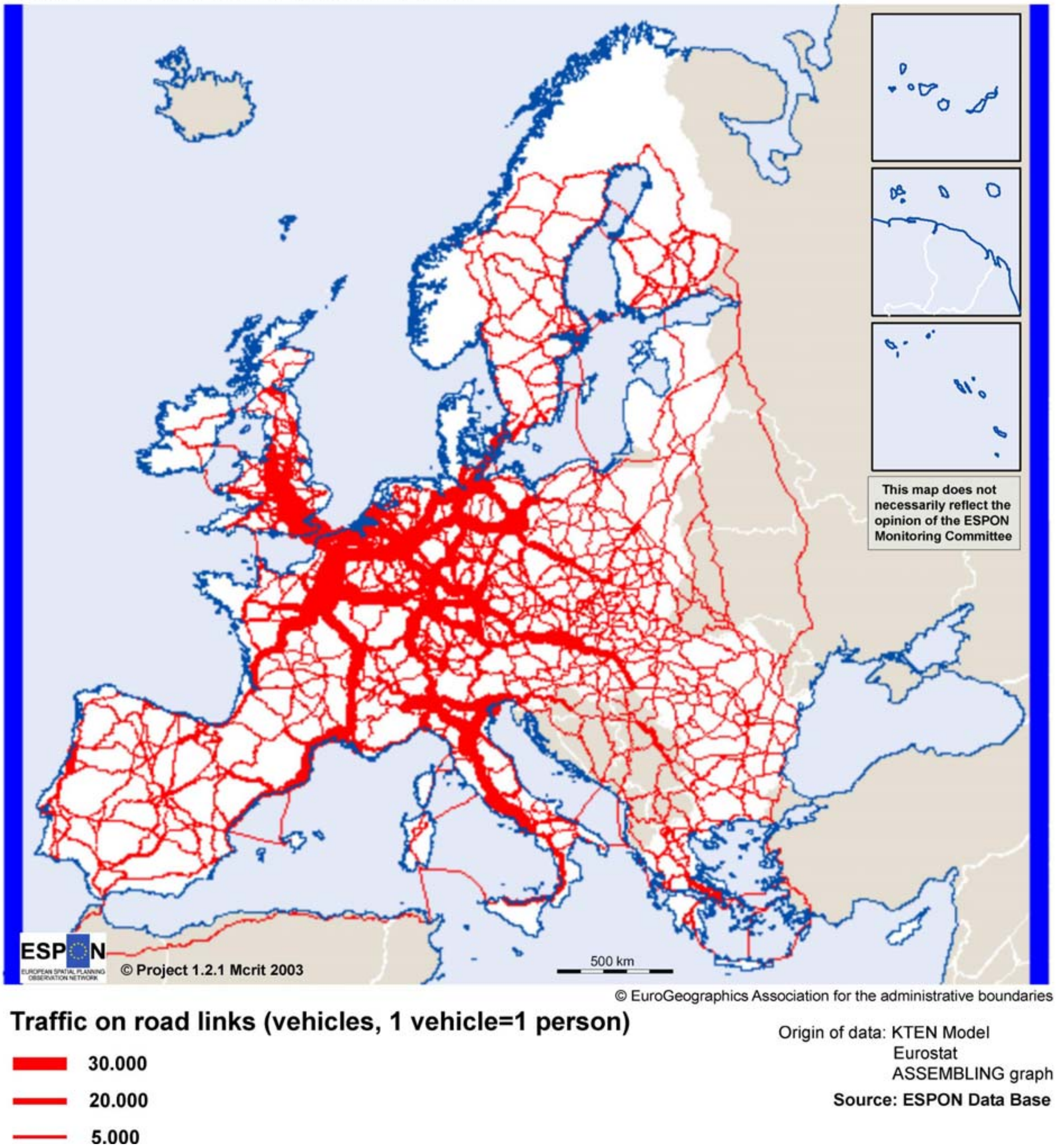
Data requirements

The transport network used to calculate the cost to travel between to zones and the assignation is from ASSEMBLING multimodal graph, which is more widely explained in a previous section.

Application to ESPON Space

Next figure shows the minimum paths routes driven by the business trips between NUTS2 in ESPON space, using road network and ferry lines (without considering the services). Main corridors are highlighted between most EU central countries capitals. It is not only the fact that they are bypasses to go from any point in the territory to another, but their highest generation and attraction index (see previous sections). For this geographical reason, road networks in peripheral regions have not such a high traffic on their links, in some cases reaching values 100 times lower

Traffic on road links / Purpose: business



Map 54 Traffic on road links / purpose: business

5.5 Freight traffic on road

5.5.1 Freight road assignment: volumes

Rationale

It is important to be able to assign goods transported on the road network for several reasons. A first consists in bringing a complement of information to the indicator of transport quantities on the paths followed by goods between regions. It permits while growing information with the indicator of network capacity, to localize the bottlenecks of the traffic to short or long time. It also permits to see the main corridors on trans – European network.

Method

We know with the databases, the goods distribution by mode. Then, we calculate with the algorithm of Floyd the shortest paths by road between every region, and we show the segments of the road network (motorway, dual carriage…) used to join every region. Then we assignment on these paths the quantity of goods according to the regions (indicated in data bases).

We can use several variables in the minimal paths calculation, the minimum time, the minimum distance or the minimum cost.

We calculate the times of way for heavy truck from point to point of the network. These times correspond in minimal paths in minutes. We consider that the average speeds depend on the quality of the infrastructure and the relief (altitude and slope). The speeds retained are the following:

- motorway: =75 km/h,
- dual carriage: 70 km/h,
- main other road: 60 km/h,
- other road (secondary network): 40 km/h.

These speeds can be reduced according to the slope (when data are specified) or according to the altitude of roads.

Besides, the relations with the ferries are raised on average of 6 hours in a first time, we will introduce a time of waiting proportional at the frequency for every relation.

We also take account the time of waiting in borders, notably between countries candidates and the other countries of the East. This time is on average of 24 hours, nevertheless this time varies meaningfully according to borders. Later, this time of waiting will be value according to countries.

We integrate for the minimal paths the legislation on times of truck driver. The European regulation 3820/85 of 12/20/1985 concern times of driving and rest.

Data requirements

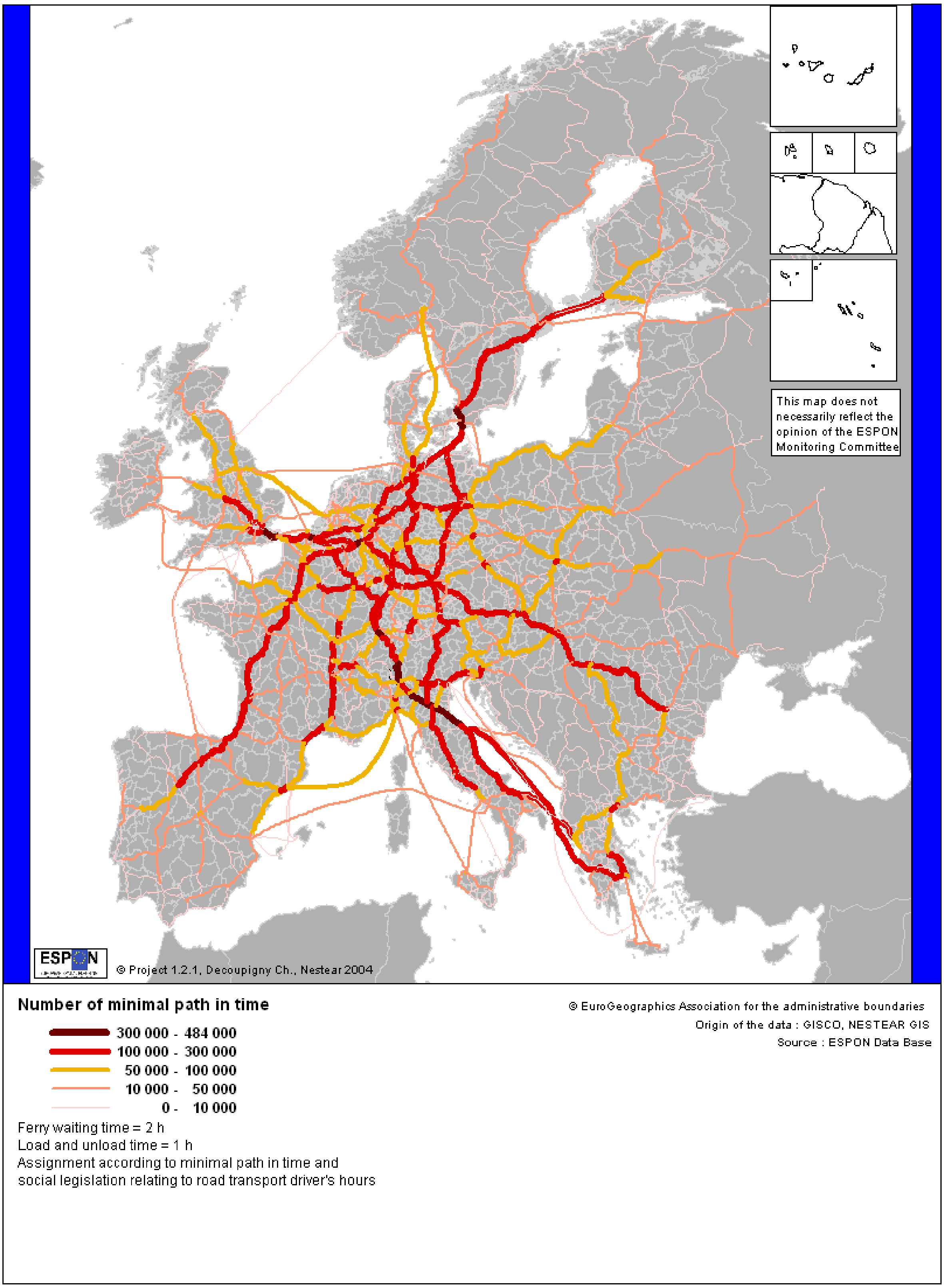
The data requirements are similar than road travel time and cost.

The method requires to know the modal distribution of the goods traffic and the quantities. We need of a sufficiently detailed network in order to be able to calculate paths between every region. The density of the network will depend on the level of the NUTS studied.

Demonstration example

We use the minimal path in time between two points for to assign the volumes of freight of these two points. The following map illustrates the minimal path on the Espon space.

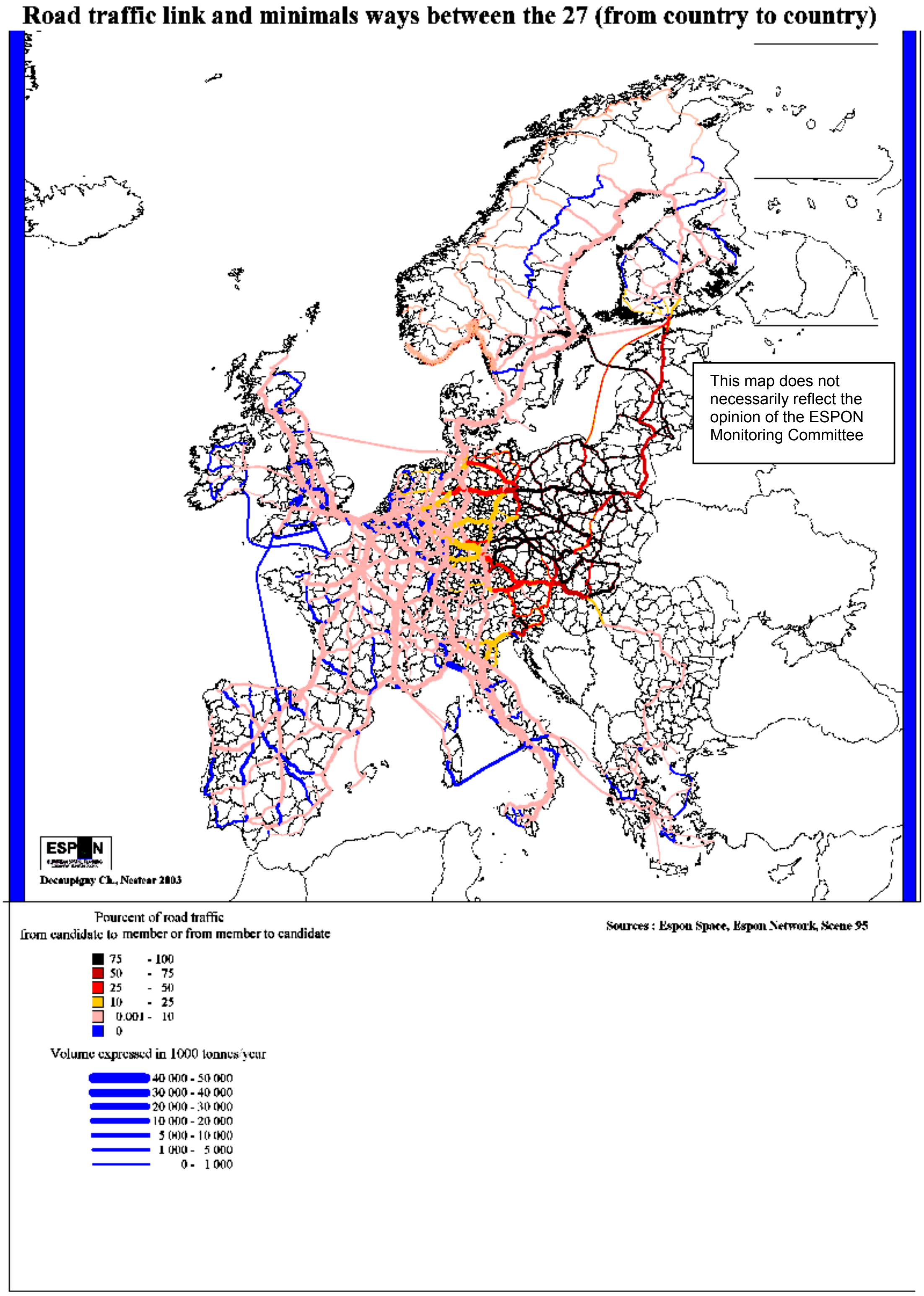
Minimal path for truck



Map 55 Minimal paths for trucks

The following map shows an assessment of the volumes of freight on the minimal paths with a difference between the flows involving new EU countries and other flows. What we can see is that main corridors are located in EU15 countries, mainly Benelux, Germany, Italy and France. By showing the road traffics involving new EU countries, the map allows us to locate the regions which can see their traffic increase in a significant way, with the enlargement of the EU. These ones are in Eastern Germany, Austria, and the North-East of Italy.

Finally, we have to note that data are given by country. It is why some peripheral areas volumes (as the Sicilia) are very important in this example.



Map 56 Road traffic links and minimal ways between the 27

5.5.2 Freight road assignment: Number of lorries

Rationale

This indicator permits to complete the freight road assignment. The calculation of the number of vehicles participates to the same reasoning that previously. It consists to complete information of tons transported while supplying an assessment number of truck on the network. This information could be used to calculate emissions of gas to greenhouse effect.

Method

The method is simple. It consists to divide quantities of goods between regions by the rate of middle replenishment of trucks (about 20 tons by truck). After that we use the same method that for the volume assignment.

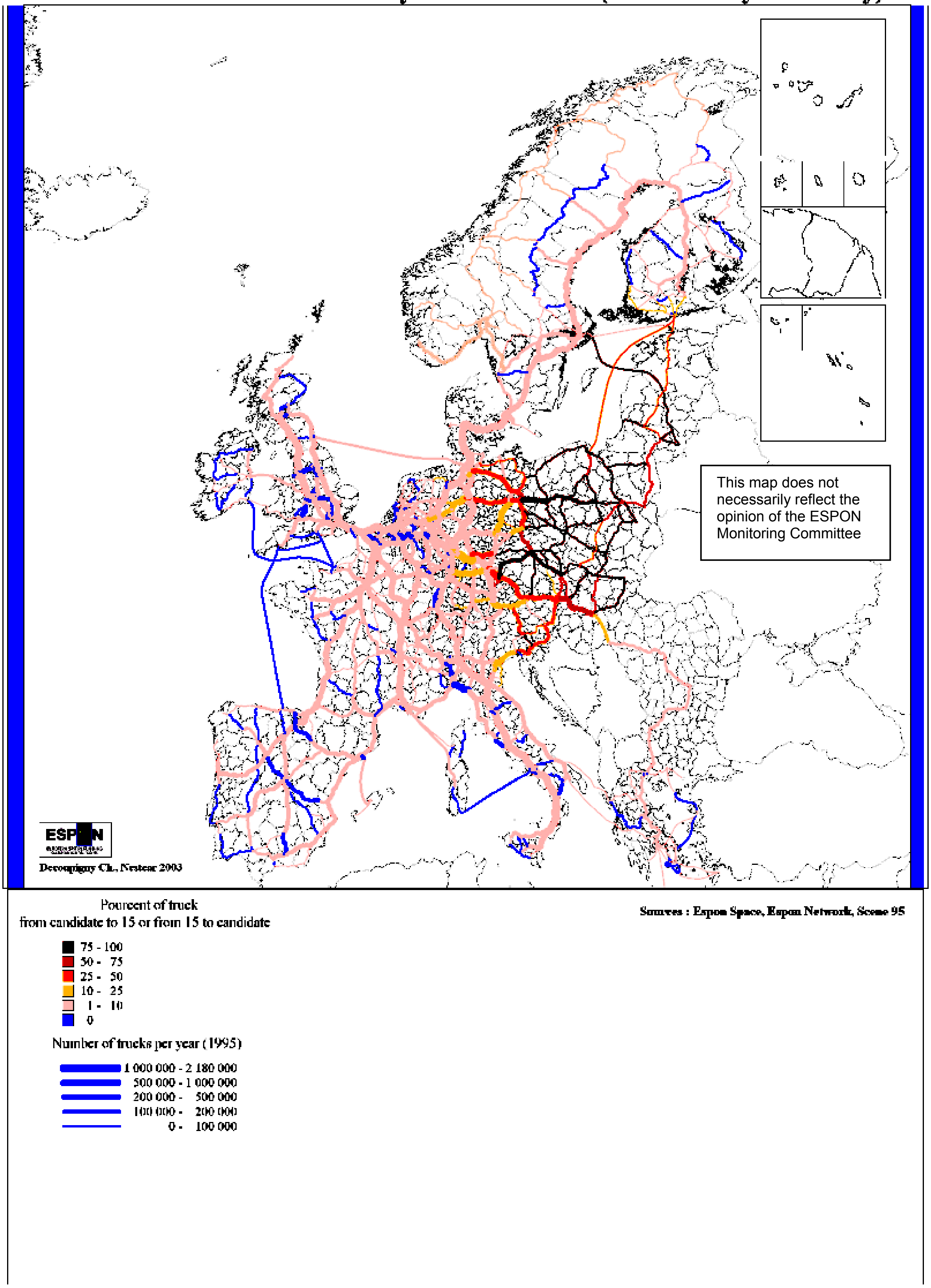
Demonstration example

The first map shows an assessment of the number of trucks on the minimal paths with a difference between the flows from origin to destination of the candidates and the members. It shows (as previously for the volumes) the corridors of road traffic. In this example we have no data for Romania and the Bulgaria, it is why we have only one way for these two countries.

The second map shows the traffic given by Gisco.

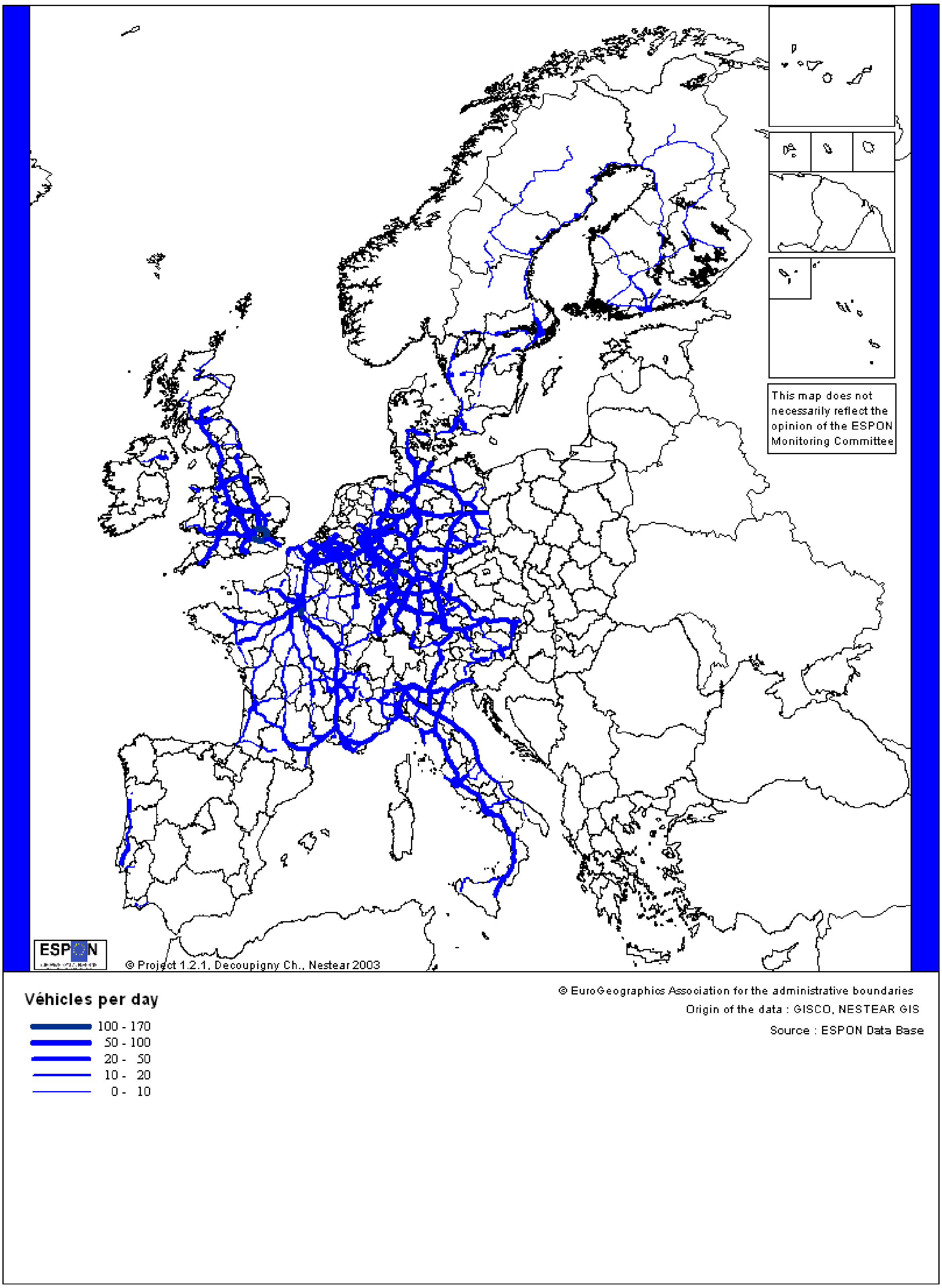
The comparison of the two maps is difficult because the traffic is not expressed with the same unit, however one observes a resemblance (when data exist) about the corridors.

Road traffic link and minimals ways between the 27 (from country to country)



Map 57 Road traffic links and number of trucks between the 27

Average daily trafic on the link for buses and trucks, i.e vehicles with a total weight >3.5 tons



Map 58 GISCO road traffic

5.6 Freight traffic on rail

5.6.1 Freight rail assignment: volumes

Rationale

The assignment of goods by direct train follows a similar reasoning that for the road.

One will be able to do a comparison between the road and the rail in term of volume or cost. This comparison will be useful to redefine the modal split.

Method

As for the road, the assignments are made according to the minimal paths while including the dedicated freight network (Eufranet). We want to take into account of the dedicated freight network proposed by EUFRANET, because there could be substantial reduction of time and cost of rail transport.

We are obliged to do an assessment of the speed of circulation of freight trains (indeed the Gisco data base gives only the maximum freight speeds). For example in French the speeds given by Gisco are bigger than real speed. These speeds depend mainly on the quality of the infrastructure, of the relief, and the waiting time some nodes of the network.

We assign volumes on the rail network according to the minimal travel time. We take into account of the border crossing time (from 30' up to 4 hours in average and often more than 10 hours for crossing border of a country like Spain).

Data request

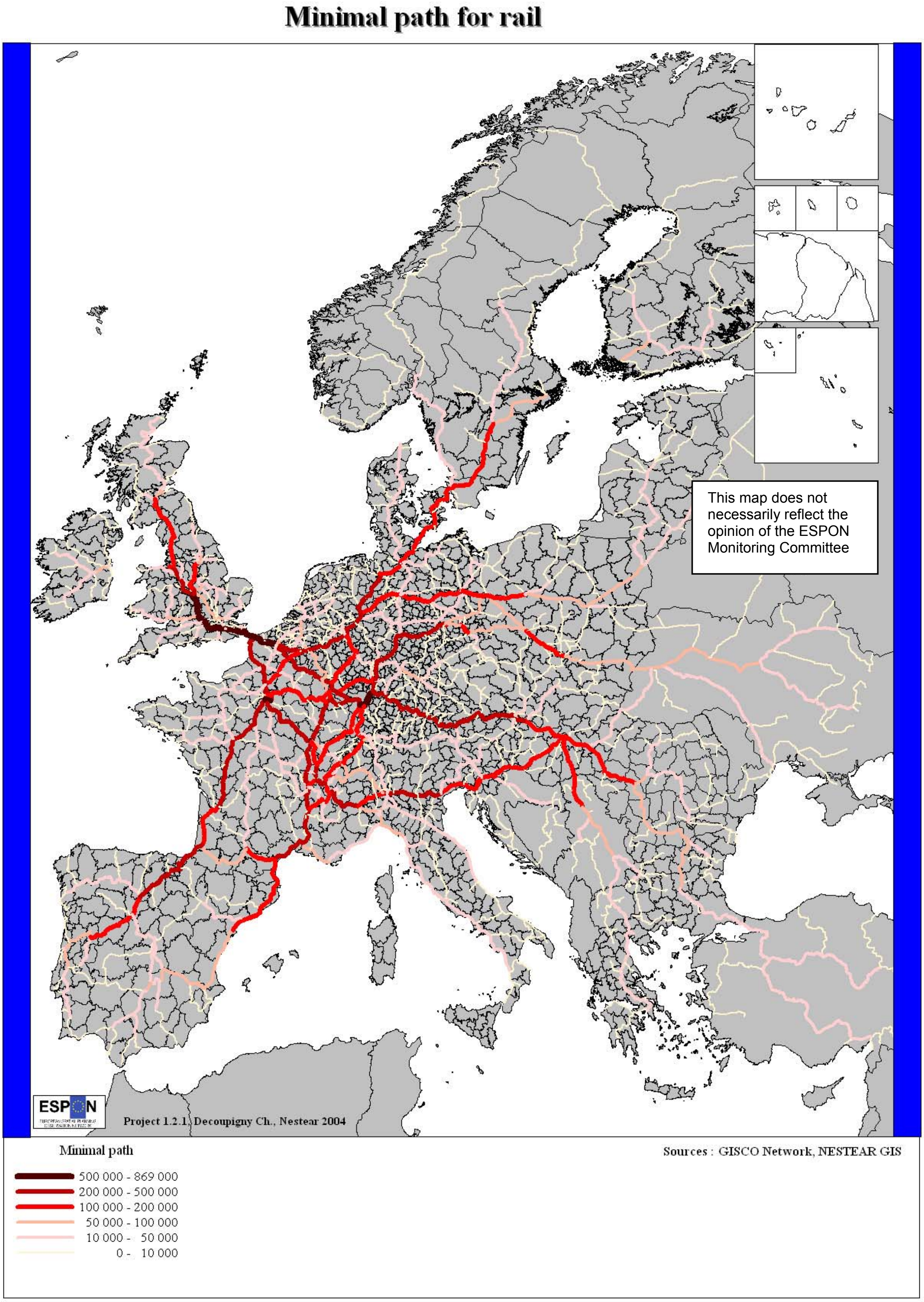
Time of waiting in some nodes for a main rail network.

Real freight trains speeds, not per O/D but per segment.

Gisco rail network.

Demonstration example

As for the road, the assignments are made according to the minimal paths.



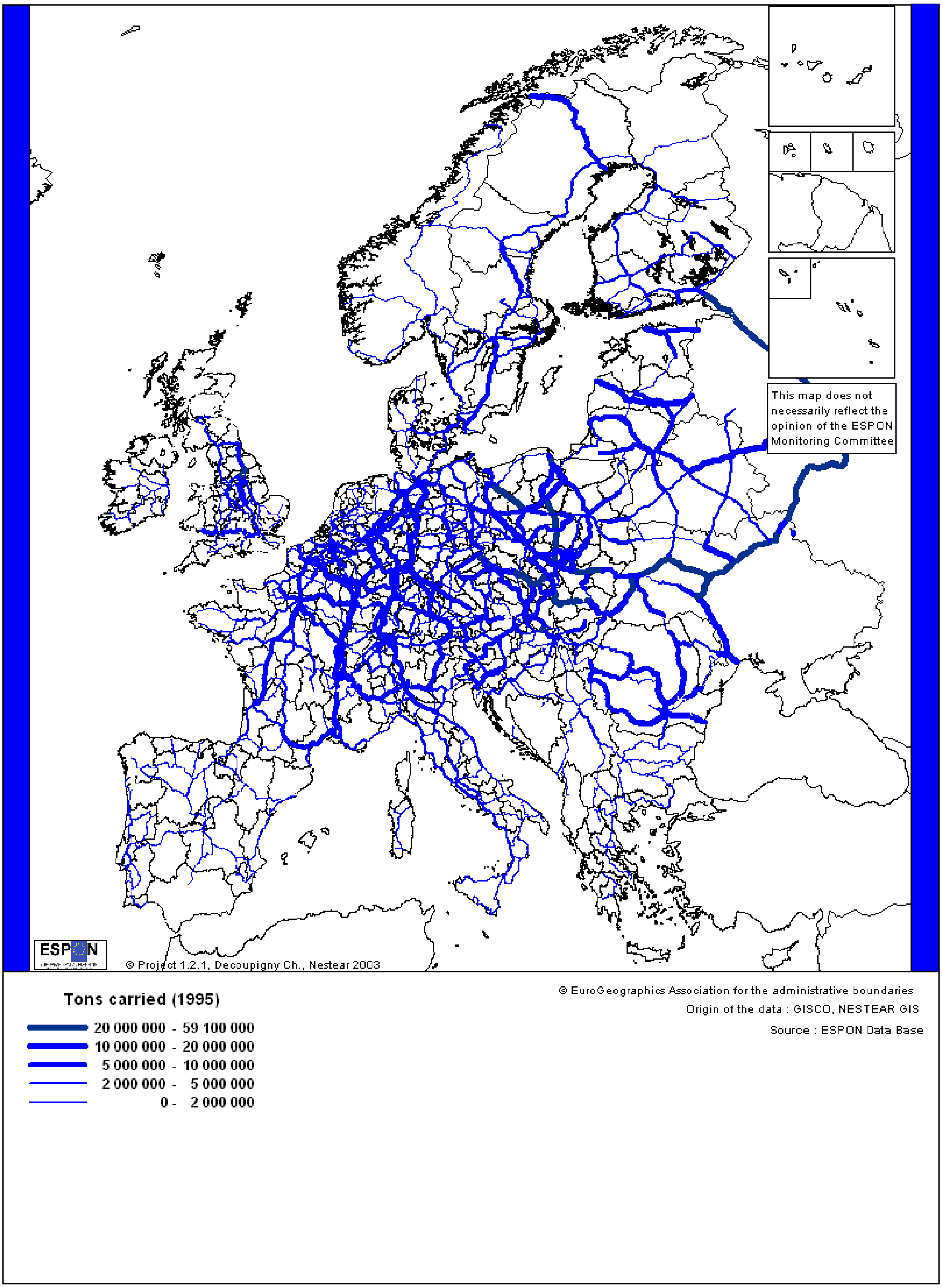
Map 59 Minimal paths for rail

The following maps show the traffic railway in tons per year. The first is an assignment of Scenes database whereas the second is the assignment of Gisco database.

We can see the similarities on the two maps about the corridors. However, in the case of the rail freight flows from CEE to CEE we do not see in Germany the corridors toward the East.

While observing the map, we see that the highest traffics are found in Benelux, Germany, North Italia and France. The second map underlines in an important way the high volumes of traffic in the Eastern countries.

Railway traffic

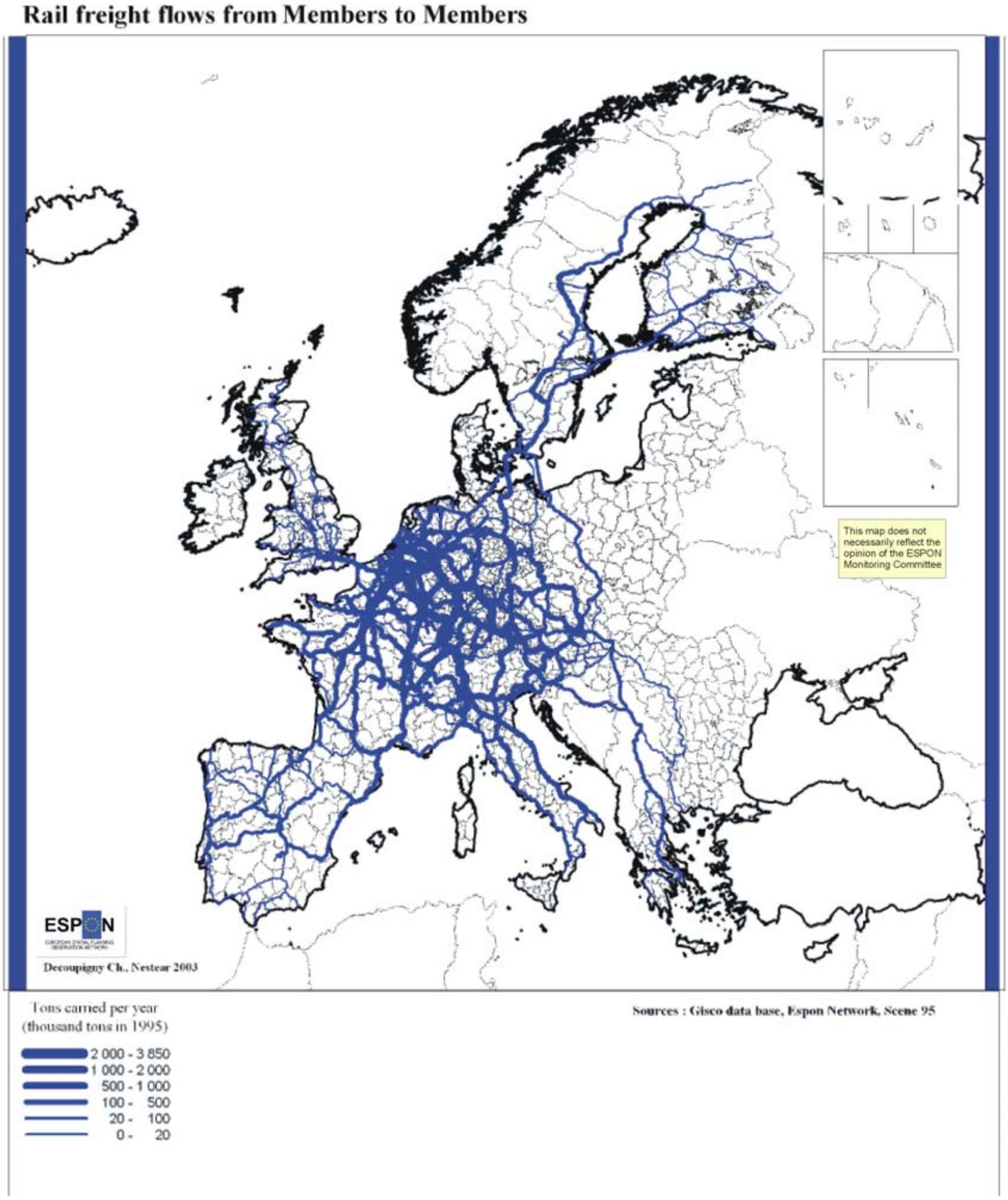


Map 60 Railway traffic

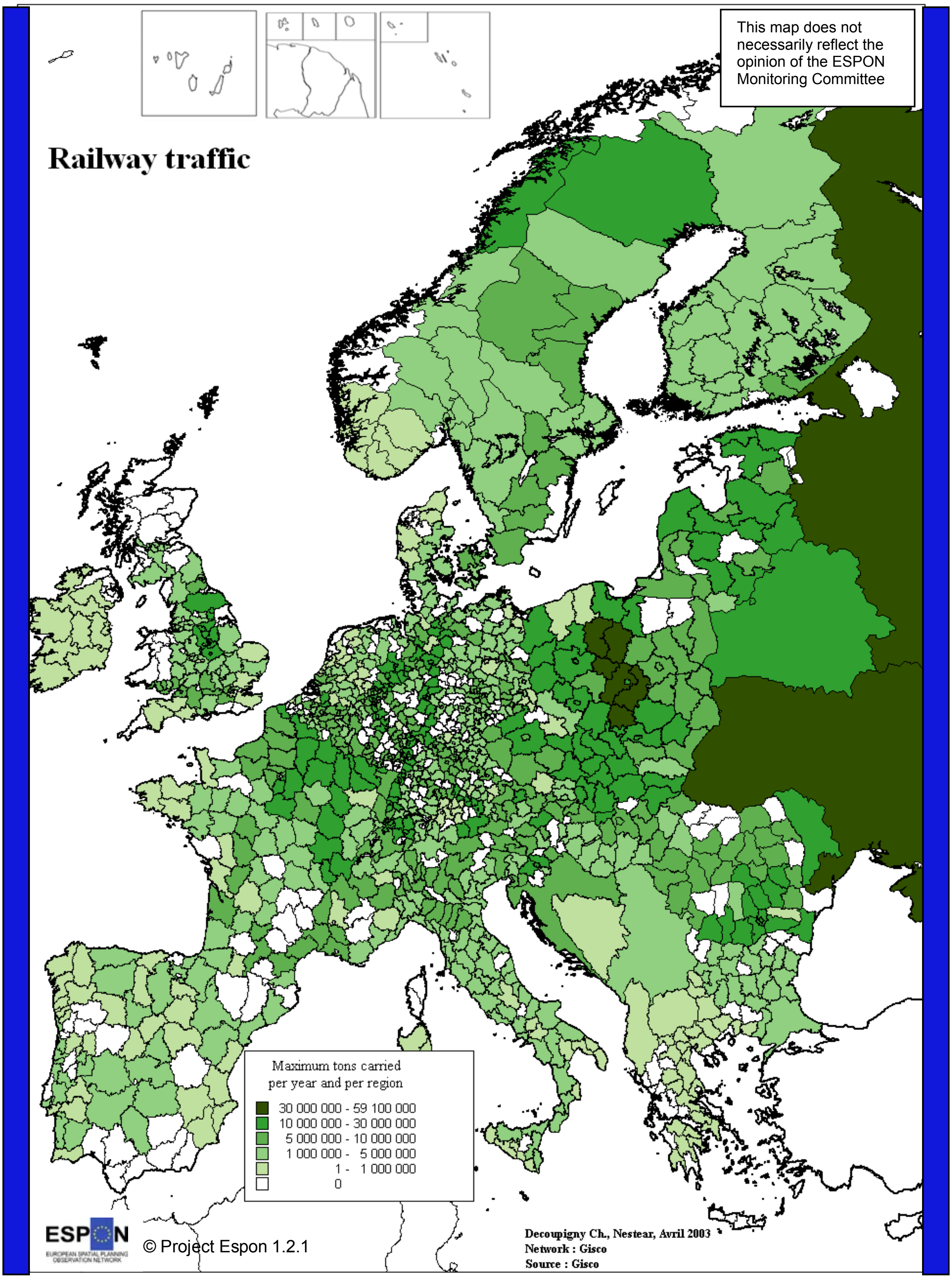
The third is the same than the second but data are given by region.

We can see the similarities on the two maps about the corridors. However, in the case of the rail freight flows from CEE to CEE we do not see in Germany the corridors toward the East.

The third map shows the poor interest of an assignment of data by region. The network dimension (capacity, corridors and bottleneck) disappears with the zoning. Only the German zoning can to put in evidence the notion of corridor. This representation homogenizes the results and makes disappear the importance of the structure and the relation of a transport network. We can not see on this map the structure of the relations between the regions.



Rail freight flows from EU of 27



Map 61 Railway traffic

5.7 Port traffic

5.7.1 Freight sea assignment and maritime routes

In short sea shipping operations different segments must again be pointed out:

- the bulk segment

This is a classical short sea shipping market, which represents most of the SSS traffic in Europe between countries and within countries. Major products concerned are petroleum, fertilisers, building materials, basic chemical products, coal, wood... are they often required specific logistics: major ports activities are related to these traffics which often do not go out the port area and are transformed in industries nearby

- the feedering segment

Feedering is the European maritime distribution of intercontinental containers. Feedering lines develop in Europe with the increase of maritime container traffic ; in general the ships are dedicated to maritime containers and they serve the major ports in Europe or major hubs for maritime containers, which are transhipment places between large "mother" vessels and smaller "feeder" boats (Algesiras, Goia Tauro, Malta..).

The feedering segment is in general organised by large maritime operators when considering the mother ship operation and their market geographic distribution ; accessibility and regional development will not be in that case the major concern.

- the intermodal segment

This segment has been presented already in the former report as a segment more directly in competition with European road transport. RoRo technique, and possibly LoLo technique can be used ; freight vessels and Ropax (mix vessel for passenger and freight) can be appropriate according to the market.

For this technique possible maritime routes have to be investigated in detail pointing the road route in competition. So far this market is not much developed except in Baltic or North Sea region where maritime routes often benefit from a geographic advantages with road routes, which are much longer to serve the same O/D relations. This is not always the case for Atlantic and Mediterranean costs and researches are underway in order to develop assignment tools, which include both road assignment and maritime route assignment.

If we define intermodal transport as the transport of a unit with at least one change of mode[68], then the land intermodal transport must also be considered as a possible alternative, or a complementary link, to a SSS transport.

Such intermodal transport will include combined transport (trailers, swap bodies) and transport of maritime containers.

So far there are not many combined transport terminals within ports so that the transfer from a ship to a train of a trailer or a swap body is not very frequent. But this would occur more often in the future with the development of SSS and the promotion in Europe of combined transport.

For maritime containers (ISO containers) the situation is quite reversed: maritime terminals of containers are better and better connected with rail and shuttle services are supplyed from major ports and terminals to inland terminals.

In the first step of application of these models it has been stressed that focus was put on Ro-Ro service directly in competition with road.

However information relative to intermodal (land) services has also been collected in several EU research projects and in particular in SPIN projects.

Therefore there is also some information about service by rail between ports and inland terminals.

In fact the improvement of rail container services to major ports has been quite significant in the recent years with, in particular, the services supplied by new entrants, when competition has increased. Quality has also improved with possibility of tracking and tracing.

The situation has become such that for several important European ports the road transport of containers is now limited for distance above 300 or 400 km; such improvement will probably continue for all major ports including Rotterdam when Betuwe line enters in service, or Genoa when new line to hinterland is constructed.

Such perspective of massification of rail transport in relation with maritime services can then be also considered although the simulation of the total chain with maritime, rail and road links with at least 3, 4 or 5 transhipments becomes fairly complex, multiplying possible combinations.

Method

The method to assess the minimal paths is the same of the road.

- Travel time by ship

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68 Definition of IQ (Intermodal Quality) IV PCRD

The travel time by ship can be estimated in two ways: an average speed of the ship when the distance is known or the time scheduled of the service when it is published.

Both approaches have been used and the available schedules of services have been entered in the database, keeping track of the name of the companies because the time of the maritime journey will depend on specific vessels and operating characteristics of the companies on the same relations: for simulation O/D averages have often been computed but there is always the possibility to analyse how the results are affected by different hypothesis of the time of the journey.

The travel time has been used for the ferries lines, but for the cargo or container we are used the average speed (30 km/h) for each relations.

Table 3 : travel time for 68 main ferries lines

Travel Time (in minutes)	Origine	Destination
20	BOGNES	SKARBERGET
1140	ANCONA	IGOUMENITSA
540	BRINDISI	IGOUMENITSA
10	BRURARVIK	BRIMNES
20	MESSINA	VILLA SAN GIOVA
20	HELSINGOER	HELSINGBORG
75	DOVER	CALAIS
120	DOVER	DUNKERQUE
150	DUBLIN	HOLYHEAD
170	STROMSTAD	SANDEFJORD
180	GOETEBORG	FREDERIKSHAVN
180	PORTSMOUTH	CAEN
210	ROSSLARE	FISHGUARD
210	TALLINN	HELSINKI
225	SASSNITZ	TRELLEBORG
240	DOVER	ZEEBRUGGE
240	RAMSGATE	OOSTENDE
260	ROSSLARE	PEMBROKE

270	POOLE	CHERBOURG
290	PORTSMOUTH	CHERBOURG
350	PORTSMOUTH	LE HAVRE
360	ROSTOCK	TRELLEBORG
390	SWINOUJSCIE	YSTAD
410	FELIXSTOWE	SCHEVENINGEN
420	VALENCIA	IBIZA
450	BARCELONA	PALMA DE MALLOR
450	TRAVEMUNDE	TRELLEBORG
480	ANCONA	SPLIT
480	NAPOLI	PALERMO
510	BARCELONA	IBIZA
510	VALENCIA	PALMA DE MALLOR
540	NAPOLI	REGGIO DI CALAB
540	SWINOUJSCIE	KOEBENHAVN
600	PIREUS	KHANIA
600	PIREUS	IRAKLION
630	TURKU	STOCKHOLM
750	BARI	IGOUMENITSA
840	HULL	ROTTERDAM
840	HULL	ZEEBRUGGE
840	GOETEBORG	KIEL
900	BARI	PATRAI
930	TALLINN	STOCKHOLM
960	ROSSLARE	CHERBOURG
1020	LIVORNO	PALERMO
1080	BARCELONA	GENOVA
1080	ANCONA	DURRES
1140	ROSTOCK	HANKO
1140	OSLO	KIEL

1200	ANCONA	PATRAI
1200	GENOVA	PALERMO
1320	PLYMOUTH	SANTANDER
1560	TRIESTE	PATRAI
1800	PORTSMOUTH	BILBAO
1860	VENEZIA	PATRAI
1920	HAMBURG	HULL
2010	STAVANGER	NEWCASTLE
2640	VALENCIA	SALERNO
3240	TRIESTE	ISTANBUL
510	BARCELONA	IBIZA
1560	GOETEBORG	HULL
2160	GOETEBORG	FELIXSTOWE
1200	ESBJERG	FELIXSTOWE
120	BELFAST	STRANRAER
90	LARNE	CAIRNRYAN
480	LARNE	FLETWOOD
2100	GDYNIA	HELSINKI
600	GDYNIA	KARLSKRONA
1200	GDYNIA	STOCKHOLM

- Transit time on node

This parameter is a very important. However, at this stage of application, hypotheses have to be taken, because of the lack of existing observations on transit time for different ports, for different techniques.

For the transit time two aspects must be taken into account:

- the part of the transit time related to the frequency of service ; to estimate this point one can consider that the driver is always aware of the time schedule and that he can adapt his arrival time to the minimum delay required for presentation at the gate before departure. However this is not always very easy because the driving time cannot be completely planned in particular on congested link

- the minimum transit time required for trans-border operations including administrative formalities and access to the terminal within the port.

For the transit time the best way to proceed was then to make hypothesis and to consider this variable on a major parameter of the modal simulation, which is consistent with the objective to use the model for testing transhipment techniques and procedures. Finally it was also be stressed that the time cycle for driving a truck cannot be analysed independently of the time spent for driving, transit in port, and on board of the vessel: for each of these segments the "status" of the time of the driver (whether it is accompanied or non accompanied transport) must be considered so that the European regulations are respected. If waiting time can sometimes be considered as resting time, part of the transit time will be considered as "time at disposal" or driving time.

Data requirements

GISCO road network

NESTEAR sea network

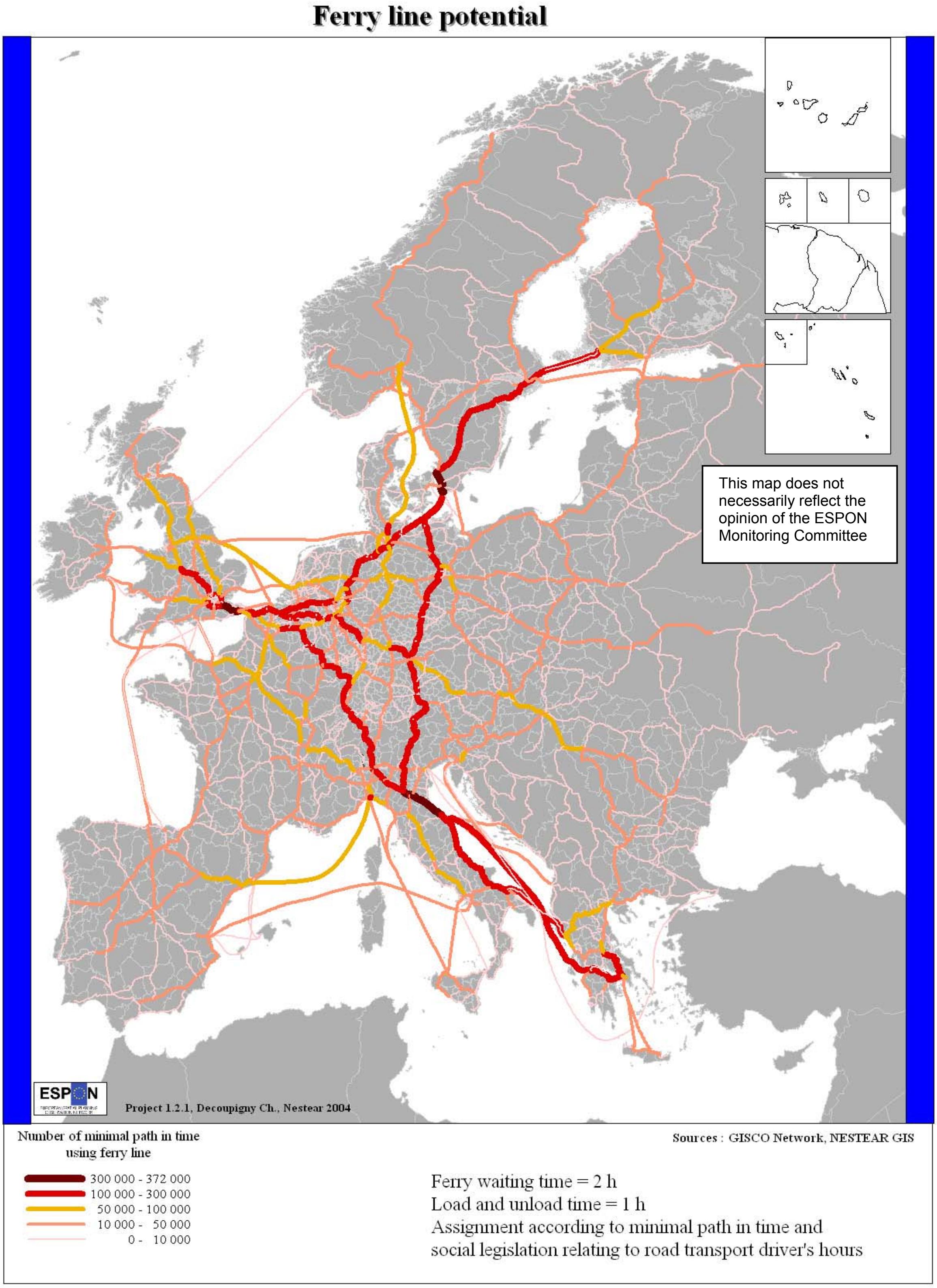
NESTEAR ferry network

Demonstrations examples

The results of minimal paths are reported on the following map. For maritime links 68 main relations have been integrated in the network, with transport time attributes, hypothesis of 3h transit time (including waiting time). 1800 entry points have been considered in the European Network which means that more than 3 millions minimum paths have been identified and assigned as shown on the following maps.

The first map proves the intermodal corridors between road and Ro-Ro services. The second map gives the number of trailers (or trucks)[69] per NUTS3 level.

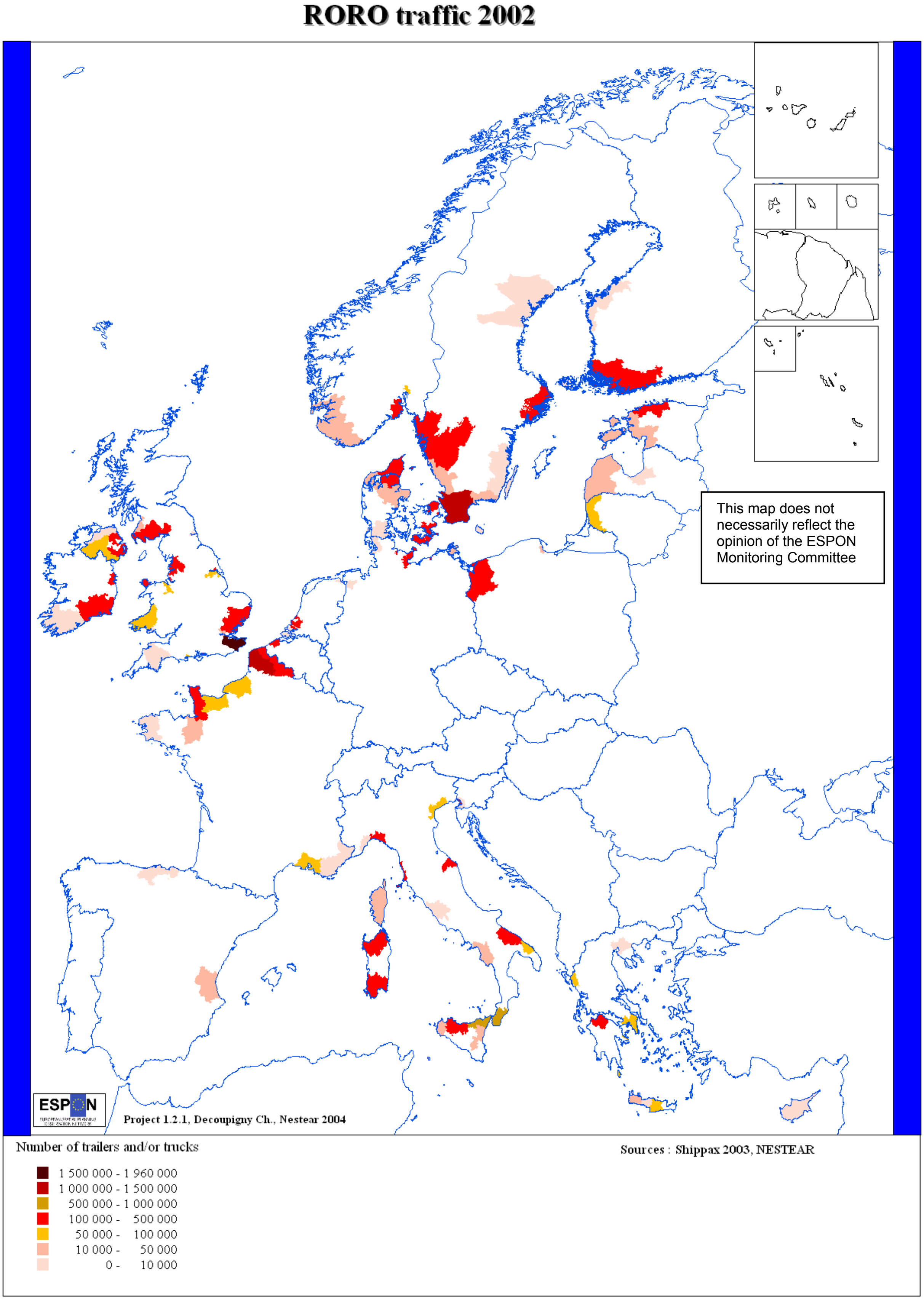
69 "The yearbook for passenger shipping traffic figures, statistics 03 », ShipPax



Map 62 Ferry line potential

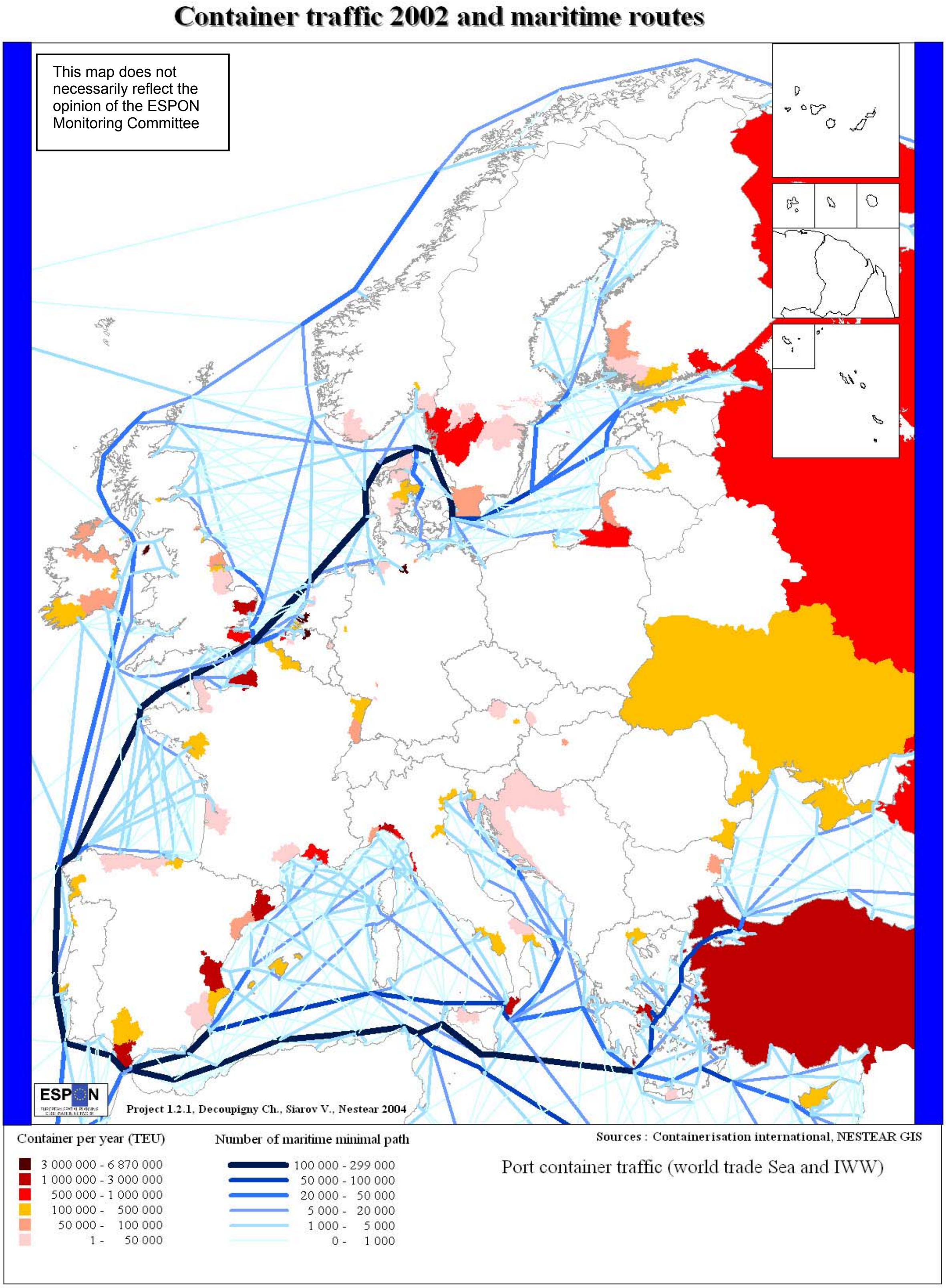
These maps show the strategic importance of a maritime link. The maps show clearly that connections with the centre of Europe are indeed concerned to some degrees with maritime links, although these maritime

links are often short distance links across the Channel, the Baltic Detroit and also in the Adriatic (with in this case longer maritime links).



Map 63 RORO traffic 2002

The following map proves the maritime routes and the number of container per NUTS3 level and the ports intra European traffic.



Map 64 container traffic 2002 and maritime roads

5.7.2 Economical potential accessible from seaports[70]

Rationale

The continental radiation is an essential element of the city-ports differentiation in Europe. It depends mainly on the situation of the city-port in the European urban structure and the conditions of transport of the goods forwarding by the port. In other terms, the radiation as considered here, is function of the location of the port compared to the wealth of the European area and of the performance of the transportation networks used. The truck being the means of transport common to all the city-ports, their radiation has been evaluated through accessibility by road to the wealth[71].

So, the goal of this indicator is to evaluate the accessibility of the maritime gateways to the economic potential of Europe. In that way, it gives an idea of the situation of seaports on the road network and their proximity to important cities and their GDP that are very important parameters for the attractivity and the development of the ports.

Method[72]

Two complementary approaches have been adopted to evaluate the radiation of the city-ports.

The first one consists in calculating the quantity of accessible wealth in a given time. It is thus possible to compare the city-ports between them for the same step of time, but also, for each one, to compare the evolution of the GDP accessible when increasing the time of travel.

The second approach is based on measurements of accessibility to an attractive economic function (here the population) and leads to the calculation of potentials. The interpretation of the potential and its justification rests on two empirical observations: the attraction of a place on the others is proportional to the M_j mass of this place and inversely proportional to the distance d_{ij} to this place [73]. The most general form of the potential is given by the formula below.

70 This part is based on a study made by Laurent Chapelon and Tristan Rambion : « Le rayonnement continental des villes-ports en Europe », 2004

71 in the original study, the population was also taken into account but we have divided to focus our analysis on the wealth.

72 For more details about the method, see by Laurent Chapelon and Tristan Rambion : « Le rayonnement continental des villes-ports en Europe », 2004

73 from GRASLAND Cl., 1991. « Potentiel de population, interaction spatiale et frontières : des deux Allemagnes à l'unification », L'Espace géographique n°3, p.244.

We note

M_j the GDP of a node j

d_{ij} the travel time between the nodes i and j

P_i the potential of a given node i

$$P_i = \sum_{j=1}^{n} \left(M_j \cdot f(d_{ij}) \right)$$

So, the potential measures the accessibility of the nodes to all the opportunities. A high potential means a good accessibility to the studied economic function.

However, reduction of the intensity of goods exchanges in Europe is not strictly proportional to the increasing of the distance. So, Laurent Chapelon and Tristan Rambion have calibrated a function of attraction for the goods transported by the trucks and the vehicles according to time of transport. As a consequence, the final formula of the potential of a city-port is[74]:

$$P_i = \sum_{j=1}^{n} \left(M_j \cdot 25_{0,8557} \cdot (d_{ij} + 25)^{-0,8557} \right)$$

In order to facilitate the interpretation of the results, it has been necessary to sometimes reason in terms of ranges of ports. The range is one of the five levels of competition for ports: it corresponds to the regional unity of a harbour system. Very used in geography and harbour economy, it describes the situation on the littoral of the ports, which ensures the interface between the same sea (or ocean) and the same continental space[75]. The classification of the ports is here based on a work of the ISEMAR[76]. The ISEMAR has classified the european ports in four ranges:

the range North of Mediterranean

the Northern Europe range (NE)

the Scandinavia-Baltic range (SB)

the Western Peripheral Areas range (WPA)

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[74] For more details about the method, see by Laurent Chapelon and Tristan Rambion : « Le rayonnement continental des villes-ports en Europe », 2004

[75] Letilleul V., 2002, Mutations récentes et aménagements dans les villes-ports de la mer du Nord, Thèse de doctorat, Université Paris 1, p.171.

[76] l'Institut Supérieur d'Économie Maritime, ISEMAR, 2001, « Les trafics portuaires européens - Le classement de 56 ports », ISEMAR, Synthèse n°44.

In a preoccupation of clarifying the representation of the results on graphs, the range North of Mediterranean has been divided into :

the North West Mediterranean range (NWM)

the North East Mediterranean range (NEM)

Table 4 Ranges of European ports

NWM	NEM	NE	SB	WPA
Algeciras	Ancona	Amsterdam	Aarhus	Belfast
Barcelona	Athena	Antwerp	Gdansk	Bilbao
Cagliari	Bari	Bremerhaven	Goteborg	Bordeaux
Catania	Istanbul	Bruges	Helsingborg	Bristol
Geneva	Koper	Calais	Helsinki	Dublin
Gioia Tauro	Ravena	Chatham	Kobenhavn	Edinburgh
La Spezia	Tarento	Dover	Kotka	Gijon
Livorno	Thessalonique	Dunkerque	St Petersburg	Glasgow
Marseille	Trieste	Hamburg	Lubeck	Grimsby
Messina	Venezia	Ipswich-Felixtowe	Oslo	Kingston Upon Hull
Napoli		Le Havre	Riga	Lisbon
Nice		Portsmouth	Rostock	Liverpool
Palermo		Rotterdam	Stockholm	Middlesbrough
Salerno		Rouen	Tallinn	Porto
Savona		Southampton		St-Nazaire
Tarragona		Wilhelmshaven		Vigo
Valencia				

To sum up, two indicators of radiation have been used:

- the quantity of wealth accessible in a given time
- the economical potential.

In each one, the location of the GDP in the European space and the time of transport play a significant role. The interest of the first one concerns its easiness of interpretation, the absence of transformations of the values, the possibility of comparisons between the ports and the characterization of the evolution of the radiation according to the time of transport. These indicators postulate that the radiation is strong when the accessible quantity is high. It has for main inconvenient its low capacity of synthesis because the values and thus the hierarchy of the ports are different according to the step of time considered. The representation in the form of graphs only partially compensates this.

More interesting in this point of view are the indicators of potential. They return a single synthetic value which takes into account the reduction of the intensity of exchanges with the increasing of the time of transport.

The inconvenient of the model resides in the weighting of data of wealth. The values take all their interest only in their comparison. In spite of this, for their synthetic character and their appropriateness to the reality of the exchanges, we consider that the indicator of potential is the most relevant for our analysis of the radiation of the city-ports. It is the reason why we are going to begin our analysis by this indicator. Then, we will consider the quantity of GDP accessible in a given time by the observation of the graphs by range.

Data requirement

CESAgraph765[77]

GDP of European cities:

- EU countries: Eurostat
- Switzerland: Office fédéral de la statistique
- Norway: Statistics sentalbrya
- Other countries: Norway
- Softwares: MAP[78] and Nod[79]

Application to ESPON Space

While looking at the map, we can see that the stronger potential concerns the ports of the Northern Europe range (NE). They easily leave behind North Italia and South East of France ones (Marseille-Fos and Nice).

Antwerp and Rotterdam present the highest potentials (Antwerp before Rotterdam). Rouen and Le Havre have also a good potential, whereas this one remains lower than for the Belgium and Dutch ports. The Spanish, Portuguese, Greek and South Italian ports are strongly penalized by their great distance to wealthy European regions and by a less efficient road network.

So, we can see that the accessibility to economical potential is very various and mainly depends from the proximity to the centre of Europe, which presents a high density of cities[80]. Indeed, ports of the Northern Europe range, where most important ports in the EU27 are located are quite near from the centre of Europe and benefit from a great economical potential. On the contrary, peripheral ports (mainly from the Scandinavia-Baltic range, the North East Mediterranean range and the Western

[77] this one has been improved by Chapelon and Rambion and so, the graph used for this work has 776 nodes and 2233 edges.
[78] A. L'Hostis, 1993/2004
[79] L. Chapelon, 2004
[80] See for more details part 3 chapter 1.3 : "Network density of cites"

Peripheral Areas range) present very low values. The situation of the North West Mediterranean ports seems to be intermediary. All these situations seem quite logical when related to the structure of European transport road network and the distribution of cities.

But this global analysis is not sufficient because there may be imbalances between the ports of a same range. It is why graphs have been made to deepen the work and add data related to the situations of each port, in relation with its own range.

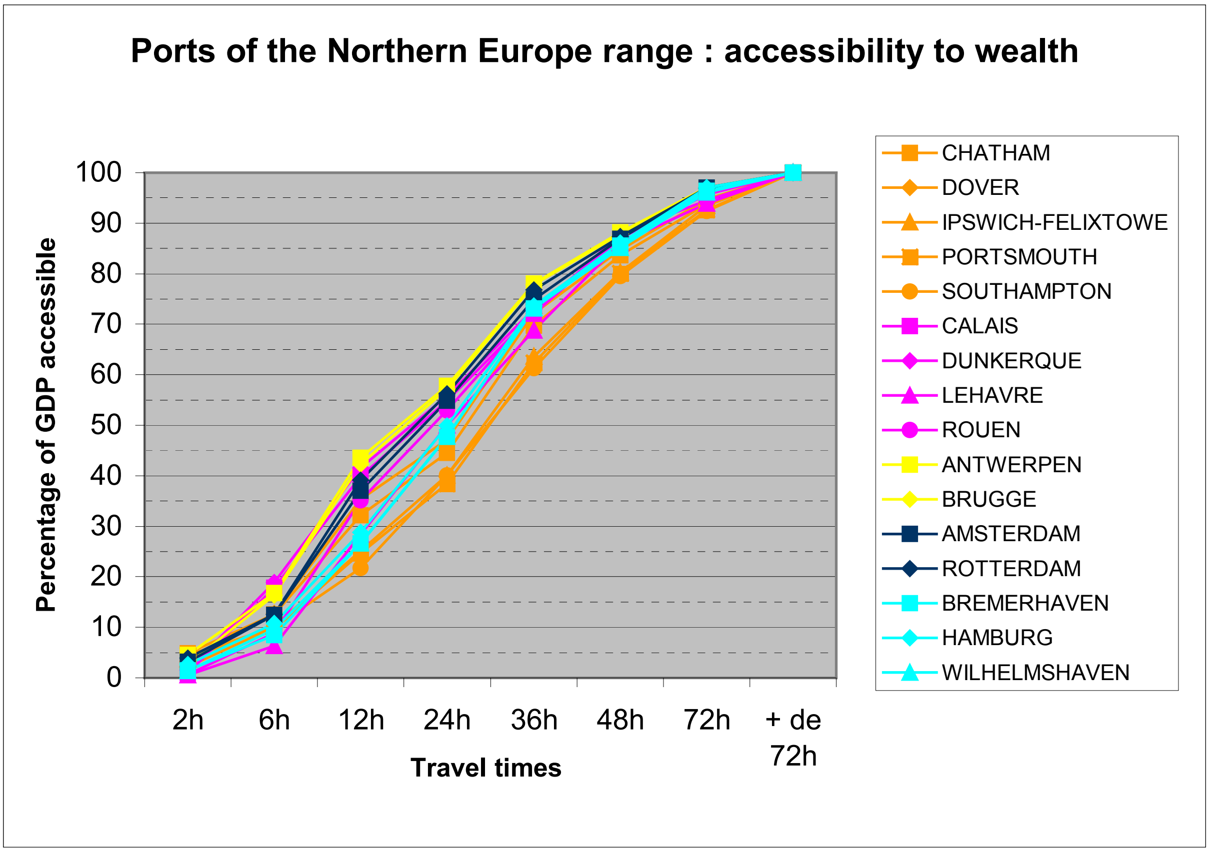

Figure 14 Ports of the Northern Europe range: accessibility to wealth

The Northern Europe range presents a very homogenous accessibility to wealth. The difference between the ports is very weak, although we can note a few particularities. The graph shows a convex curve, which traduces the proximity of these ports to the wealthiest areas of Europe. The accessibility to the wealth is thus very good: for half of the ports the threshold of the 50% of accessible wealth is exceeded in 24 hours of transport. The higher level of accessibility is for Belgian and Dutch ports.

So, the Northern Europe range supplys the best results in term of radiation and is also the most homogeneous. To belong to this range is thus a considerable asset for the development of harbour activity.

But we can just say here that this parameter in not the only factor of choice. The logistic services are also very important and this explains why these ports may have very different values of tonnage[81].

The ports of the other ranges present lower and more heterogeneous values of accessibility to GDP. The localisation seems the principle factor of the imbalances between the ports of a same range. Because of the great heterogeneity of values, the graphs below will not be described but are here to show the situation of each port concerning accessibility. We refer for more details to the original study.

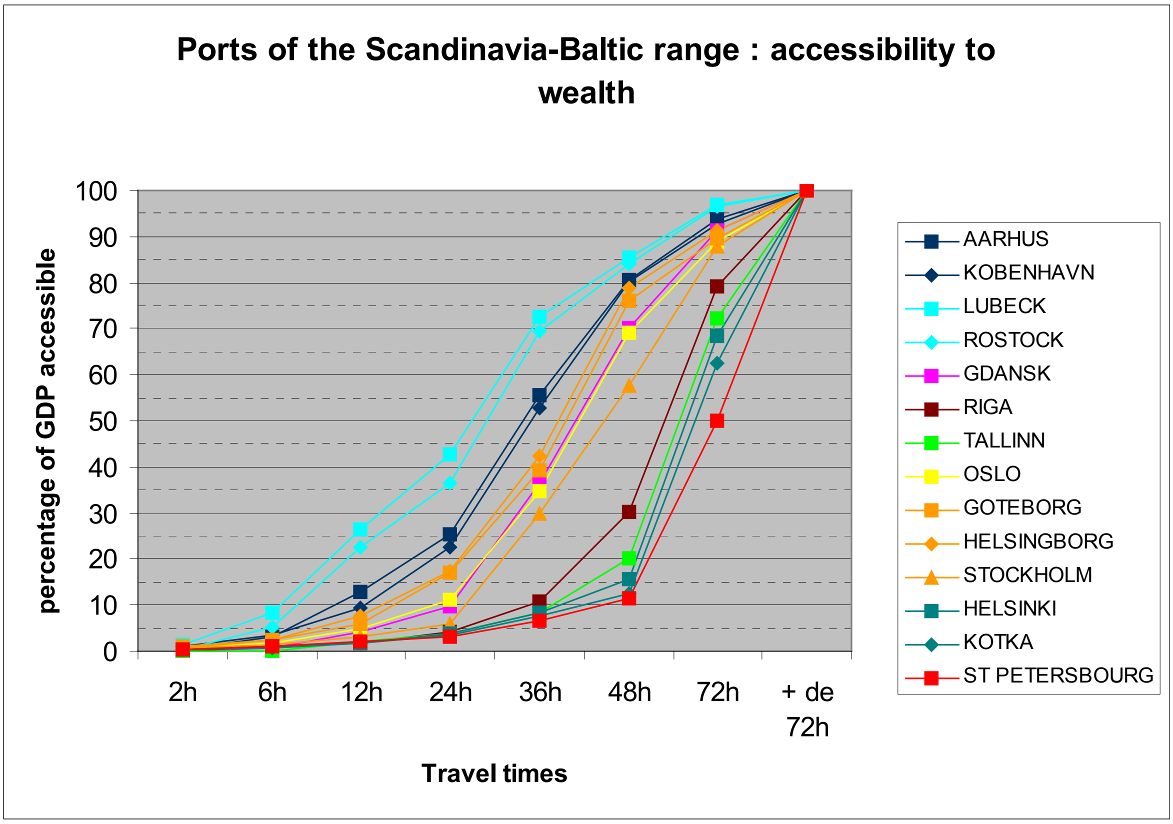

Figure 15 Ports of the Scandinavia-Baltic range: accessibility to wealth

[81] see map 3.4 in this part

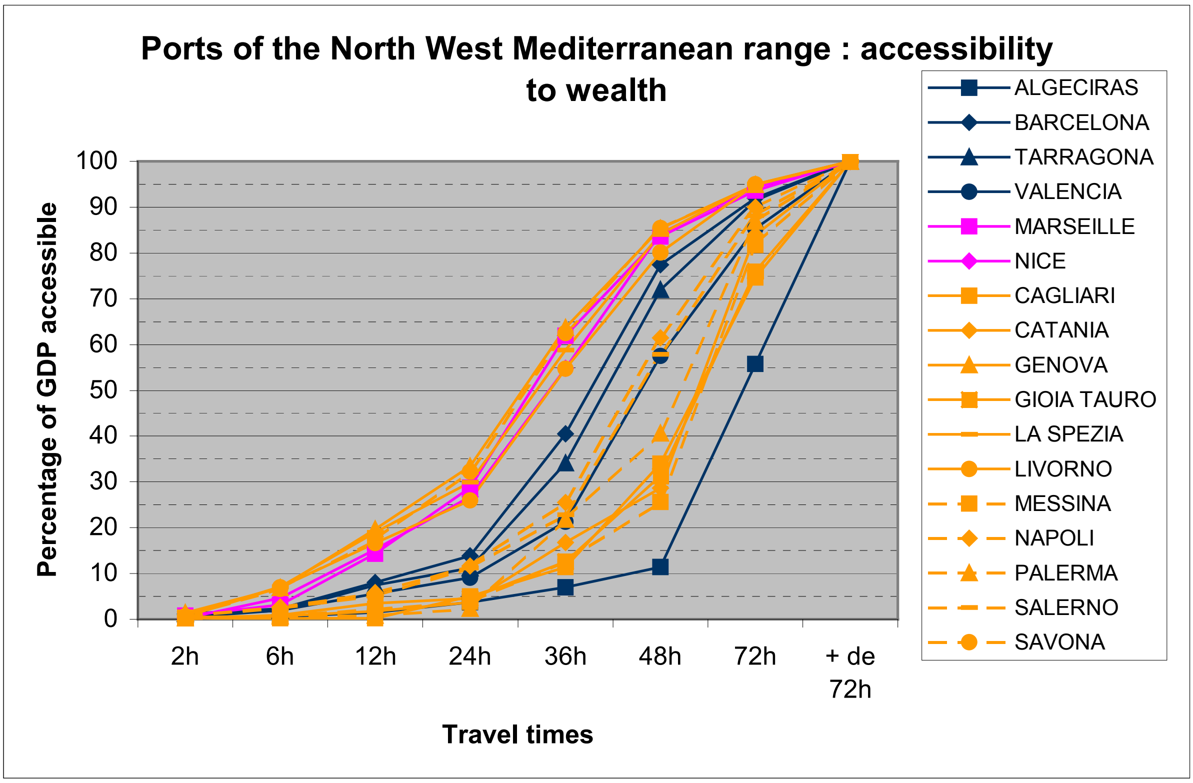

Figure 16 **Ports of the North West Mediterranean range: accessibility to wealth**

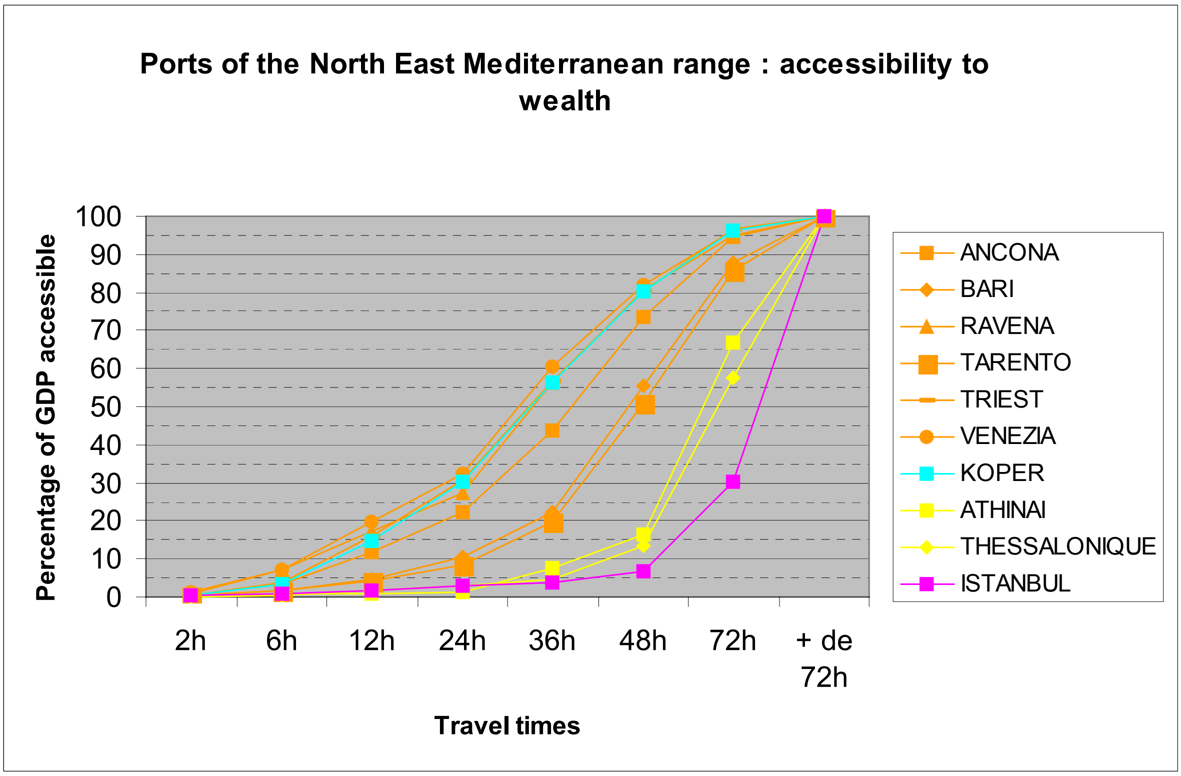

Figure 17 **Ports of the North East Mediterranean range: accessibility to wealth**

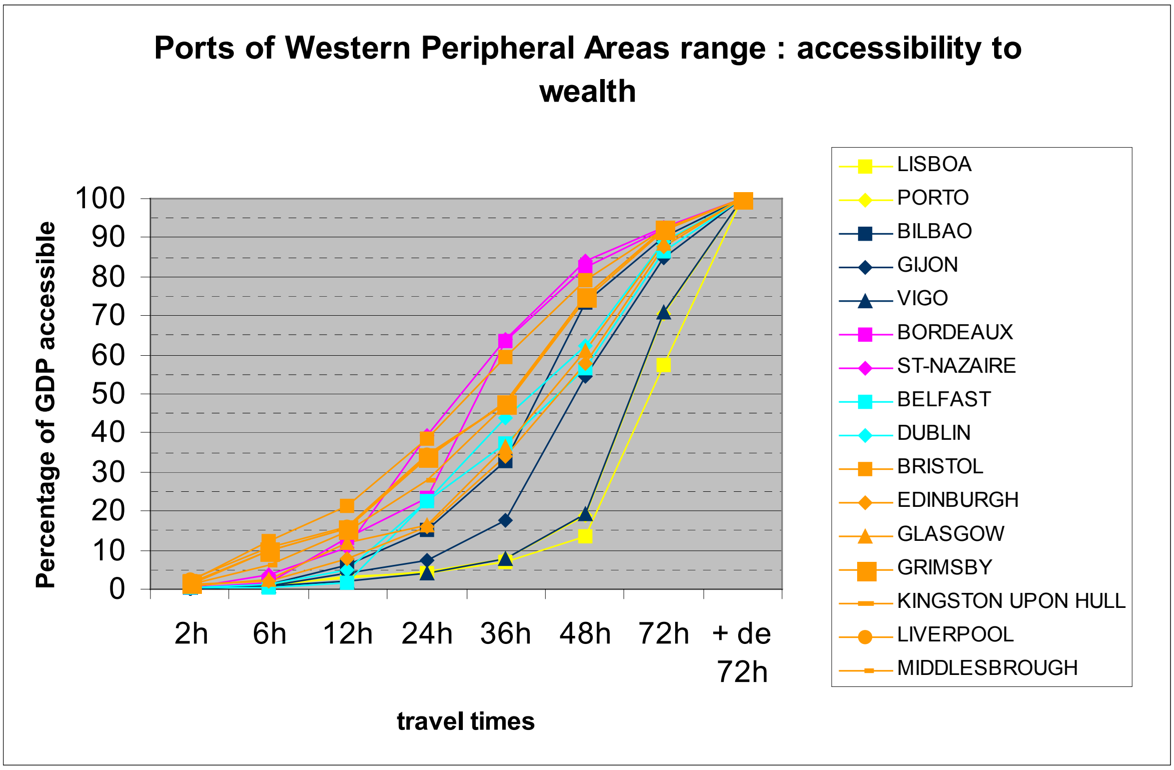

Figure 18 Ports of Western Peripheral Areas range: accessibility to wealth

This work on the accessibility or European ports to GDP leads us to evoke the fact that the ports can play a significant role in a modal shift for freight transportation and this kind of study, which furnishes data about the respective situation of each port, is in our opinion necessary[82]. But it is also important to study the flows potentially induced by the European ports. Indeed, the maritime transport has a significant impact on the distribution of flows on the road and railway network.

5.7.3 Potential freight corridors from European maritime gateways

Rationale

This indicator permits to estimate with a gravity model the potential level of freight flow at the departure or at the arrival of the main European maritime ports and its distribution in tons on the road network. It is an approximation by modelling and must be considered in consequence, with all needed precautions in interpretations.

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[82] see the policy recommendations for more details about the possibilities of development of the maritime transport.

Method

Our method can be decomposed in three steps:

- Generation:

We consider the major maritime ports in Europe according to traffic of containers. We only have retained the 42 European ports accommodating more than 100 000 T.E.U. (Twenty Equivalent Units) for the year 2002.

We note Mj this number of containers for the ports j with $j \in [1, 42]$. According to various statistics, we decide that an average of 20 % of all these containers is only in transit in the ports and will be carried again by the sea to their final destination. So we consider that the **emission/reception mass of a port *j* is equal to 80% * M*j*.**

The mass of emission/reception of other nodes (not associating to a maritime port) is assimilated to the **population** affected to them. For a node *i*, we note it P_i, $i \in [1, N]$ with N the total number of nodes of our graph.

- Distribution:

We use a classical gravity model. As for the other indicators, the distance taken into account is the time-distance. This distance is relative to the travel times and is expressed in minutes. We consider a friction's coefficient of 1.5 to reinforce the relative importance of the distance.

Thus, for a giving node i, $i \in [1, N]$, and a giving port j, $j \in [1, 42]$, we note $E_{i,j}$ the number total of container from i to j.

$$E_{i,j} = \frac{0.8 * P_i * M_j}{T_{i,j}^{1,5}} * \frac{\sum_{i=1}^{N} T_{i,j}^{1,5}}{\sum_{i=1}^{N} P_i}$$

- Affectation:

The third step is relative to the affectation of flow on roads. We consider that each travel uses the minimal path in terms of travel times corresponding to the couple (origin, destination) nodes (hypothesis of perfect knowledge of the existing network[83]).

Data requirement

[83] which is, as we have already said in part 3 chapter 4.2, a strong but necessary hypothesis for our modelling work.

CESA graph 4172

Tonnage of the European main maritime ports in T.E.U. furnished by the I.S.E.M.A.R[84]

Application to ESPON Space

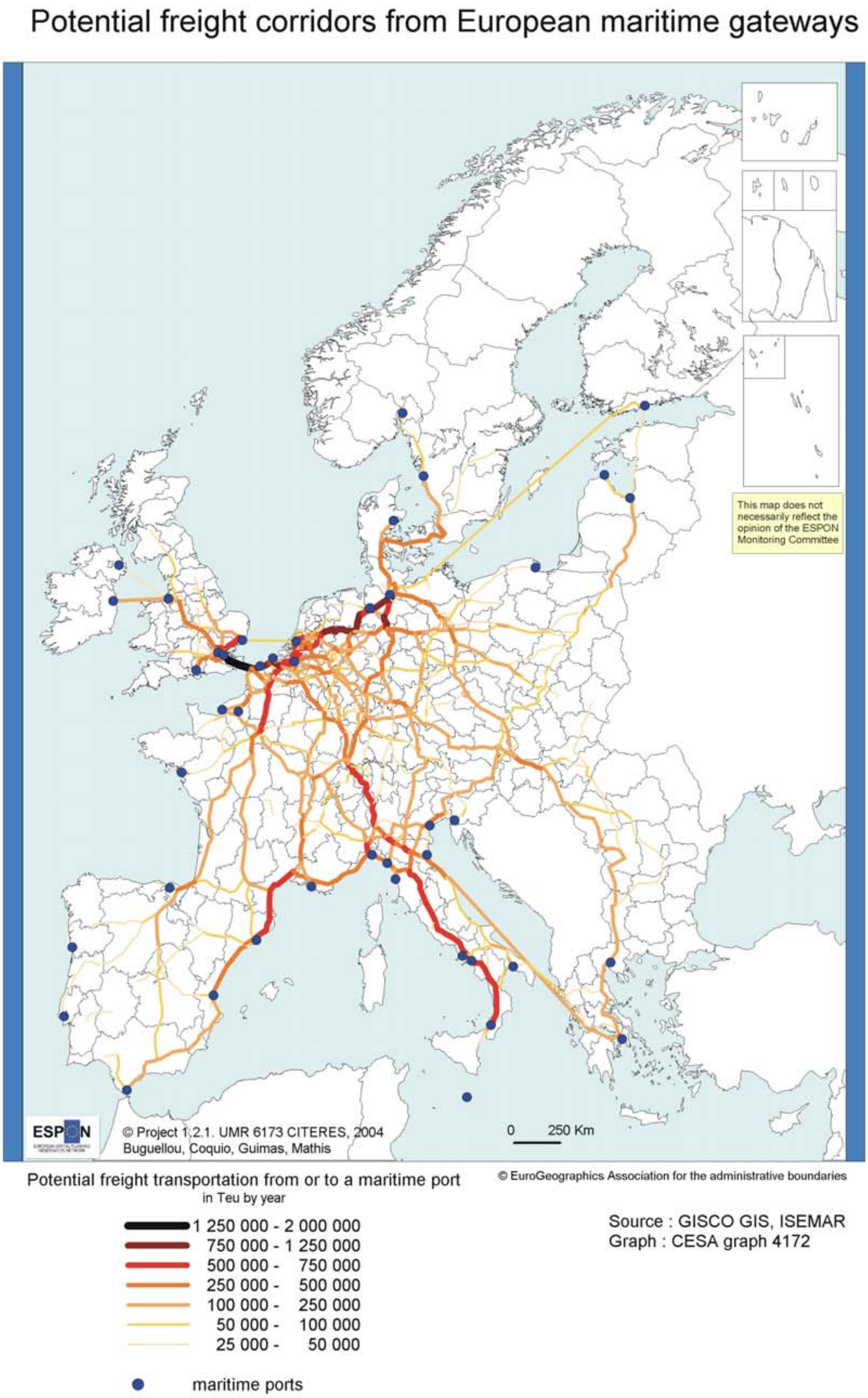
First of all, let us remind once again that these results come from a model and must therefore be considered with precautions. In particular, it is really too difficult to know which part of the tonnage of the ports will effectively leave by the road infrastructure. Indeed, a proportion is only in transit or leaves by other infrastructures (waterways or railways). For example, some ports located on the Mediterranean Sea have more important proportions of transit in their tonnage. Nevertheless, the model gives some interesting data. It is here more the relative values than absolute ones that must be considered.

The map presented above shows the corridors potentially used from European maritime gateways. These ones are mainly located in Benelux, Germany, France, Switzerland and Great Britain.

Using our method, we bring to the fore the importance of big cities through the use of a gravity model. These cities are located on corridors, and this is why the map presented here is very similar to the different maps in this report showing the corridors. But we here the importance of the links located near the sea is accentuated and this is why we can see the high values for the edges concerned. The most stringent case is for the links located near the Mediterranean Sea (from Valence to Gioia Tauro).

Finally, we can observe that the road corridors starting from Atlantic ports have lower traffic values than for North Sea and Mediterranean ones and there may be opportunities to develop their traffic.

[84] Institut Supérieur d'Economie MARitime



Map 65 Potential freight corridors from European maritime gateways

5.8 Airport traffic

Rationale and policy relevance

Commercial airports infrastructure follows the same rationale as the previous section. Airports' network, in a more liberalised and globalised market of air services follow and intensive reorganisation, as maritime ports, leading to hub-and-spoke configurations, with airports of different levels playing different roles according both the commercial strategies of the different groups of private air companies and the national or local interest. The indicator calculated here provides just for the first approach to the geography of European airports.

Method

The methodology used is the same as the one explained in the previous sections.

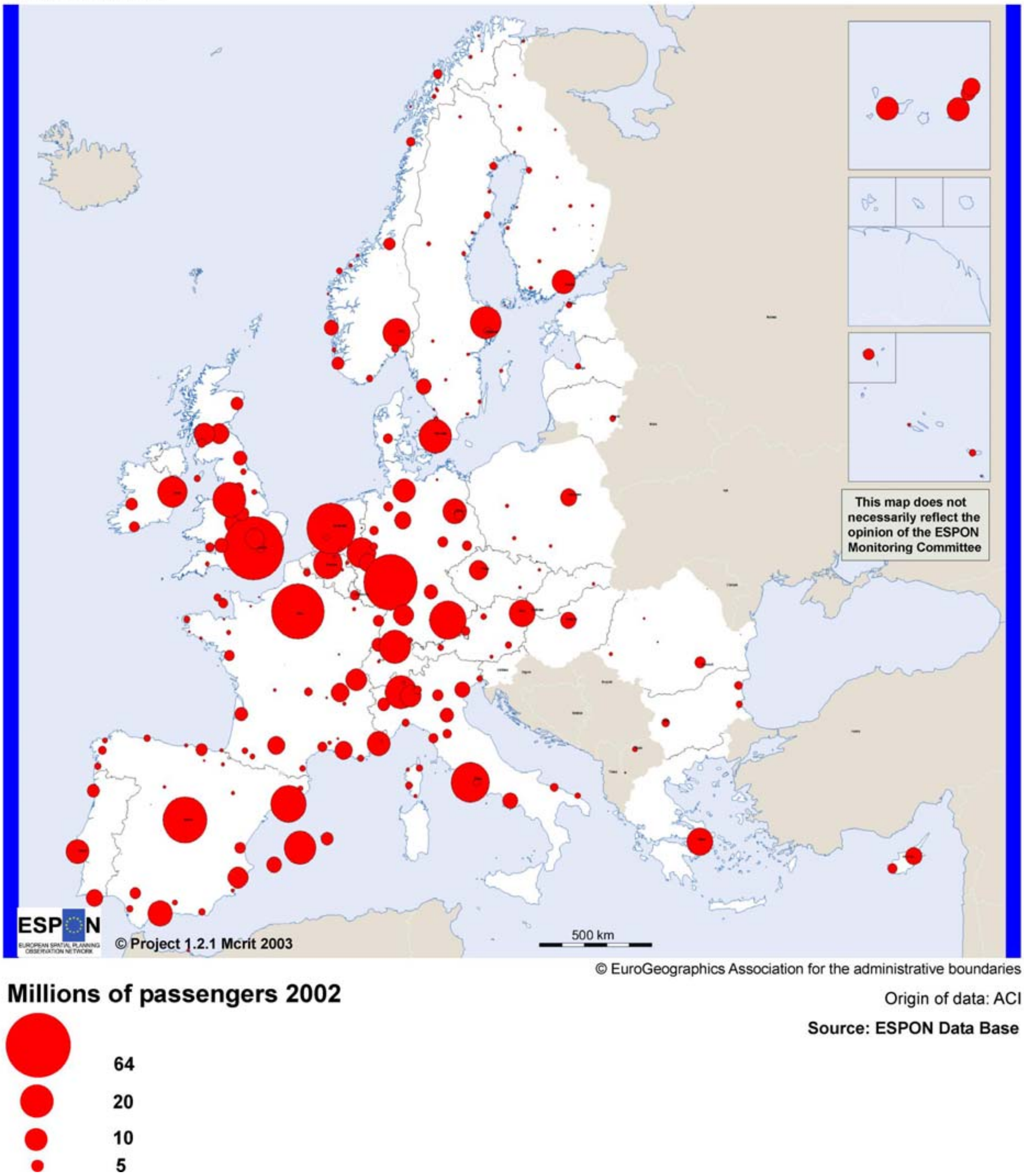
Data requirements

The data requirements are the airports traffic in 2002, taken from ACI (that is why airports who do not belong to this Association are not represented on the map).

Application to ESPON Space

Traffic of airport's belonging ACI has been mappified for all NUTS 3 regions of the ESPON space. Different categories of commercial airports can be distinguished from the map: most major and secondary hubs are located in EU country and macro-region capitals, like London, Paris, Frankfurt and Milan, Madrid, etc. There are also airports, most tourist meeting points, with high traffic volume in the periphery, like Palma de Mallorca, Malaga and Athens as a tourist hub for destinations within Greek, and the ones in the Scandinavian countries and Finland. Regional airports have lower traffic and usually provide services to the country's capital airport and to some of the major hubs. It has to be noted that in EU countries there is a complete hierarchy of all airports, weather in most of the accession countries this is still to be completed. There are just the airports in the capital acting as a hub of the few (if existing) regional airports which are spread all over the territory (this is the case of Poland and Baltic countries).

Airport traffic



Map 66 Airport traffic

5.9 Flows between MEGAs

Rationale

This indicator has for main aim to show **the corridors used for freight transportation between MEGAs**. It is in fact divided in two parts: first of all the real number of tons exchanged by the MEGAs and affected to the edges of the graph, and secondly the potential traffic between MEGAs in the aim to add a prospective view. The first calculation will permit to determinate **the effective relation** between all the MEGAs in term of freight transportation and the respective induce on each edge. The second one supplies **a potential view** of these relations, without taken into account the real level of exchange.

Method

For the first indicator, we simultaneously use the matrix of precedents on the CESA graph 4172 and the Scene database. As it is explained in the general method (see part 2 chapter 4.2), we assign the flow of goods between NUTS2, but no on the whole graph, but only the emission/reception from/to the European MEGAS. In other words, we only consider effective flow between MEGAs.

For the second part, dedicated to the potential relation between MEGAs, we only use the *matrix of precedents*, for all the paths at the departure and/or at the arrival of a node representing a MEGAS.

Data requirement

CESA graph 4172

Minimal path matrix and *matrix of precedents* for trucks

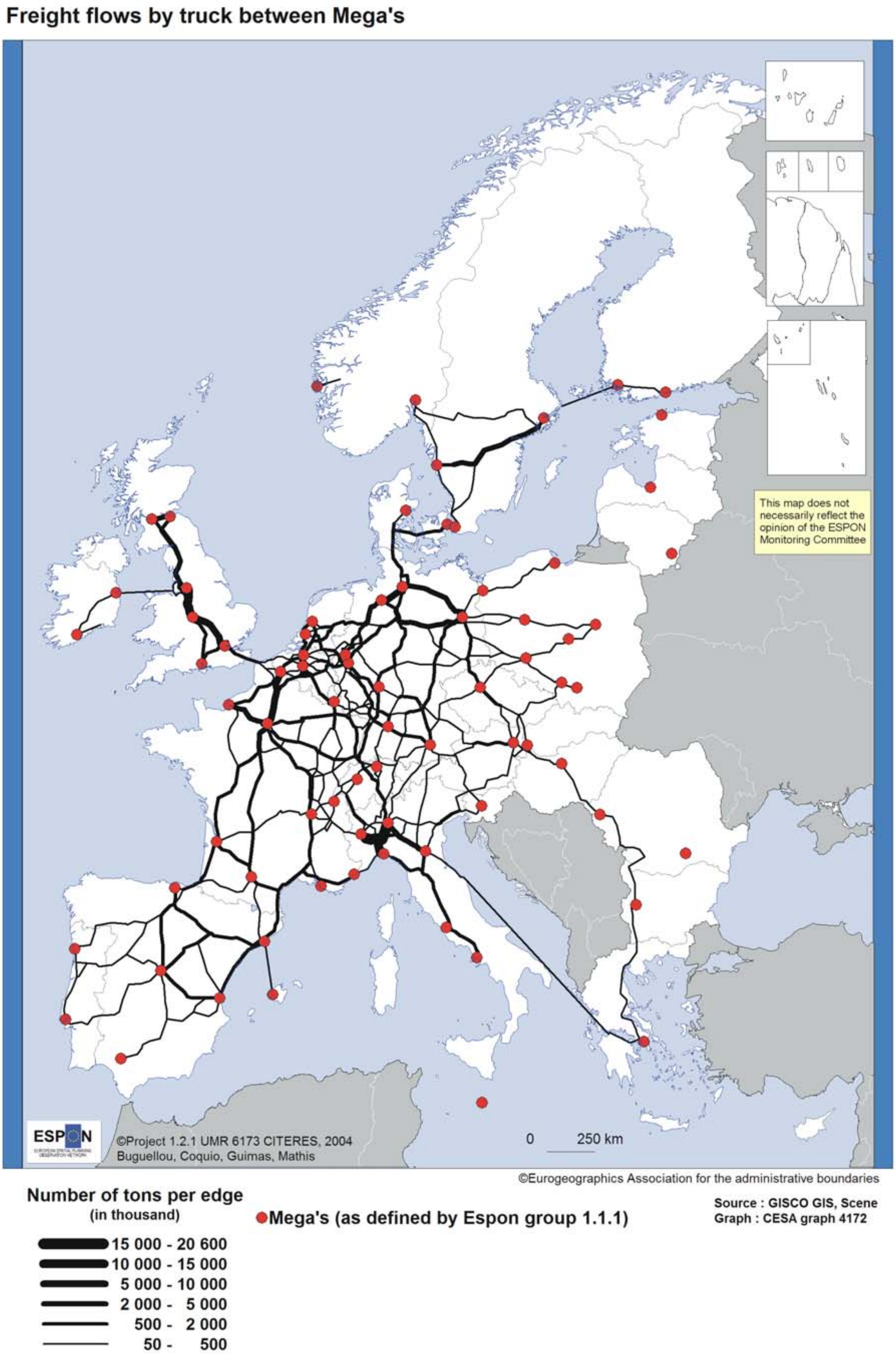
List of European MEGAS furnished by the ESPON Group 1.1.1

Scenes database for goods

Application to ESPON Space

The map presenting freight flows between MEGAs displays the proximity between them. Indeed, we can see high values of traffic for edges linking: Milan and Turin, Berlin, Hamburg and Bremen, London, Manchester, Birmingham, Glasgow and Edinburgh, and finally Göteborg and Stockholm.

The values in the Eastern part of Europe are very low but this is mainly due to the structure of the Scenes database, which gives very low values of exchanges for this area.



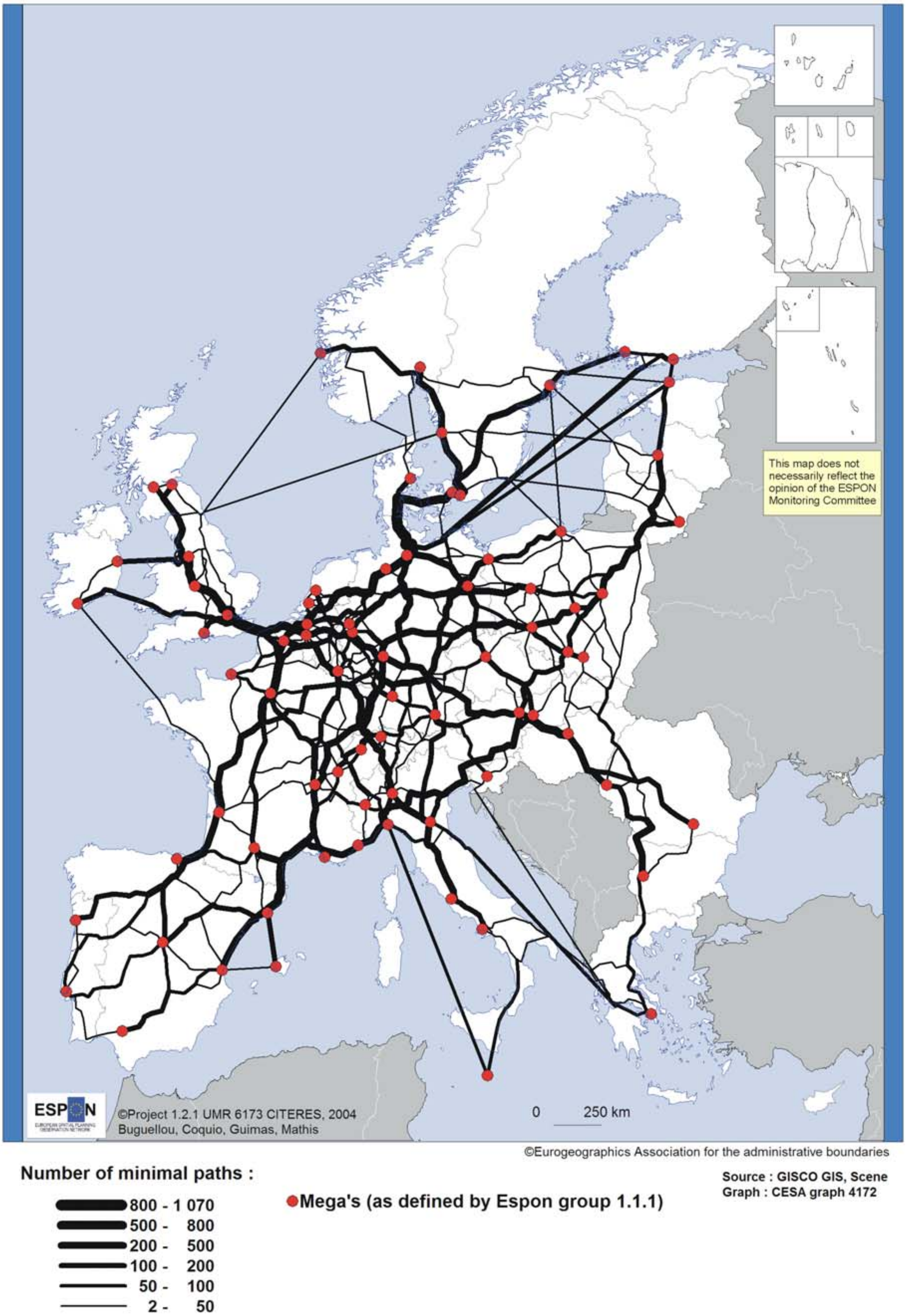
Map 67 Freight flows by trucks between MEGAs

While looking at this map, we could say that Benelux and the Rhine valley are at the crossroads of these flows but we have to be aware that it is not possible here to know if the traffic on these edges is due to relations inside this area or to exchanges between MEGAs located outside this area. This is one of the reasons why we have mapped the minimal paths.

This map presents the potential relations between MEGAs, not depending on their proximity. First of all, it allows us to show where **the crossroads** are located in Europe. It is clear that the area containing Benelux, the East of France, the West of Germany and Switzerland contains most of them. Secondly, this map adds **a prospective view** to the work by showing the relations with and between new European Union countries MEGAs more explicitly. In this aspect, we can once again as in part 5.1.3 note the potential importance of **the triangle Berlin-Vienna-Warsaw** for relations concerning these countries.

Thirdly, this map shows "narrow passages" (i.e. weak links) for these potential relationships : the Channel Tunnel, the Pyrenees tunnels, the "Nyborg-Stagelse" bridge. We will work more precisely on these links in the part 3 chapter 7 "Network vulnerability".

Minimal paths by truck between Mega's



Map 68 Minimal paths by trucks between MEGAs

6 Transport externalities

Transport is facilitating social and economic relations and, at the same time, is generating environmental externalities that reduce and constrain the capability of a given region to attract new activities, as well as to some extent the productivity of the already existing activities. Accidents, emissions, land occupation and land fragmentation are the most important strategic impacts of transport in this respect. Others are energy consumption or noise exposure. The presentation of a few such impacts at regional level will complement the previously described transport-based indicators.

6.1 Road traffic deaths

Rationale

Deaths and injuries in road accidents are one of the most direct negative impacts of the transport system on human beings. Road traffic deaths have been selected here as transport externality indicator.

Method

The method applied here is data collection from harmonised sources and standardisation of data by relating traffic deaths to regional population to make the data comparable across regions.

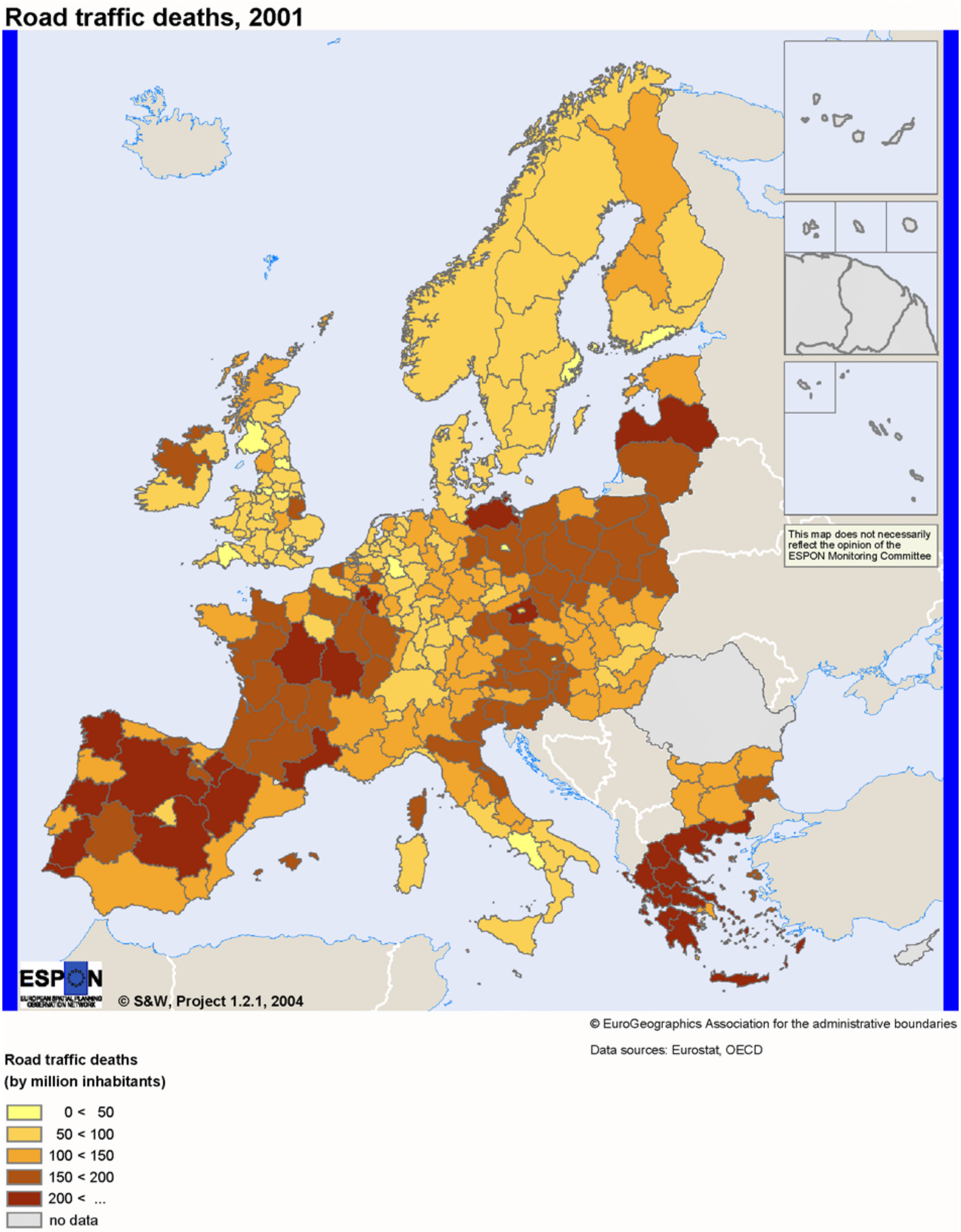
Data requirements

The REGIO database of Eurostat contains data on deaths and injuries in road accidents at NUTS-2 level in a time series going back to 1988 (European Commission, 2002). Harmonised data on NUTS-3 level are not available. Data for Switzerland and Norway are taken from the OECD "International Road Traffic and Accidents Database" (OECD, 2004).

Application to ESPON Space

The map displays the number of people died in road accidents per one million inhabitants of the NUTS-2 regions. There are extreme differences between the European regions ranging from 22 deaths in accidents per million of inhabitants in Ceuta Y Mellila in Spain up to 369 in Alentejo in Portugal

The highest figures exist in regions of Greece, Spain, Portugal, France and Eastern Germany. Road traffic deaths are also very high in regions of the candidate countries, mainly in Latvia, Lithuania, and Poland and in the Western parts of the Czech Republic. Most regions in the UK, the Netherlands, Western Germany and in the Nordic countries have relatively low figures



Map 69 Road traffic deaths, 2000

6.2 Number of tons of goods going through nodes and edges

Rationale

This indicator permits to underline **the importance of each node in terms of flows exchanged**[85]. It completes maps and indicators based on flow by edge by supplying a nodal interpretation of these values. The role of crossroads node is reinforced. It is a first step to evaluate the externalities by measuring the level of goods' transport (contamination, traffic jam, …)

Method

We calculate the quantity of flow at the departure, at the arrival or simply going through each node of our graph.

N is the total number of nodes, E the total number of edges for the studying graph

$\forall k \in [1, E]$, we note *i(k)* the origin node of the edge k and j*(k)* the destination node of this edge.

$\forall\ i \in [1, N]$, **NT***i* the value of the indicators presented in this part for the *i*th node

For a given node *n* with $n \in [1, N]$, we have

$$\mathbf{NT}_n = \sum_{k=1}^{E} F_k \text{ with } i_{(k)} = n \text{ or } j_{(k)} = n$$

Let us note that the calculation made is not so simple than this equation. Indeed, we have separated the traffic which only passed through the nodes and the traffic which was at the departure or arrival of these nodes. For the transit, we only consider one flow (for two edges). As a consequence, the value calculated here is not exactly the sum of the values of edges.

Data requirement

CESA graph 765[86]

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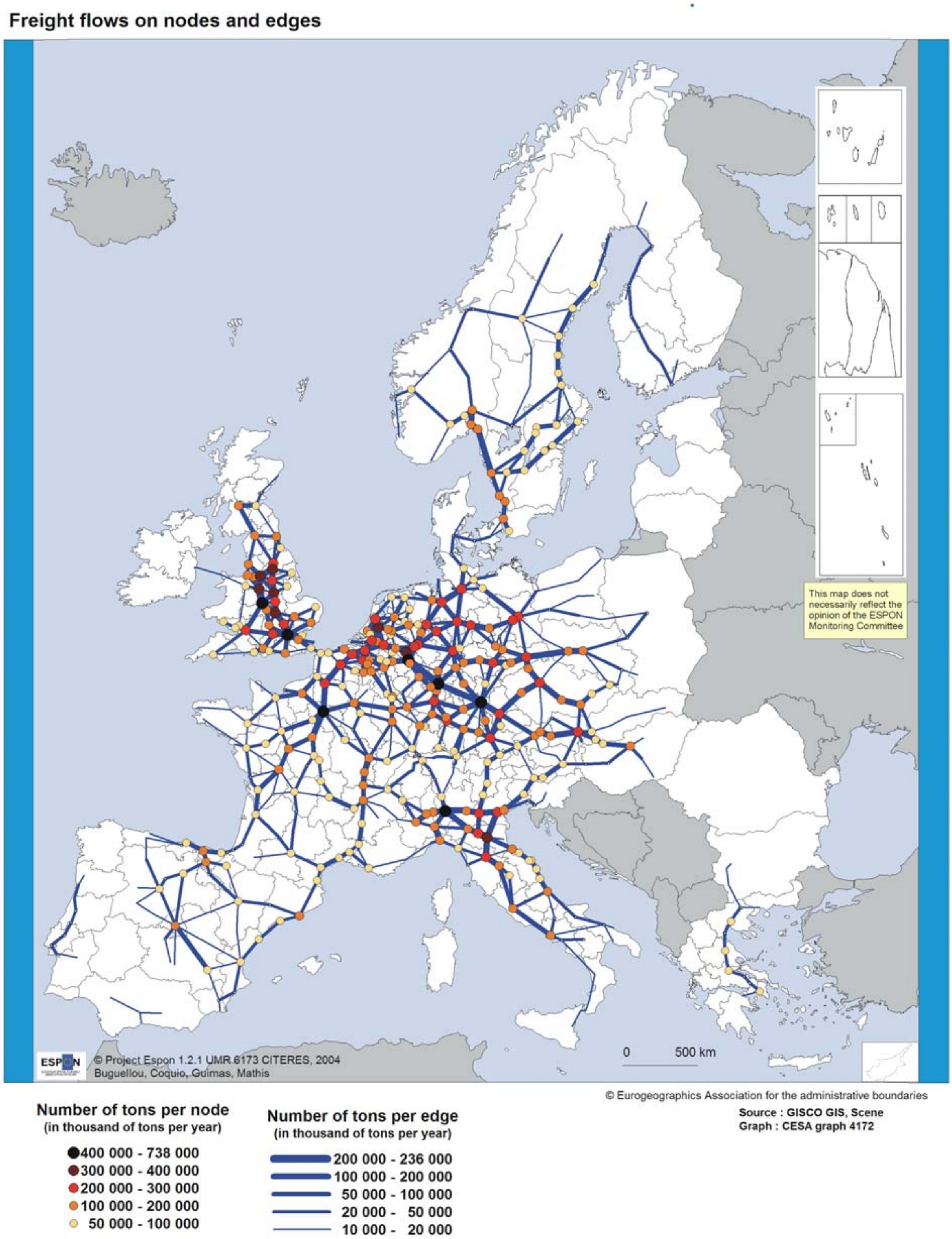
[85] We add for this indicator transit flow and flow at the departure/arrival

[86] We have decided to work on *CESA graph 765* because each node represents a city and so, we can have values by urban areas. If we had worked on *CESA graph 4172*, we would have had values et a very local scale, which is not the aim here and too precise when considering the data available.

Edges’ values matrix for freight



Map 70 Freight flows on nodes and edges

Application to ESPON Space

Let us begin reminding of the specificity of the point of view supplyed by this map. The number of tons per node includes on one hand the **quantity of goods emitted/received** by the node, according to the Scene database for freight, and on an other hand **the goods only in transit across** the node. In consequence, all trucks do not go through cities and the level of traffic depends **simultaneously** of the level of emission/reception of the city (relative to the number of inhabitants and to the importance of the production in the concerned area) and to the role of the city in terms of transit, according to its geographical location and to its relative position in the transport network.

The map "Number of tons exchanged by nodes" presented in the part 2 chapter 4.2 "Travel times and cost" can be seen in a complementary way, because only the goods effectively emitted/received by nodes being taken into account. The map and graphs of the part 3 chapter 6.3 relative to the level of freight transit by areas (expressed in tons.kilometres) comes also to bring a different information, because, in this case, it is only the goods on transit that are considered, independently of the local emission/reception.

The map above should be interpreted as integrating these two pieces of information:

First of all, this indicator shows **the main corridors** of Europe which lead to potential high negative externalities for the areas concerned: the Rhone and Po valleys, the Cologne-Nuremberg axis, the British corridor...

While looking at the map, we can say that **the central part of Europe** is the area suffering the most from concentration of emission of pollutants because of the number of inhabitants and cities. We can add to this area the South of Great Britain which presents very high values, mainly for London and Birmingham.

Secondly, thanks to the calculation of the number of tons per node, we bring to the fore **the crossroads of main European flow axes**, which would not have been possible by simply working on edges. So, cities such as **Nuremberg, Bologna and Frankfort** present very high values, together with other important cities (Paris, Milan, London).

Finally, we must add that the results for these cities would have been much higher if we had been able to take into account the **infra-regional freight and individual vehicles flows**[87] which seriously

[87] Which has not been able because of the lack of data.

accentuate the problem of congestion and negative externalities in a general manner. Moreover, the map presented above shows **very low values for Eastern countries** but flows concerning these countries are going to grow considerably in the future[88].

The graphs below, constructed from the same data, underlines the variety of situations by country:

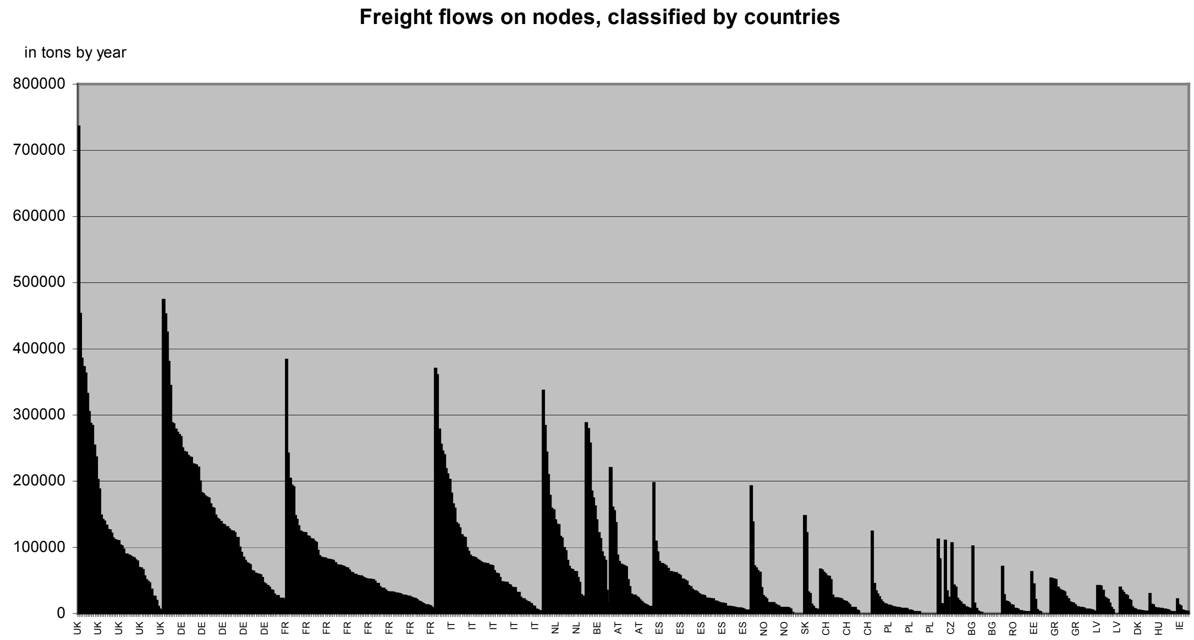


Figure 19 Freight flows on nodes, classified by countries

If first, it is interesting to note the domination of some countries with a lot of nodes of big values, the most important in this graph is the **great heterogeneity inside the different countries themselves**. For example, we can note very high peaks in the United Kingdom, in Germany or in France. These peaks correspond to **national capitals** like London in England or Paris in France and to **major crossroads** like Nuremberg in Germany, that concentrate an important part of flows from Eastern countries.

In a general manner, **nodes of Western countries are really more used** than Eastern ones, due simultaneously to the density of cities in these parts of Europe (see part 3 chapter 1.3. "Network densities of network), the importance of their level of emission/reception (Cf. part 2 chapter 4.2 "travel times and cost") and their specific role in terms of

[88] We can add to complete this remark the very low values in the Scenes database for freight emissions and receptions for these part of Europe.

transit because of their specific geographical localisation in the whole territory and in the global network.

6.3 Transit flow per area

Rationale

The transit flows are often badly considered in the areas concerned because people suffer from pollution problems for a traffic, which does not benefit to them. As an illustration, let us remind important demonstrations in areas concerned taking place in various parts of the EU. We could have worked on all international flows but the choice has been made to only consider transit flow. Indeed, the symbolic value is much higher for this kind of flow.

We have worked at 3 different levels (countries, NUTS2 and NUTS3) to show different views of the problem.

Furthermore, we have produced indicators of real values or taking into account the surface of the area concerned. But, except for the transit by country, the choice has been made to present here only values taking into account the surface of the areas. The other results are available in the annexes.

Method

We have worked on the Scenes database. After having calculated the freight flow on each edge of the graph, we have only kept the transit flow. After that, by multiplying the number of tons by the length of the edge, we have been able to calculate the number of tons.km. It was then possible to have the number of tons.km by area (country, NUTS2 and NUTS3) and eventually to divide the value by the surface.

Data requirement

CESA graph 4172

Matrix of precedents for trucks

Scenes database

Application to ESPON Space

If we consider the number of tons.km by country, we can see that the countries presenting the highest values are France, Germany, Switzerland and Belgium. After these countries come countries such as Austria, Italy, Check Republic and Spain.

Several remarks can be made. First of all, the surface of countries plays an important role, particularly for France and Germany. Secondly, the value of Switzerland must be moderated by the fact that this country has very strict laws concerning transit flows.

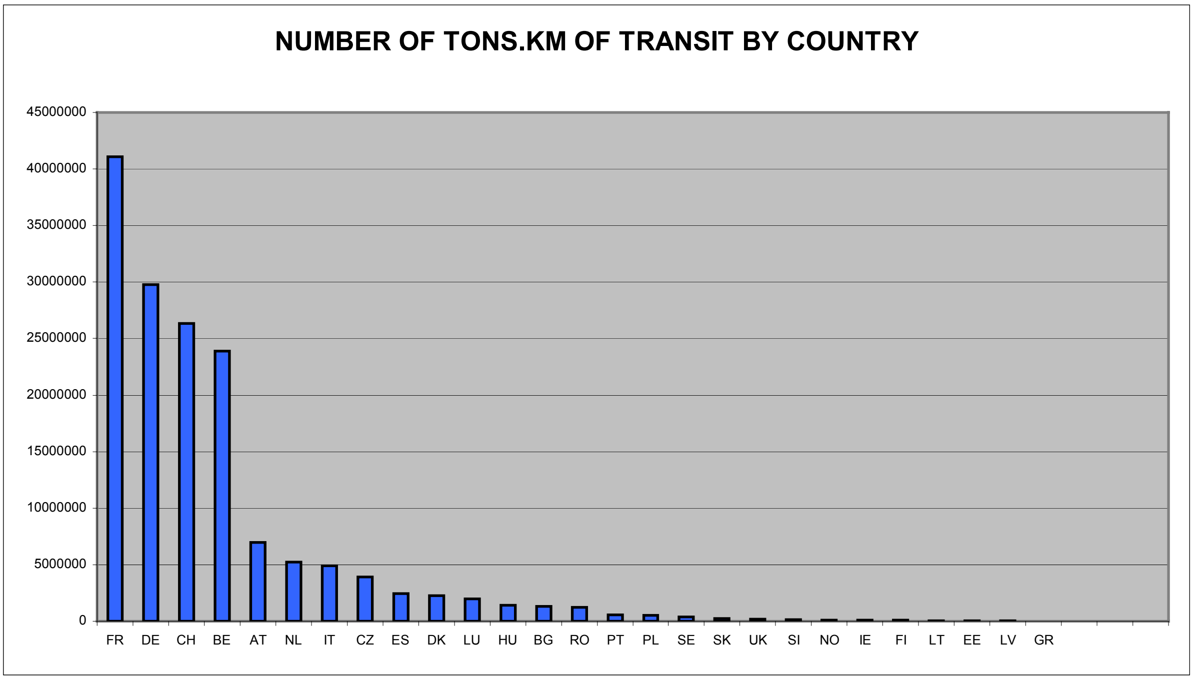


Figure 20 **Number of tons.km by country**

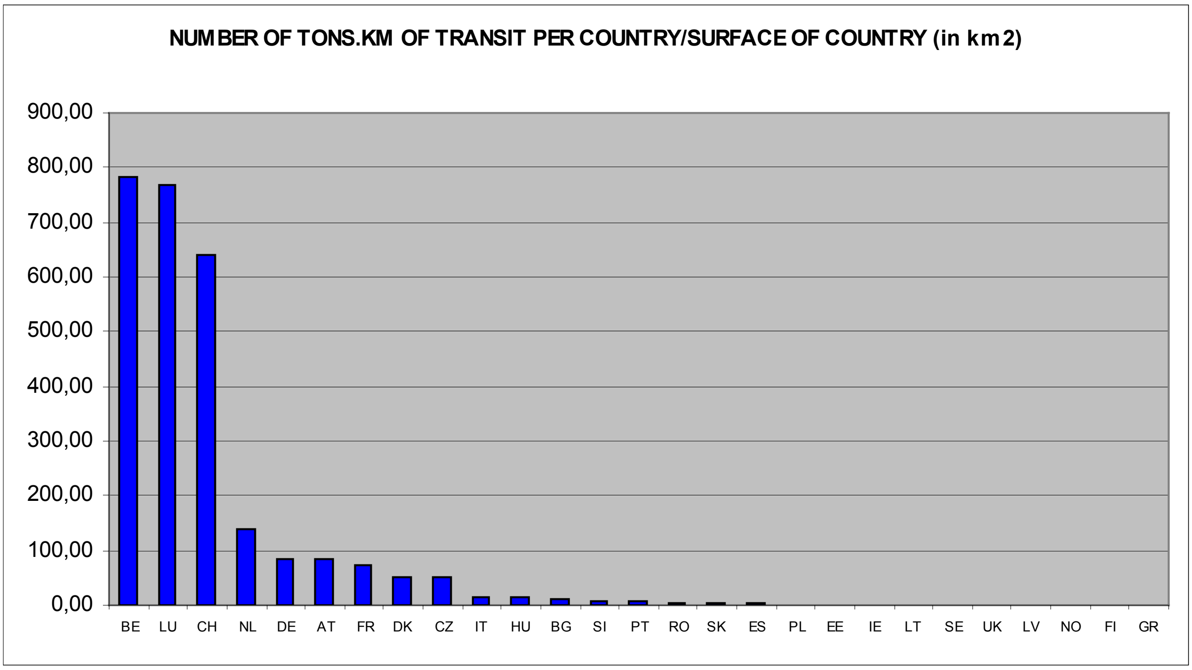
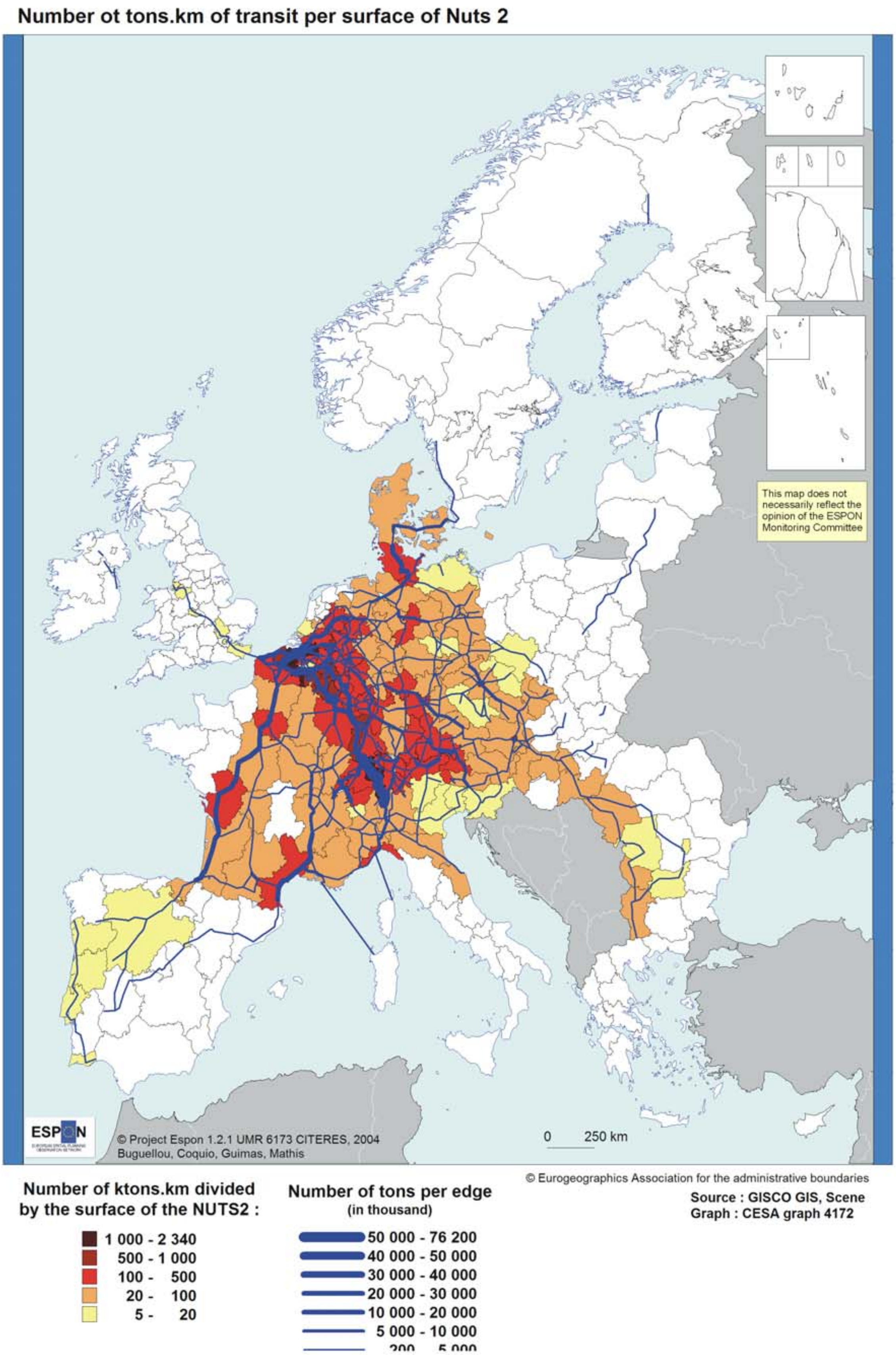


Figure 21 **Number of tons.km of transit per country/surface of country**



Map 71 Number of tons.km of transit per area of NUTS-2

While taking into account the surface of the country, the graph presents a very different aspect. Little countries such as Belgium, Luxembourg and Switzerland present the highest values. Nevertheless, the values for France, Germany, Austria and Check Republic confirm their situation of important transit areas. The other countries, excepted maybe Denmark, do not suffer from transit flow externalities problems.

The remark made about the difference between the two graphs leads us to complete the think by working at more local scales. It is why we have chosen to work at the NUTS2 and NUTS3 levels in order to show various aspects of the phenomenon of transit. When working at the NUTS2 level, we see, logically that the NUTS2 presenting the highest values are in the EU 15 countries, and mainly in Benelux, Germany, France, Switzerland and Austria. But we can see that the distribution of these flows is very different from one country to another. For example, there are in France two or three corridors for transit flows and some part of the territory are not used for this kind of traffic. On the contrary, the distribution of flows in Germany is more evenly distributed through the territory as we can see on the following graph.

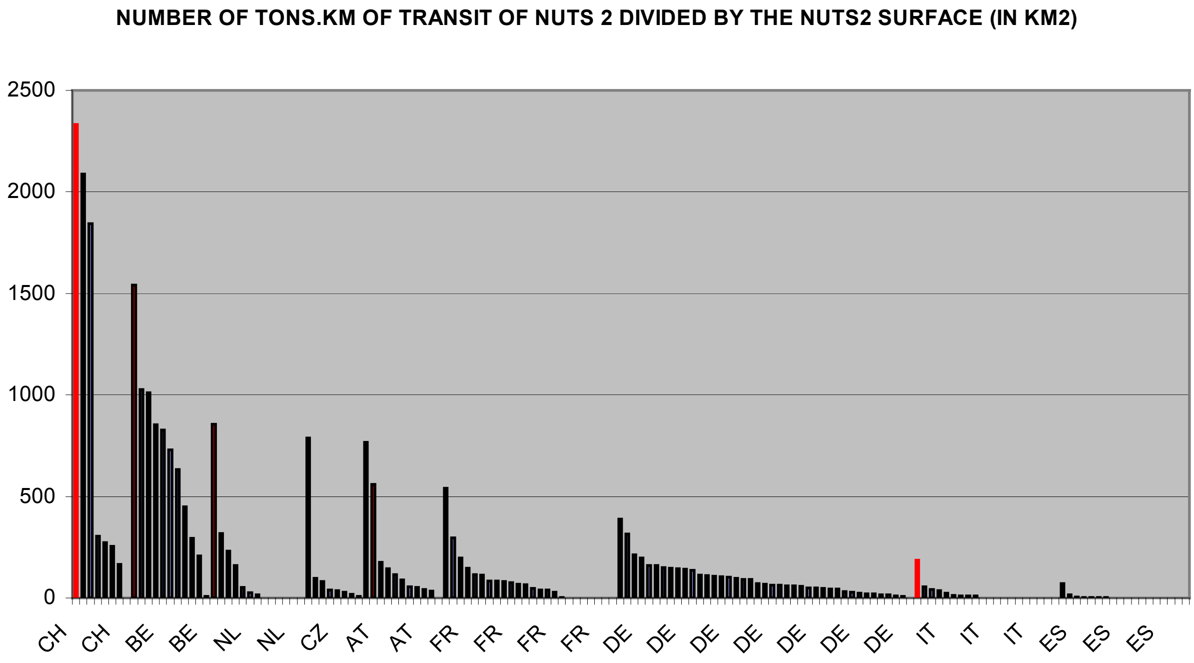


Figure 22 Number of tons.km of transit of NUTS2 divided by the NUTS2 surface

Finally, the results for NUTS3 areas give to us some complementary data. Even if the values highly depend on the size of the NUTS, which is not equal, we can see once again at his level the different kinds of distribution of flows in the countries. The graph shows a very regular decrease of values in Germany (with roughly the same phenomenon in Belgium) contrary to countries such as France, Switzerland and Denmark.

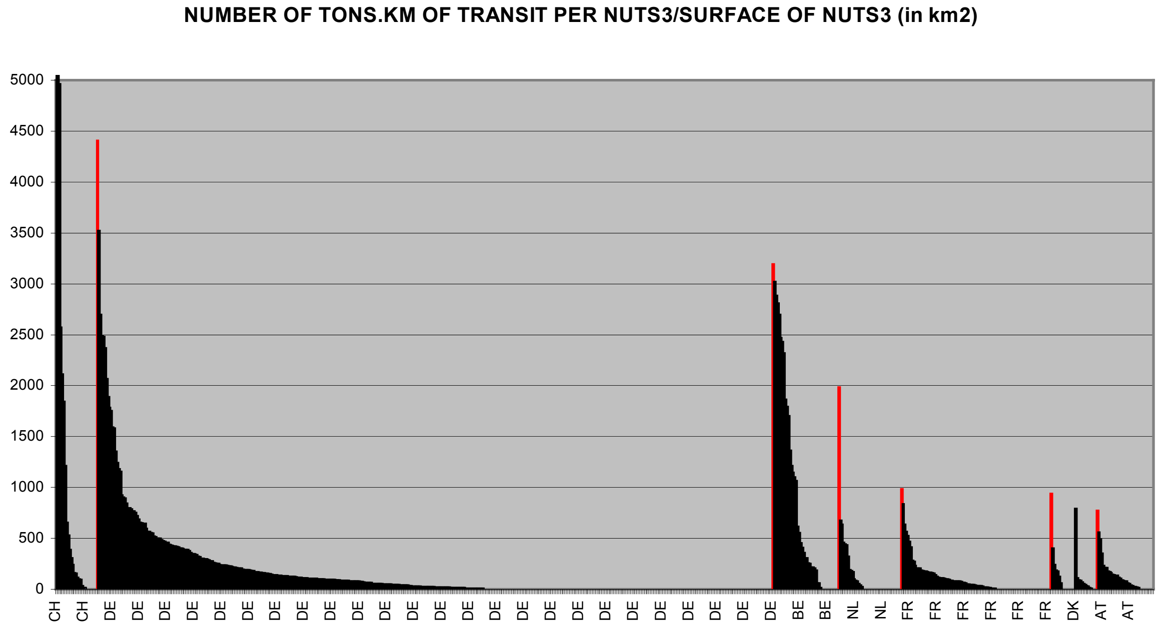


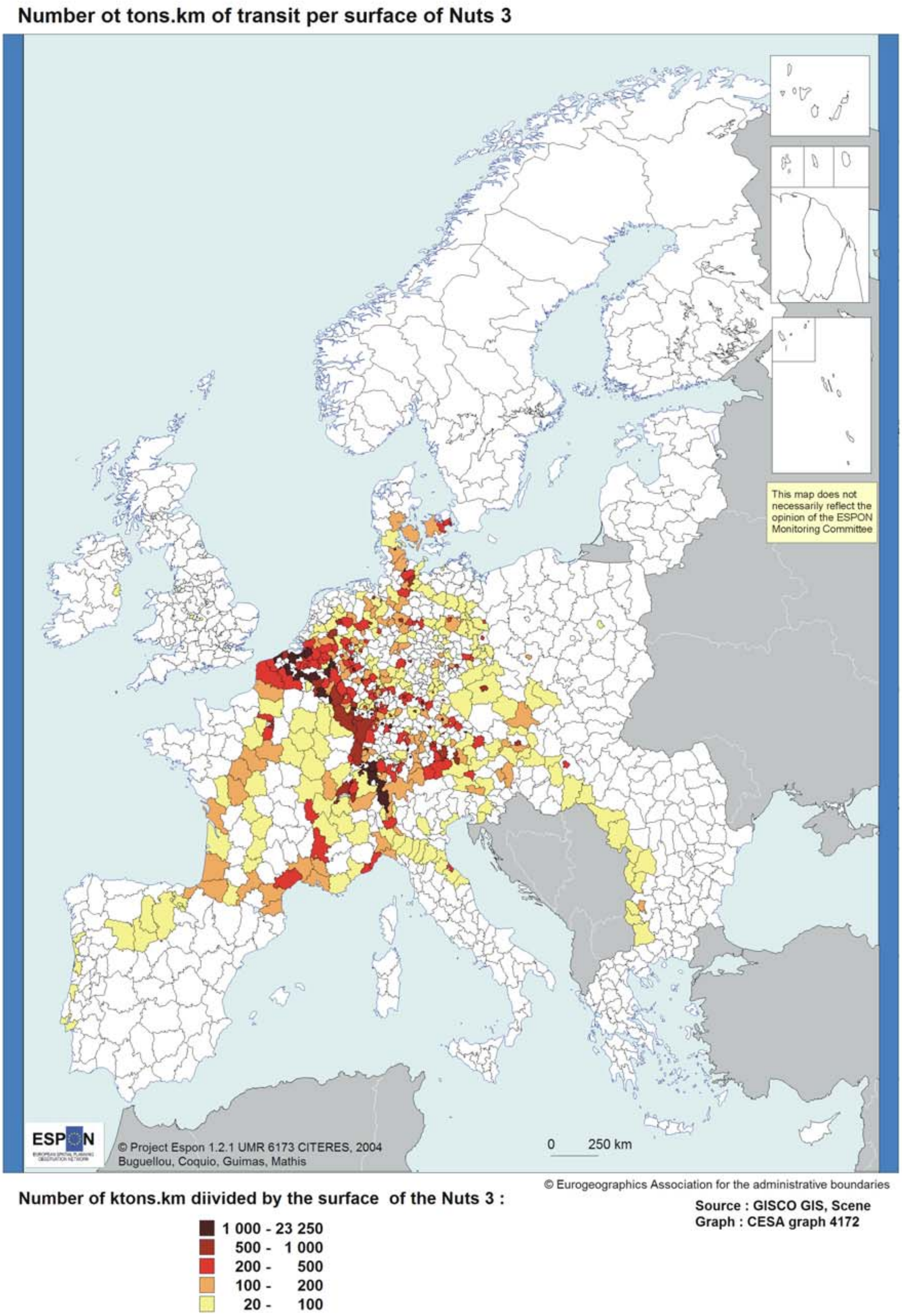
Figure 23 Number of tons.km of transit of NUTS3 divided by the NUTS3 surface

Nevertheless, this analysis must be taken with many precautions. Indeed, the surface of NUTS2 and NUTS3 is very different in the European countries. It is very weak in Germany, Switzerland and Belgium and is quite important in countries such as France, Spain, and Poland. Moreover, the NUTS can have various shapes, which can influence the results in a significant way. For example, if we only keep the values in tons.km (without taking into account the surface of the areas), the results are very different: all the little NUTS have low values because the number of kilometres cannot be high.

So, the results produced here are interesting but show clearly that the nodal analyses are very important to compensate the defects of classical analyses by surfaces (by NUTS), which give false conclusions if they are taken alone[89]. Furthermore, to deal with this problem of surface of the NUTS and the consecutive dispersion of values (in Germany for NUTS3 particularly), we have made calculations on equal surfaces around the road links. This allows us to have a number of tons of transit on each surface and to divide it by the surface of the NUTS. In that way, we can know the proportion of each NUTS suffering from externalities due to transit traffic and therefore integrate the surface of the NUTS in another

[89] It is why we have chosen to make a nodal analysis showing the number of tons of freight going through nodes (see next part 3 chapter 4.2)

way. Indeed, we are convinced that the only solution to deal with this kind of problem is to multiply the points of view.



Map 72 Number of tons.km of transit per area of NUTS-3

6.4 Emission of air pollutants

Rationale

This indicator gives an idea of the level of pollution induce by freight transportation. Taking into account the flow of trucks and the characteristic of their emission of air pollutants, it permits to express the importance of this negative externality. It is successively express in a network logic (i.e. by edges) and in a spatial one (i.e. by NUTS2).

Method

We consider a graph G with N nodes and E edges

For a given edge k such as $k \in [1, E]$

F_k is the total flow going through the edge k, expressed in tons.kilometres.

We distinguish the local or regional flows and the international ones (i.e. transit flows).

We note Fl_k the total local flows and Fi_k the total international going through the edge k

With these notations we have: $\boxed{F_k = Fl_k + Fi_k}$

By hypothesis, coherent simplification of reality, we consider that international carriages are realized by heavy trucks of 38 tons and regional ones by trucks of 16 to 32 tons. We also suppose that, in average, the trucks are only charged at a half of their capacity that includes totally full trucks but also empty ones as sometimes for return travel.

From this hypothesis, we can know the number of trucks circulating by edges and by kilometres, and by geographic aggregation by NUTS.

The calculation of emission is based on following equations validated by the INRETS[90].

The first one consider **empty trucks**:

$$\boldsymbol{\varepsilon = K + av + bv^2 + cv^3 + d/v + e/v^2 + f/v^3}$$

ε is the rate of emission in g/km for an unloaded goods vehicle

K is a constant

a and f are coefficients

[90] The source is available on the INRETS website : www.inrets.fr. We do not integrate the gradient of roads because of the lack of sufficiently precise data at the European scale.

v is the mean velocity of the vehicle in km/h

The second equation permits to obtain a correction factor for load

$$\Phi(\lambda) = l + n + p + q + rv + sv^2 + tv^3 + u/v$$

$\Phi(\lambda)$ is the load correction factor.

l is a constant

n and u are coefficients

v is the mean velocity of the vehicle in km/h

Subsequently we combine the emissions of empty trucks and the correction factor for load

$$\varepsilon \lambda = \varepsilon * \Phi$$

The below tables gives the value of coefficient for the studied case and for the different categories of pollutant.

Table 5 Coefficients of emission functions for heavy goods vehicles (HGVs) with gross vehicle weights from 16 to 32 tonnes:

	K	*a*	*b*	*c*	*d*	*e*	*f*
CO	1.53	0	0	0	60.6	117	0
CO_2	765	-7.04	0	0.000632	8334	0	0
VOC	0.207	0	0	0	58.3	0	0
NO_X	9.45	-0.107	0	7.55E-6	132	0	0
PM	0.184	0	0	1.72E-7	15.2	0	0

Table 6 Coefficients of emission functions for heavy goods vehicles with gross vehicle weights from 32 to 40 tonnes:

	K	*a*	*b*	*c*	*d*	*e*	*f*
CO	0.349	0.0101	0	0	79.6	0	0
CO_2	1576	-17.6	0	0.00117	0	36067	0
VOC	0.254	0	0	0	53.9	0	0
NO_X	5.27	0	0	0	343	-552	0
PM	0.246	0	0	0	18.2	0	0

Table 7 Coefficients of the load correction functions for HGVs from 7.5 to 16 tonnes:

	l	*n*	*p*	*q*	*r*	*s*	*t*	*u*
CO	1.03	0.0345	0	-7.55E-4	9.77E-4	0	0	0
CO_2	1.26	0.0790	0	-0.00109	0	0	-2.03E-7	-1.14
VOC	0.985	0.00367	0	0	0.00135	0	0	0.201
NO_X	1.19	0.0594	0	-9.69E-4	0	0	0	-0.977
PM	1.02	0.0437	0	-9.16E-4	0.00234	0	0	0

Table 8 Coefficients of the load correction functions for HGVs from 16 to 32 tonnes:

	κ	*n*	*p*	*q*	*r*	*s*	*t*	*u*
CO	1.17	0.0563	0	-8.19E-4	0	0	0	-0.755
CO_2	1.27	0.0882	0	-0.00101	0	0	0	-0.483
VOC	1.01	-0.00660	0	2.09E-4	8.89E-4	0	-2.54E-7	0
NO_X	1.28	0.0795	-0.00105	-0.00117	0	0	0	-0.874
PM	1.24	0.0727	0	-0.00113	0	0	0	-1.06

By multiplying the value of emission (in g/km/trucks) by the number of trucks*kilometres by edges, we finally obtained the number total of emitted grams of pollutants by edges. We note it P_k for the edge *k*.

$$P_k = Fl_k/38 * \varepsilon\,\lambda_1 + Fi_k/24 * \varepsilon\,\lambda_2$$

With λ1 corresponding to a load of 19 tons and λ2 to a load of 12 tons.

We have decided to only present results for CO_2 and NO_X.

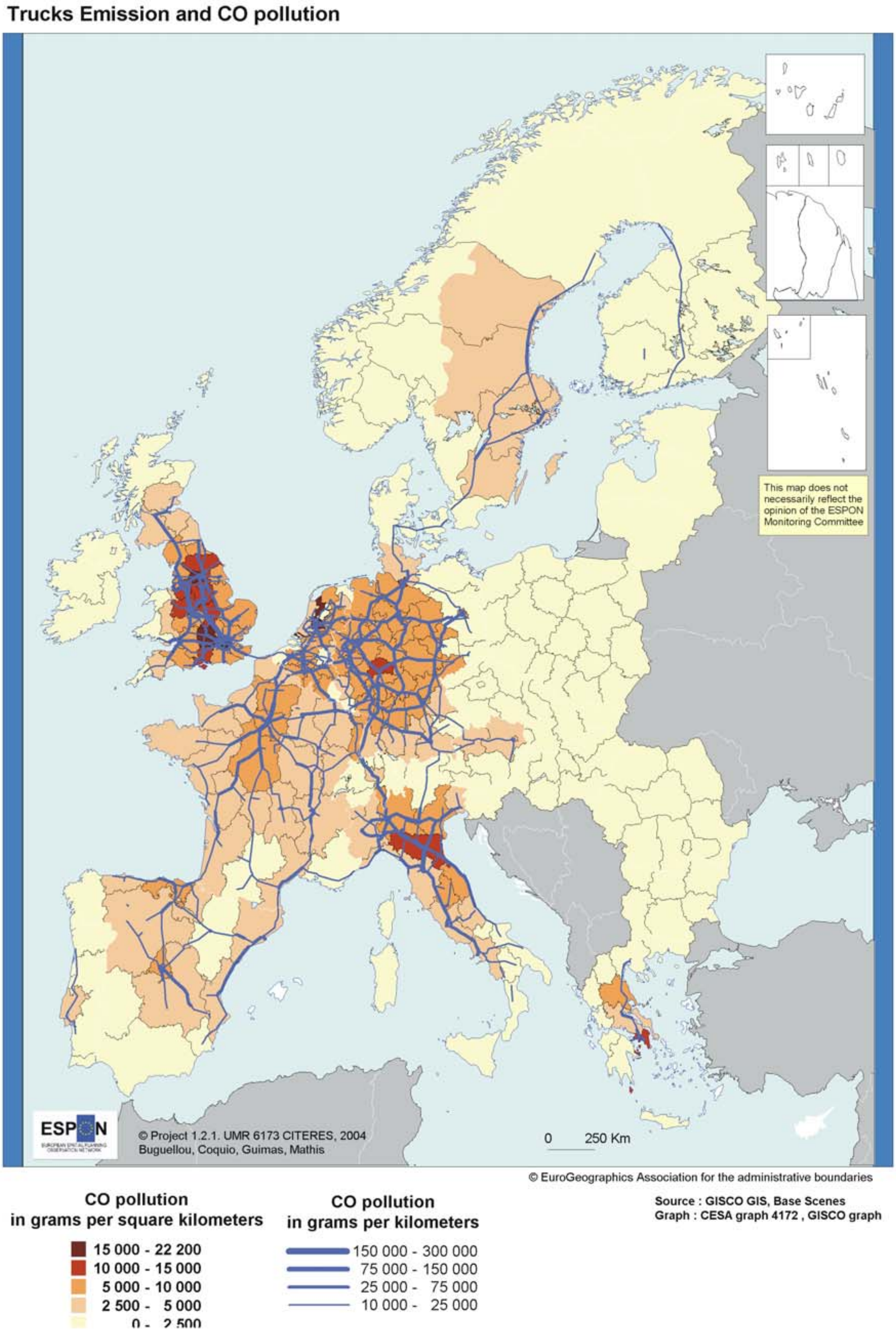
Data requirement

INRETS’ equations

Scene database for freight

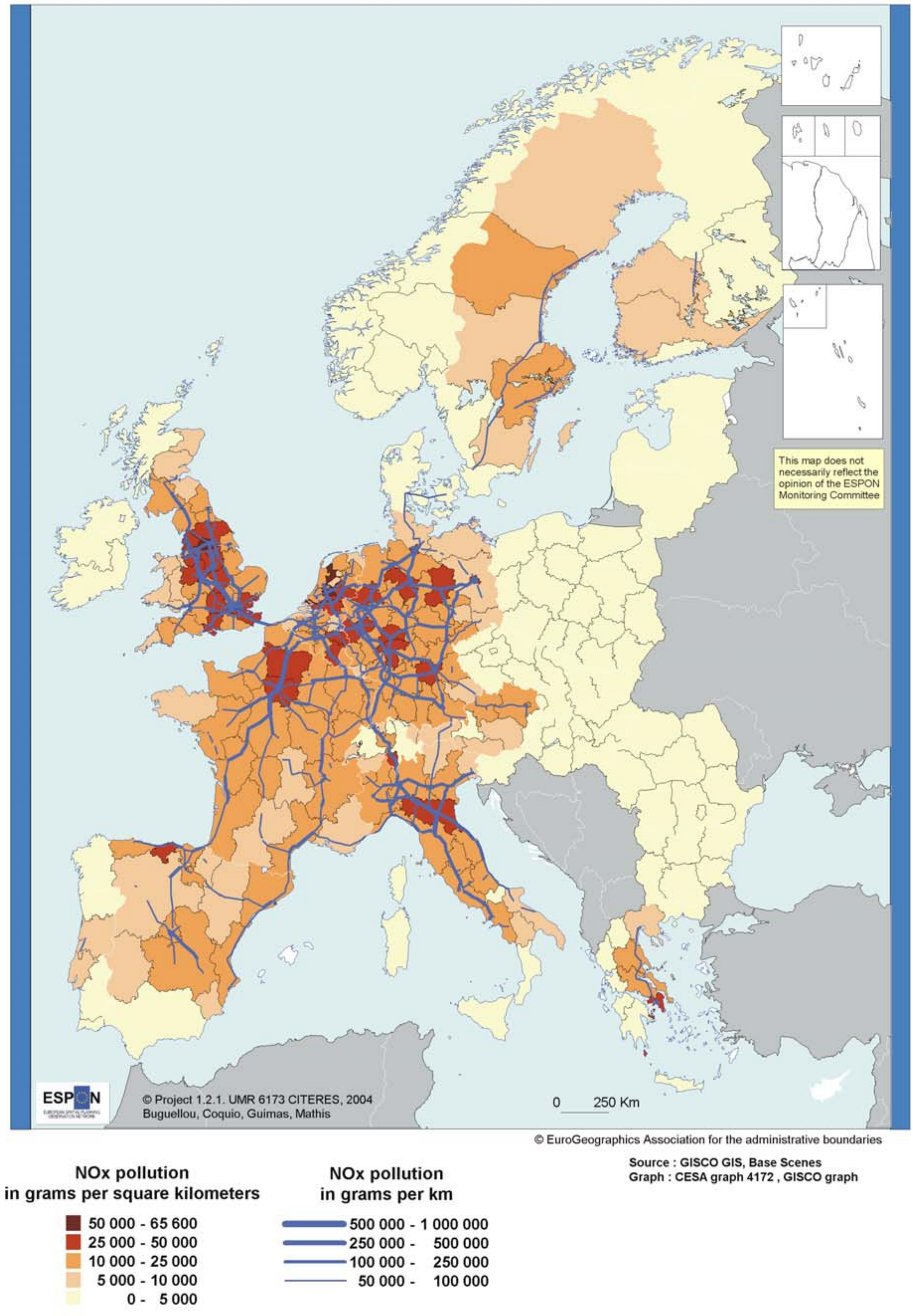
Minimal paths matrix

CESA graph 4172



Map 73 CO emissions of trucks

Trucks Emission and NOx pollution



Map 74 NOx emissions of trucks

Comments

The emissions of pollutants induced by transport constitute one of the main negative externalities on the social, natural but also economic environment. They are linked to the kind of traffic (local, regional, national or international), the speeds and the traffic concentration. The major impacts are concentrated on the strongly urbanised spaces, the transit corridors, the areas of goods' production and the crossroads.

Concerning the specific cases studied, we can observe that the CO pollution is relatively diffused on the whole territory. Nevertheless, the externalities are particularly strong in England, notably along the axes between London -Liverpool and London - Leeds. The core of Europe also suffers from a high pressure, as in the plain of the Po and along the Via Emilia (crossroads of Bologna in Italy).

Furthermore, in these areas where pollution by CO is concentrated, we can distinguish another kind of spatial repercussion. Thus, we can see radial moves around certain capitals, as around Paris, Madrid and Athens. In France, Spain and Greece, pollution is less generalised but centralised around capitals: place of concentration of people, activities, and transport infrastructure.

A few transit corridors appears also in a remarkable way, as the French A10, the axis Milan – Saint Gothard – Base, the valley of the Rhone.

A weak level of pollution appears on the "Finistères" (i.e. peripheral areas) and Eastern Countries. These low values express a weak level of goods exchange.

The map of pollution by the NO_x reinforces the transit axis. Indeed, this kind of pollution is greatly stronger for the heaviest trucks, intensifying the impact of transit. The areas of high concentration stay identical to those mentioned above but new axis appears. It is the case of the corridors from Lille to Bilbao, Milano – Saint Gothard – Basel, the valley of the Rhone.

7 Network Vulnerability

The effectiveness of a network depends on its functionality, of its connectivity but also on its continuity and of its durability and thus, on its vulnerability to the risks. Various phenomena can cause problems in the accessibility of some areas. The intensity of this problem depends simultaneously on the probability of the problem, on its intensity, on its size and on the importance of the link it concerns.

In this logic we have decided to realize two different studies:

The first concerns the relative role played by **each node and each edge**. It permits us to underline the **respective weight** of these elements of a network according to global connectivity and to the level of their use for freight transportation.

The second is about **specific hazards**, **anthropogenic** such as a collapse in mountains or a car accident in a tunnel but also **natural** such as the flooding of rivers or snowstorms. In these cases, we have dealt with the consequences in terms of transfer of flows in the network resulting from this kind of situation.

Of course neither the list of these risks not the example chosen to describe it, claim to be exhaustive. The aim is just to give a preliminary idea of the consequences of such phenomena.

7.1 Systematic evaluation of nodes' and edges' respective weight

7.1.1 Suppression of edges

Rationale

This indicator permits to evaluate, **in a systematic way**, **the cost**, expressed in number of tons*minutes, **induced by the suppression of an edge**. It permits to give to each edge a value representing its relative importance in the domain of freight transportation.

Two elements are integrated into this calculation and it is not necessarily the edge with the greatest level of transit that is the most important . The localisation of that edge is also determinant, relatively to its role in terms of connexion in the transport network. The rerouting can be very long after the suppression of an edge that has a specific role in the homogeneity of roads' distribution. The fact that we work in terms of time-distance accentuates also the importance of edges corresponding to a high-speed link, as motorways. The rerouting on local network increases necessary the minimal potential travel time.

Method

We note *G* the original graph with E edges

For a given edge *e* with $e \in [1, E]$, we note G' the new graph with E-1 edges by definition

We recalculate the matrix of minimal paths and assign the freight flow on this graph G'.[91]

We note:

$\forall k \in [1, E]$, F_k is the total flow going through the edge k in the graph *G*

$\forall k \in [1, E-1]$, F'_k is the total flow going through the edge k in the graph *G'*

$\forall k \in [1, E]$, $i_{(k)}$ the origin node of the edge k and $j_{(k)}$ the destination node of this edge.

We add that $F'_e = 0$; F'_k is yet defined in $[1, E]$

Then we represent the transfer of flow to underline the decrease and the increase of number of tons going through each edge. We express the result in difference of number of tons*kilometres between the reference (all links could be used) and the truncated network, unit that gives a good idea of the cost of such a suppression and permits to take simultaneously into account the level of traffic and the importance of rerouting.

$\forall k \in [1, E]$ we call S_k the value of the indicators presented above

$$S_k = (F'_k - F_k) * T_{i(k), j(k)}$$

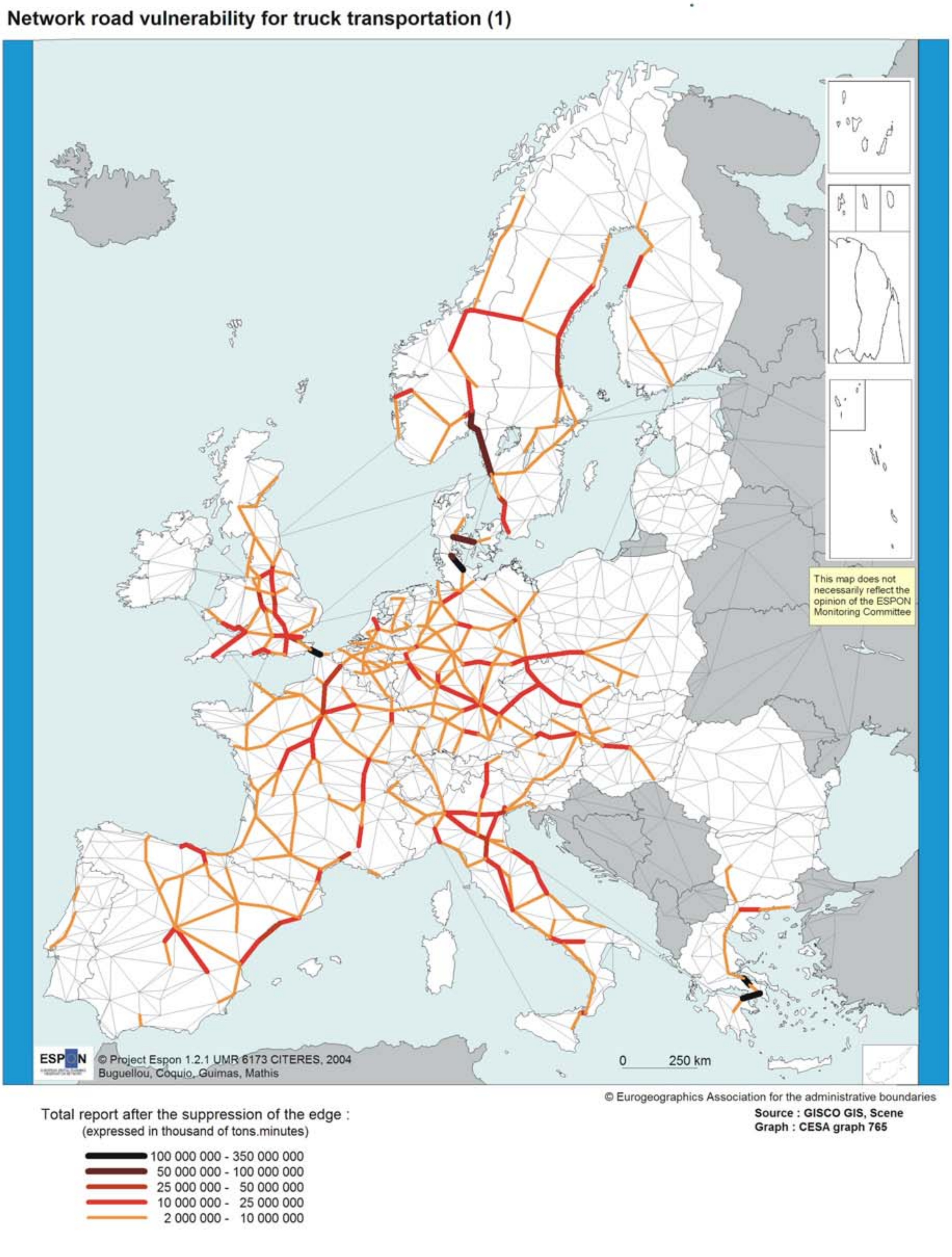
Data requirement

CESA graph 765[92]

Scene databases for freight

[91] As for others indicators we have not dealt with eventual capacities' problems

[92] We have not been able to use the *CESA graph 4172* because of the necessary time for the recalculation of *Minimal path matrix* and affectation on new graphs (4172 calculations of Floyd in this case)



Map 75 Network road vulnerability for truck transportation (1)

Application to ESPON Space

The first observation of this map gives an impression of **relative homogeneity** of the main edges' distribution (in the sense of importance explained above), that seems to cover all the European countries, except for few Eastern countries. For these latter, the low level of freight emission/reception, according to the database used, is the discriminating factor and the conclusion has to be moderated because of the lack of updated data, accentuated by the great growth of the level of importation/exportation of these countries.

If the quasi-totality of the main European corridors are represented, it can be interpreted as real coherence between the reality and our model. It is interesting to note moreover, the natural importance of the edges linked (directly or by the intermediary of another edge) to the main **European metropolis** such as Paris, London, Madrid, Roma, and so on. The high level of emission/reception of goods of these capitals explain for a major part this phenomenon to a great extent, accentuated by the fact that, in general, these kind of cities are very accessible in terms of transport because of the density of the high speed roads around them, which are simultaneously the causes and consequences of their development.

We can also note that some edges represent very important links because of their **specific role in the local connectivity of the network**. It concerns mainly roads around mountains (as to the East and to the West of the Pyrenees), bridges (as in Denmark) and tunnel (as Frejus and Saint Gothard in the Alps or under the English Channel). The graph below illustrates this observation with some "peaks" corresponding to these fundamental links, for example for the United Kingdom, in Germany to reach the to reach the Scandinavian countries and Finland or in Greece with the Corinthian Gulf. On the other hand, it is interesting to note that, in Germany and countries of the Benelux for example, the average costs of rerouting are finally quite weak: the density of network compensates for the important quantity of goods going through this country by the weakness of the supplementary time.

It finally illustrates the importance of the differences of the edges' weight, even when they are located in a same area. The graph below completes the map, aggregating the result by country.

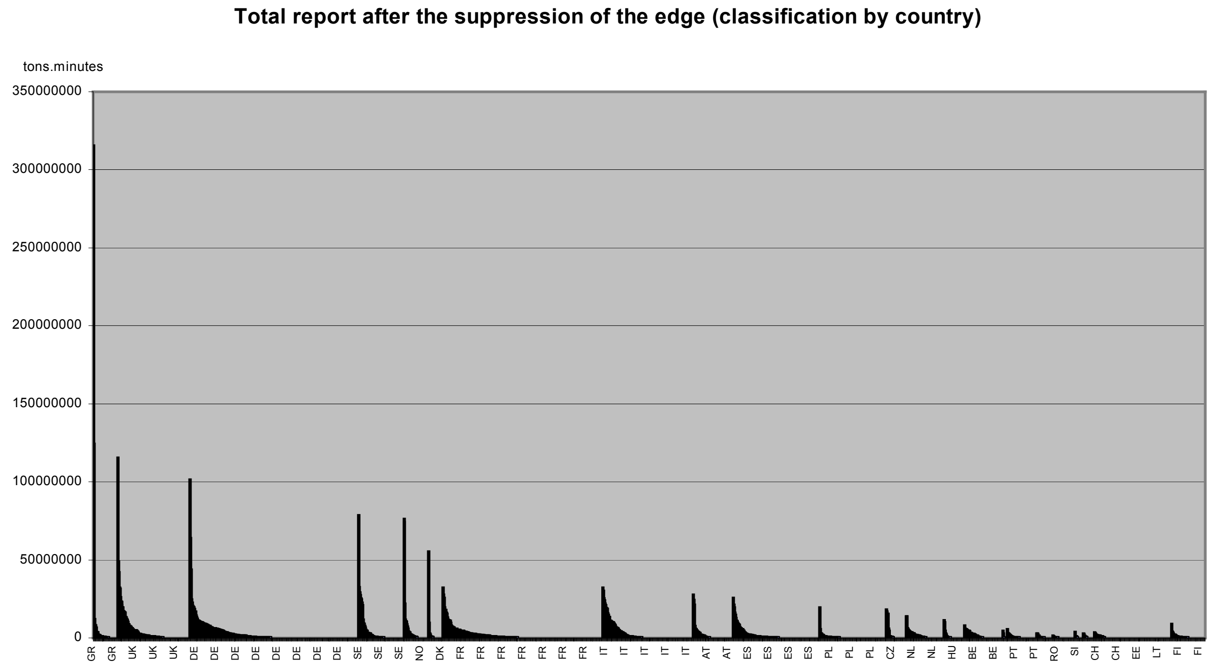


Figure 24 Total report after the suppression of the edge (classification by country)

Finally, to summarize our analyse, we can say that this indicator, by allowing a measure of the network's heterogeneity, is a good tool to point out the place **where it is necessary to build a new or a redundant road for the global security of the network**. Of course this is only the result of modelling, with a partial (even if we to try to be as realist as possible) network that sometimes allows low rerouting whereas level of capacities in local network does not permit it in reality. The data must be consider as a general outline of the situation and should not be used in a literal interpretation.

7.1.2 Suppression of nodes

Rationale

This indicator is a combination of the indicators "suppression of edges" and "number of tons exchanged by nodes". It deals with consequence, in term of freight flow report in the case of the suppression of a node of the graph. It permits to understand the relative importance of each node concerning freight transportation. Each node obtains a value corresponding to the tons*minutes supplementary induced by its own suppression, because of turning for trucks that cannot use the minimal paths going through it.

We have not taken into account goods' emission/reception from/to the suppressed node in the goal of facilitating the comparison, notably for major cities as Paris or London that are great sources of emission.[93]

Method

We note *G* the original graph with N nodes and E edges.

For a given node *i* with $n \in [1, N]$, we note G' the new graph with N-1 nodes

After that, we suppress all the edges whose origin or destination node is this node n.

We note E' the total edges' number of G' ; by construction E'<E.

We recalculate the matrix of minimal path and assign the freight flow on this graph G'.

We note:

$\forall k \in [1, E]$, we note $i_{(k)}$ the origin node of the edge k and $j_{(k)}$ the destination node of this edge.

$\forall k \in [1, E]$, F_k is the total flow going through the edge k in the graph *G*

$\forall k \in [1, E']$, F'_k is the total flow going through the edge k in the graph *G'*

We logically have E-E' edges suppressed between G and G'. By simplification of writing, we consider that the suppressed edges are all the edge with $k \in]E', E]$

We add $\forall k \in]E', E]$ $F'_k = 0$; in this way F'_k is defined in $[1, E]$

Then we calculate the difference of flow on each edge between the truncated graph G' and the original one G. As for the suppression of edge indicator we note S_k this difference for the edge k.

$\forall k \in [1, E]$, $S_k = (F'_k - F_k) * T_{i(k), j(k)}$

Then we use the same method as the one used to for the indicator "Number of tons exchanged by nodes".

$\forall\ i \in [1, N]$, SN_i the value of the indicators presented in this part for the i^{th} node

For a given node *n* with $n \in [1, N]$, we have

93 That hypothesis is not unrealistic, with, for example the strike of long-distance lorry drivers in 1992 what had isolated the city of Lyon for three or four days during the Sixth World Conference on Transport Research, roads and rail blocked

$$SN_n = \sum_{k=1}^{E} S_k \text{ with } i_{(k)} = n \text{ or } j_{(k)} = n$$

Data requirement

CESA graph 765 [94]

Scene databases for freight

Application to ESPON Space

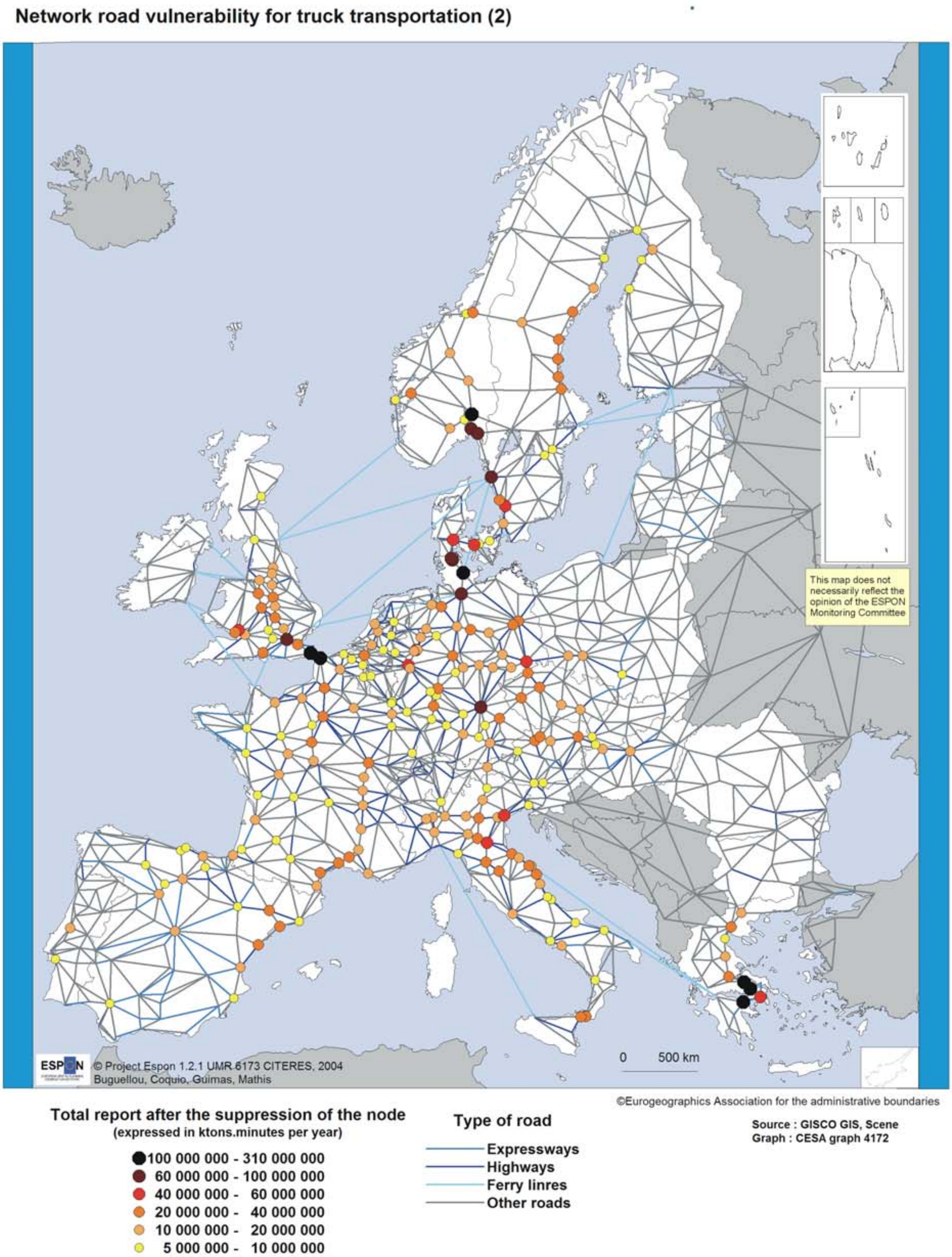
Three remarks can be made with the observation of this map.

First, and foremost, we can note that **the jamming of major European** capitals does not induce a high rerouting in terms of tons*minutes supplementary, contrary to the suppression of an edge link to one of them, as it is shown in the previous map. This is due to the fact that other possibilities of routes are often available around these big metropolises, because of the density of the local network. The goods can take others roads, without a too important increase in travel time. This does not diminish the importance of these cities in freight transportation but only their role in terms of transit (because, as mentioned above in the method, we does not take into account the emission /reception from/to these cities)

Once again, the roles of specific areas are underlined. Nodes associated to a bridge for example appear as fundamental to the good distribution of freight. The nodes linked to the Channel are also part of this category because of their connectivity role.

Lastly, the case of Nuremberg, in Germany shows the importance of this node as a European crossroads, as a kind of door open on the Eastern European countries.

[94] We have not be able to use the *CESA graph 4172* because of the necessary time for the recalculation of *Minimal path matrix* and affectation on new graphs (4172 calculations of Floyd in this case)



Map 76 Network road vulnerability for truck transportation

7.2 Vulnerability to a selection of natural or anthropogenic hazards

Rationale

This indicator permit us to evaluate **the potential consequence**, in terms of flow distribution, **of the suppression of certain important link** in the cases of the **destruction of a bridge or obstruction of a tunnel** (as after the catastrophe in the Saint Gothard in Switzerland in October 2001 or the Mont Blanc in 1999), of major European rivers flooding (such as the Elbe in Germany in August 2002) or of snow storm and ice (as in the Pyrenees in January 2003) . It permits to anticipate the transfer of total (i.e. local and national) freight flows on the network in terms of tons.

When the rerouting is local, we do not know if the capacity of the new used roads is sufficient. We have clarified before that these data are not available. Consequently our results present the minimum of rerouting, the second speediest path being necessarily (by hypothesis of assignation of freight on minimal path) longer in terms of travel times .

We have decided to represent our result in an original way, coherent with the relatively local (depending on the link suppressed) consequences. **Six little maps** are presented for each kind of hazards, **each one at a specific scale** adapted to show with all the necessary precision the rerouting induced by the suppression of the six chosen links. A graph comes to precise the results, by giving a single indicator for each case, summarizing the global consequences of the suppression of each link.

Method

We suppress the edges corresponding to the links we study.

In the case of a single link, we suppress just it, only authorizing local traffic (i.e. between the 2 two NUTS linked by the edge or into the NUTS including the edge) on small road existing (because of capacities problem). Then we recalculate the matrix of minimal path and affect the freight flow on this new network.

In the case of problems due to flood, we suppress all the links of which origin or destination node are located at less than 5 km of the river.

In the case of problems due to snow or ice, we suppress all the links of which origin or destination nodes are located at more than 750m of altitude.

We note *G* the original graph and *G′* the simplified graph after a suppression as described just above. E is the total number of edges for the graph *G*, E′ this number for *G′* .In an obvious way E′ < E.

We recalculate the matrix of minimal path and assign the freight flow on this new network.

We note:

$\forall k \in [1, E]$, F_k is the total flow going through the edge k in the graph *G*

$\forall k \in [1, E']$, F'_k is the total flow going through the edge k in the graph *G′*

We logically have E-E′ edges suppressed between G and G′. By simplification of writing, we consider that the suppressed edges are all the edges with $k \in]E', E]$

We add $\forall k \in]E', E]$ F'_k = 0 ; F'_k is yet defined in $[1, E]$

Then we represent the transfer of flow to underline the decrease and the increase of number of tons going through each edge. We express the result in difference of number of tons between the reference (all links could be used) and the truncated network.

$\forall k \in [1, E]$ we call D_k this difference for the edge *k*[95]

$$D_k = F'_k - F_k$$

Data requirement

CESA graph 4172

Minimal path matrix for trucks

List of hazardous link (tunnels, bridges)

Localisation of main European river and results on natural hazards of the ESPON group 1.3.1

Level line of altitude in the whole Europe

Scene database for freight

95 We recall that we do not take into account capacities of roads because of the unavailability of relative data.

7.2.1 Suppression of hazardous link

We have selected six links for this exercise, weak in terms of vulnerability because a technical, technological or human error could provoke a temporarily or definitively stop to their functionalities, whatever the reason or the means are. We have decided to work on:

- Nice-San Remo
- Narbonne-Perpignan (to the West of the Pyrenees)
- Irun-Hendaye (to the East of the Pyrenees)
- Nyborg-Slagelse
- Tunnel of the Saint-Gothard (in the Alps)
- Tunnel of Fréjus (in the Alps)

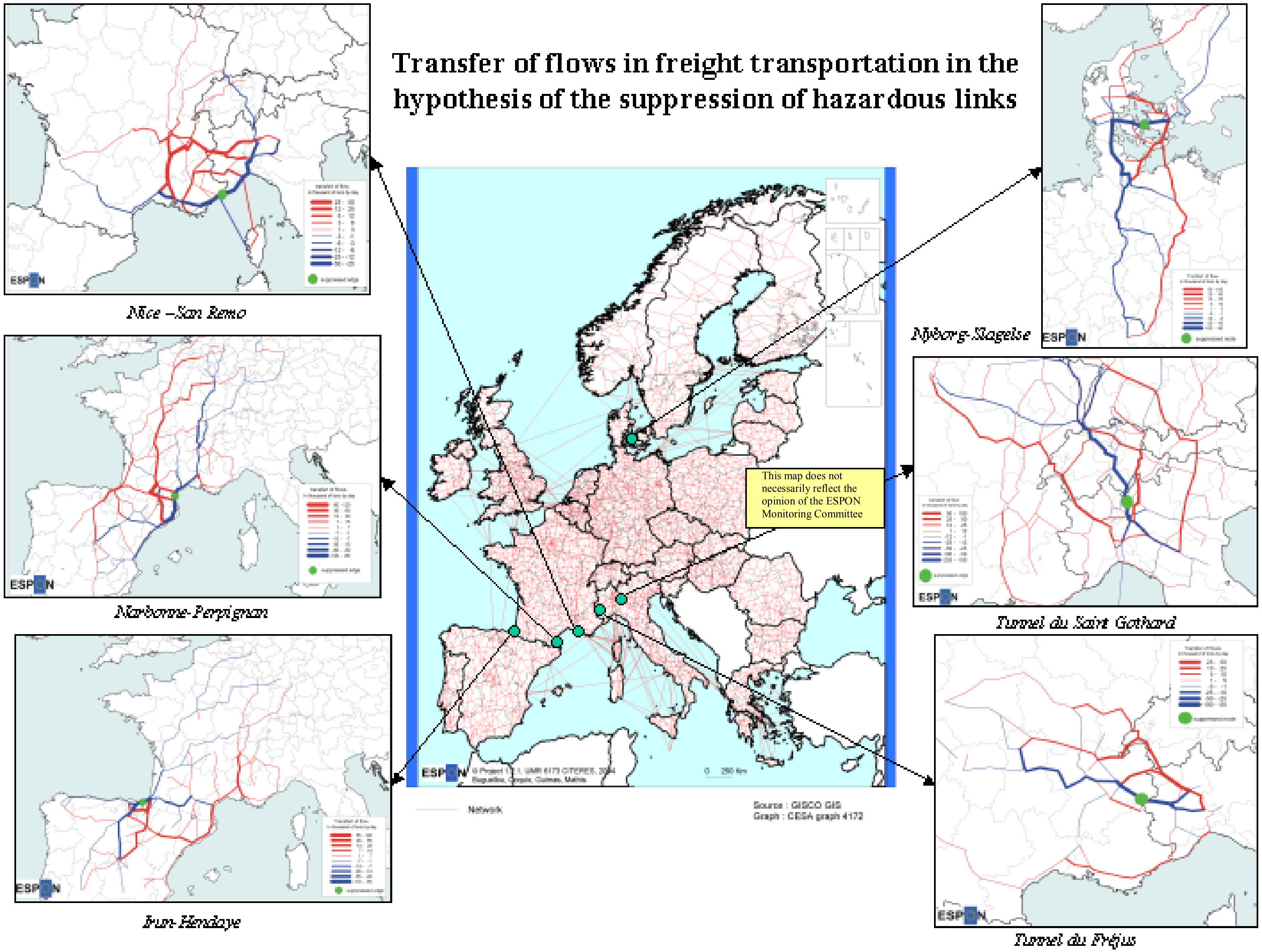
We have not worked on the Channel because the specific situation of this link makes it as the unique solution to go by road from England to Western European continent. Indeed, all the goods necessary take the ferry increasing travel time but not using a different path. It is just a modal transfer. We have neither considered the case of the tunnel of Mont-blanc because we have already studied two tunnels and because this one is the less important in terms of freight and number of tons, according to our data.

Application to ESPON Space

In a general manner we can note that for each case the **rerouting begins far away from the removed edge**. It concerns mainly the international transport by heavy trucks, drivers preferring to rerouting on the nearest corridor rather than to use local network, which is not very fast. The use of local network depends greatly on the local's level of exchange (i.e. inside a given NUTS or between two adjacent NUTS)

When suppressed links concern tunnels, as for Frejus and Saint Gothard, the transport is in the direction of **the nearest tunnel**.

Concerning the Pyrenees, the rerouting is mainly on **the opposite side** of this massif: the West side when we suppress the link between Irun and Hendaye and the East one when we remove the link between Narbonne and Perpignan.



Map 77 Transfer of flows in freight transportation in the hypothesis of suppression of hazardous links

The importance of rerouting in this hypothesis depends to the property of "h-connectivity" of the graph theory.

With the suppression of one or several edge, the graph becomes not connected for the road mode. The connection can be maintained if we are other available modes as ferries' lines for example. If the travel times necessary become higher (hypothesis of minimal paths), the distance in kilometres can decrease.

The h-connectivity, that is to say the minimum number of edges whose elimination disconnect the graph, could be an other measurement of vulnerability of multi-modal graph.

The graph below completes our analysis giving a global idea of the consequences of each of the six examples:

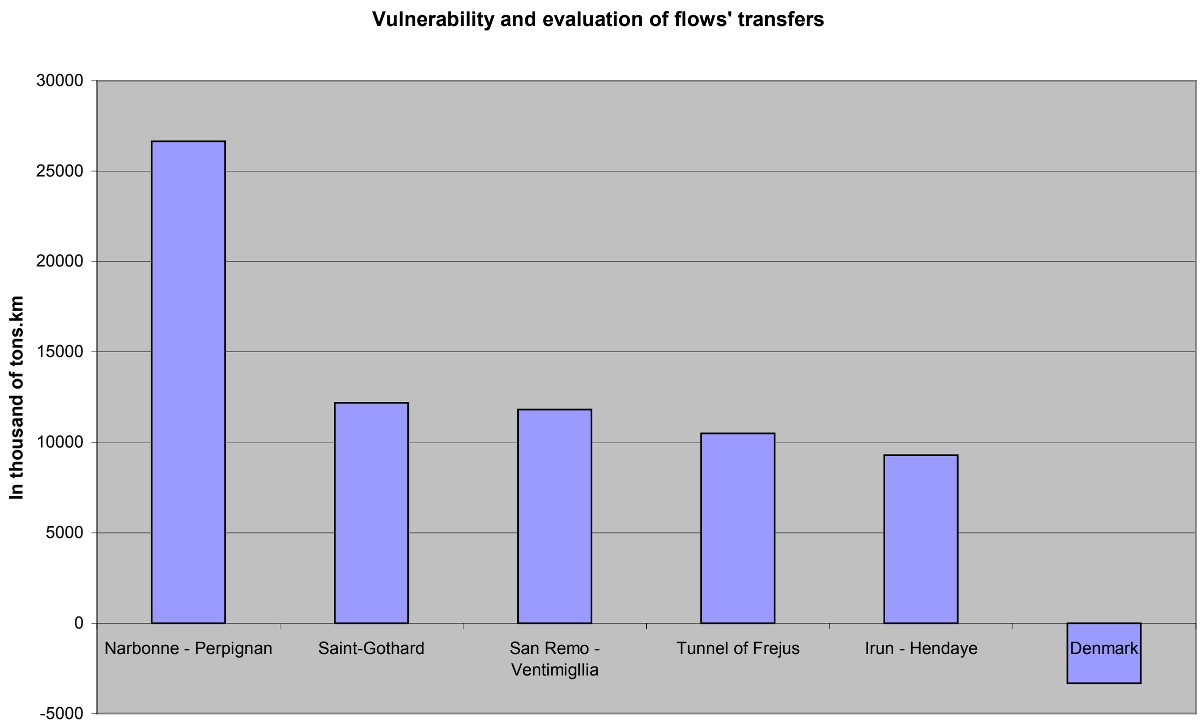


Figure 25 Vulnerability and evaluation of flows' transfers

In terms of global consequences, as it is represented in the graph above, we can note three elements:

- the great importance of the transfer in the Narbonne-Perpignan's case, due simultaneously to the original level of use of this link and to the high increase of the number of kilometres to connect Iberian Peninsula to France, and to the rest of Europe in general. The transfer begins very far of the Pyrenees.

- The relative homogeneity between Nice-San-Remo, Irun-Hendaye, and the two tunnel between nine and twelve millions of tons*kilometres supplementary
- The negative value for the suppression of the bridge between Nyborg and Slagelse in Denmark that can appear surprising in a first time. The choice of our units explains this phenomenon. Indeed, the value of the indicator is expressed in tons.kilometres while the determination of the minimal path is based on travel times. The suppression of this bridge induces not only a modification of paths but also a modal transfer, with a report on ferries' lines. Well, if the use of a ferry is slower than roads, it is sometimes shorter in terms of kilometres, because it does not imply a skirting around seas. It is the case of this example.

7.2.2 Vulnerability to flooding

Great width floods that hit various countries during recent years clearly show the need for having quantitative forecasting studies to evaluate the availability of the transport systems during these events and their levels of disturbances The risks on transport networks and the capacities of the crossing of the valley in case of risings (centennial or five centennial) have not been evaluated yet.

Of course, the probability that all floods are simultaneous is low but for presentation's reasons we decide to show six different cases on the same map, at different scales. We also want to remind of the fact that, because of the lack of precise data about altitude, but also because our edges are line's segment, the selection of the edges that are suppressed is an approximation and has to be considered with all the necessary precaution inherent to this kind of work[96].

We have decided to work on six rivers or part of rivers, chosen because of the frequency and/or importance of their floods:

- The Moselle and the Rhine in France, Germany and Luxembourg
- The Rhone in France
- The Danube in its German part
- The Elbe in Germany and Check Republic
- The Danube in Austria and Hungary
- The Po in Italy

[96] We have to add that we only can use an interpretation of the data furnished by the ESPON group 1.3.1 because we have been able to obtain numerical data used by them to produce their maps.

Application to ESPON Space

In a general manner, the transfer of flow is more local than for the precedent maps dealing with hazardous single links in spite of the fact that more edges are suppressed at the same time. It can be explained by the relative importance of these links in freight transportation. Indeed, the majority of remaining edges exposed to the flooding risk **do not correspond to fundamental links** for the global connectivity of the network.

The rerouting provokes the use of new edges located **at the limit of the catchments' areas**. It seems coherent with the fact that the network is truncated inside the local basin. At the same time we can distinguish **the main bridges**, that is to say those which lost a greatest number of tons.

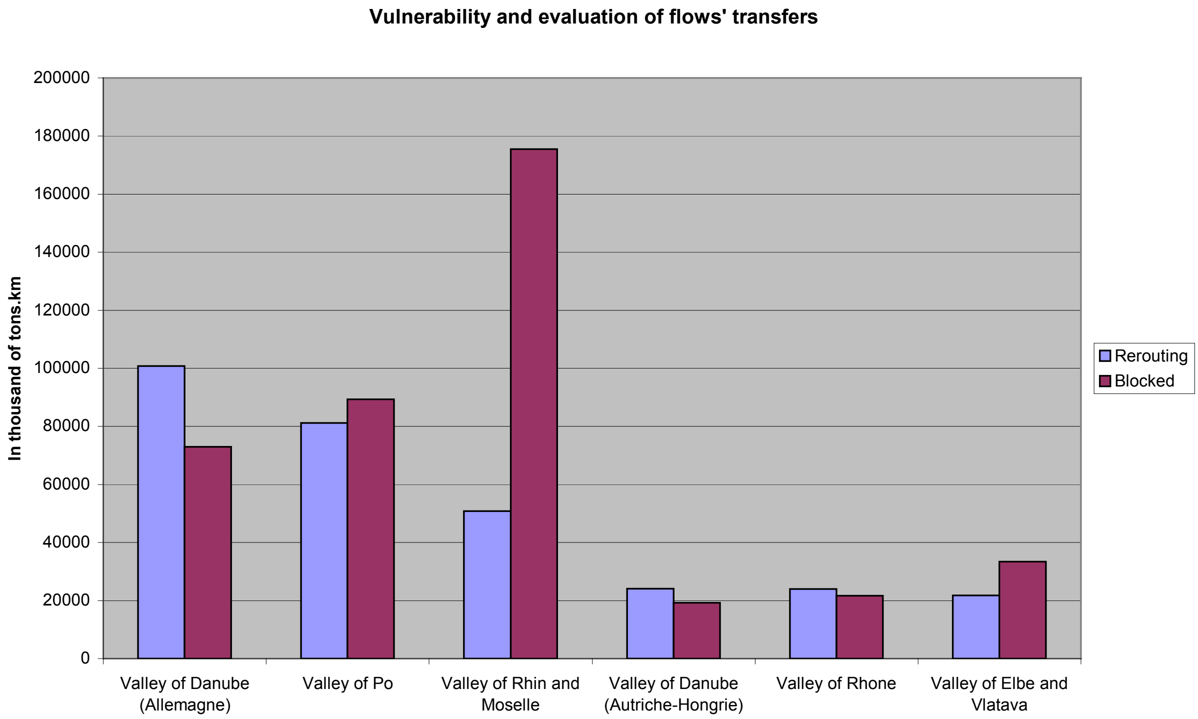
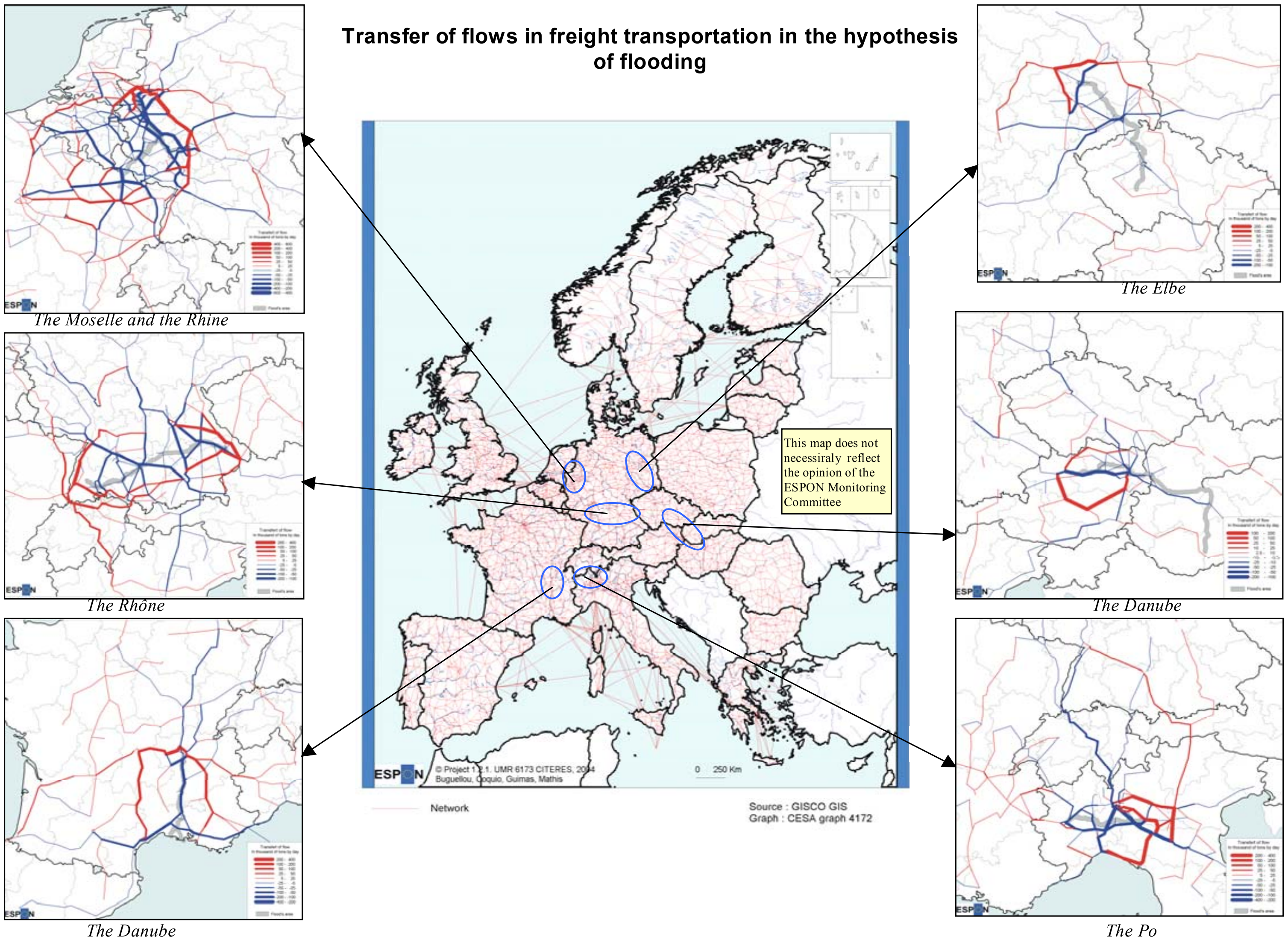


Figure 26 Vulnerability and evaluation of flows' transfers

The graph just above completes this information.

There is two data by example: the blue columns concern the global coast of the effective rerouting after the suppression of edges, the pink one is about the goods that are not give out or receive, because of the suppression of nodes, that sometimes represent an important quantity.



Map 78 Transfer of flows in freight transportation in the hypothesis of flooding

First, we can see that the global transfer, expressed in tons*kilometres is r**eally greater than in the in the previous case**, that is to say, the suppression of a single link. It is logical considering the fact that, for flooding risks, all the edges included in the zone of flood are no longer usable. This figures is **really important in the case of the Rhine, the Danube in its German part and the Po** with a value between 50 and 100 millions of tons*kilometres. Two explanation can be formulate: on one side **the strong level of the local traffic** (that is particularly true for the Rhine because of the high number of trucks using the link between Koblenz and Cologne) and on an other side **the importance of rerouting in terms of kilometres** (notably for the Po, because of the cut of the link between Milan and Genoa). It is the conjunction of these two phenomena that explain these great value (that is the case for the Danube in Germany).

For the third other examples, values oscillate near 20 millions of tons*kilometres, less important because of the level of original use of these edges (for the Danube in Austria and Hungary) and low rerouting in distance (for the Rhone).

In terms of blocked tons, the values are higher for the same three example. It can be explained by the suppression, in our exercise, of **some very important cities**. It is notably the case of the Po with Turin, the Rhine because of the proximity of the Ruhr, and the Danube because of the high density of emission/reception in this area due to the **important density of people** in this area. For the three other cases studied the local situation (no major cities suppressed or low flow of goods originally) explains these results.

To conclude, it is good to remind that, in the case of a such problems, the modal transfer from ferries or railway, seems to be difficult because of the hazard of navigation on flood rivers and the general localisation in the valley's bottom of railway, reinforcing the difficulties of management of these kind of situation.

7.2.3 Vulnerability to snow and black ice

We have decided to work on six examples of problems of traffic due to snow and black ice, concerning four mountains' massifs:

- The Ardennes
- The Western part of the Alps
- The Pyrenees
- A part of the Alps included in Italy and Switzerland
- A part of the Alps included in Italy, Switzerland and Austria

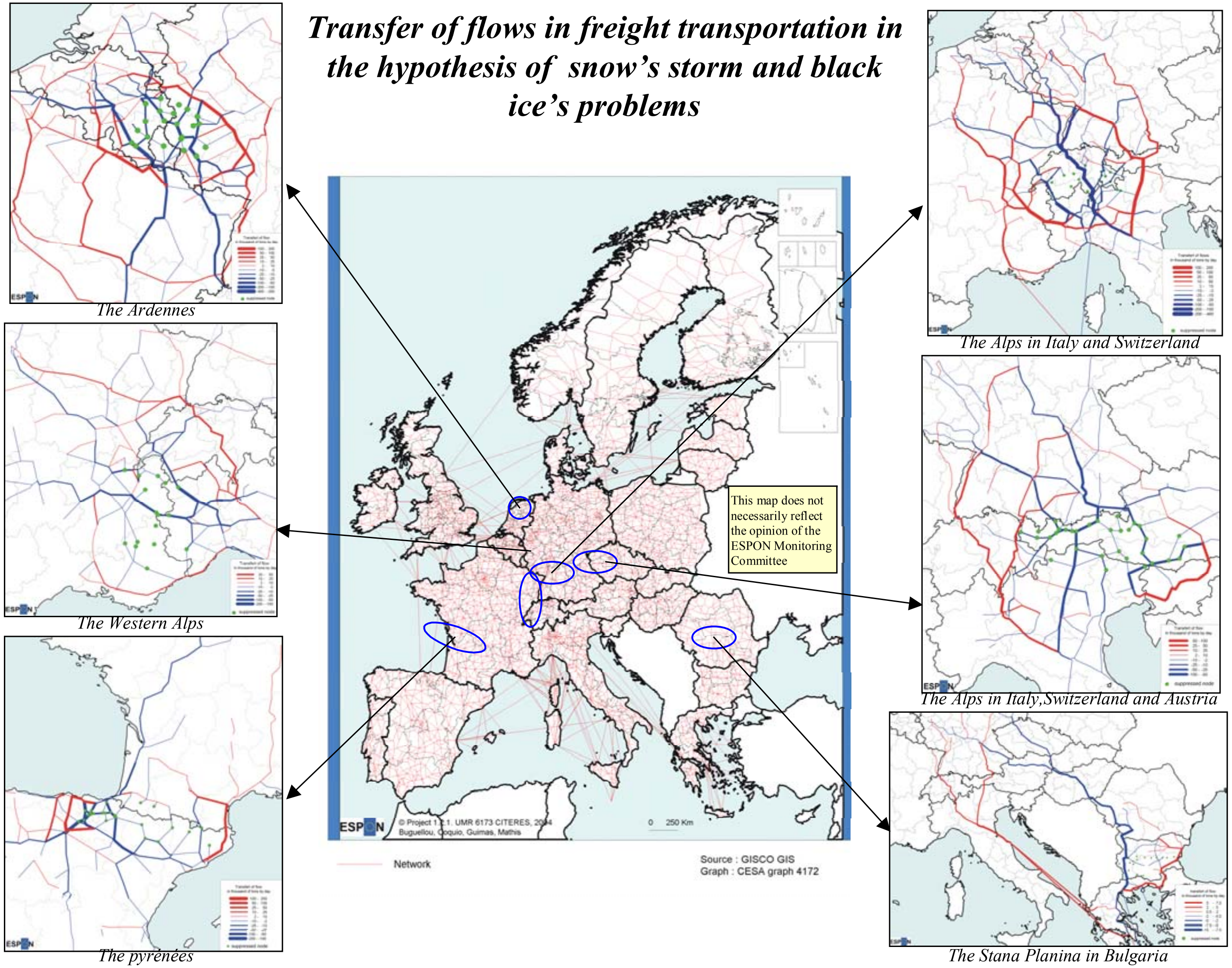
- The Stara Planina in Bulgaria

Of course it is only a partial selection of all the areas susceptible to present trouble consequently to snows' storm but they are representative of the different situation in terms of rerouting in the field of freight transportation. One more time it is good to remind that it is only approximation because of the lack of precise data concerning frequencies and level of these kind of troubles. In more, the data of altitude those are available for the whole Europe has only a level of precision of 250 meters.

As in the previous case of flooding, transfer of flow **are more local** than in the case of the suppression of bridges and tunnels, probably because of the weak level of road infrastructure existing in the mountains. The rerouting concerns essentially **the network around the massif** (or the parts of the massif) studied with a massive use of roads in the valleys.

In this case, **the h-connectivity is equal or greater than two**. When the indicator of connectivity is equal at two the rerouting can be very important.

The case of the Stana Planina in Bulgaria is a bit different because of the specific configuration of the local network. Suppression of edges with a high altitude provokes an important transfer with a great modal change at the **benefice of ferry lines** permitting to link Italy and Greece. The supplementary time due to the slowness of ferries, accentuated by the waiting time, is compensated by decrease of the travel kilometric distance supplyed by this solution. It is not always the case, this possibility depending on the existence of a ferry line and of the scale of the potential transfer (as in the example of Nyborg-Slagelse in the previous case, in which the use of ferry is not an interesting solution because of the short distance to roam).



Map 79 Transfer of flows in freight transportation in the hypothesis of snow's storm and black ices' problems

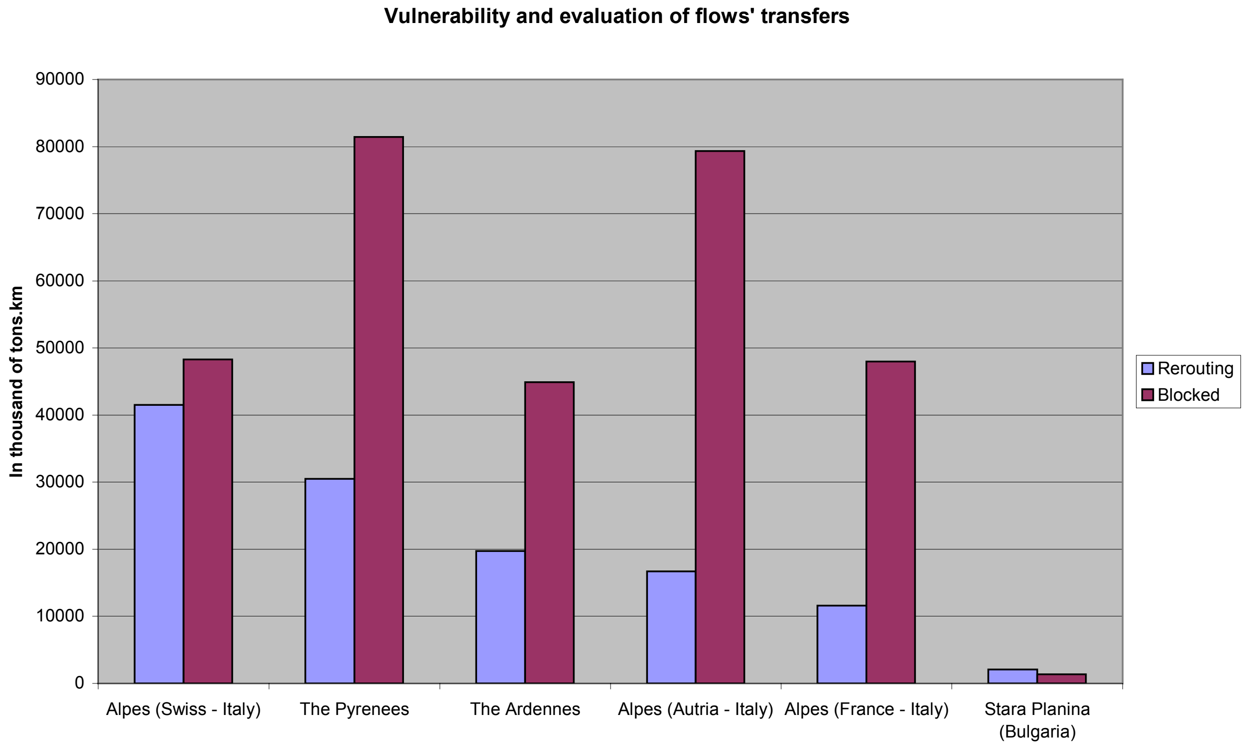


Figure 27 Vulnerability and evaluation of flows' transfers

The graph above permits to complete our analyses.

First of all, we note that, in each case, except the specific one of the Stara Planina, we **number of tons*kilometres blocked are superior to the supplementary tons*kilometres** induce by the rerouting. It is due to the local character of the transfer and to the great number of nodes suppressed because of a work no more on punctual troubles (as in the first case dealing with single hazardous link) nor linear ones (as in the second case dedicated to floods) but in a logic of surface. It is not the importance of the removed nodes but their number that is the determinant factor.

The case of the Stara-Planina is particular because of the permanent low level of transit in this area.

PART 4: INTERPRETATION AND RECOMMENDATIONS

1 Typologies

Typologies are proposed through the combination of at least two different indicators. We propose here three different typology approaches:

- a typology confronting the infrastructure endowment with the density of population
- a typology of regions according to two dimension, accessibility and economic performance
- a typology of regions suffering from transport externalities produced by road traffic flows

1.1 Regional Infrastructure Endowment and Population Density

The comparison between the infrastructural equipment of the Nuts 3 regions and the capacity of the infrastructural network is finalized to meet the needs of the potential request, expressed as number of inhabitants.

The infrastructural equipment, at the NUTS 3 level, is calculated as density of infrastructures dividing the total length of the main roads, motor-roads and rails (high speed trains and main lines) by the NUTS3 surfaces. The potential request of infrastructures is simplified dividing the NUTS3 inhabitants by the total length of infrastructures. Data used come from the Espon 1.2.1 Database (version 2.1).

The different settlements are investigated as a condition interfering with the infrastructure endowments introducing the distinction (source: Nordregio, time reference 1985-2001) between:

- NUTS3 with a high population density and with a rural[97] profile;
- NUTS3 with a high population density and with a composite profile;
- NUTS3 with a high density and with a urban profile(HD-urban);
- NUTS3 with a medium and low population density and with a rural profile;
- NUTS3 with a medium and low density and with a composite profile;
- NUTS3 with a medium and low density with a urban profile(MLD-urban).

The comparative study about infrastructural endowment that links the potential use level (inhabitants/infrastructure km) to the network density (infrastructure km/ NUTS3 area km2) in the different NUTS3 areas, singles

[97] Relative rurality: share of rural population, index country average=100, < 90 low (urban), 90-110 medium (composite), >110 high (rural).

out four ideal typical situations which ascribe to take policies for integration between land use and transport supply.

The aim is to identify different types of the regions based on their position in the following diagram that classifies the regions crossing the infrastructures endowment and the infrastructures density.

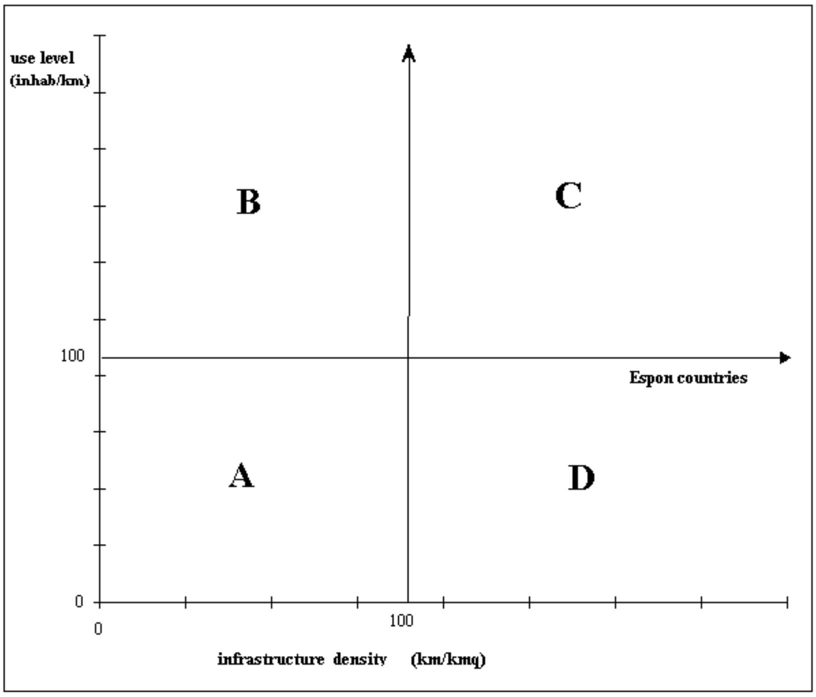


Figure 28 Diagram of the comparative study on infrastructures endowment

Four types of regions, corresponding to the four quadrants of the diagram, can be distinguished:

- in the "A" quadrant (infrastructural density below average datum, but with a good use level), there can be found the peripheral regions, dominated by small cities, characterized by a low population density and rural settlements. These areas remain far from the important plurimodal corridors, they have an almost unchanged infrastructural network in the last years. The few polarised towns and their agrarian vocation, even if integrated with productive zones in "specialized islands", do not make the poor infrastructural endowment problematical, but uncertain (because a scenario is not easy to forecast).
- in the **"B"** quadrant there are potentially congested regions, presenting a deficit in the infrastructural equipment (infrastructure density below average datum) with an high settlement density (use

level above average datum), result of a long-term economic growth development. In this condition (potential structural deficit), traffic congestion is widespread. In these areas it is necessary to improve the infrastructure supply, but also to select new locations.

- in the "C" quadrant fall situations of congestion because a good infrastructure density is matched by a low use level. These are situations in which there is not a structural deficit, but a combined deficit on which actions should be taken, particularly by taking steps on the distribution of activities and functions on the territory.
- in the "D" quadrant (high level of infrastructural density and good use level) it is necessary to govern the growth processes and the transformations of the territory that are, here, strongly dependent upon vehicular mobility.

A further distinction is introduced in order to analyse the infrastructures endowment in reference to the geographical position of the different NUTS3 regions, considering:

- the Northern Europe countries as DK, FI, SE;
- the Central Europe countries as AT, BE, DE, FR, LU, NL;
- the Southern Europe countries as ES, GR, IT, PT;
- UK and IE;
- the Accession Countries

The comparative study about infrastructural endowment that links the potential use level to the network density examines, at first, each single infrastructural network (roads, motor-roads, main rails) and then the whole infrastructural endowments, introducing as reference the average Espon countries data. The red lines in the following diagrams refer to the Espon average data.

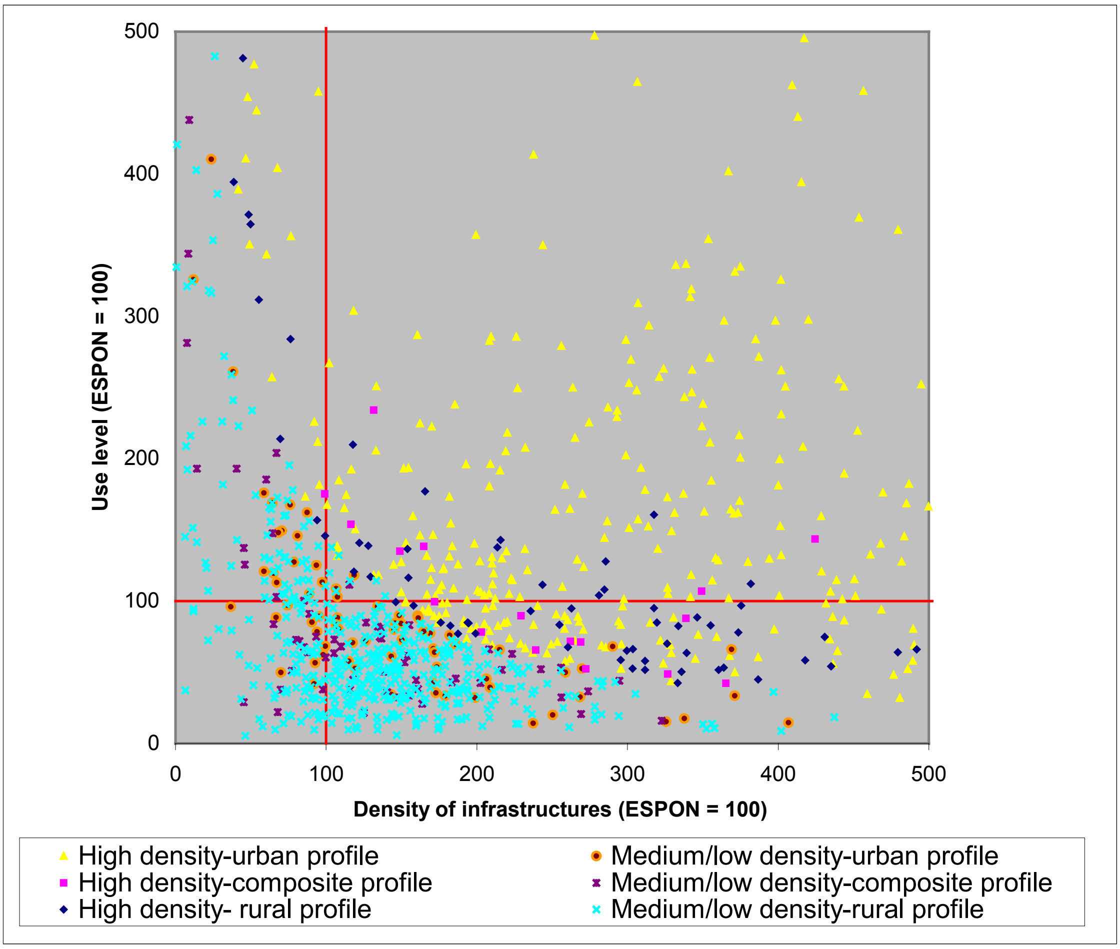


Figure 29 Diagram of use level and density of infrastructures in Nuts 3 regions. Colours refer to urban-rural profile

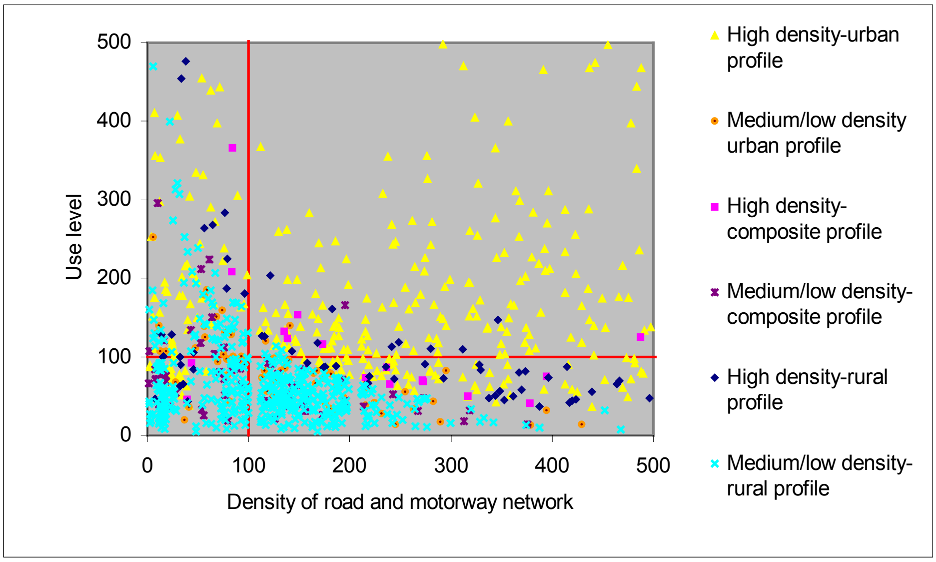


Figure 30 Diagram of use level and density of road and motorway network in Nuts 3 regions

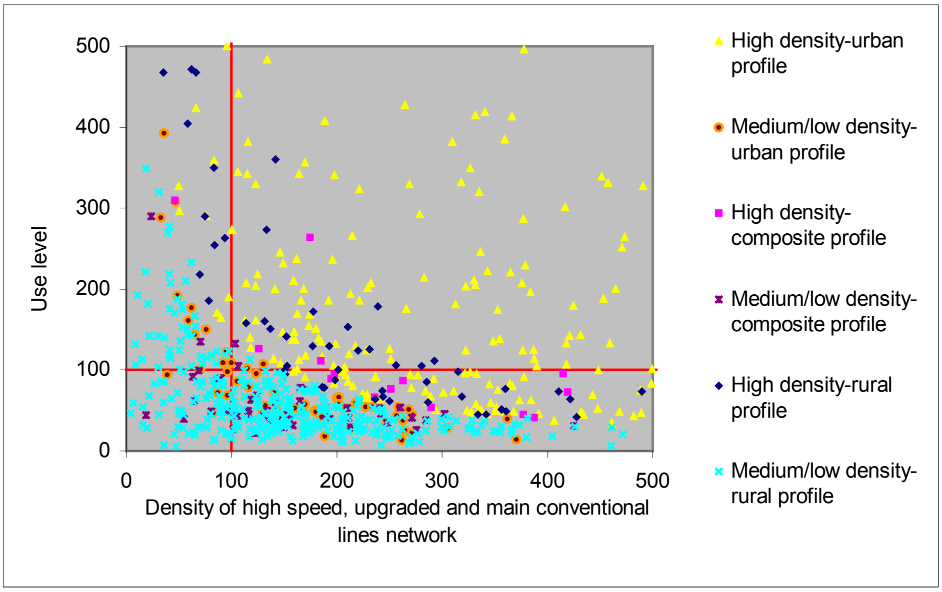


Figure 31 Diagram of use level and density of motorway and high speed network in Nuts 3 regions

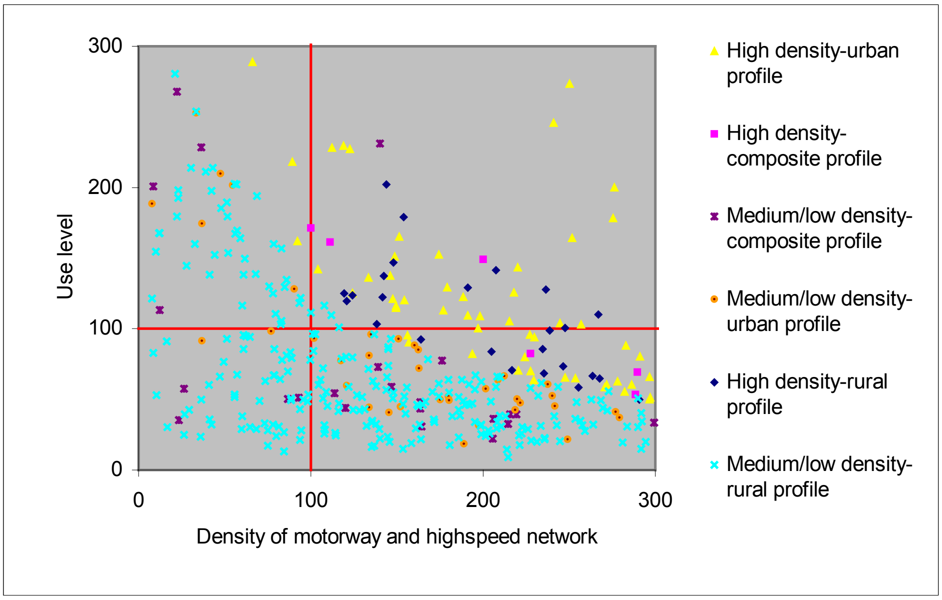
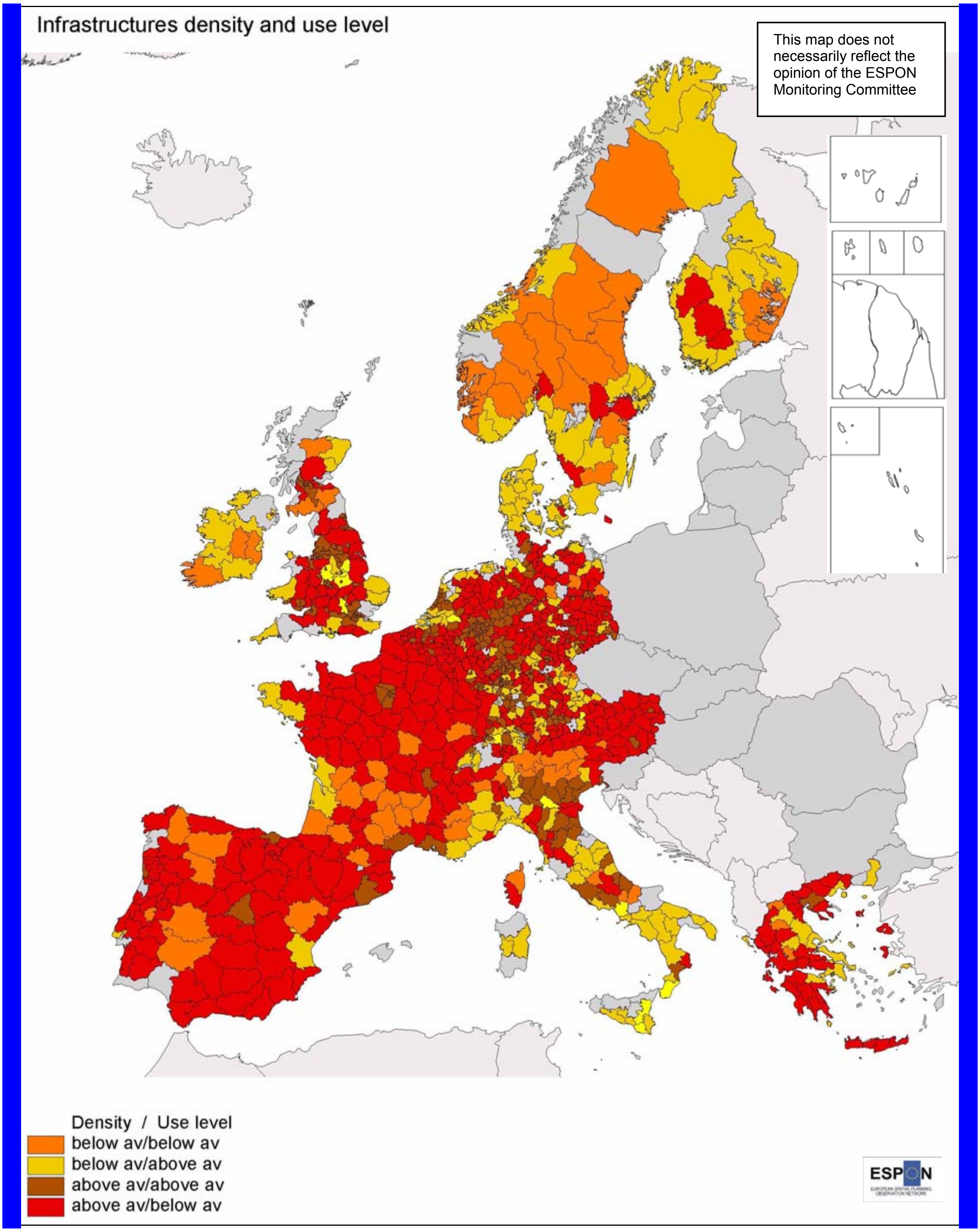


Figure 32 Diagram of use level and density of high speed trains, upgraded and main lines network in Nuts 3 regions



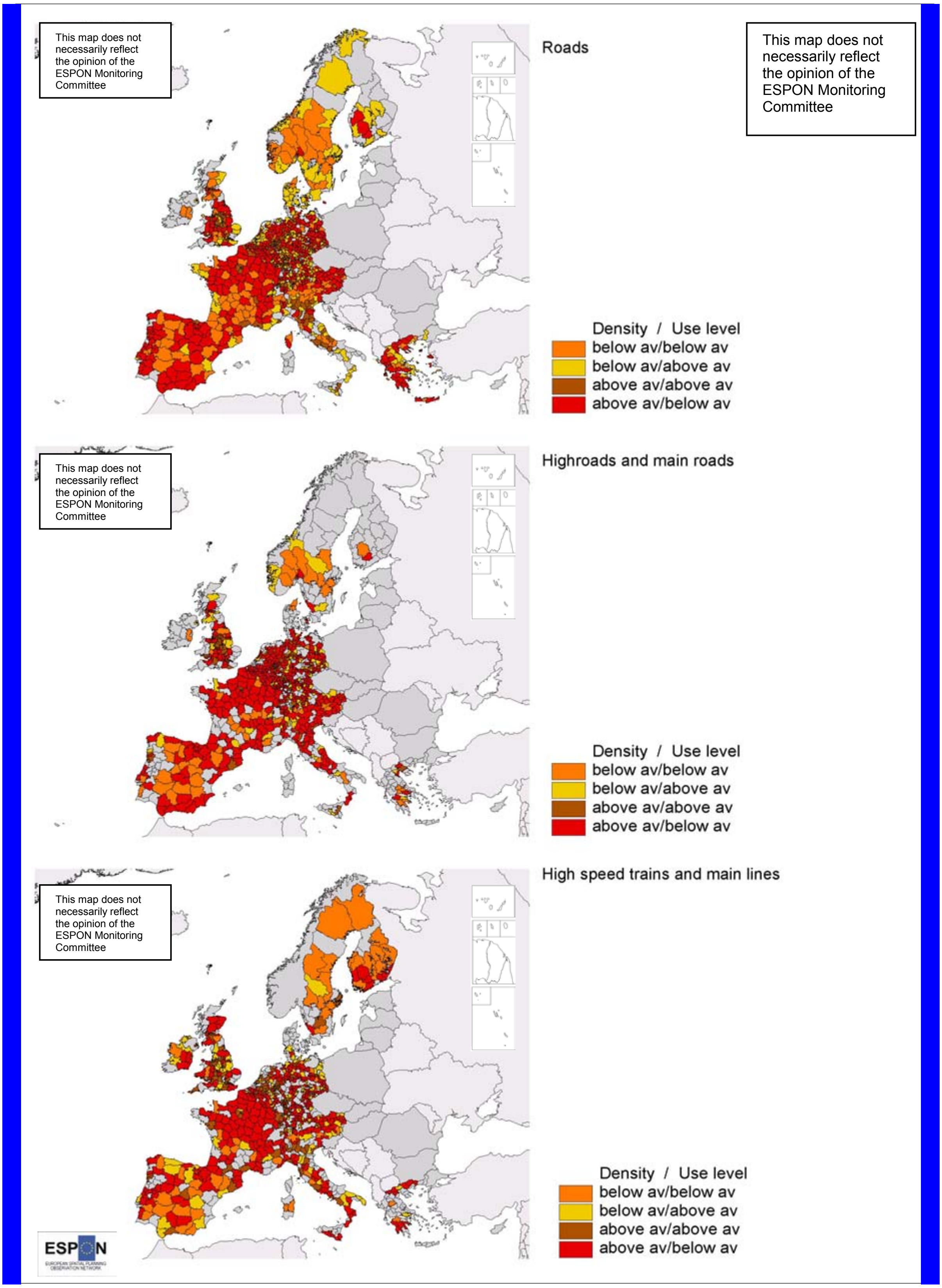
Map 80 Map of use level and density of infrastructures in Nuts 3 regions

Reading the results on the round of administrative subdivision for the NUTS3, but also in reference to different settlements composing the territories of Espon countries, it is possible to observe:

- in the **"A"** quadrant (infrastructural density below average datum, but with a good use level), the prevalent typology of the NUTS3 is characterized by a medium and low population density, by small cities, with a rural profile, as the Western regions of Spain (Lugo, Leon, Zamora, Caceres, Badajoz), the Southern part of the Scandinavian Region (Telemark, Buskerud, Oppland, Vaermland…) and concerns also mountain territories (as the Alpin Regions, the Hautes Alpes, the Ardeche, Cantal, Lozere, Aveyron in the Midi Pyrénées Region in France). Nevertheless there are also few NUTS3 with a medium low population density and with a urban profile as the Italian NUTS of Bolzano, Valle d'Aosta, Verbania, Trento, and Rogalend (No) and Kymenlaakso (Fi). For these regions, and specially for the NUTS 3 characterized by a low infrastructural density and by a use level near to the average datum, it is possible to find an infrastructural deficit, specially in the main roads endowments.
- in the "**B"** quadrant the NUTS 3 present a potential deficit whether in use level (above datum of the Espon countries), or in the infrastructural density (below average datum), like the metropolitan areas of Valencia, Lisboa, Bordeaux (Gironda NUTS), Milan, Torino, Napoli, Genova (It), Athina (GR), Frankfurt, Schaffhausen, Stockholm, Dublin, with an high density of the settlement, mature expression of the long-term growth and of the economic and social development. In these conditions it is possible to find many situations of traffic congestion that make impossible to assure economic development. In these areas it is necessary to proceed improving the infrastructural supply (above all in the industrial districts where a non-planned process of growth has caused an infrastructural deficit that risks to limit the development, like in Italian district), but also promoting policies of new localisations. In these conditions (potential structural deficit), are also some of the rural regions dominated by smaller cities as the NUTS of the Finland and Scandinavian Region, the NUTS of the Center and of the Southern Italy, Thessalia, Anatoliki in Greace, the Cornwalland the South-West Wales, the Norfolk and the Suffolk and Hamshire in UK and the South-East, and West of the Ireland (Limerik, Galway, Wexford), the Alpes Marittimes (in the South-East of France).
- in the **"C"** typology is it possible to find situations of congestion because to a good infrastructural density corresponds – on the contrary - an high use level. Here there are the biggest Metropolitan

Areas as Paris, London, Madrid, Barcelona, Rome, Wien, Bruxelles, big cities as Graz, Bilbao, Porto, Marseille, Montpellier, Hamburg, Muenchen, but also high density NUTS with a urban profile, often located in a polycentric territorial system as the Ramstrad Holand, the Ruhr territorial system, the Hessen Lander (Frankfurt am Main, Heidelberg, Koblenz, Mainz, Wiesbaden), the Northern Italy Regions (Varese, Como, Bergamo, Brescia, Cremona, Mantova, Reggio Emilia, Brescia, Verona, Vicenza), that present an high use level associated to one of the hightest density of the infrastructrural networks in the Espon countries. These situations, rather of conjunctural deficit than of structural deficit, must be screened to plan the distribution of the impact of the settlements, congruent with infrastructural endowments, differently by means of plans that forecast new infrastructures layout but with a weak relapses on the land-use policies. In effect, in these situations it is the main roads endowments presenting a potential deficit whether in use level (above datum of the Espon countries), or in the infrastructural density (below average datum).

- in the **"D"** typology (high infrastructural densities and adequate use level) there are the NUTS 3 with the best performances, localized in the Continental Europe as the Belgium NUTS, and the Northern France regions (the Nord-Pas-de-Calais, Picardie, Ile de France, Bourgogne, France Comte and the Alsace region), Germany and Austria where we can find big cities or metropolitan areas, but also the polycentric medium-sized cities.
- The Southern Regions falling in the **"D"** typology, are dominated by medium and small cities in the NUTS 3 rural profile as in Portugal, in Greece (Peloponissos, Ipiros and Thraki), in the South of the Spain (Cadiz, Malaga, Granada, Almeria, Murcia, Cordoba), and around Madrid Region (Toledo, Avila, Guadalajara, Segovia), where the configuration of the road networks, characterized by a "Christaller structure" hierarchical, simplified, converging on the existing medium-sized cities of the areas, make necessary to govern the growth processes and the transformations of the territory that are, here, strongly dependent upon vehicular mobility.



Map 81 Maps of use level and density of road, main roads and high speed trains in Nuts 3 regions.

Analyzing the infrastructures endowments in reference to the geographical position of the NUTS3 regions, we can find:

- an high presence of the NUTS 3 of the Accession Countries in the "A" (infrastructural density below average datum, but with a good use level), and in the "B" (infrastructural density below average datum and use level above datum of the Espon countries) and in the "D" typologies (infrastructural density above average datum and use level below average datum of the Espon countries), often converging to the reference Espon data. A few NUTS, instead, fall in the "C" typology, typical of regions with high infrastructural density and use level above the Espon average datum;
- an high density of the Continental Europe NUTS 3 in the "D" typology (high infrastructural densities and good use level), especially these regions with medium-sized cities, with medium-low population density and rural profile as, for example, the Belgium NUTS, the Nord-Pas-de-Calais region (FR) and the Alsace region (FR), the Central Netherlands regions and Austria;
- a distribution of Northern Europe NUTS mainly in the "A" and in the "B" typologies, due to the geographical constraints and to the low number of inhabitants in many Nuts 3;
- a distribution of Southern Europe NUTS in the four typologies. A great number of the Southern Europe NUTS3 is in the "A" (infrastructural density below average datum, but with a good use level) and in the "D" typologies, especially for Portugal, Spain and Greece, characterized by regions dominated by small cities, with medium-low population density and a rural profile. The Italian condition is more heterogeneous, with many NUTS 3 where we can find possible situations of congestion because to a good infrastructural density corresponds – on the contrary - an high use level as in Padania where metropolitan areas (Torino, Milano, Venezia) are mixed in a polycentric territorial system with medium-sized cities, and as in the Centre and in the South of Italy (Firenze, Roma, Napoli,, Reggio Calabra, Bari)

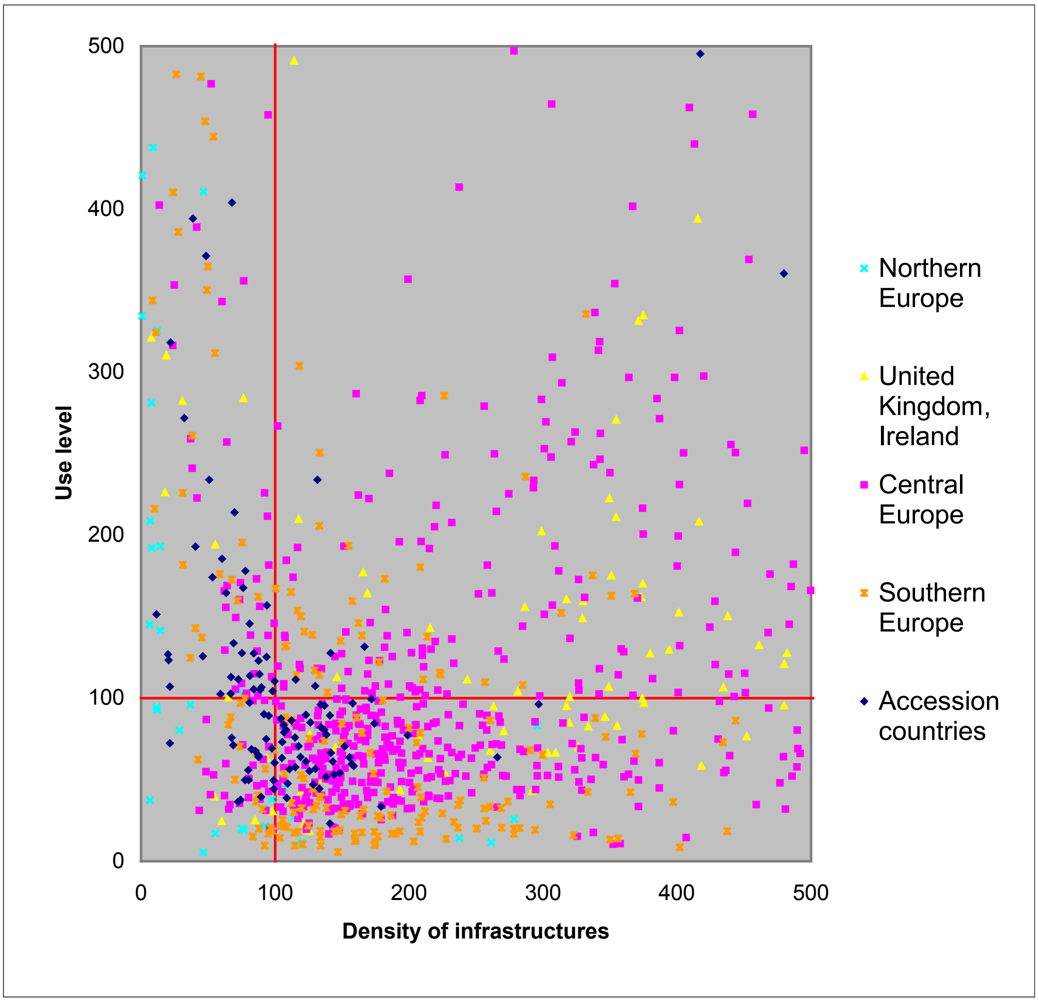


Figure 33 Diagram of use level and density of infrastructures in Nuts 3 regions. Colours refer to location in Europe

Comparing, in an aggregated analysis, the infrastructural performances of the EU15, CC10, and CC12, we can find the whole good condition of the Eu15 countries infrastructural endowments, with an high infrastructural densities and good use level; on the contrary, the CC10 countries present a potential deficit whether in use level (above datum of the Espon countries), or in the infrastructural density (below average datum). The CC12 countries find an infrastructural density below average datum (Espon countries), but with a good use level, justified by the low population densities.

1.2 Accessibility and Regional Economic Performance

There are essentially two ways to classify regions by their location in Europe, i.e. by their accessibility:

- The most straightforward way to classify regions by accessibility is to rank-order them by decreasing accessibility and define a suitable number of classes, from very central (i.e. high accessible) to very remote. This is the familiar central-peripheral dichotomy and has been done in Section 5.4.
- A more sophisticated way of classifying regions by accessibility if to take also their economic performance into account. Economic theory suggests that regions that have better access to raw materials, suppliers and markets are, ceteris paribus, economically more successful than regions in remote, peripheral locations. As transport infrastructure is an important policy instrument to promote regional economic development, it is highly policy-relevant to know which regions have been able to take advantage of their location and which regions have not.

In order to explore the more interesting second way of classification, the NUTS-3 regions in EU-27 plus Norway and Switzerland are plotted in Figure 33 by GDP per capita for the year 2000 and multimodal (road/rail/air) potential accessibility for the year 2001 as presented in Section 5.4. Both indicators are standardised with respect to the average of the former European Union with 15 member states. Each dot represents one region. The dots are colour-coded to indicate regions in the core of Europe (red), regions in the Nordic countries (orange), Mediterranean regions (blue), regions in Ireland and the UK (pink) and regions in the accession countries (light green).

The diagram confirms that in general the more accessible regions are the economically more successful ones. The most affluent and productive regions, such as Munich, Frankfurt, Paris and Düsseldorf are also most central, i.e. most accessible, and the most peripheral regions with poor accessibility are among the poorest regions. However, it is not surprising that at the highly disaggregate level of NUTS-3 regions also other factors, such as the distinction between urban and rural regions, play a role, with the effect that there is a significant dispersion of dots around the main diagonal of the graph. However, it has to be acknowledged that in countries with small NUTS-3 territories such as Germany the GDP/capita figures in agglomerations which are consisting of several NUTS-3 regions are not reflecting the income transfer from the centre to the suburban regions via commuting.

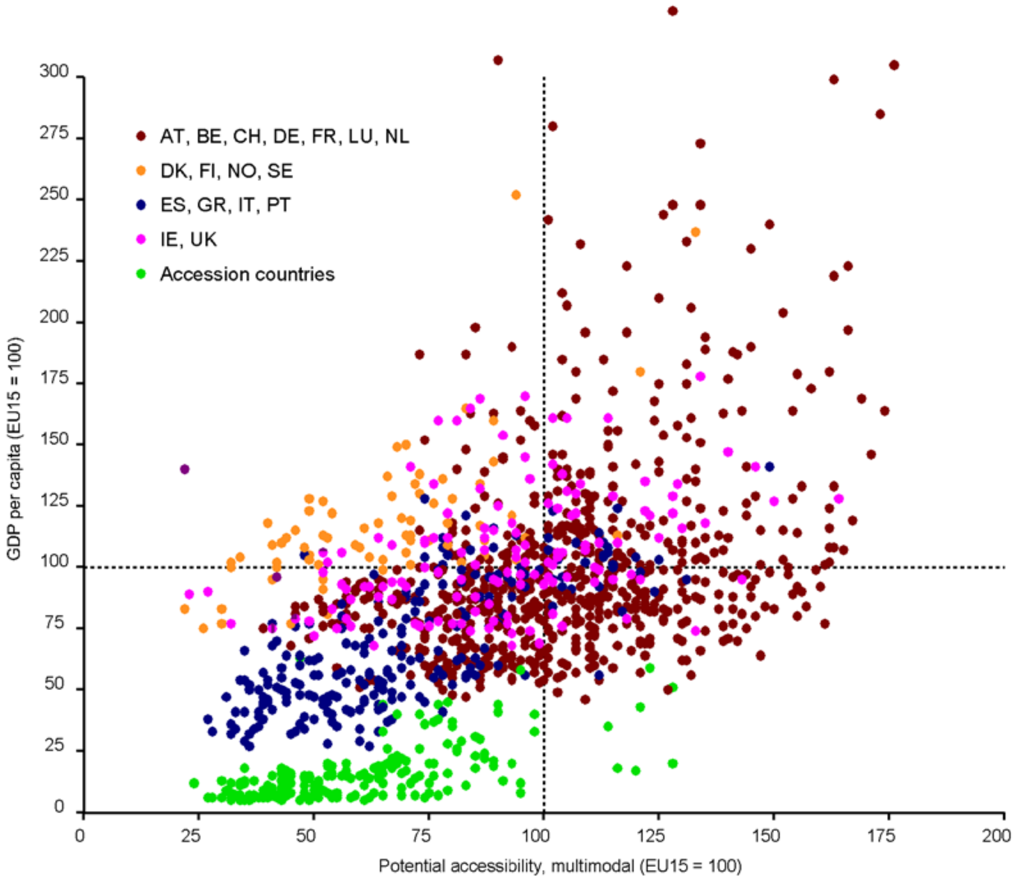


Figure 34 Accessibility and GDP per capita in NUTS-3 regions

This dispersion suggests a typology of regions which is based on their position in the diagram of Figure 33. Actually, two different types of typologies were constructed from the diagram, the first looks at the position of the region in the diagram, the second looks at the difference between accessibility and GDP.

For the first typology, five types of regions corresponding mainly to the four quadrants of the diagram can be distinguished:

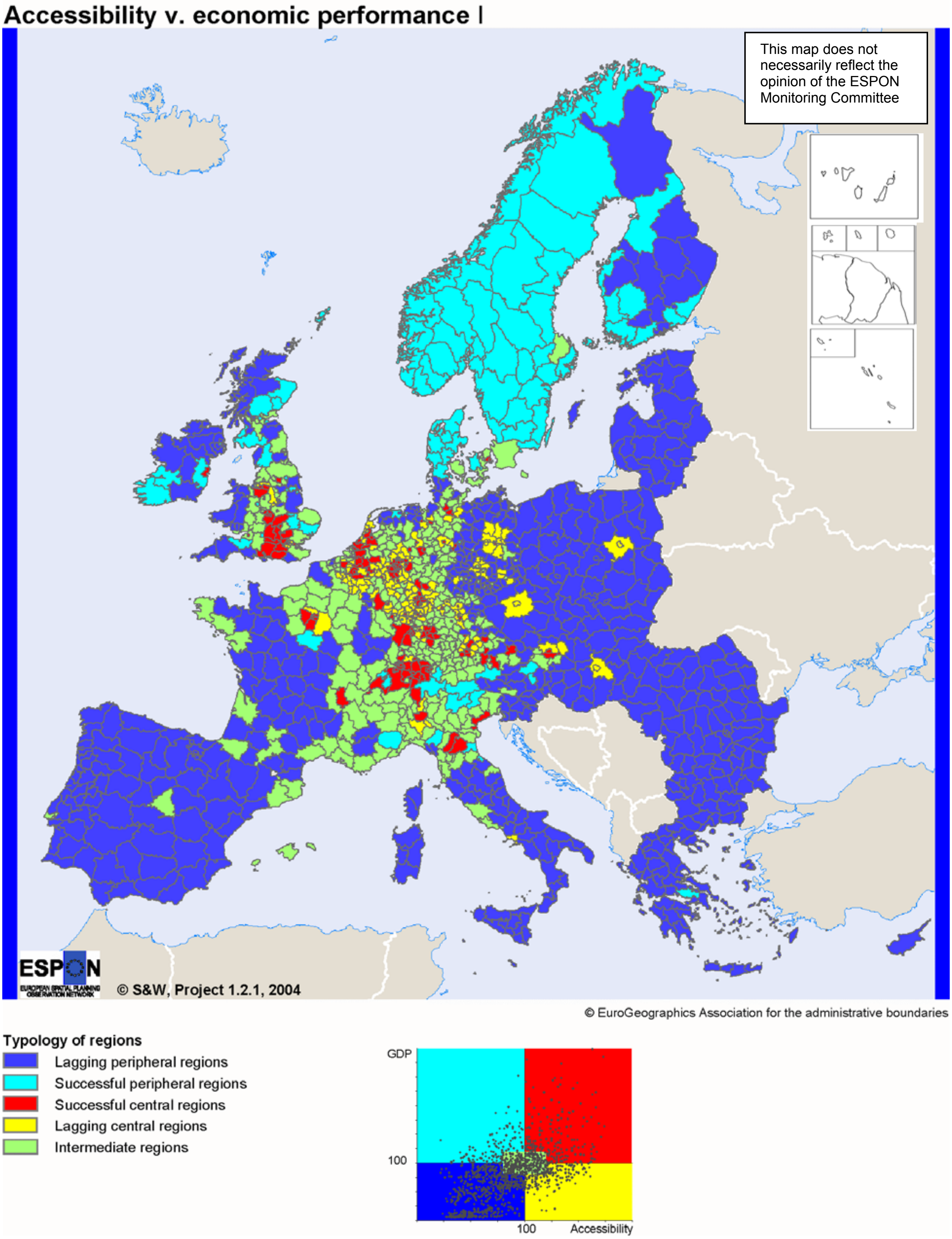
- *Successful central regions*. Regions with above-average accessibility and above-average GDP per capita are in the upper right quadrant of the diagram. These regions confirm the theoretical expectation that the most central regions in the European core are also the most prosperous regions. It can be seen that predominantly regions in central Europe and the UK fall into this category.
- *Successful peripheral regions*. These regions are located in the upper left quadrant of the diagram. They are regions which, for whatever reasons, have been able to be economically successful despite their peripheral

location. It can be seen that most regions in the Nordic countries fall into this category.

- *Lagging central regions in the European core* These regions with above-average accessibility and below-average GDP per capita lie in the lower right quadrant of the diagram. They consist mostly of regions in central Europe, presumably in part old industrial regions with an outdated economic structure which have not been able to restructure their economy despite their favourable location in Europe. There are also some regions in accession countries in this category, mainly from the Czech Republic and Hungary.
- *Lagging peripheral regions*. Regions with below-average accessibility and below-average GDP per capita are located in the lower left quadrant of the diagram. These regions again confirm the theoretical expectation that peripheral regions tend to be poorer. Most Mediterranean regions, except the successful industrialised regions in northern Italy and Spain, fall into this category. Nearly all regions in the accession countries are found here, with a distinct gap in GDP per capita between them and the regions in the present EU countries.
- *Intermediate regions.* These regions with about average accessibility and about average GDP lie in the centre of the diagram. Here, regions of all locations are represented except the accession countries.

Map 83 shows the geographical location of the regions analysed in Figure 33, the colours indicate their position in the four quadrants. It can be seen that indeed the distinction between urban and rural regions plays an important role for the economic success of a region besides accessibility. Predominantly the large rural regions in the Mediterranean countries and the accession countries are in the lower left quadrant (below-average accessibility and below-average GDP per capita), whereas the regions in the upper right quadrant (above-average accessibility and above-average GDP per capita) are mostly urban regions in central Europe, northern Italy, the south of England and Denmark and Sweden.

Again the most remarkable feature is the economic performance of the regions in the upper left quadrant (below-average accessibility yet above-average GDP per capita) comprising most rural regions in the Nordic countries and some in Ireland, Scotland, France and northern Italy – many of them represent well-known success stories of economic competitiveness and regional governance.

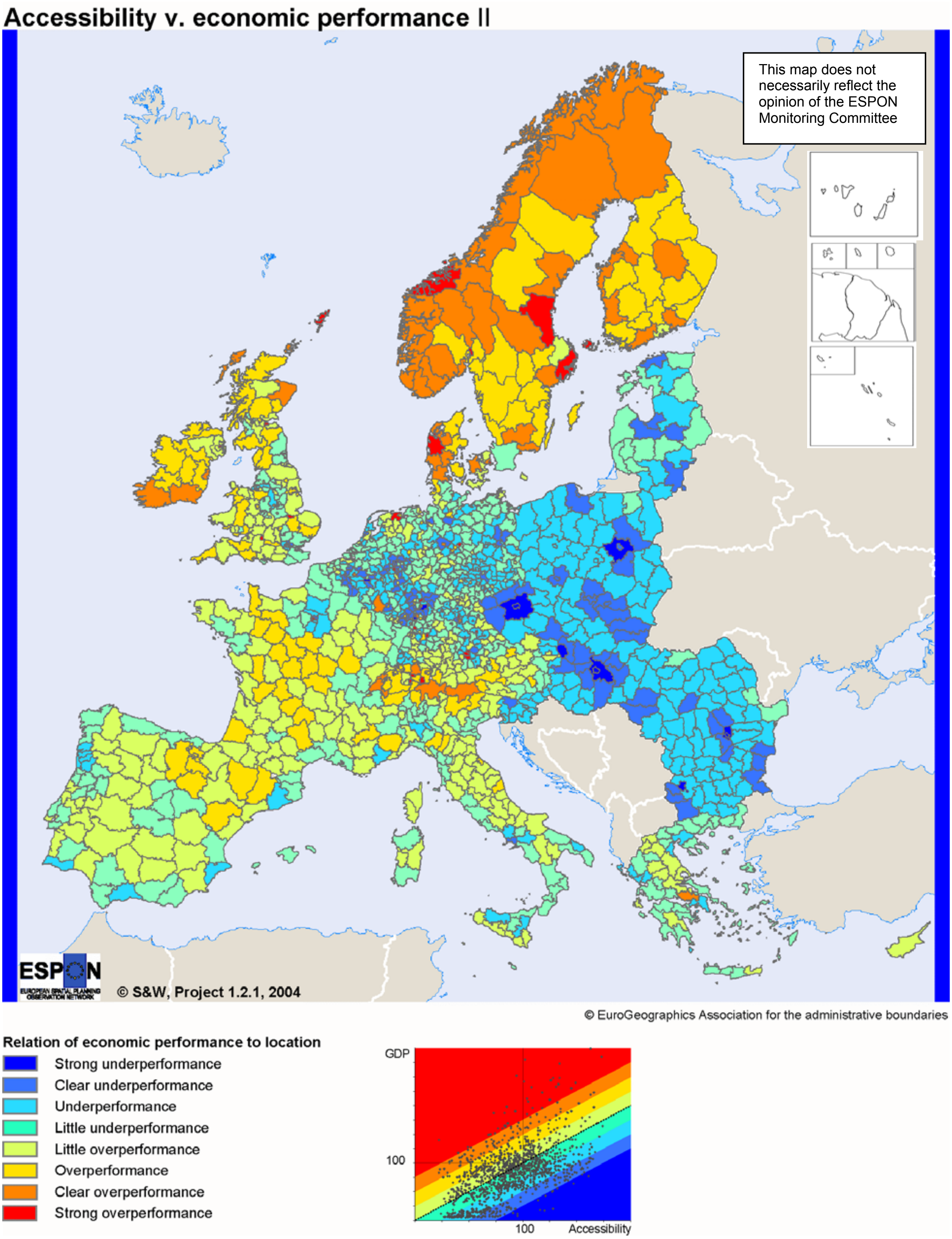


Map 82 Accessibility and GDP per capita in NUTS-3 regions

The second typology based on Figure 33 looks more closely at the relationship between accessibility and GDP, i.e. it is analysed whether the level of GDP can be explained by the level of accessibility or whether there are deviations from this. The typology is constructed by subtracting for each region the accessibility index from the GDP index. Regions with positive values are labelled as regions overperforming related to their location, regions with negative values are labelled as underperforming related to their location. Map 84 shows the spatial distributions of these residuals of accessibility and GDP.

Regions indicated in yellow and red colours are those in which the GDP index is much higher than the accessibility index, i.e., these are regions which have a better or even much better economic performance than their location would suggest. Regions with clear and strong overperformance are primarily located in the four Nordic countries. Apparently, the regional economies here are based on other assets such as skilled labour and technology orientation than location. Many regions in the Alps and also in Ireland and Scotland are also in a much better economic position than their location would indicate. A number of urban NUTS-3 regions in Germany belong also to this high-performing type; however, this might be an artefact of the small NUTS-3 regions in that country. More rural regions in France and Spain have an economic performance that is somewhat better than their location.

Regions indicated in blue colours are those in which the GDP index is below the accessibility index. Those regions are not able to utilise the economic potential the location within Europe offers. Nearly all regions of the accession countries belong to this type. However, also some old-industrialised regions in Germany and Belgium belong to this group. In addition, some regions in southern Europe are underperforming as well.



Map 83 Accessibility and GDP per capita in NUTS-3 regions

1.3 Regions Suffering from Transport Externalities

Rationale

The aim is here to show the potential impacts and externalities linked to freight transportation by truck. The areas considered are NUTS 2. First, we have taken into account the proportion of each NUTS 2 located at less than one kilometre of a road axis, showing in this way the spatial extension of the phenomenon. In a second time, we have evaluated the use of the network, through the calculation of the number of tons.kilometres. This parameter will constitute the intensity of the externalities.

The conjunction of extension and intensity parameters permits to evaluate the potential spatial impact of externalities linked to freight transportation.

Method

The calculation of this indicator unfolds **in three steps**.

First, for each NUTS2, we calculated **the proportion of the surface at less than one kilometre of the road network in comparison with the whole surface of the NUTS**. Here we used the most precise network we have, in terms of spatial localisation, which is the network GISCO. In this goal we have drawn a buffer area around each segment of the network and then cut this last one at the NUTS2 boundaries. We determined the surface covered by the buffer and divided it by the total surface of the area concerned, this for each NUTS2.

According to the obtained results, we have decided to distinguish three classes:

The first one, called **A**, contains all the NUTS2, with a proportion of covered surface superior to 20%

The second one, noted **B**, contains the NUTS, with a result between 10% and 20%

The third and last class (the class **C**) is constituted by the NUTS with a percentage inferior to 10%

The second step is the calculation of the **total number of tons*kilometres, going through each NUTS2.** It is done from CESA graph 4172 because it is was easier for calculations.

We note *G* the original graph with E edges.

We note:

$\forall k \in [1, E]$, F_k is the total flow going through the edge *k* in the graph *G*

$\forall k \in [1, E]$, D_k is the length, in kilometres, of the edge *k.*

$\forall k \in [1, E]$, i*(k)* the origin node of the edge *k* and j*(k)* the destination node of this edge.

$\forall k \in [1, E]$, **NU** i*(k)* the NUTS2 including the node i*(k)* and **NU** j*(k)* the NUTS2 including the node j*(k)*

For a given NUTS2 *x*, **NUT***x* the value of the total numbers of tons*kilometres going through it and **NUTS***x* the set of nodes included in this NUTS.

Considering a NUTS2, we calculate

NUT*x*1 = $F_k * D_k$, $\forall k \in [1, E]$ and (i*(k)*$\in$ **NUTS***x* and j*(k)* $\in$ **NUTS***x*)

NUT*x*2 = ($F_k * D_k$) / 2, $\forall k \in [1, E]$ and (i*(k)*$\in$ **NUTS**x or j*(k)* $\in$ **NUTS***x*)

NUT*x* = **NUT***x*1 + **NUT***x*2

From the value obtained by this last calculation, we have decided to distinguish three classes:

the first one, called **1**, is for NUTS2 with a value superior to 20 000 000 tons*kilometres

the second, noted **2**, contains all NUTS 2 with values between 5 and 20 millions of tons*kilometres

the third, **3**, is for NUTS 2 with less than 5 000 000 of tons*kilometres.

Finally, the last step combines the two results obtained above. Each NUTS2 belongs to a class A, B or C and to a class 1,2 or 3.

We cross this two data in a single one, distinguishing in this purpose five final classes. The table below explains our typology:

	A	B	C
1	Fifth	Fourth	Third
2	Fifth	Third	Second
3	Fourth	Second	First

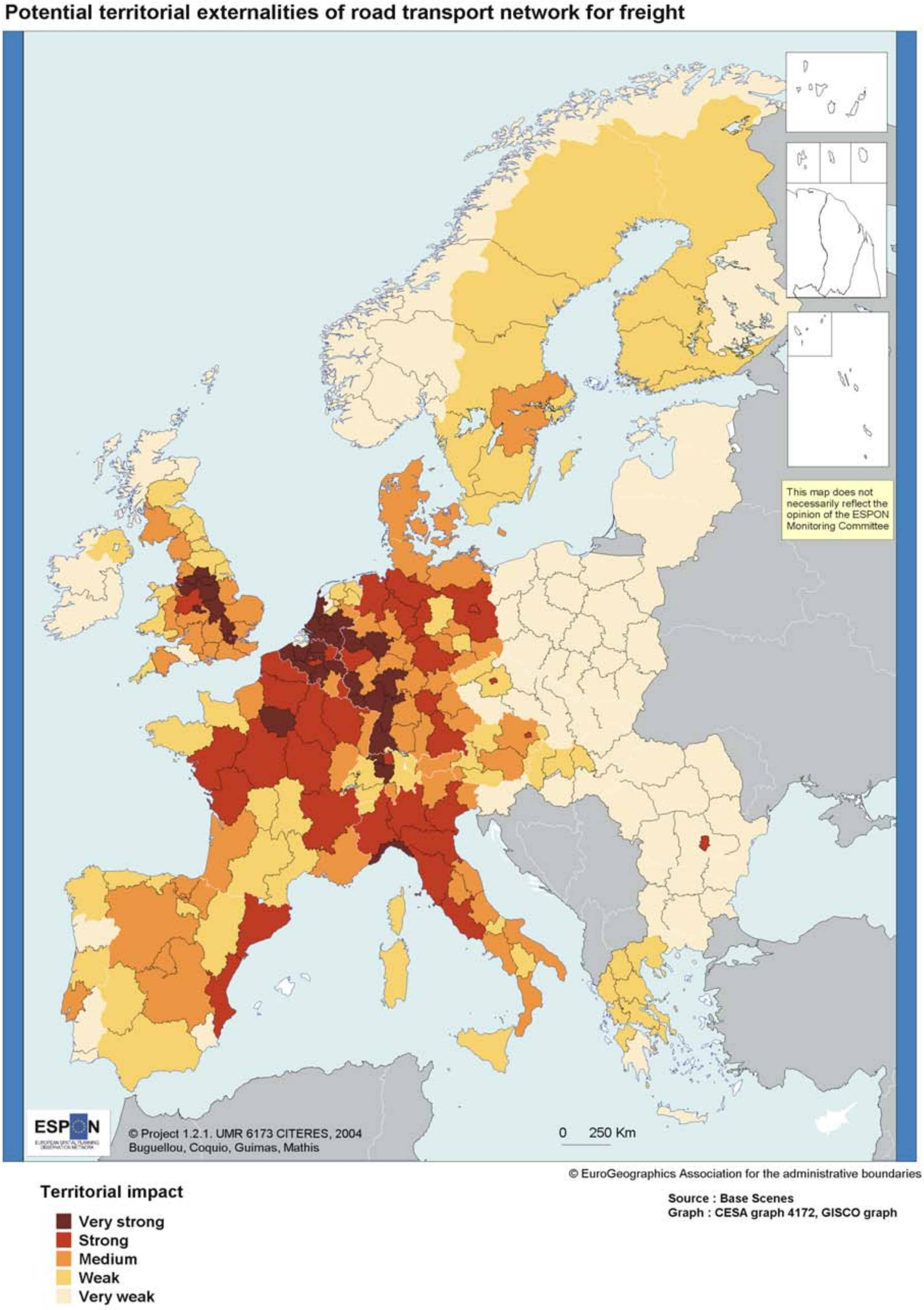
The colours of the table above correspond to the colours chosen for the map presented below.

Data requirement

GISCO graph *and* CESA graph 4172

Minimal path matrix for trucks

Scenes Database for freight



Map 84 Potential territorial externalities of road transport for freight

The map above presents the results obtained for each NUTS region. First, we have to say that NUTS included in the same group can correspond to very various territorial realities. Indeed, the results obtained highly depend on the surface of the NUTS because of its impact on the structure of the network and the number of tons.km. The results are more liable for the extremes (groups very strong and very weak)[98].

Nevertheless, this map seems to be quite coherent with what we could expected through such a work. Indeed, it shows clearly the areas where the intensity of traffic is high and the density of network high-ranking: Benelux, the Rhine valley in Germany, Paris and the London-Manchester axis.

After these areas with very high values we can observe other zones with quite high results: North Italia, a large part of France and Germany and the East of Spain.

More globally, this map shows 2 types of dichotomy: the first one is core of Europe-periphery and the second one West-East.

To sum up, the potential externalities are not distributed in a homogenous way on the European territory: the areas presenting a good accessibility[99] seem to be those which suffer the more from transport externalities.

98 Like for part 5 it is once again the problems occurring when working on surfaces.

99 See for example part 3 of this report

2 Major territorial imbalances

The corrections of imbalances, which seem necessary, not only require us to identify them, to measure them, but also to know the main causes and evaluate whether they are corrigible or not. Starting from the geographical characteristics of the European space, we will focus successively on the hydraulic networks, the urban localizations, the road and railways networks, the centralization and the polycentrism, the modal transfers and the problems of pollution, the consequences of enlargement, and finally the temporality of offer and demand, which is an essential constraint for the policy recommendations. So, we link the current situation, underlined by the indicators developed in the report, in its context, thanks to a historic perspective, which could not be denied.

So, we can replace the action in this context that is essential because there is a dynamic, which must be taken into account.

In the European space, the first imbalance is geographical, depending on the shape, the littoral or continental position of the zone considered, its latitude, its relief. In this field the traditional map is particularly necessary to observe:

Source: Atlas mondial HATIER 1968-80

Map 85 The European space

When looking at this map, we can see that the European system of transport undergoes two strong constraints:

- on one hand, a **cutting in a succession of peninsulas** which make almost impossible the comparison with the very continental American system of transport: 13 countries out of 15 have a maritime frontage, 2 are islands and 6 are peninsular. Only Luxembourg and Austria do not have any maritime outlet. With the enlargement, the EU has acquired an opening on the Black Sea and 7 future new members will have a maritime frontage.

- On the other hand several mountainous areas partition the EU: the Pyrenees, the Alps, Carpates, Appenins…

Furthermore, without taking into account overseas regions, the EU spreads in latitude from 70° to 35°[100] (Crete being definitely more in the South than Alger) and from the 10° Western longitude to the 30°[101].

With such a structure, homogeneity can only be relative taking into account the different types of climate (polar, Mediterranean, continental or oceanic, of plain or high mountain), which naturally influence the establishments of population and the transport networks.

Moreover, there is an **imbalance of the distribution of these constraints**, the majority of mountainous solid masses being in the South and the plains in the North. The consequence is naturally **a hydrographical network essentially directed Northern-West**, which consecutively influences the spatial distribution of the channels[102] and the harbours[103] which are very often and for historical reasons located on the estuaries. As regards inland waterways, current imbalance is obvious: two large rivers navigable in all Europe run towards the West particularly Danube which irrigates the lately adherent countries and the Rhone. All the other rivers and channels currently navigable and used are located between the Seine and the Vistula. The Rhine-Danube connection is with the large gauge but the Rhone-Rhine Project is currently abandoned.

Naturally, geographical constraints influenced the settlement, as shown in part 3 chapter 1.3 ("Network density of cities") and part 3 chapter 2.11 ("Cities within given travel time"). Most of the indicators developed in this report have shown in this field a centre-periphery organization, with a very urbanized centre (with either a pentagon or "blue banana" structure) and peripheries with less cities. Moreover, there are other differentiations (North/South, West/East), and finally very contrasted North, South and West littorals, where we can observe very urbanized areas in the Mediterranean, zones which are less populated in the Atlantic, and vacuums in North Atlantic.

These geographical imbalances are more or less constraining according to the period, modes of production and techniques. For example in the **19th**

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[100] which roughly corresponds to 8 000 km
[101] which roughly corresponds to 2700 km
[102] see part 3 chapter 1.6 on Inlands waterways
[103] see part 3 chapter 1.6 "Seaports" and part 3 chapter 5.8 "Port traffic"

century the dominating means of transport was the railway and this one could not accept slopes of more than 4%. As a result, there was a **depopulation of the mountainous zones to the profit of the towns in valleys or plains where industries could locate**. The phenomenon was amplified by the localization of the principal iron and coal deposits. **Then, the development of the road transport softened this constraint** by its capacity to get over stronger slopes and especially sinuous roads. The valleys developed but also mountains: the tourism is one of the consequences, which generates much traffic and a significant demand for infrastructures of transport. A phenomenon of comparable nature develops on the littorals with tourism, first in the South then in the West. Space becomes a very rare resource for countries with high density of population.

As a result, the localization of cities, first in the centre of hydrographical networks and estuaries for transport by waterways and agriculture and then according to the mining resources, together with other phenomena has led to an **imbalanced distribution of the cities on the European territory.** We noted with several indicators[104] the central structures of pentagon and/or "banana blue" type that could, more or less according to the indicator considered, extend to the Mediterranean coast. On the contrary, Scandinavia and Finland have a very weak density of population and cities mainly located in the South of its territory. Greece and Ireland also have a very low population, Spain and France have regions that are very little metropolized. Many new members regions are relatively more populated than in the West.

The modification of these imbalances hardly seems possible currently.

Moreover, this urban structure has been the main cause of the development of the transport networks and their hierarchisation[105]. The networks are denser in the core of Europe in particular in the case of motorways which are relatively rare in peripheral areas. Urban imbalance is amplified by the networks generated by the cities themselves. Between cities and transport systems there is a loop of positive feedback.

The main network is the one which connects the capitals and then the cities the most populated (see maps below). However it should be noted that **transport networks have in the first place been national**, which explains the variety of forms according to the countries and their own history. Large and centralized countries (mainly France, Spain, and Great Britain) have a network centered on the capital. Countries which have been unificated later developed more evenly distributed networks (for example Germany).

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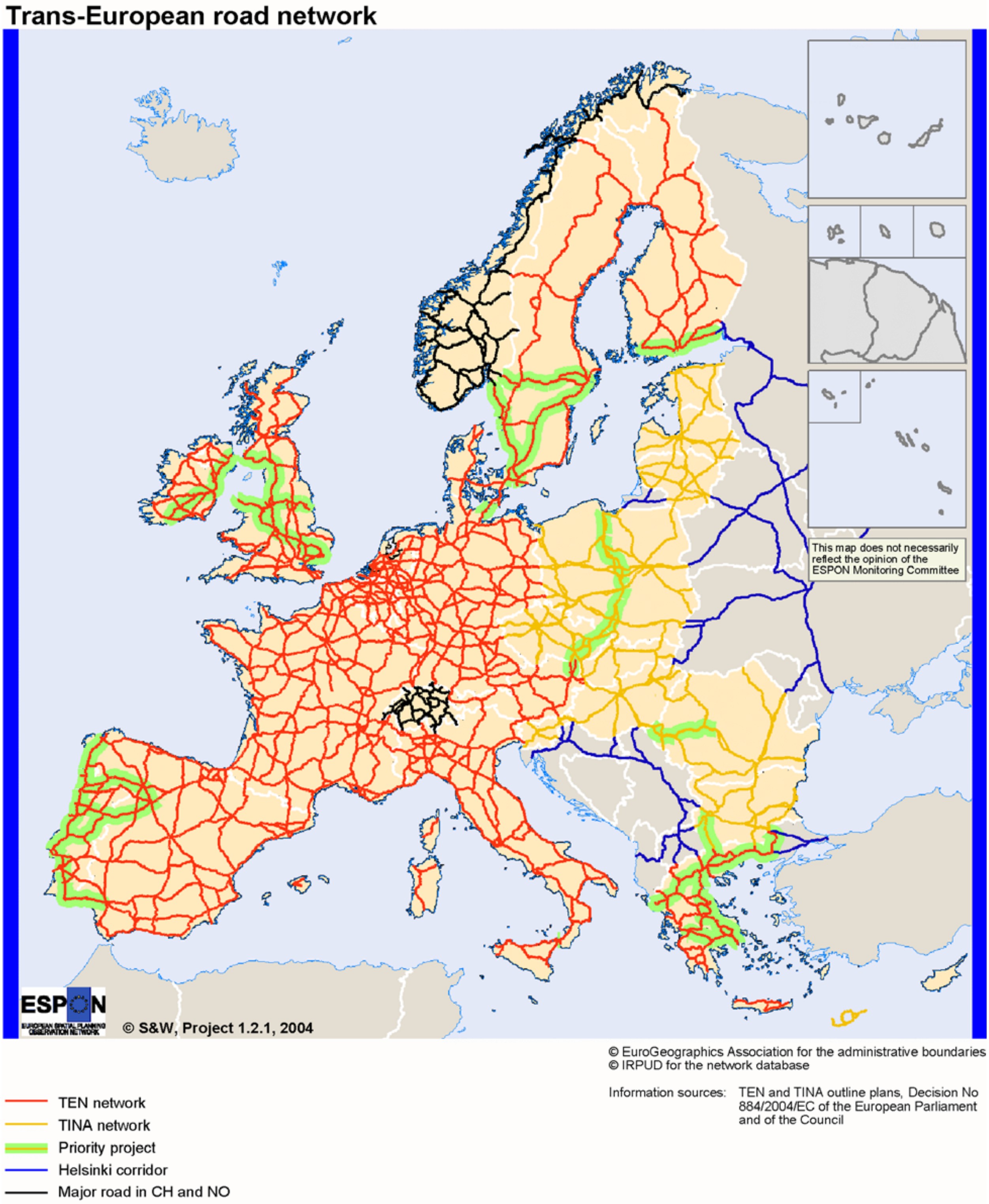
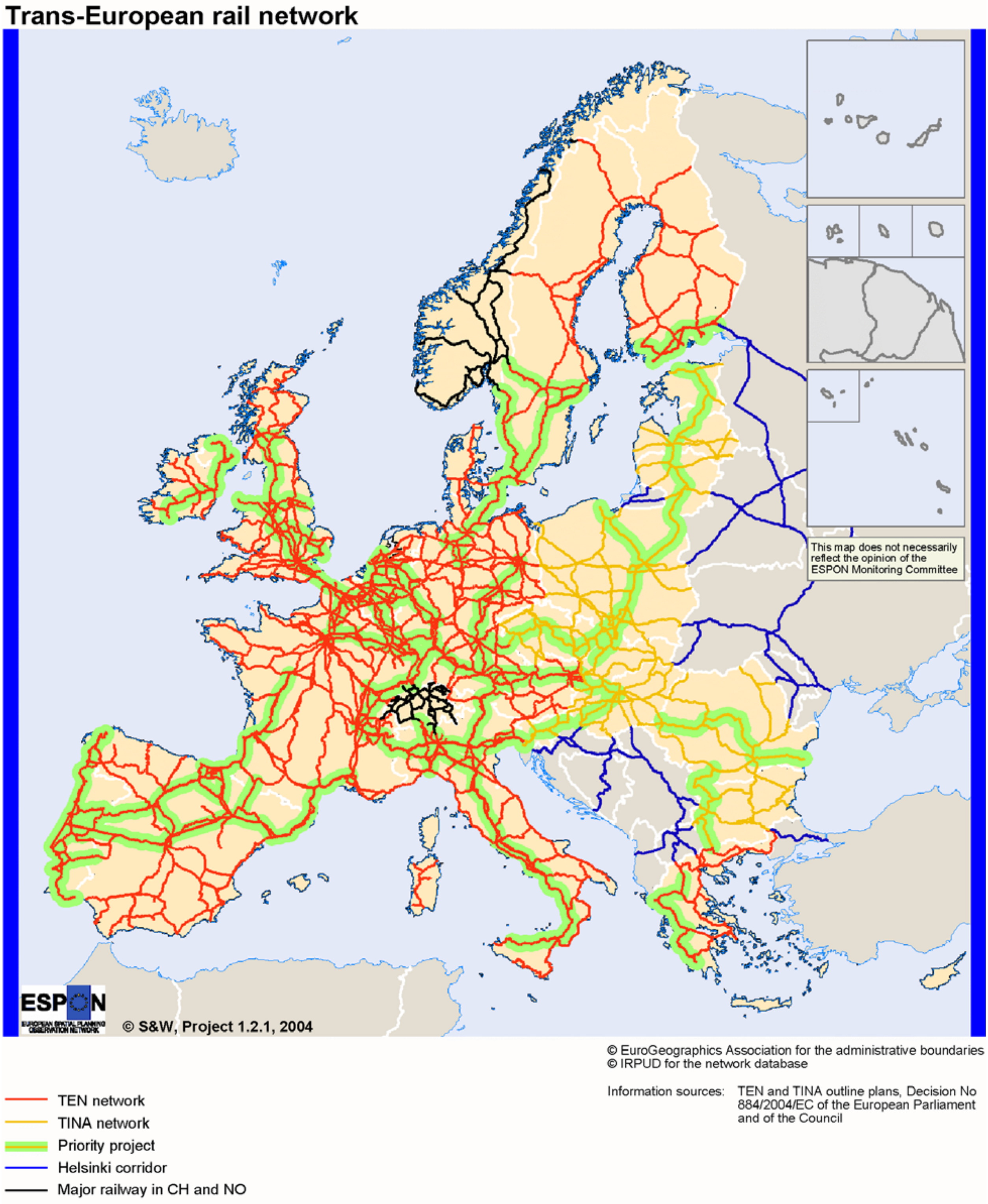
[104] for example part 3 chapters 1.3.1 and part 1.3.2
[105] see part 3 chapter 1.3.3



Map 86 Trans-European road network



Map 87 Trans-European rail network

Finally, other countries, such as Poland, have mixed networks, because of space-divisions which have led to different organization principles. This last observation applies to railway perhaps more than to road. To balance the European network implies to **integrate former national networks** that still function nationally for the largest part of them, although they are in a community structure with **community interests**. This naturally leads to problems of borders especially when there are geographical constraints, and even strategic interests in the past, which can lead to **vulnerable edges**[106].

From the point of view of efficiency, the disadvantage of a centralized network compared to a grid one is the most probable hypothesis, but this is not completely demonstrated, in terms of increase of distance, time, cost and obstruction. Nevertheless, our simulations on a more reduced scale show than the urban polycentrism generates displacements that are globally less long. On the contrary, it is demonstrated that a **centralized network facilitates a preferential development of the centre** considered and this in the long term for a country. It is probable that this kind of observation is transposable on a broader territorial scale if, as many elements seem to corroborate it, there is a similarity of structure.

Moreover, another element to take into account is the development of **international exchanges, which were superimposed with the three types of networks met** (more or less centralized, grid or " ladder shaped"), according to whether the country is or is not a zone of transit. These flows have contributed to modify the pre-existent networks as in France, transforming the centralized network, in a network partially " ladder shaped" with two large international corridors from the Iberian peninsula to Belgium and to Germany. **On the contrary, they consolidated the very grid German network**, because crossed by transit flows from various orientations. In the same way the Italian network is reinforced in its ladder shape structure by transit flows from/to Greece, which in their majority transit by the ports of Bari and Ancona. For this kind of exchanges, **there is another source of imbalance related to the spatial position:** Great Britain, Finland, Scandinavia and the Iberian Peninsula are not transit areas for the time being. Only countries such as France, Germany, Switzerland, Belgium, Netherlands, Austria and Denmark are crossed by significant flows that may be subject to modal shift. These flows are important for the economic activity of EU but do not benefit the crossed country, and are sources of externalities problems. In this report, we have mainly focused on

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[106] see part 3 chapter 5.7 on Network vulnerability

these international flows, which lead to community problems and not national.

Imbalances linked to the geographical position of a country cannot easily be compensated, excepted maybe in the cases where a modal transfer by the maritime mode is possible, partially or completely. But if **the centrality** of certain countries is an old and socially still powerful phenomenon, it can nevertheless be **compensated by a polycentrism** that can develop at various scales. **Polycentrism at the scale** of the **capitals** has first of all been expressed politically between Paris and London, then with the growth of other capitals, integrating the processes of construction of Europe. **Currently, the cities networks of more than one million inhabitants dominates the space spatially, economically, administratively and intellectually**. They are relayed by the MEGAs, defined by the TPG ESPON 1.1.1[107], although we could and in our opinion must widen this category by including some other cities to facilitate a spatial balance[108]. It is very important to have a relevant list of MEGAs, which does not lead to reinforce areas, already dense of the "banana".

As regards polycentrism, the various daily accessibilities calculated in the report are good indicators. It is the same for the average travel time by cars to reach the three nearest cities of more than 100 000 inhabitants[109]. These indicators give an idea of the proximity (in time) between cities and the density of the city network.

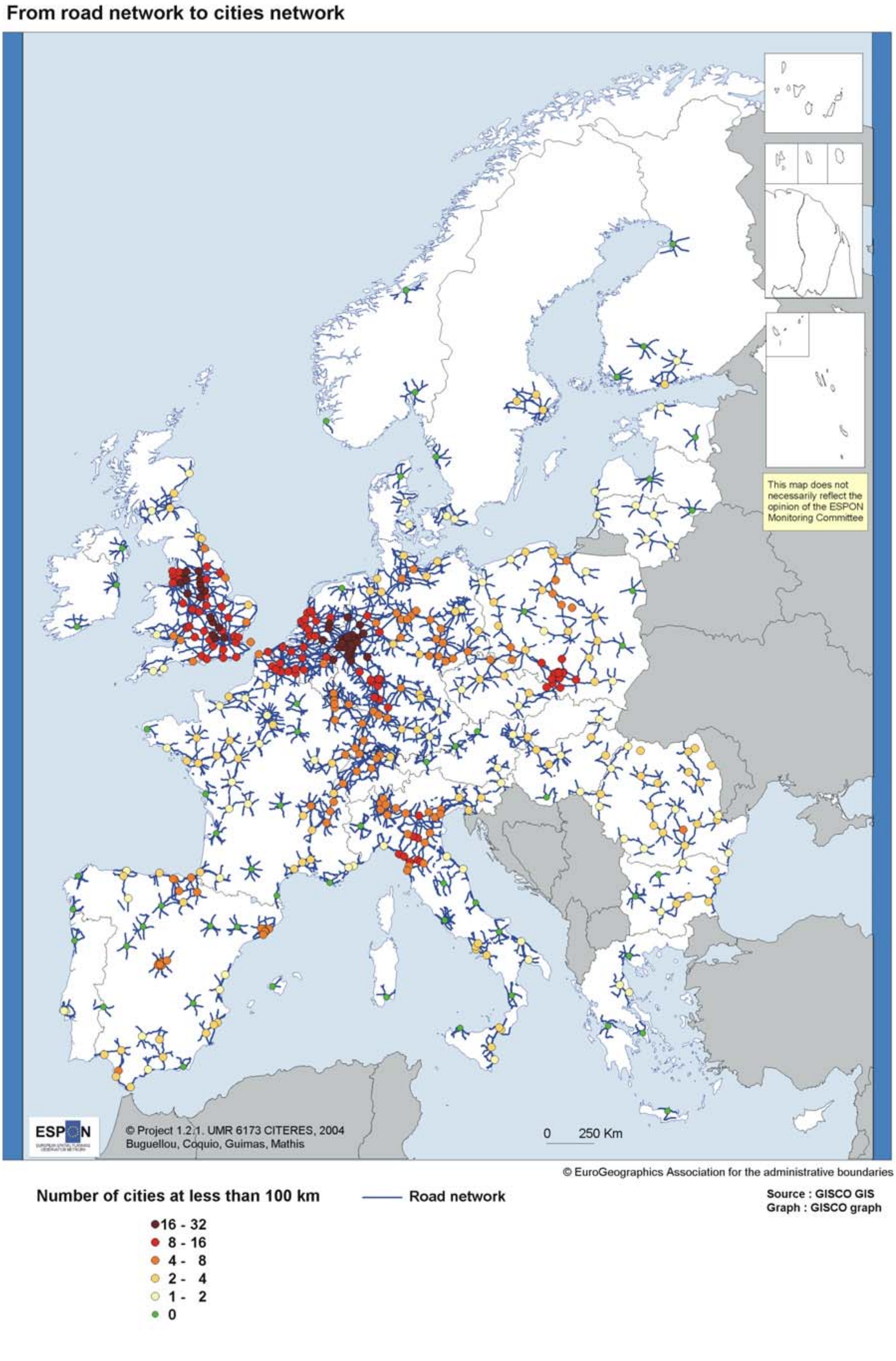
Polycentrism questions transport at another level namely the "**potential Polycentrism of proximity**", as is showed by the map below for a criterion of distance of 100 km. This map is realized by calculating a distance network of 50km around each city of more than 100 000 inhabitants. When the networks are in space continuity, distance between the cities is less than 100 km.

This map allows us to see what kind of cities networks would be possible, according to the area concerned. For example, the development of networks of proximity seems possible in areas such as Benelux, Western Germany, North-Italia or South-Poland whereas it is impossible in numerous other areas. For cities having no or very few cities at less than 100 km, fast means of transport take all their importance. in theses cases, the possession of an airport well connected to the European space seems really necessary.

[107] The role, specific situation and potentials of urban areas as nodes in a polycentric development, ESPON 111

[108] as has been shown in part 3 chapters 4 (Potential accessibility) and 5.10 (Accessibility to MEGAs by truck).

[109] See part 3 chapter 1.3.1



Map 88 From road network to cities network

In order to study more precisely this aspect, it would be necessary to consider simultaneously all the modes of transport and calculate **a daily accessibility** door to door, including notably the publicmeans of transport. It is technically possible, but requires the knowledge of the whole timetables of air services, as developed in the ESPON 121 group, but also of TGV, classical trains and buses.

If **urban polycentrism is a notion more and more accepted by the community** and recognized as a solution for a more sustainable development, it is really curious to notice that **the extreme form** of economic polycentrism is just weakly denounced in spite of its numerous disadvantages. Indeed it is a **polycentrism of production**, generator of an important part of the traffic ; it can be **justified at an individual scale**, or at the level of firms but **not at the one of community,** in an perspective of general interest. The car's industry is a flagrant example. Considering the inequalities of market, wages, but also of land taxes, numerous delocalizations have induced a polycentrism of production generator of transport of raw materials, spare parts, and final products sometimes at very long distances because of the **low internal transport costs**. In this way, firms externalise the stockpiling on the carriers and the environmental costs on the community.

This aspect of the polycentrism of production **makes necessary a good distribution of the gateways**, notably the ports, which is not already the case. Indeed, we observe **a very unequal distribution of ports** with a great concentration around the Northern Sea close to the "Pentagon" (i.e. the core of Europe), that logically induces very long distances of transport for others regions[110].

This aspect allows to raise the question of the **internalisation of transport costs, notably those linked to pollution**. A major part of displacements is hardly avoidable ; it is notably the case of the home-work mobility, or of moves linked to local and regional economic activities. These movements, even if they are sources of pollution, especially in agglomerated areas, can be transferred for part on collective modes. But we do not dispose of required data to study this aspect at the European scale.

Nevertheless, we have evaluated emissions of trucks for inter-regional displacements, knowing the number of tons.kilometres going through each edges (see part 3 chapter 6.2) and by corollary at each NUTS level (see part 3 chapter 6.3). We have been able to deduce in a quantitative way the emission of greenhouse gases and other pollutants (cf. part 3 chapter 6.4). but the problem is that a great part of these emissions are located in very

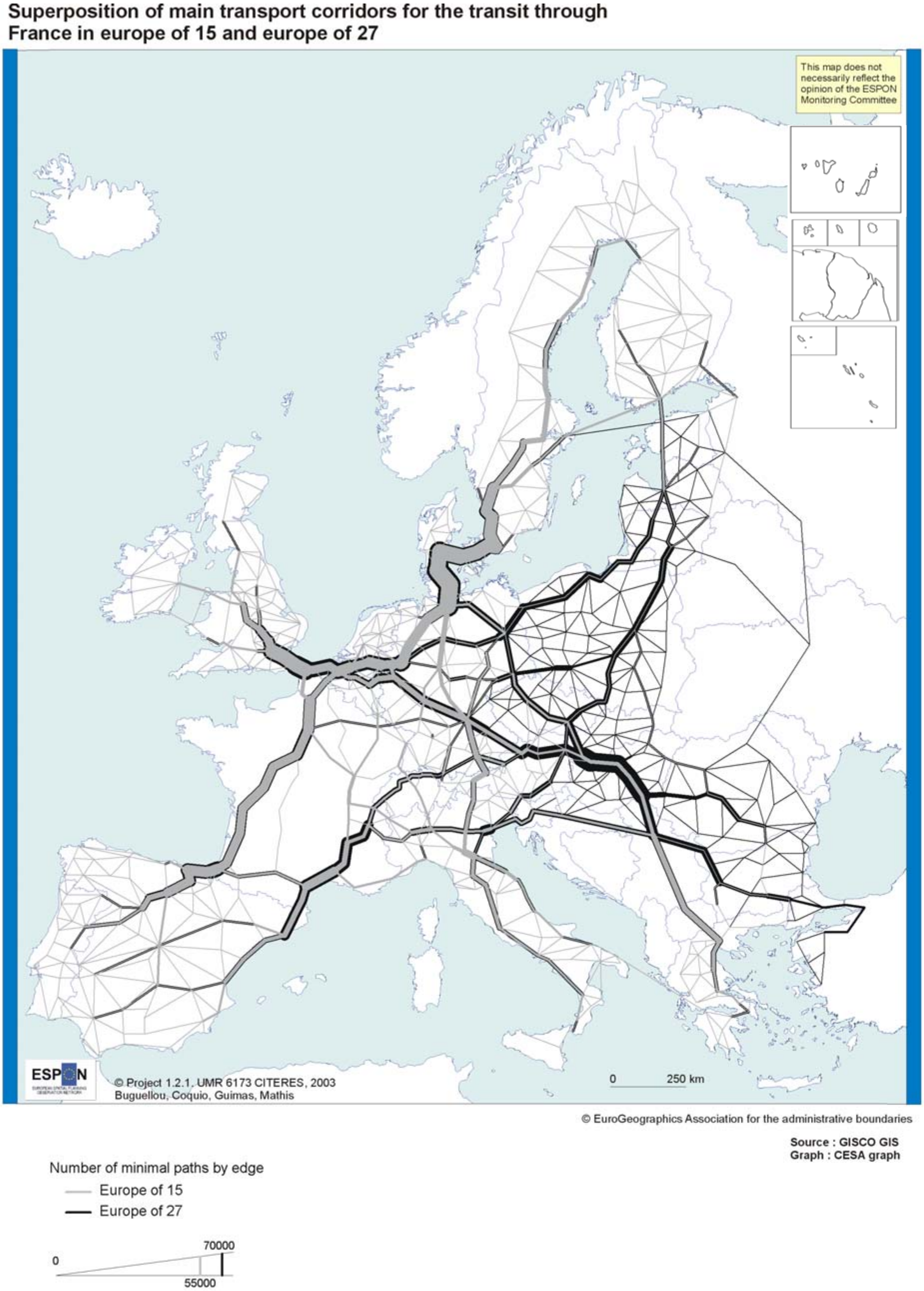
[110] see part 3 chapter 5.8.3 (Potential accessibility from gateways)

dense areas, exposing local population to important sanitary risks with a part of these emissions constituted of polycyclic carcinogenic aromatics. This aspect is underlined by the calculation of the number of tons going through nodes (cf. part 3 chapter 6.2) which shows that most of the high values are found in important urban areas. The transit traffic must be transferred, at least partially, in a less dense space, or on less pollutant modes[111].

In this domain, the spatial unbalance is high and at different levels. Indeed, for example, the pollution by ozone is locally stronger in campaign than in cities in summer.

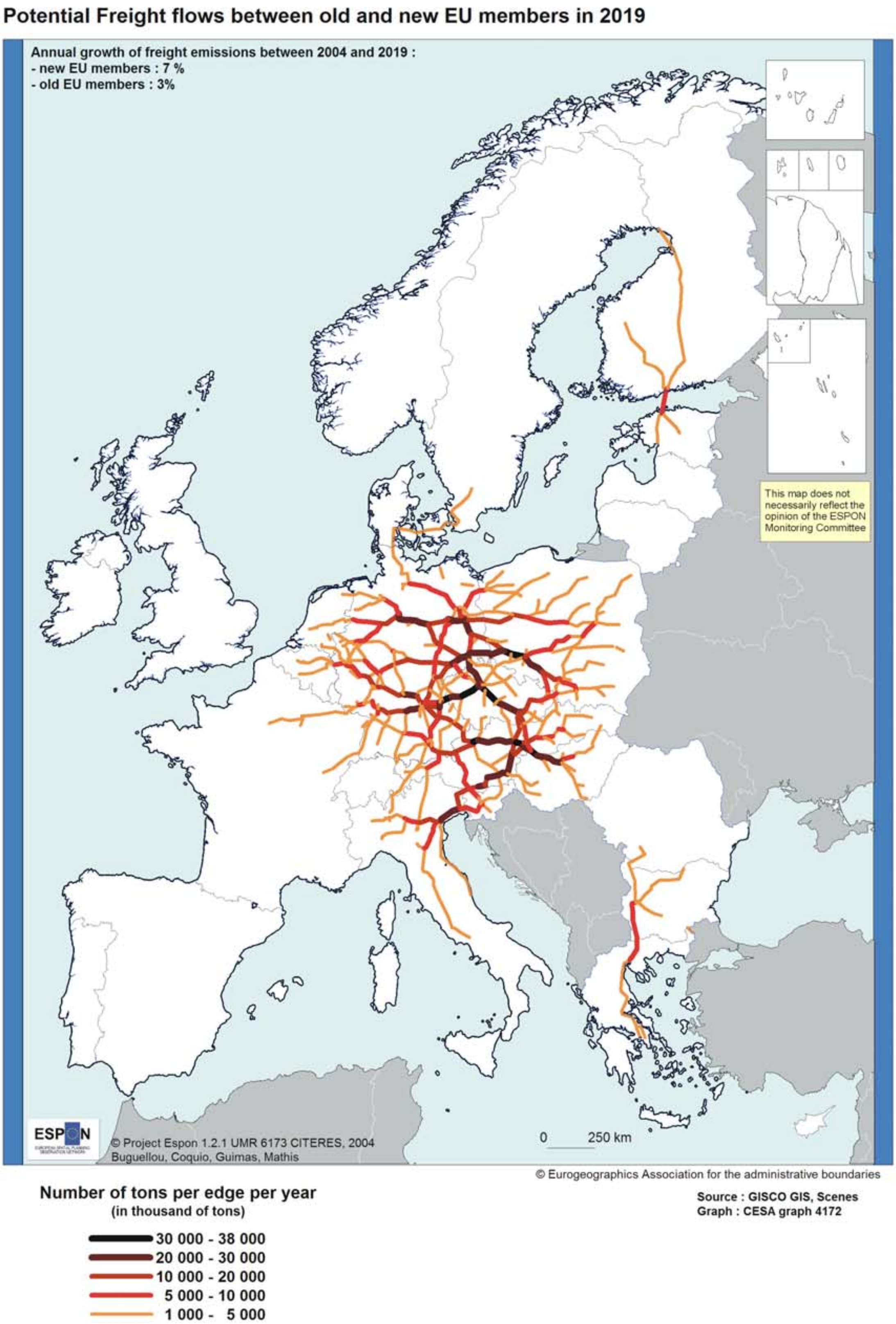
The enlargement is presently a source of unbalances in the domain of transport as the Iberia Peninsula was at the time of the adhesion of Spain and Portugal. Indeed, the enlargement has modified the average values for the fifteen in downplaying it, but it also contributes to change the direction of the exchanges, from a North-South domination to an East-West one, or at least to accentuate this last orientation. The numerous delocalizations already done, and the others in project, will accentuate this phenomenon. The map of the potential modifications of displacement linked to the new adherent countries illustrates the consequences of this reality.

[111] see part 3 chapters 5.4 (Freight volume generated) and part 5.5 (Freight traffic on road)



Map 89 Superposition of main transport corridors for the transit through France in Europe of 15 and Europe of 27

Of course, these modifications will take time and the projections realised for the exchanges of freight between regions do not underline it in a sufficient way. Indeed the database used (Scene Database) dates from 1995 and the major increases that appear are mainly located in the core of Europe, essentially in Germany. The map below shows the potential flows in 2019 between new and old EU members, with a hypothesis of growth of 3% for old EU members and 7% for new EU members. The maps for 2004, 2009, and 2014 and are available. Nevertheless, the results must be taken with lots of precautions. Indeed, as stated before, the scene database dates from 1995. So, the localization of firms, which generate flows on the network, is based on data which are 9 years old. Even if we have increased the values to estimate data for 2004, we are not able to take into account in these projections the delocalizations of industries, which have already happened and will occur in the future. The aim of this map is to give an idea of the regions which can potentially suffer the most of an increase of exchanges, linked to the enlargement of the EU. These ones are mainly located in Germany, Austria and North-Italia for old EU-members and Czech Republic for new EU members. But the results would have been quite different if we had considered the flows between new EU-members, what we have not done because of the extremely low values in the database. This leads us once again to say that there is an important lack of data to produce correct projections. Furthermore, we can suppose that the growth will be higher, reaching 7 to 12 % by year.



Map 90 Potential freight flows between and old EU members in 2019

Finally, this phenomenon is normal and **each modification induces imbalances** that are compensated later, more or less slowly. It is interesting to note that a system in equilibrium is an inert one, which is absolutely not the desired goal. **Imbalance is not intrinsically and is inseparable of the dynamic.** Furthermore, the map showing the minimal paths between MEGAs (part 3 chapter 5.10) by expressing potential relations shows that the enlargement could be a factor of a better distribution of the flows on the network, if the capacities are sufficient.

In our domain, dynamic can be seen as a confrontation between two different temporalities.

The temporality of the transport supply that is expressed in the easiest way by **creations of road and rail infrastructures** (presently, it roughly takes **13 to 15 years**) but also in the functioning of transport modes.

The temporality of the transport demand that is those of firms for goods and that is roughly of **3 or 5 years**, for the creation of a production unit and for a delocalization.

It is why our anticipations have to be of great quality in order to integrate on a temporal horizon three times longer and we have to envisage actions at a very shorter term and with quasi constant networks, that impose to turn ourselves to others kinds of solution like modal transfer, financial incentives, capacities development by speeds degradation as it is beginning to be done in urban areas.

In spite of the fact that we do not have, for the moment, the data necessary to scientifically tackle these problems of capacities and saturation, our common and concrete experience of networks permits ourselves to make the observation of a constant intensification of flows and saturation that have to be treated to avoid an increase of firms' delocalizations. That is the object of our proposed policy recommendations, in the next chapter.

3 Policy recommendations

3.1 Policy recommendations at the European level

The aim of the policy recommendations at the European level is first of all to draw principles that could guide these recommendations, then to explicate the nature of these ones, before applying them, partially or totally to macro-regions of:

- Atlantic Arc area
- Mediterranean Sea area
- Nordic area
- Central area
- Eastern Europe

The objective is to have a **more balanced, polycentric and sustainable spatial development and to ensure the territorial cohesion of the European Union**. First of all, it is important to have a development: economic, social, demographic, and cultural. The transport system must thus facilitate the economic activity, but without being too costly, and allow to everyone the freedom of displacement, to have access to fundamental goods and services. It must participate to the reduction of the spatial inequalities, so that everyone can have fair chances. Finally, it must be more sustainable, preserve resources for the future generations, together with ecological diversity.

With these objectives and according to the elements developed in the report, it is clear that territorial cohesion can be ensured only at certain levels and with a certain diversity, a compensatory equity, because the European space, as we have seen with the fractal perspective, is deeply heterogeneous and this at every scale.

We have briefly presented in the last chapter the geographical constraints that undergo the transport system. Some of them cannot be changed, at least at our scale. This fact is not necessarily a handicap, but can be a resource. Some territories, which were turning into a desert, are now tourism areas with lots of secondary residences, with some negative effects, but nevertheless leading to a new dynamic.

No situation is really definitive and the vocations change according to cultural and technical capacities and the periods of time. Some worlds can disappear, as the poet Paul Valery expressed with wonderful words, but other ones are appearing in the same time. A spatial system at a given time results of the superposition, the sedimentation of different historic periods and we have observed that the **transport system itself is the product of past ages and of desires of futures.** Heir of past and geography it is the stake of economic social, cultural, scientific debates and conflicts. We have evocated briefly, on the subject of the internalisation or not by the traveller or the carrier of external costs, the fundamental right of displacement but which has for consequence an important increase of flows and consecutive negative effects.

The consequences of a profitable transport system for a great number of activities, taken individually, are collectively costly. The awareness of these environmental problems is historically recent and the tools to measure it even more. But these ones exist, as shown by the maps on pollutants emissions[112]. So, we must attempt to preserve the inhabitants from risks linked to these situations.

The general objectives of ESPON give us some criteria for action: economic efficiency, accessibility, struggle against imbalances, sustainable development, cohesion together with a modal shift, polycentrism, but also regulations, directives… But, **the coherence between economic efficiency and sustainability can be discussed and requires for us at least the introduction of the temporality in the previsions** and thus of dynamic of choices, some prospective of which we have attempted to give some elements with the maps showing potential flows.

The transport system is an area where two dynamic conceptions are fighting. The first is the transport demand coming from individuals and firms and which is essentially at short term, and which has dramatically grown in the previous century and could saturate, block the functioning of the system. This micro-economic demand leads to the transfer to the collectivity of some direct but mainly indirect costs of the transport. The demand of the private sphere is a short-tem demand (about 2 or 5 years for enterprises). If this demand is not satisfied, the risks of delocalizations are very important, because of the concurrence. And the risks are amplified by other present and structural factors, which are out of our study area.

The transport supply firstly consists in roads, railways, ports and airports infrastructures. These ones are characterised by the long term: a road supposes at least two centuries of functioning. Some axis dates from several centuries, mainly because of geographical constraints, which have for a long time limited and still reduce the possibilities of choice.

The current creation of an infrastructure lasts roughly 15 years because of expropriations, studies on economic and environmental impact,

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[112] See part III.6.4 ? on transport externalities

which is globally 5 times more than for investments of industries. These two durations illustrate one of the difficulties of the problem. Let us add that the creation of an infrastructure is in a general manner of public initiative even if the operator is private. As a consequence, it seems evident that **response to demand by a policy of infrastructures building is not sufficient** because firms, potentially facing difficulties linked to deficiencies of the transport system, would have about largely enough time to delocalise their activities before the projects would be achieved. And this even if the anticipations and prospective, which remain necessary, are well-made.

After such an observation, we can not limit ourselves to mechanist models of projection based on past trends, and relatively constant, because the current modifications are more structural that cyclical: delocalizations, saturations of infrastructures, modifications of the international distribution of work… Any prevision, which would not integrate these scenarios would be false and dangerous.

This does not mean that a policy of infrastructures building is useless because this one is necessary to give a response in the long term to the demand but it implies **to develop short and medium-term policies** to adapt the system to such a demand, which is in fast growth. These medium and short term means of action concern the modes of transport and the use of the infrastructures. They have begun to be introduced with the end of the geographical monopoles of networks operators, like for example with the opening of railways infrastructures, which is in some ways a come-back to what was done earlier, but now with a separation of the infrastructures and their use.

The means that we propose are in fact in application in numerous agglomerations. They consist in a **regulation of traffics to increase the capacities, diminish the pollutants, the casualties…** These means are the **statutory and relating to pricing policies, the increase of intermodality to facilitate a modal shift and the degradation of speeds.**

On the road, concerning interregional and international travels, the problem at short or medium-term according to the corridors concerned is the saturation because of the fastest growth of the transport, compared to the economy: the decoupling is wanted but will it occur ?

The increase of the capacities of road corridors is currently impossible for most of highways. Indeed, these ones with two lanes have been calibrated with viaducts, bridges and tunnels with a maximum of three lanes. To increase the number of lanes corresponds to a creation, without taking into account possible numerous local oppositions of ecological movements.

Moreover, the capacities available on the railways are insufficient to permit a modal shift, without any logistic preoccupation of travel times for example. Moreover, the transport of passengers seems more profitable for the operator. So, in order to increase the terrestrial capacity, **the solution is to do the same as in the USA: limit the speed.** On a road with a fluid flow, the capacity in number of vehicles is roughly twice at 65 km/h than at 100 km/h[113][114] with nuances according to the layout of the infrastructure and to the kind of vehicles. So, we propose to reduce the speed by legislation, limiting it in a first time to 70 km/h for trucks and 100 km/h for cars, and then to 60 and 70 km/h. In this way, we will reach the present situation of the USA (40 Miles/h), one of the only that do not fascinate our managers but that is really efficient. A direct consequence of this limitation is a reduction of the fuel consummation, so of the emission, of casualties, etc…

A second way to increase the capacity is **the improvement not on the edges, of the segments of roads or motorways, but of the intersection at all the scales**. If, in urban networks, we use nodes to slowdown flows, with roundabouts, for traffic transit we use bypasses to avoid congestion problems as in the case of Bordeaux in the French A10. Simultaneous use of these two previous means permits a non-negligible increase of capacities for constant facilities.

Nevertheless, the transport system is a system partially subdued, with its own regulation and its own dynamics. Each amelioration of capacity or speed between two points risks to develop the flows. **It is why it is a necessity to simultaneous promote other policies at short and medium terms.**

The modal shift is the first one. It is the only possibility at short term because maritime facilities currently existing, even if they need ameliorations and construction of ships only require three years, studies included.

The second only begins to be developed, in a timid way: It is **the transformation of classical railways into freight-dedicated lines**. It can be done by the reusing of traditional lines, vacated by the creation of High-speed rail network for passengers.

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[113] P.H. DERYCKE L'Economie urbaine Presses Universitaires de France Paris 1970

[114] B.D.GREENSHIELDS, A Study of Traffic Capacity, In Hightway, Research Board Volume 14,1935.

Indeed, we propose the degradation of speeds on highways and motorways and the non-exclusive goal of developed capacities of existing infrastructure ; we also propose a maritime transfer of certain kind of goods, linked to heavy containers.

But we are totally conscious of the **necessity to furnish to the private economic system modes of high speed.** The proposal is to create for freight transportation, at the contrary of the American model, a system of fast transport with trains limited in number of wagons but at a high frequency able to carry goods at high-speed, roughly at the maximal speed of passengers' trains using classical lines, that is to say nearly to 150 km/h. These lines should have a reduced number of stop, as in the case of the TGV and would cross 1000 km in less than 9 hours (load and unload included), that corresponds to the obligatory breaks for drivers, according to the present legislation. Presently, in conditions of concurrency really less favourable, rail transport is only competitive from 500 to 700 km. The difficulty is mostly linked to the additional time necessary for loads/unloads. This is why we propose relatively small trains (in number of wagons) but at high frequency. Technical solution already exists and Switzerland has shown on shorter distances the possibilities of this kind of transport, which are most cost-effective for long journey.

For light but urgent goods, transport by air seems to be a good solution, notably for long distance. Trucks could be used for initial and terminal phases for which it is not replaceable.

To avoid perverse effect relative to low capacity vehicles authorized to circulate at the same speed than individual vehicles all goods vehicles should be compelled to the limitations of trucks.

For travellers, and for a certain number of years now, speed is not associated to individual cars but to High-speed trains and plane. The flexibility may be achieved by rented cars at the arrival. This kind of fast displacement will also contribute to the safety of people and goods, to the decrease of pollution, and, in this way, to the sustainability of the transportation system. It can also participate to the development of the polycentrism because of the reduction of travel times makes the cities getting closer one another, as we have been able to observe in the case of France and the development of the TGV, inducing a better distribution of productions' and services' poles in the functional territory and a better global accessibility.

A policy of infrastructure creation is also necessary. We must diminish the vulnerability of network by a minimum of modal redundancy when it is possible and a multimodal redundancy when

it is not. The recent catastrophes in the Alps tunnel show that everything is possible. Some anthropogenic activities, and some natural events, make these hazards always more probable.

Finally, it is necessary to separate the different flows in the aim to prevent the transit of trucks in the densest areas, source of supplementary pollution to the one naturally induced by human concentration.

The heterogeneity of the European space is so important, that it seems difficult to us to emit more precise recommendations at this level, not having the possibility to produce prospective analysis, domain reserved to the ESPON group 3.2 "SPATIAL SCENARIOS AND ORIENTATIONS IN RELATION TO THE ESDP AND EU COHESION POLICY".

So, we will envisage more precise propositions at the level of each macro region.

3.2 Policy recommendations for macro-regions

3.2.1 Atlantic Arc area[115]

3.2.1.1 Findings of indicators

This chapter is decomposed in three parts, directly linked to the available indicators and representative of our whole conclusion about the studied space:

- Transport network and network of cities
- Accessibility
- Flows

3.2.1.1.1 Transport network and network of cities

3.2.1.1.1.1 Infrastructure endowment and transport network general morphology

- Road network

The regions of **North of Atlantic space are less furnished** in terms of highway and express lanes **relatively to their population**. There are two main reasons of this observation: On one side the **strong concentration of inhabitants** in countries as Great Britain and, on the other side, the very **poor endowment of rapid transport network** in specific areas as Cornouailles or Wales. The case of France is more contrasted with great heterogeneity drawing separation between different areas. It is important to note **the weakness of the network density in littoral areas**, with poor links between the smallest studied cities. It is roughly the same phenomenon for Spain and Portugal, mainly because of the great concentration of population on the coasts (exception done of Madrid). In fact **this duality** is visible in all countries of the Atlantic space, unless in the West Gallice.

- Rail network

The density of kilometre of railway by population is clearly **more heterogeneous than for highways**. There is globally a low density in the Great Britain. The concentration of population seems to play a major role in this unbalances. Indeed, the quasi-totality of areas with low density of population offers a high density of railway (it is the case of North of Scotland, of the Western Ireland, of the French regions Massif Central and Limousin and of the frontiers between Spain and Portugal. By contrast, **the**

[115] This area includes the whole France and Great Britain, and so does not correspond to the Atlantic space defined by INTEREG 3B

littoral areas have a low endowment generally illustrating a higher density of population on the coast.

- Maritime Ports

There is a real and **strong potential** for maritime transportation according to the numerous existing port facilities and a great tradition for this mode. The port are **roughly well distributed** along the façade, with nevertheless a greater density around the Ireland see permitting exchanges between Great Britain and Ireland. We can also note an important concentration of ports linking England and France, for freight and for passengers.

That situation contrasts with the port of the so-called Northern range, much more concentrated in local areas. But, in reality, if the ports are numerous, they generally have **low capacities**, and present **problems of connexion** with their hinterland but also between them. The intermodality is really less developed than for the ports of Northern Europe, as symbolises the case of Rotterdam.

- Airports

The distribution of airports is **relatively homogeneous along the littoral facade**, some of them offering mainly seasonal activities due to the importance of tourism in these areas. We can note that the **inside of countries is less well endowed**, notably in the core of the Iberian Peninsula. We can also note the major role play by some metropolises, as Toulouse, Malaga, Glasgow, Manchester ,etc…) that played **a role of pivot** thanks to well developed facilities, compensating the lack of secondary airports near main capitals, as Paris, Dublin or Madrid.

More generally, the whole Great Britain is well endowed, probably for part because of its high density of population and to its geographical specificity.

Concerning the littoral areas, the Atlantic regions of Spain and Portugal are in general less well equipped in terms of facilities.

3.2.1.1.1.2 Network of cities

The Atlantic space seems to be divided in **two different areas**:

On one side the "Finistère" and more generally **the peripheral regions** like the North of Scotland, the Western part of Ireland, the whole Portugal and the Gallice have a weak urban armature. It is also the case of some internal areas as Massif Central, Limousin but also of the area **around the frontiers between Spain and Portugal**.

On the other side, two kinds of areas seem to present a great density of cities. Logically, we firstly find **areas around capitals and metropolises**, with generally secondary poles near. It is for example the case of Madrid, Paris and Lisbon. Roughly the whole territory of Great Britain presents a high density of cities, as a corollary to the very high national density.

Secondly, we can see other areas, with a low density of cities, but with a **high level of connexion** between them, that can compensate for part the spatial distance by a temporal proximity. These functional networks are located in Andalusia, in Scotland, Basque region, South of French Brittany and around the river Loire in France. In a general manner, **the coastal areas present a good urban structure**, even if their interconnexion is not always well developed (network centred around major metropolises and node to medium cities).

If we look more deeply on the case of MEGAs[116], the situation is roughly the same, nevertheless with a conspicuous absence of cities as Nantes and Rennes in the Western France, provoking an important gap in this part of the Atlantic space. We can note that the list of MEGAs proposed by the CRPM is a bit different, with the addition of Bilbao, Nantes, Bristol, Birmingham, Leeds and Newcastle.

3.2.1.1.2 Accessibility

Accessibility depends on many factors: the **spatial situation**, according to relative localisation and geographical specificities, and the **quality of global network** and local connectivity.

The Atlantic space is clearly a **peripheral area** relatively to the economical and geographical core of Europe, notably for its "finisteres". Nevertheless the transport network can diminish this spatial distance by offering high-speed mode reducing the temporal remoteness.

- Road

The **littoral part is globally less accessible than the whole Atlantic space**. This tendency is reinforced for the "finistère", notably for the South of the Iberian Peninsula, Scotland and Ireland. This observation underlines the difference between the centre and the periphery in the studied areas.

- Rail

It is globally the same situation than for the road mode. Nevertheless, a nuance can be brought. Indeed, the **high-speed links** permit a contraction of space in terms of travel times (in others words a space-time contraction). It is particularly true in France with the TGV network that brings closer the

[116] According to the list proposes by the ESPON Group 1.1.1, different front the CRPM's one

Western part of France (Tours, Le Mans, ..) to the core of Europe. It is also true, in a more reduce way, for the valley of the Rhone.

- Air

Globally, **the air accessibility of the Atlantic space is inferior to the European average**. But the interest of this mode is in the reduction of the distance effect (on the peripheral areas).

In this way, the accessibility by air is better for certain regions of Atlantic space than for some regions in the core of Europe. It is the case of the major metropolises that dispose of an airport offering a high level of service, as Bordeaux, Toulouse, Bilbao, Nantes, Nice, the majority of airports in Great Britain but also around national capitals like Paris, Madrid and Lisbon.

3.2.1.1.3 Flows

3.2.1.1.3.1 Effective flows

- Road flows

The road is the most used mode for transportation in the Atlantic space, representing the majority of moving for freight. It is mainly used for regional and local service and improves the accessibility to European "Finistère" as Iberian Peninsula and Ireland. Nevertheless, we can underline the specific role of **transit** played by **four main axes** at a trans-national level:

- Lille-Paris
- Paris – Bilbao
- Paris – Lyon - Perpignan
- Londres – Manchester – Liverpool – Dublin et Glasgow.

As we can see, the regions supporting the most important part of the **transit traffic are located in France**, as an obligatory way to reach the North and the South of the Atlantic space.

National capitals also have a fundamental importance because of the radial orientation of flows. They have a role of crossroads.

Finally, there is still a strong relation to centres, whatever the scale considered is.

At a more local level, we can note some **discontinuities** around national frontiers as between Spain and Portugal and between France and Spain. The specific geography of that last area underlines the necessity for trucks to pass by the extreme West (Bayonne – San Sebastian) or East (Perpignan – Barcelona) of the Pyrenees It is the same phenomenon for the tunnel under the sea Channel, single terrestrial passage between France and Great Britain.

- Railway flows

The global configuration of railway network is highly dependent on **national logic** for the whole set of studied countries. Indeed, the majority of railway network have been realised at the end of the 19th century and at the beginning of the 20th answering to strictly national preoccupation. The development of high-speed network seems to continue in this way, as the example of French TGV shows it. It is why, in the majority of case, **flows are orientated in direction of national capitals**. This phenomenon is reinforced by **problems of interoperability** between these national networks. Flows are mainly intra-national as it is illustrated for example by their local weakness between Perpignan in France and Barcelona in Spain. It is also important to note the importance of concentric flows around Paris, London, Madrid, Dublin and Lisbon

Nevertheless, few corridors appear as playing a major role for **international freight transportation**, even if they are less visible than for the road case:

- Paris – Bilbao
- Marseille –Paris
- Marseille -Ruhr
- London – Manchester – Liverpool – Glasgow and Dublin
- Lisbon and Madrid

- Maritime flows

The Atlantic facade has a good level of endowment in terms of port facilities, illustrating an historical orientation of this space for this mode of transportation. But these ports have globally a **low level of traffic**, mainly due to their **remoteness to the major European production areas**. The most important ports are those that beneficiate of powerful hinterland, as the London ports, Le Havre-Rouen, Southampton, Liverpool, Bilbao,…. The weakness corresponds to the area between Nantes and Lisbon. Lots of goods are dispatched in direction of more important European ports, mainly located in Northern European countries, as Belgium and the Netherlands. These flows linked to gateways increase the level of use of road North-South axes, as those presented above.

- Air flows

The comparison between the endowment in airports and their real level of use shows great differences. If the spatial distribution of airports is relatively homogeneous in the whole Atlantic space, **the traffic is much more localised on few major hubs**, generally close to metropolises as Paris, London, Manchester and Dublin. It is really close to the situation described for railway transportation. A **secondary category** appears (Lisbon, Malaga, Nice, Lyon, Glasgow and Birmingham) with a medium offer, **more seasonal** because of the importance of tourism in the concerned areas.

In a general manner, direct flies between Atlantic metropolises are weak and must probably be reinforced to permit a real functionality of this space.

3.2.1.1.4 Potential flows

The technique of minimal path, in terms of travel times, permits to apprehend the potential flows, giving the same weight to each region.

- Road flows

Some axes greatly appear:

- London – Glasgow via Manchester
- London - Newcastle
- Lille – Bilbao - Madrid via Paris
- Paris – Perpignan – Barcelona - Madrid via Lyon
- Paris – Perpignan via Toulouse
- The East of France in a general manner, crossroads between the relations East-West (Germany-Paris) and North-South (Valley of the Rhone-Benelux. Lyon appears as a pivot for relation between France and Italy.

The Southern part of Spain and the whole Great Britain also include important corridors, but less used than the previouss.

- Railway flows

Four corridors appear in a strong way:

Lille - Paris – Bilbao – Burgos – Lisbon and Porto

Tunnel under the sea channel- London – Manchester – Glasgow

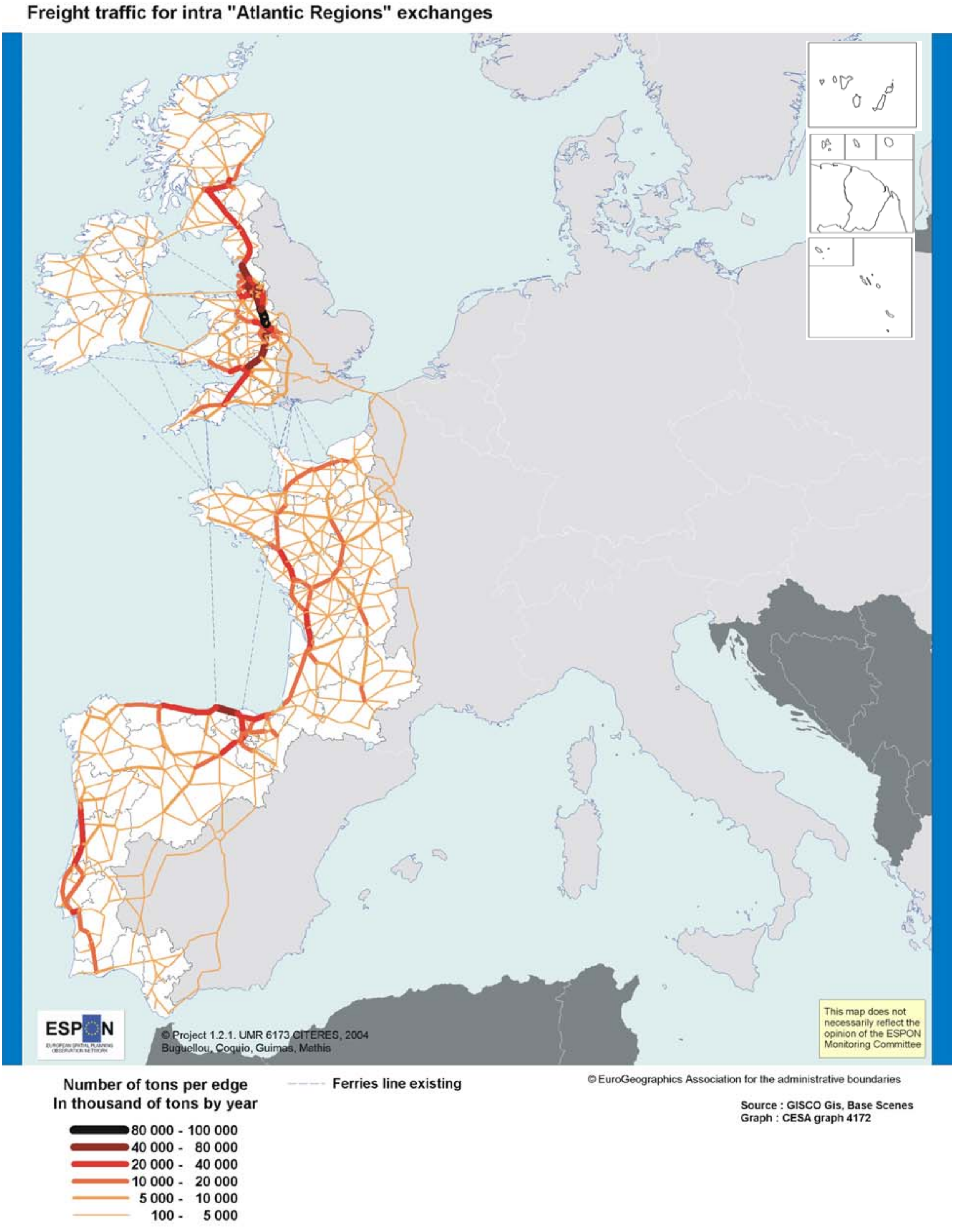
Paris – Lyon - Perpignan – Barcelona

The position of cross-roads of Nancy and Lyon

- Maritime flows

Ferries lines permit fundamental links for the accessibility of islands, as between Scotland and Ireland, England and Ireland (Liverpool-Dublin) and Wales-Ireland (Cardiff-Dublin). These relations are also important for trans-channel transport, mainly between the Western part of France and the Great Britain. They offer a possibility to double the tunnel under the sea channel, major axe and very vulnerable in the sense of global connectivity of the network.

If we concentrate ourselves on freight flows and specifically on the Atlantic space, as defined by Interreg IIIB program, we can see that the main corridors used for exchanges between "Atlantic regions", thus putting forward the "Estuaries motorway", the axis Lisbon-Porto and the axis Bristol-Glasgow-Edinburgh. Moreover, we can see that exchanges between countries are not very developed.



Map 91 Freight traffic for intra "Atlantic arc area" exchanges

To sum up, the observation on Western Europe is quite simple: for historical reasons, the structure of the network is directed centre-periphery and not at all periphery-periphery. Excepted areas for which it exists a parallel corridor with the coast, the remainder of the littoral is dominated by capitals: Madrid, Paris, London and Dublin.

This zone is partitioned and the relations centre-periphery have been facilitated for a long time. In diagonal of this space there is the large European Western axis Lisbon / Porto-Valladolid- Bordeaux-Paris-Lille, Rotterdam or London-Liverpool. On this very charged axis where the traffic grows very quickly, saturations begin to increase with the passage of the Pyrenees, Bordeaux, Paris and the very attended portion Paris-Lille. It appears aberrant that such significant flows of transit use the networks of Parisian skirting, one of the densest European zones and whose lands are very expensive.

Any increase in circulation in this zone will have as a consequence significant increases the travel times. For example in Bordeaux, skirting takes two hours in peak periods (which roughly corresponds to 150 km on highways).

3.2.1.2 Existing transport and spatial planning policy orientations

At European Scale, **nine** of the transport projects of *the Quick Start Programme* will be held in this area to reinforce the Trans-border connections:

- **High-speed rail axis of the European Southern (3)**

The project consists of constructing some new high-speed lines and of upgrading some existing lines to a standard suitable for high-speed ; about three quarters of the project concerns Spain. It will create a standard-gauge link between the network of the Iberian Peninsula and the French network.

The Madrid-Barcelona section should be completed by 2005, the Barcelona-Figueres-Perpignan section by 2008, and the Madrid-Vitoria-Hendaya section by 2010

- **Multimodal axis Spain – Portugal - Rest of Europe (8)**

The project n° 8 is conceived as a multimodal link between Portugal and Spain and the rest of Europe. It has the objective of complementing and re-structuring the rail, road, maritime and air links in the West of the Iberian Peninsula.

The project consists of three main Iberian corridors:

- Galicia (La Coruña)/Portugal (Lisbon)
- Spain (Irún)/Portugal (Lisbon) and

- South-West Corridor (Lisbon-Seville)

From the territorial point of view, the project is included in the structure of the main Iberian axis and therefore the project is of great importance for the interconnection of the Portuguese and Spanish sections of the trans-European transport network. It also facilitates the link between the transport networks of the Iberian Peninsula and the West and South of France, emphasising the whole area of the Peninsula in its function as a Western European gateway.

For this multimodal link, the Coruña-Lisboa-Sines and Lisboa-Valladolid rail lines should be completed by 2010, and the Lisboa-Faro rail line should be completed by 2004. The new Coruña-Lisboa road should be completed in 2003, and the Lisboa-Valladolid road by 2010.

- **Rail axis Cork – Dublin – Belfast – Stanraer (9)**

The project consists of upgrading the existing rail link between the island of Ireland's three large cities – Belfast in Northern Ireland, Dublin and Cork in the Republic of Ireland, and the ferry links to Scotland (the same corridor as for Priority Project No 13, the Ireland-UK-Benelux Road Link). The route is 502 km long, and will be upgraded to take both passenger and freight trains, the passenger trains at speeds up to 200 km/h. The Londonderry-Belfast line is a feeder route into the priority rail link.

- **Road axis Ireland – United Kingdom – Benelux (13)**

The project links the three main cities in Ireland –Belfast, Dublin and Cork – by road and ferry to Scotland and Wales, and via M6 and A14 roads in England to the ferry ports of Felixstowe and Harwich. The route is nearly 1500km long; it will be upgraded to motorway, expressway, or high-quality single carriageway as traffic densities require. This upgrading is being carried out via individual schemes along the route.

The UK/Ireland/Benelux road link should be completed by 2010 and the UK West Coast rail line upgrading (linking London with the North West) should be completed by 2007

- **Rail link "West coast main line" (14)**

The project constitutes the upgrading of the present 850km of the Glasgow-Liverpool/Manchester- Birmingham-London line, linking to the Channel Tunnel Rail Link in London and so providing for through-running HST services. It will specifically allow through passenger trains running at up to 225 km/h. Freight capacity will also be developed to allow use by high gauge rolling stock and provide interoperability. The promoter is Railtrack plc, a wholly private sector company which now owns all the former British Rail track and signalling equipment, and is responsible for their upkeep and development.

- **Freight railway axis through the Pyrenees Sine/Algeciras – Madrid – Paris (16)**
- **Interoperability of the high-speed rail network in the Iberian Peninsula (19)**
- **Motorways of the sea (21)**

(from the Baltic Sea to Western Europe, from Iberia to the North and Irish Seas, from the Adriatic and Ionian Seas to the Eastern Mediterranean, and linking the Western Mediterranean with Malta)

- **Rail/road axis Ireland / United Kingdom / Continental Europe (26)**

Furthermore, other European projects will be held to develop the use of maritime transport. It mainly concerns specialisation of some ports, reinforced by the program "*Atlantis-Esturiales*" reinforcing the role of hub, in the goal to develop a **feedering** ("cabotage") traffic, linking the medium port to assure inter-regional exchange and unblock terrestrial traffic:

- Nantes-Saint Nazaire: reinforcement of road-rail traffic
- Le Havre: begin of feedering with Ireland
- Algésiras: Hub of the Sealand
- Liverpool, because of a railway freight terminal and the Channel, gives to itself a Continental European hinterland

3.2.1.3 Policy recommendations

The problem of the response to the needs for displacement of people and/or goods is mainly temporal: road or railway infrastructure creation[117] currently requests about 15 years, whereas firms have shorter time perspectives: the time for renewal of material or delocalisation is currently about 3 to 5 years. So, a consequence is that firms can delocalise their activities because of transport problems. That is why our anticipations must be adapted to this situation, which is not necessarily the case, especially for policies where the constraints at short terms seem sometimes dominate at different levels.

[117] We can add to this remark that the time necessary to develop a road infrastructure (for example to pass from two to three ways on a motorway France) is roughly the same that the time necessary to create a new motorway, mainly because of numerous bridges calibrated (the same remark could be made for the rail).

Taking into account this very simple observation, it is necessary to envisage policies facilitating a fast economic and sustainable transfer modal, to make this territories attractive, and, in the medium term, to propose a carriage of goods faster than the truck, less expensive and less pollutant. In long term, the continuation of construction of a high-speed railway network for travellers is necessary.

So, our policy recommendations correspond to different time dimensions and have to be coordinated in order to have a coherent transport system for this part of Europe.

3.2.1.3.1 Short term recommendations

First of all, **a differential pricing policy** between the axes concerned could be incitative for a better use of the network.

Secondly we have to **facilitate the use of the maritime way and the existing harbour infrastructures**, even if they have to be modernized after. Indeed, the construction of a ship takes about 3 years, time of studies included, and the comparative cost is relatively weak. There are important ports in Lisbon, Porto, Nantes-Saint Nazaire, The Havre, Bristol, Liverpool, Dublin and others in Gijon, La Rochelle, Lorient, Brest, Cherbourg, Caen, Plymouth, Cardiff etc. Furthermore, there is a long maritime tradition.

Another solution, technically simple, is to improve the flow of the infrastructure. We would qualify it of "American solution". The traditional speed-low diagram shows us that the flow is maximum for a speed of 60-65 km/h on edges, that corresponds to fluid traffic. This speed roughly corresponds to the terrestrial 40 Miles/h speeds maximum in a great number of American states. So, to increase the capacity of the infrastructures we could **voluntarily degrade speed by limiting it for the heavy lorries to 60 km/h and for the car to 70 km/h**. This degradation could be made in two stages: a first limitation from 90 to 75 km/h for the trucks and from 130 to 100 for cars, and then a second stage to reach the proposed speeds. The consequence would be a transport much more sustainable, with less road deaths, emissions of carcinogenic pollutants, greenhouse gases and noises. The second one would be an increase in costs induced by the increasing of time. For example for the 1000 km of French transit, the drivers make in theory a maximum of 900 km in 10 hours (taking into account the legislation). A fraud of 10% on speed and/or time of driving make it possible to cross France in one day which would be impossible with this proposal and thus would make modal transfer attractive either by sea or by rail. In both cases the driver could use this time as a break time and the truck just would be used as initial and final mode in which its spatial and temporal flexibility would be employed perfectly.

3.2.1.3.2 Medium term recommendations

For the goods a fast solution is necessary in medium terms for transits. There is a railway line dedicated for goods, parallel with "the Estuaries motorway" which continues up to Gijon. It would have to be continued to La Coruna and the junction with the Lisbon-Oporto line could be done. But, there remains the problem of interoperability between France and Spain. **A modernization and setting with the B2 gauge would make possible to create a real multimodal corridor Lille-Hendaye-Bilbao-Oviedo- La Coruna-Vigo-Porto**. Thus, the link Lille-Hendaye will just take roughly 7 hours, including of hour of loading/unloading, that is really better than in the present situation. Furthermore, if the frequencies is high, this time could correspond with the break time for truck drivers, according to the European legislation. This line could be extend up to Spain and Portugal in the South and tunnel under the sea Channel in the North. This proposal is based on what is observed on the "North and the Mediterranean arcs": a road and railway corridor, modern version of the great Roman policy in transport, which doubled the road by the sea.

Moreover, taking into account the existing techniques, a carriage of goods by rail does not have to imitate here the continental American model of large very heavy and slow trains. **It is possible on renovated ways to make circulate trains at high frequencies and remaining speeds close to classical trains' speeds of for travellers**. Thus, it is possible to not modify the profile of the ways.

3.2.1.3.3 Long-term recommendations

For travellers, high-speed railway solution is infinitely faster and more comfortable with a possible to hire of car at destination or use the public transport. In long term, the network has to be completed in order to facilitate fast exchanges of travellers in this area.

The following scheme recapitulates spatially the recommendations for this area, thus giving a vision of a coherent transport system.

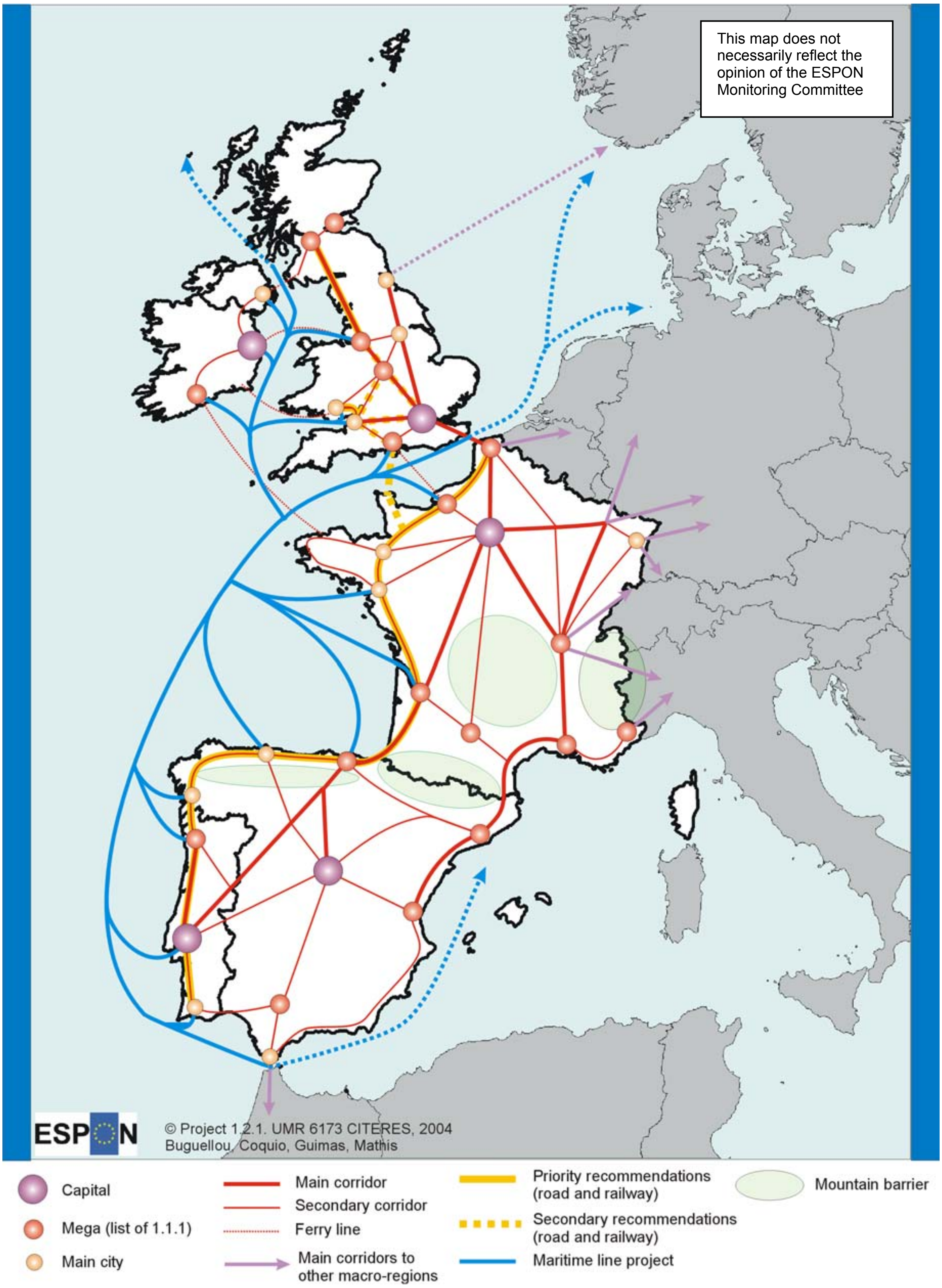


Figure 35 Policy recommendations for Atlantic arc area

3.2.2 Mediterranean area

3.2.2.1 Findings of the indicators

Mediterranean regions have poor accessibility in comparison to other areas in EU (central Europe and the UK). In the Mediterranean area there are some of the weakest links in transport networks of EU countries: the Eastern border through the Pyrenees between France and Spain is an important pass for freight transport from and to the EU countries to Portugal, to Spain and to the Maghreb countries. Regarding railways there is a clear gap of high-speed rail network between the Iberia Peninsula with France, Italy and to the rest of Europe.

Road density is very different for regions of the Western part of this area (Iberia Peninsula and the South of France) and the Eastern part (Greece and Cyprus).

- For the first group the road density is higher in respect to the ESPON space average except from those regions with important urban centres (Barcelona and Marseille), due to the population density distribution.
- The second group has clearly a lower value in respect to this average due to the low length of the road network. This is not the case of the rail network density which is in most regions of this area lower than the average of the ESPON space, which means that existing rail networks need to be enlarged to reach this average value (Iberia peninsula and South of France), and non-existing network must be built (Greece and Cyprus).

Due to the topography of this area, most regions are dependent on maritime transport, specially islands. The same happens with commercial airports as most islands are dependant on their regional airports.

Coastal areas with important urban centres have good connectivity due of the existence of important transport nodes, which is not the case of most of the rest of the area, specially Greece which lies far from the rest of the EU, separated by the Balkan Countries with a low infrastructure endowment. Most islands have low connectivity due to the low road and rail network and the regional and local characteristics of their seaports and airports.

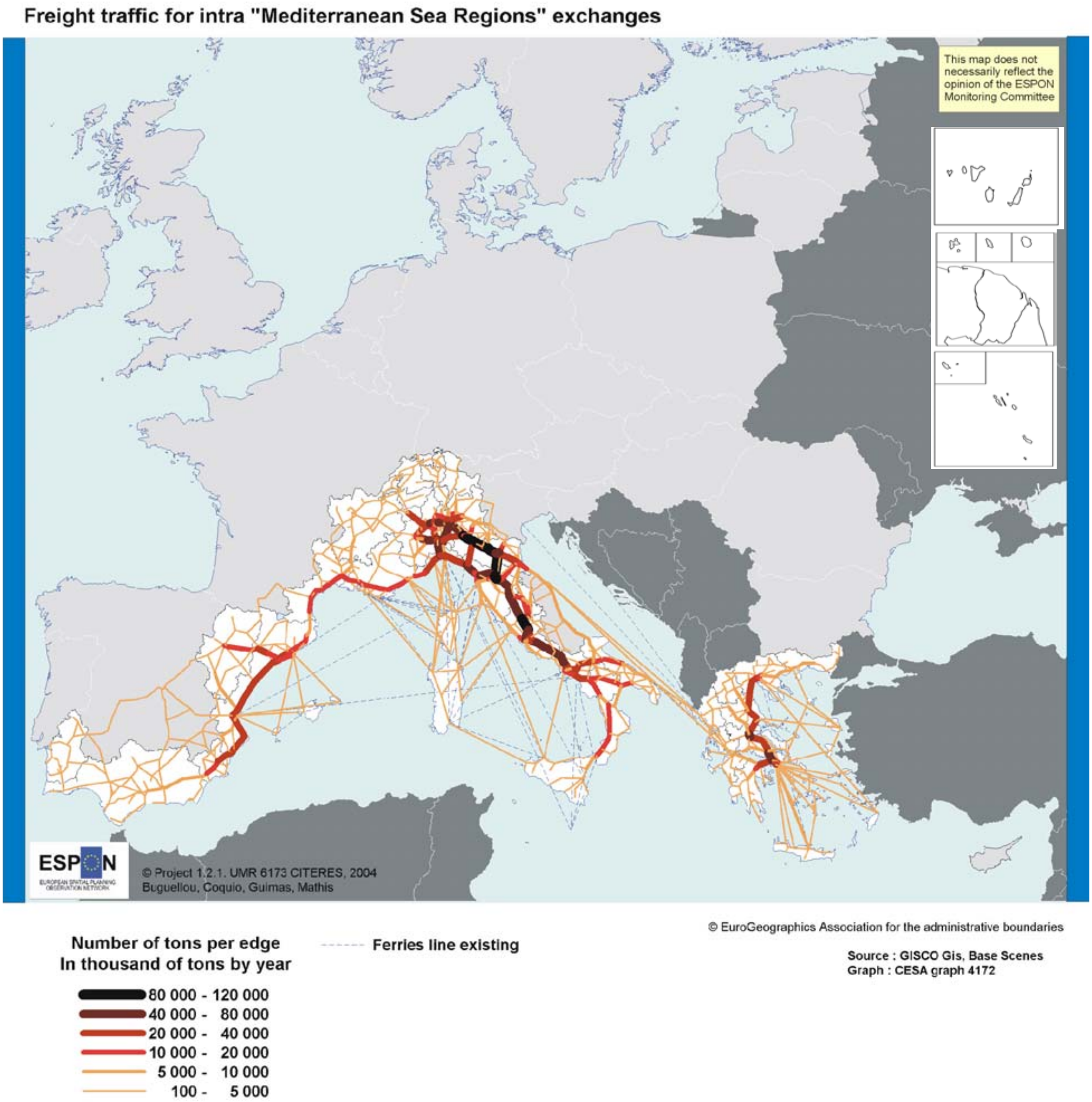
Due to the distance that separates most of the important urban centres in this area there are not many international air links with a time distance of 1 hour or less by air. Daily accessibility by air is only possible between the main urban centres, except from those in Greece.

Potential multimodal accessibility is low in most of the area except from those with capitals of important urban centres. Peripheral regions do not have good access to international flight services.

Regions with high population and high GDP generate high interregional trips. That is the reason why the Spanish, French and Italians regions generate more trips than Greece and Cyprus. The same distribution results from the interregional trip attraction, as it depends on the population, the GPD and also the cost to travel between zones; Greece is more peripheral than the rest of the regions in respect to all ESPON space.

The average distance travelled in each interregional trip is higher in the Spanish coast as it is more peripheral than France and Italy, and the value for Greek regions is lower as the trips generated have nearer destinations (the cost to reach other regions is to high).

Spanish coast corridor bears all road traffic from the Maghreb countries, and from some parts of Spain and Portugal to France and to the rest of Europe, and vice versa. It is one of the most important corridors of Europe. Italy bears another important traffic corridor. The geography of the area is not the only reason, the generation and attraction of trips is also important. Greece is also a peripheral region but as it does not generate and attract as much traffic as the other regions the traffic in its road network is lower.



Map 92 Freight traffic for intra "Mediterranean sea regions" exchanges

3.2.2.2 Existing transport and spatial planning policy orientations

At European Scale, eight of the transport projects of the Quick Start Programme will be held in this area to reinforce the Trans-border connections:

- rail axis Berlin-Verona/Milan-Bolonia-Napoles-Mesina-Palermo (1)
- rail axis Figueres-Perpignan (3)
- rail axis Lyon-Trieste/Koper-Ljubljana-Budapest-Ukranian border (6)

- motorway Igoumenitsa/Patra-Atenas-Sofia-Budapest (7)
- Malpensa airport (10, operating since 2001)
- interoperability of the high-speed rail network in the Iberian Peninsula (19)
- motorways of the sea (21)
- rail axis Atenas-Sofia-Budapest-Viena-Praga-Nüremberg/Dresde (22)

Spain, France and Italy, together with other Northern European countries, will be part of a rail network exclusive for freight transport (projects 1 will improve the connections between Italy and the Northern European seaports, projects 3 the connection of the Iberian Peninsula with the rest of Europe and Project 22 the rail connectivity of Greece to the rest of Europe); the process of liberalisation of this kind of transport has as the main objective the promotion of this transport mode in front of the road transport. The White Transport Book of the EU proposes to dedicate a part of the rail lines exclusively for freight transport to reach this goal. Road transport represents 44% of the total of freight transport, short sea shipping 41 %, rail 8% and 4% inland waterways.

Concerning this issue, the policy of the Spanish government is to increase the intermodality for freight transport creating corridors and logistic areas to facilitate the modal split with the goal to transfer 15-30% of the freights which are transported using road to rail transport through the Pyrenees to approach to the percentages through the Alps. The increase of the freight volume through the Pyrenees during the next 20 years is been foreseen between 120 and 150 millions of tones. Road network will be able to carry on some 40 or 50 millions of these tones, which means 15.000 hgv (heavy goods vehicles) per day through the main crossing roads, and if adding the current 17.000, it makes a total of more than 30.000 hgv per day in 2020. This volume, even if considering new rail infrastructures, points to the need of other roads through the Pyrenees, and the duplication of the existing motorways and expressways in the oriental and occidental borders. Project 21 will improve the short sea-shipping network and therefore it will unload freight transport from road transport.

French government main policies for rail transport are the development of a high-speed or mix rail network and the modernisation of the existing network to develop the needed capacities for the different traffics (passengers and freight). In the Mediterranean area, the main rail project is the enlargement of the South-East high-speed line to Spain in two main sections: Perpignan-Figueres (50 km) and Nîmes-Montpellier, mix for passengers and freight, is necessary to solve the international connection of

Spain. French government also promotes the freight transport through inland waterways, with the goal to duplicate this kind of transport in ten years, and sea transport, with one of the main port projects in Marseille-Fos. This project consist on improving the container transport by means of building a new container terminal in Fos and the improvement of the rail-seaport links in both Marseille and Fos.

Regarding road policies, in order to unload the road traffic in the Mediterranean corridor French government has promoted the construction of an alternative route, A 75, to go from Spain to the North of Europe by means of building a bridge on the Millau river.

In Italy, Messina bridge will have a significant impact on the local and social economic situation and also as part of the national transport network, which will bring the Mediterranean closer to Europe. In fact, once completed, the bridge will be an integral part of a set of trans-European road, rail and sea systems: corridor eight between Bari and Varna, corridor five from Lisbon to Kiev, and the Berlin-Palermo axis of which the bridge is a pivotal element.

Greece government promotes also sea links and rail modes to enable intermodality and encourage greater movement of freight by water, the revitalisation of railways to improve competitiveness for freight and later on for passenger movements and the market share of rail freight transport through multimodal freight priority corridors.

Cyprus pushes hardly to improve the air transport due to its geographical situation in respect to the rest of EU countries. Co financed by the EIB, the Larnaca and Paphos international airports will be improved with the construction of new passenger terminal buildings and associated facilities. This project is aimed at ensuring the timely development of airport facilities to acceptable international standards to match the growing needs of the Cyprus economy. Regarding maritime transport, Cyprus is to be considered now an international maritime centre. The policy of the Government of Cyprus in the shipping sector is the continuous improvement of the existing infrastructure and the incentives available to both residents and non-residents.

3.2.2.3 Policy recommendations from 121 perspective

At European scale, the first recommendations from 121 perspective is to delete the weak links which exists in the main corridors of the current transport network of the Mediterranean area:

- Trans-Pyrenees passages
- Trans-Alpine passages

- Greek connection to the rest of EU countries

As mentioned in the previous chapter, some priority projects can solve this weak links in future time, like the high-speed rail line through the East part of the Pyrenees and the upgrading of the road connection of the Western part of this passage. The Trans-Alpine connection is regarded in the priority projects except from the French-Italian rail connection: to give continuity to the high-speed rail line from Marseille and the North of Italy along the coast. The connection of Greece to the rest of the EU countries could be improved not only by strengthening the motorways of the sea, but with a corridor along the Balkan coast as an alterative of the TINA corridors. In Figure 8.2.2.3.1 major flows of the main transport corridors in the Mediterranean areas are represented: red arrows represent corridors with the highest flows, orange arrows represent strategic corridors with the highest national flows, blue and green arrows are potential flows which will grow in the future with the disappearance of the weak links.

The second recommendation is to strengthen the intermodal connections by way of defining a network between the coastal transport nodes and inland transport nodes which can act as intermodal centres. For example, Zaragoza in Spain, is connected to Madrid with a high-speed line and will be connected to the seaport of Barcelona by the same mode and is also situated in a region where the network density is not high, and therefore, where there is the possibility to improve the capacity of the existing one. In figure 8.2.2.3.2 major corridors are represented linked from the sea to the inland. Motorways of the sea must be connected to the seaport, which must be connected to intermodal centres. In figure 8.2.2.3.3 there are the main transport nodes (in blue coastal nodes and in red inland nodes) of this network.

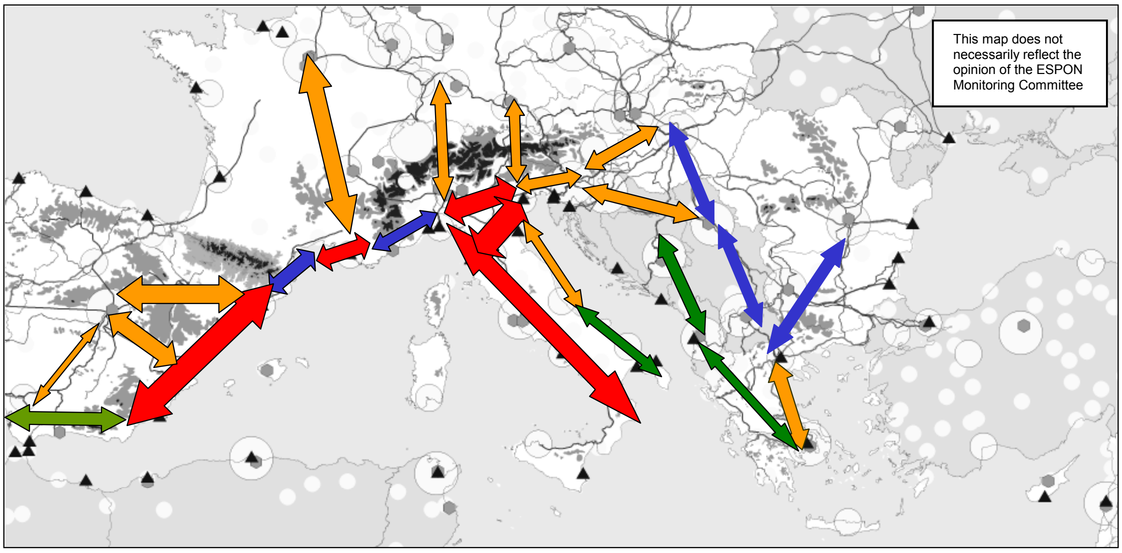


Figure 36 Main connections between the main cities in the Mediterranean area

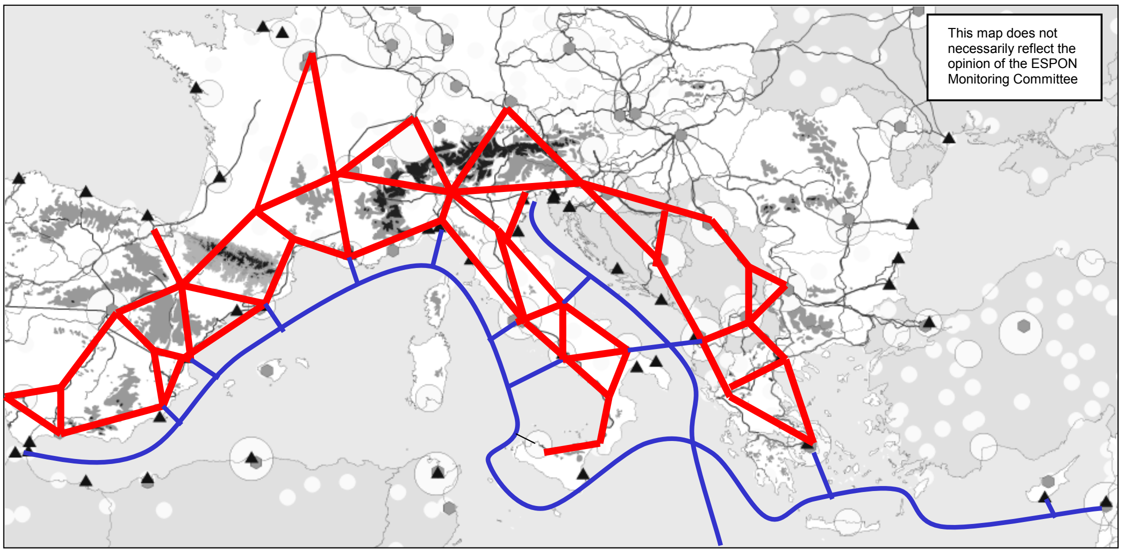


Figure 37 Scheme of the proposed transport network of the Mediterranean area

Figure 38 Main transport nodes in the Mediterranean area

3.2.3 Policy recommendations for the Nordic area

The Nordic area from the ESPON 121 group perspective includes the Nordic countries –Denmark, Norway, Sweden, Finland– and the Baltic states – Latvia, Lithuania, Estonia.

3.2.3.1 Findings of the indicators

- Infrastructure densities:

Reported to population distribution the expressways endowment in the Nordic countries appears at the level for the denser parts of the continent.

In the Baltic countries, all the main cities are linked to the international railways network, but the overall quality of the railway services is insufficient in the majority of the transition countries.

Airports are well developed in terms of traffic, in the Nordic countries but also in the capitals of the Baltic states.

Seaports endowment is relatively high as compared of the average endowment in Europe.

- Access to transport infrastructure:

The cost to motorway and highways is inferior to 30 minutes in most of the area, exception made of the Atlantic facade of Norway, and in internal Baltic states. This high performance of the indicator must be tempered by the fact the large NUTS zoning gives and the speed level considered for highways is low and then includes most of the road network in the Nordic area.

Since no proper High-Speed train, with 300 km/h, exists in the Baltic area, this indicator of cost to HST performs at its lowest level.

The time to reach airports indicator shows high levels of accessibility for large cities equipped with international airports: Kobenhavn, Oslo, Stockholm, Helsinki, Tallinn, Riga and Vilnius.

- Time space:

The highest speed in terrestrial networks in the Nordic and Baltic area is given by the road network. The hierarchy in the quality of the network, expressed by differences in speed generates a deep time-space relief affecting most of the zone exception made of the surroundings of the majors cities and settlement. In Norway and at a lesser extent in Finland, the long distances crossed at relatively low speed because of a weak motorway network displays on the relief map under the form of "time-space mountains" that expresses the lower accessibility in the periphery of the Nordic area.

In the denser parts of the area –Denmark, and Southern Sweden– the time space relief is almost flat, expressing a high accessibility level.

Projection of the time-space in 2020 shows a dramatic contraction of the internal part of the continent, but the reduction of the Nordic periphery is much less important, due to remaining long distances and lack of heavy high speed projects in the north of Stockholm and Helsinki.

- Daily accessibility:

The daily population accessible by car indicator, being strongly orientated towards a core-periphery pattern, shows low levels in the Nordic space. This only expresses the idea that the most densely populated areas, delimitated by the pentagon, appears quite far away as seen from the Nordic or Baltic space.

The city network daily accessibility indicator expresses the high level of connectivity existing in the Nordic city network. High levels of service, allowing to accomplish daily return trips, can be observed between the major settlements in the Nordic area. The Baltic area by contrast shows poor performance regarding the daily accessibility air return trips indicator.

- Potential accessibility:

On the potential accessibility by road indicator, the core-periphery pattern being dominant, the Nordic area appears as a remote zone with accessibility levels above the ESPON average.

The multimodal potential accessibility indicators that integrates the air mode shows high levels of accessibility for regions surrounding the major air nodes of Europe. In this perspective, the main gateways –Copenhagen, Göteborg, Oslo, Helsinki, Tallinn, Riga, Vilnius– are clearly favoured. Nevertheless, the quality of the land transport that allows to access to the air mode, is not even in the region. To that respect, the relatively high levels observed in the capitals does not propagates itself in the Baltic states as it does in the other countries.

3.2.3.2 Existing transport and spatial planning policy orientations

In the field of European transport policy the Nordic area involves a series of transport corridors:

- The corridor I called Via Baltica consisting in a land transport route from Finland, through St-Petersburg, the Baltic states, to Poland
- The Nordic triangle joining Copenhagen, Oslo, Stockholm and Helsinki and its extensions towards Germany and Moscow with road and rail developments corresponds to the corridor IX

- The Baltic Sea Motorway (21)

Corridor I is multi-modal corridor, both road and rail as well as a sea link, passes through the countries of Finland, Estonia, Latvia, Lithuania, Poland, and Kaliningrad for the branch to Gdansk. According to the latest European level decisions, the priority on the corridor has been set on rail, since the rail link project belongs to the Quick Start list established in 2003. Corridor I together with corridor IX and corridor VI define the North-South axes of network development involving Eastern Europe.

Corridor IX is made of two parts. Its western part stretches from Copenhagen to Mall, Stockholm and Helsinki; its Eastern part from Helsinki to St. Petersburg and from there on to Moscow. This corridor can be seen in the Western part as a continuation of the Øresund fixed link. In this area, developments will be greatly influenced by the possible construction of a fixed link between Germany and Denmark across the Femer Belt. The Eastern part of the corridor onto Moscow is one of the future priority extensions to the CIS. This connection is furthermore of particular interest for Finland and the Baltic States in relation to corridor I.

Nordic section of the maritime transport priority of the Union, the Baltic sea motorway will activate the already well developed set of seaports available in the Baltic sea.

The major ESDP policy orientation, namely polycentrism, must be applied in the Nordic area. In terms of urban hierarchy a remarkable organisation can be observed in the Nordic countries. From the perspective of polycentrism, the only weakness regarding the relations at the top level of the urban hierarchy is observed among the Baltic states.

3.2.3.3 Policy recommendations from 121 perspective

If one tries to establish the correspondence between the polycentrism option of the ESDP and the transport policy orientations as expressed through the priority corridors, one must admit a deep consistency.

On the one hand, the Nordic triangle and its extensions to Helsinki and Russia in the east and Germany in the South which can be seen as the major axis in the area is taken into account by the corridor IX.

On the hand part the internal and external links in the urban network in the Baltic states will directly benefit from the development of the corridor I.

In the Nordic space, the huge potential for maritime transport through short-sea shipping intra- and extra-Union can be activated by the development of the Baltic sea motorway project.

Beyond these three major points what can be stated?

In a polycentric perspective the only real weaknesses in terms of relations in the urban structure, assessed through the quality of passenger transport services, can be observed in the Baltic states capitals. To answer to this major stake, transport can play a major role, and the development of the corridor I with the Via Baltica and Rail Baltica projects, will contribute significantly to improve the terrestrial and maritime relations. Nevertheless, the accessibility to the rest of the Union can not be based only on terrestrial networks, for Riga and Vilnius where long distances are needed to reach the closest MEGAs. So we propose to encourage the development of air service in Riga and Vilnius airports. Indeed, the remoteness of their location at the scale of the continent can be only corrected by the air mode. A development of the air services to the closest MEGAs would seek to develop relations to Poland, to Finland and to Sweden in the first place, and to more remote locations at a lower level of priority.

Figure 39 Policy recommendations for the Nordic space

3.2.4 Central Area

In the ESPON 1.2.1 definition of European macro-region used for the policy recommendations the central area consists of the countries Belgium, the Netherlands, Luxembourg, Switzerland, Germany and Austria.

3.2.4.1 Findings of the indicators

The analysis of this report on transport indicators and maps provides a widely homogenous picture of the central area for most of the themes looked at:

- Transport infrastructure endowment in the central area is extremely good compared with all other macro regions. The central area has well established motorway and railway networks which belong to the densest in the world if measured against space, but due to the high population density is not so pronounced if related to population. Important is the emerging high-speed rail network linked via Lille to the French TGV network. The central area has a well developed infrastructure for inland waterway and sea transport, the densest inland waterway network in Europe is to be found here. In addition, the central area hosts also a good number of the airports with international relevance.
- Regarding travel time and costs, the access to transport infrastructure such as motorways, long-distance and high-speed rail services, ports and airports is best in Europe. Only very few parts within the central area such as regions in the new German Länder have poorer access. Because of the dense urban system here, travel time between MEGAs if very often below one hour.
- Accessibility of the central area is best within Europe. Most of the indicators of daily and potential accessibility display the regions in Belgium, the Netherlands and the Western parts of Germany highest in Europe. However, the spatial extension of highest accessibility varies from mode to mode. Road offers the largest area of high accessibility, rail is more concentrated along high-speed lines and indicates very quickly lower accessibilities going eastwards in Germany, and, highest air accessibility is very much concentrated around the international airports and falls down from there very quickly. The integrated multimodal accessibility depicts a corridor of 200 to 300 km width along the river Rhine as the area having highest accessibility potential in Europe, nearly redrawing the "Blue Banana" - but not the Pentagon.

- Traffic volumes on the network, in particular on the road network, in the central area are the highest in Europe. Traffic flows within the central area, but also the corridors towards France and Italy are important, whereas traffic flows towards Eastern Europe, i.e. the new member states are minor. Airport traffic is most important in Amsterdam and Frankfurt which belong with Paris and London to the four major airports in Europe. Because of the high traffic volumes, most parts of the central area are also suffering from transport externalities such as noise, emissions of pollutants or land fragmentation.

3.2.4.2 Existing policy orientations

The different networks of the central area play also key roles as backbones in the trans-European transport networks. However, because a relatively good motorway infrastructure is already in place in most parts of the central area, none of the road priority projects of the European Union is located within the central area, however, one priority road project links an outermost point of the central area to other territories:

- *(25) Motorway Gdans-Brno/Bratislava-Wien* is primarily a North-South axis in the new member states, however, heading to Wien.

There is a relatively large number of rail priority projects located in the central area, many of them are contributing to the emerging European high-speed rail network. The rail priority projects are:

- *(1) Rail axis Berlin-Verona/Milan-Palermo* of which the German and Austrian sections belong to the central area. The priority project consists of several sections of high-speed rail which are expected to be in operation by 2015. Probably the most difficult section is the Brenner Tunnel linking the central area with Italy.
- *(2) High-speed rail axis Paris-Bruxelles-Köln-Amsterdam-London* of which the Belgian, Dutch and German sections are part of the central area. The priority project is the first international high-speed rail infrastructure in Europe of which several parts, in particular outside the central area in France are in operation for years now. Most remaining sections in the central area are expected to be in operation within this decade.
- *(4) TGV East* linking Paris with Luxembourg and South-western Germany, i.e. another priority project linking the central area with France. The different sections are expected to be in operation at the end of decade.

- *(5) Betuwe line* is a new rail freight line from the port of Rotterdam to the German border. The purpose is to improve rail freight transport to connect the port's hinterland as an alternative to freight traffic on roads. The line is expected to be in operation in a couple of years from now.
- *(17) Rail axis Paris-Strasbourg-Stuttgart-Wien-Bratislava* of which the German and Austrian parts belong to the central area. Most sections are expected to be in operation in ten to fifteen years from now.
- *(20) Rail axis of Fehmarn Belt* links the central area to Denmark and thus to the Nordic countries. However, besides the fixed link, also several rail sections in Germany serving as access links to the Fehmarn Belt belong to the project. The different sections of the project are expected to be ready in ten to fifteen years.
- *(22) Rail axis Athina-Sofia-Budapest-Wien-Praha-Nürnberg/Dresden* is primarily a priority project in the new member states. However, at the same times it connects the Eastern parts of the central area with the South-eastern new member states. Projects in the central area will be in operation in a couple of years, in the new member states within a decade.
- *(23) Rail axis Gdansk-Warszawa-Brno/Bratislava-Wien* is also primarily priority project in the new member states. However, Wien as most Eastern capital of the central area is end point of this axis which is expected to be in operation within twelve years from now.
- *(24) Rail axis Lyon/Genova-Basel-Duisburg-Rotterdam-Antwerp* is a priority rail project in the river Rhine corridor and mostly within the central area. Most sections are expected to be in operation within ten years from now.
- *(28) "Eurocaprail" on the Brussels-Luxembourg-Strasbourg rail axis.*

Only two out of the thirty priority projects are concerned with inland waterway transport. However, both of them are located at least partly in the central area:

- *(18) Rhine/Meuse-Main-Danube inland waterway route* is one of the two inland waterway priority projects. Its main purpose is to better link the inland waterway system of Western Europe with that of the new member states. It is expected that the sections to be developed are in operation within the next fifteen years.

- *(30) Seine-Scheldt inland waterway* is a cross-regional project which links the inland waterway system and the sea ports of the central area with the French system. It is assumed that the project will be in operation by 2016.

3.2.4.3 Policy recommendations from ESPON 1.2.1 perspective

It is not an easy task to give policy recommendations for the central area. On the one hand, there might be a couple of deficits in transport infrastructure endowment in certain places of the central area. On the other hand, it would be ironical to recommend new large scale infrastructure in the central area, if territorial cohesion comes into consideration. Because then, it has to be taken into account that the central area is already best performing in Europe with respect to many territorial aspects of transport networks and services such as transport infrastructure endowment and accessibility, however, at the expense of suffering of transport externalities. Another issue for the central area is the question of European integration and enlargement which have also to be reflected in appropriate transport services and networks. Therefore, from the perspective of ESPON 1.2.1, two broad transport policy recommendations can be given (see also sketch map):

- *Enable modal shift*. The central area is suffering from road transport to a very high degree. Given the good road infrastructure endowment already in place, investments in more road infrastructure would be probably of no help. Therefore, alternatives to road have to be further supported. For passenger transport this is basically rail, in particular high-speed rail. Efforts should be intensified to link the already existing sections with new and upgraded lines in order to have a real high-speed rail network. Given the history of recent rail development, particular attention has to be given to trans-border corridors. For freight transport, there are two alternatives. rail and inland waterways. For both, it seems to be less an issue of missing network links, but a question of missing intermodal terminals and improved logistics to allow the provision of competitive services.
- *Enable European integration.* The central area is an important territory in the ongoing EU enlargement and integration process. Because of the economic dominance of the central area the new member states have to be linked by appropriate transport infrastructure. However, there is a strong tendency in Europe that road infrastructure is easier implemented than other even if priorities are in favour of other (see for instance the statements made in the White Paper on Transport). That is also to be expected in the enlargement process. This means that road infrastructure

development does not need support from spatial planning; it will be in place anyhow, but that other modes need specific attention. Therefore, the first recommendation above for the central area, enable modal shift, should be taken into account when approaching European integration via transport infrastructure.

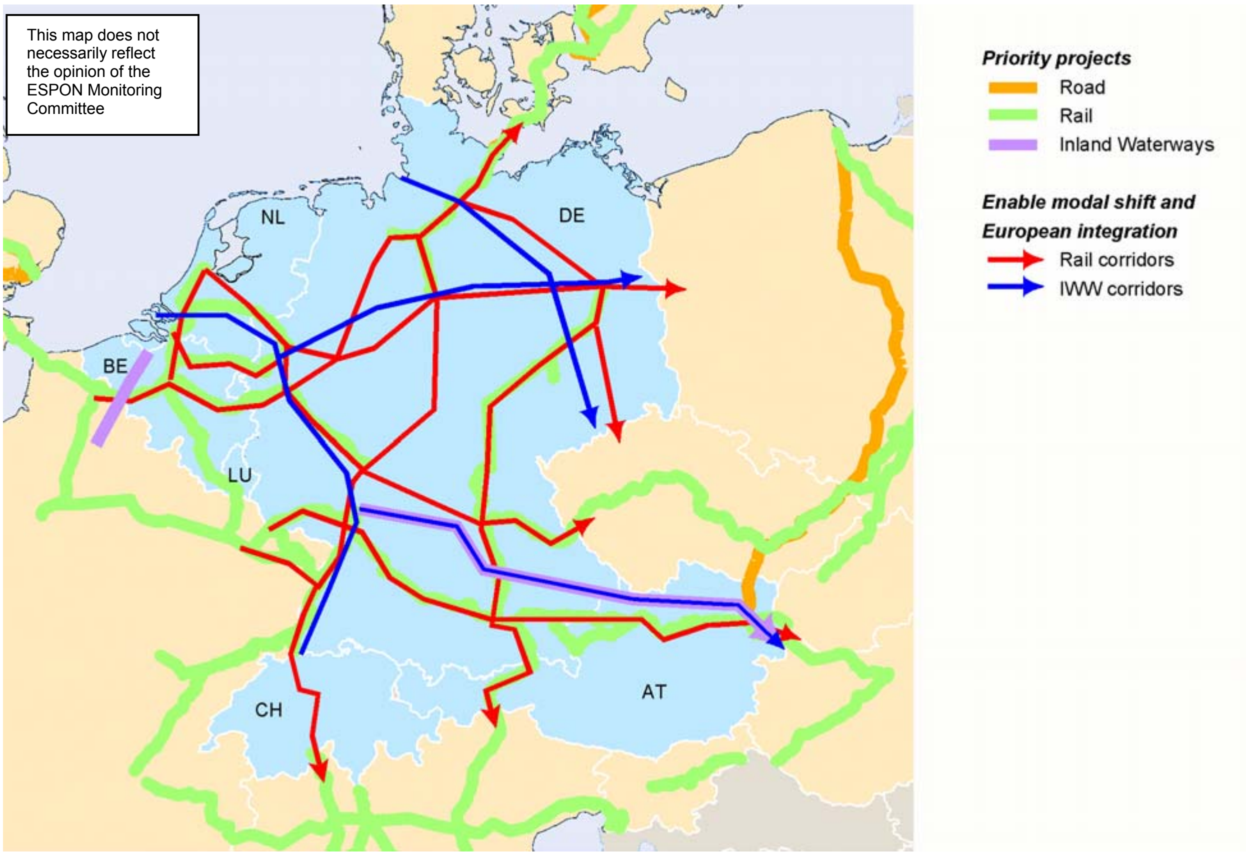


Figure 40 Basic transport policy recommendations for the central area.

3.2.5 Policy recommendations for the Eastern area

The Eastern Europe area from the ESPON 121 group perspective includes:

- the new members as Poland, Hungary, Slovakia, Czech Republic,
- the candidates as Romania and Bulgaria

This space establish the link between the Europe Community and the East news neighbours as Russia, Ukraine, Belarus and Turkey.

3.2.5.1 Findings of the indicators

Density of motorways and expressways by population is very low compared with European average, it does not exit a real motorway network as within West European countries.

If the motorways are not developed, the rail presents a good network, the main cities are linked to the international railways network.

Airports are developed in terms of traffic, but also in the capitals of the Eastern area.

Seaports endowment is relatively low as compared of the average endowment in Europe.

The cost to motorway and highways is inferior to 2 hours in most of the area, exception made of the Romania and the North East of the Poland which are more important. Nevertheless, the cost to rail station is better with less than 90 minutes.

The daily population accessible by car indicator, shows the same levels than Mediterranean area.

On the potential accessibility by road indicator (or for the rail), the Eastern area shows two space:

- One with an accessibility levels above the ESPON average as West of Poland, North of Hungary, West of Slovakia and Czech Republic,
- A second appears less than the ESPON average as the Romania, the Bulgaria, South of the Hungary and East of the Poland

3.2.5.2 Policy recommendations from 121 perspective

The Pan European Network were relevant to structure the Eastern area. Ten corridors were defined by Helsinki and Crete conference, the following table gives the details of 10 corridors

Table 9 Pan European Network (PAN)[118]

Corridors	Mains links
Corridor 1 or via Baltica from Finland to Poland is formed by one rail corridor and one road corridor	Helsinki – Tallinn – Riga – Kaunas – Klaipeda – Varsovie – Gdansk - kaliningrad
Corridor 2 from Berlin to Moscow, presents two parallel road and rail axes.	Berlin – Poznam – Varsovie – Brest – Minsk – Smolensk - Novgorod
Corridor 3 is a multimodal corridor from Berlin to Kiev, the rail and road sections are parallel.	Berlin – Dresde – Wroclaw – katowice – Cracovie – Lvov - Kiev
Corridor 4 make the link between the Europe of 15 and the South East of Europe.	Berlin/Dresde – Nurmberg – Prague – Brno / Wien – Bratislava – Gyorg – Budapest – Arad – Craiova – Bucarest – Constanta / Sofia –

[118] Thesis of Vesselin Siarov : ***Évaluation stratégique des projets d'infrastructure de transport :*** *Le corridor paneuropéen N°10 «Salzbourg – Thessalonique*

	Plovdiv – Istanbul / Thessalonique
Corridor 5 is a road and rail multimodal corridor.	Venise – Trieste – Koper – Ljubljana – Maribor – Rijeka – Zagreb – Osijek – Ploce - Sarajevo
Corridor 6 from Poland to Czech Republic is a multimodal corridor, the links exist with the corridor 5.	Budapest – Uzhhoorod – Lvov – Kiev / Bratislava – Zilina - Kosice
Corridor 7 is the Danube corridor.	Ratisbonne – Wien – Bratisliva – Gyor – Vukovar – Belgrad – Lom – Ruse – Cernavoda – Contanta - Reni
Corridor 8 is a multimodal corridor with a ferry extension (between Durrés and Bari) and from Bulgarian ports to Novorossisk (Russia).	Bari – Durres – Tirana – Skopje – Bitola – Sofia – Dimitrovgrad – Burgas – varna - Novorossisk
Corridor 9 a multimodal corridor road and rail with several ports extensions.	Helsinki – Vyborg – St Petersbourg _ Pskov – Moscou / Kaliningrad – Vilnius – kaunas – Klapeida – Minsk / Kiev – Odessa – Chisinau – Bucarest – Russe – Dimitrovgrad – Orménioin - Alexandropouli
Corridor 10 a multimodal corridor which troughs the Balkans countries.	Salzbourg / Graz – Ljubljana / maribor – Zagreb / Budapest – Belgrad – Nis – Veles / Bitola / Florina – Via Egnatia / Thessalonique

The stakes of Eastern European transport policy are doubles. The Eastern area must be organized with the others macro regions (Nordic, Central and Mediterranean area) and the news neighbours (Russia, Belarus, Ukraine and Turkish) to establish links between the European Union and the Eastern neighbours. But this area must improve the relations between the countries on its space.

Its why, the pan European corridors appears relevant to serve these objectives.

The corridors 1 connects Eastern area with Baltic area, the corridors 2, 4 and 7 are the links with the central macro region, the corridors 10 and 5 connects Eastern area with Mediterranean space.

The corridor 2 permits the transit between North of Eastern space and the neighbours as Russia, whereas the corridor ten creates the link with the turkey.

The corridors 4, 7 and 10 are the links between the central macro region and the black sea and the Egean sea and giving an access on the sea motorways.

The corridors 1, 6, 7 and 10 presents a continuity between the North of Poland and the South of Bulgaria and create in particular a virtual corridor between the East of Mediterranean sea and the Baltic sea.

The modernization of the corridors 1, 2, 7 and 10 are very important for the structuring of this space at the European scale. The multimodal dimension of these corridors is a real opportunity to inscribe and to organize the Eastern area within the internationals flows.

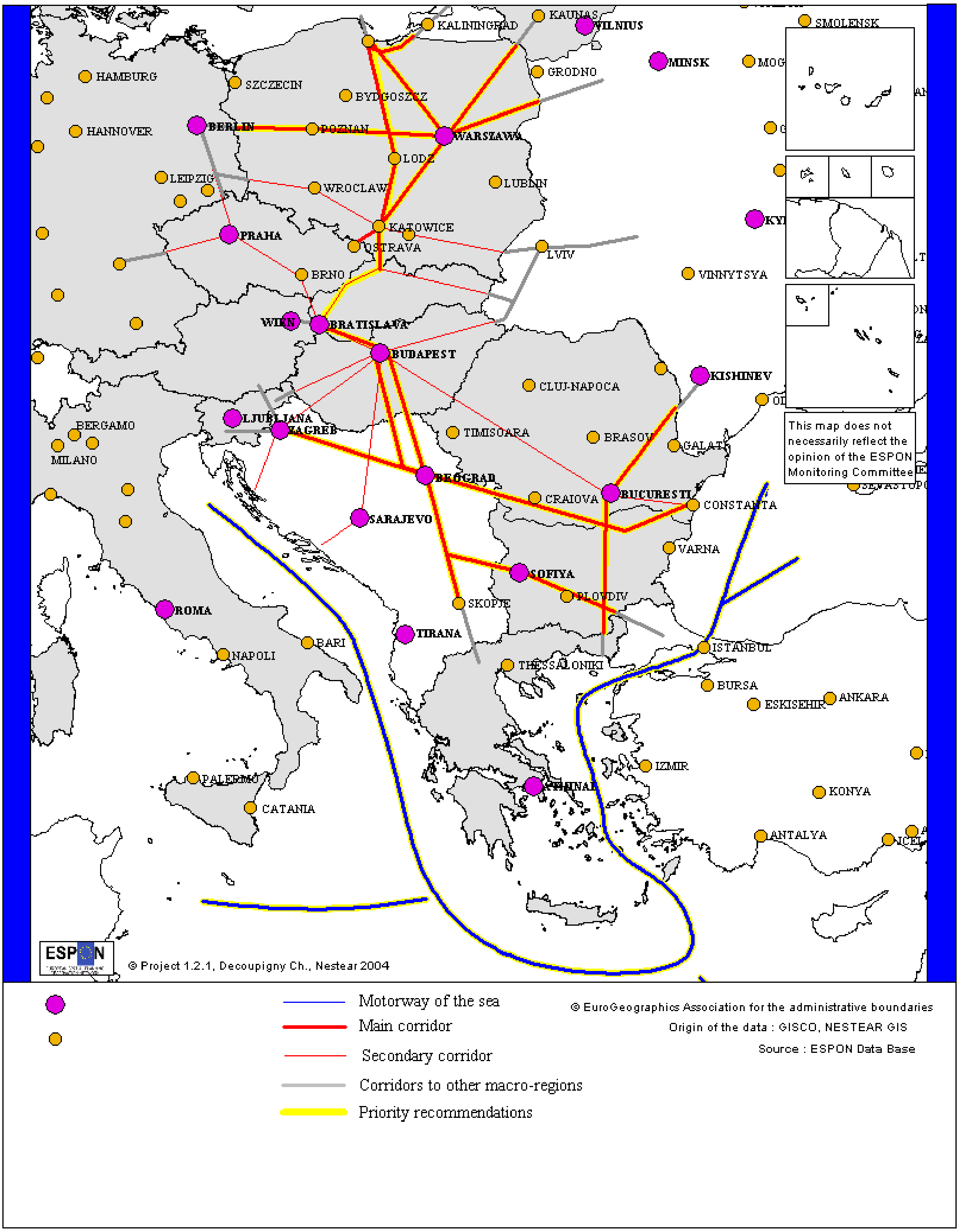


Figure 41 Policy recommendations for the Eastern areas

3.2.5.3 Synthesis of policy recommendations for macro-regions

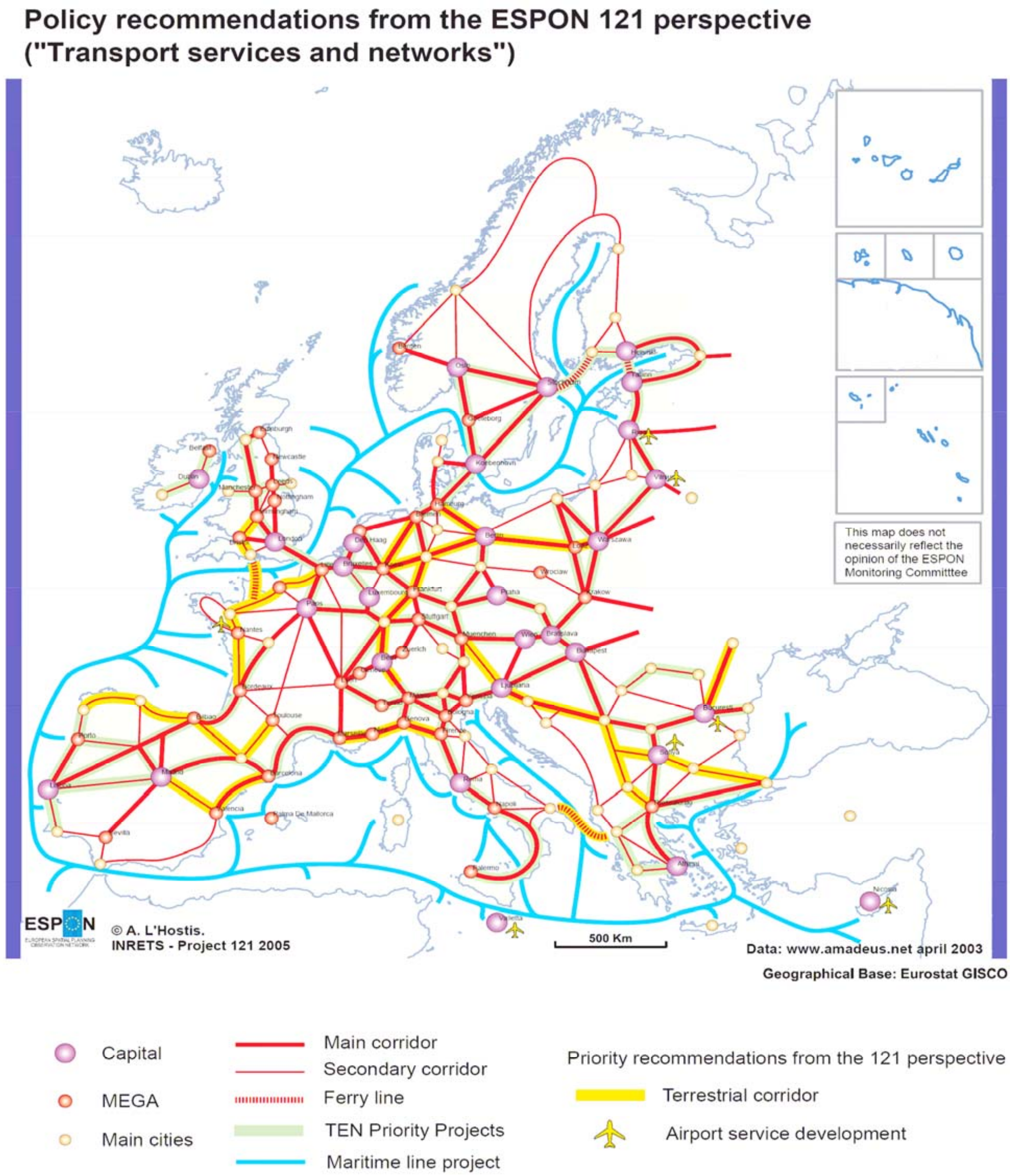
The policy recommendations proposed by the ESPON group 121 are reported on the following map. In order to build a coherent policy recommendation we have divided the ESPON space in four regional areas. The gathering of all the regional proposals are shown on the map.

Our priority recommendation list of actions:

- has for aim to address the ESDP orientations with a particular emphasis on polycentrism ;
- considers the existing European Transport Policy priorities based on the TEN Priority Projects list ;
- is based on the findings of the indicators proposed in the final report.

From the modal point of view, concerning the maritime transport mode our proposal resides in developing the network of communication along all the coasts of the ESPON space. For the most remote MEGAs, according to the indicator of return trips, we propose to develop the air services. This measure concerns Riga, Vilnius, Bucuresti, Sofiya, Nicosia, Valletta and Nantes.

From the multimodal point of view, we proposed to develop a series of new multimodal terrestrial corridors developing the set of TEN priority projects: an Atlantic Arc corridor, new crossing in Pyrenees and Alps, an East-West corridor in Germany and Poland, and a Balkan corridor. According to the global transport policy option developed in this report, these corridors privileges rail, inland waterways and ferries when necessary.



Map 93 Global policy recommendation from the "transport services and networks" perspective

Conclusion

The theme of the transnational Project Group 1.2.1: "Transport services and networks: territorial trend and basic supply of infrastructure for territorial cohesion" was large and an upstream activity of the whole ESPON network.

The starting point has been the SPESP. We have broaden the field of our task from these first results and answer to three main interrogations:

- how may the transport network constitute a key factor of more balanced, more polycentric, and more sustainable spatial development ?
- how to develop the accessibility to basic services and knowledge , in order to increase the territorial cohesion ?
- and what will be the consequences of enlargement on the preceding objective?

We are able to bring some replies and have open many questions, which is usual in a research.

The result of the diagnosis was relatively known with the classical approaches: a centre-periphery structure, a pentagon so-called blue banana and peripheral spaces less inhabited and less served by networks.

The generally accepted idea was simple: more network for better accessibility for more GDP !

The reality is more complex: networks generate traffic and even in a central good served region there still are enclosed zones. The space is heterogeneous at all scales from national to the local ones …

But this heterogeneity, this diversity is also a wealth and must be considered as such.

The European space is structured by the corridors and we have shown the potential and the effective use of the networks with the main classical indicators: travel times, daily accessibilities, externalities for transport modes as road traffic deaths, emissions of greenhouse gases and air pollutants (which are unfortunately located everywhere and particularly in great cities), …

It is possible to plan the modal transfer for transit.

The enlargement will have impacts in the central countries with traffic increase. And if the infrastructure endowment is not sufficient the firms could relocate themselves.

The temporality of transport supply and transport demand are very different, and that is the main problem.

The road network is almost sufficient in many countries and build an expressway; a motorway or a railway takes a long time. Furthermore, construction of new facilities will be more difficult tomorrow than yesterday because of the reactions of local populations and the increasing consideration for environmental problems.

It is necessary to act in the short term and to adapt the network use to the traffic evolution, in the goal of promoting modal transfer on maritime traffic and dedicated railway thanks to cost and speed voluntary policies.

Drastic measures are necessary to respect the environment and not avoid the gridlock or the relocation of firms.

The freedom of travel is a fundamental right but the obligatory travels must be limited by a polycentric organisation and also by a better organisation of production systems in the aim of developed a sustainable transport.

Our classical and new results are important but not yet sufficient and too static. Presently, it is necessary to build a prospective model to explore the scenarios set for the future.

“Gouverner c’est savoir afin de prévoir”

“Governing is knowing in order to anticipate”

Number of indicators, maps, charts and graphs

Thematic indicators	46
Synthetic indicators	3
Maps	94
Charts	23
Graphs	39

Indicators classified by issue

	Accessibility	Imbalance	Polycentrism	cohesion	Sustenable spatial devlopment	Modal transfert	consequences of enlargement	Missing links
TRANSPORT NETWORK								
ENDOWMENT								
Evolution of the motorway network (5.1.1)								
Motorway density (5.1.2)								
Railway network (5.1.4)								
Rail density(5.1.5)								
Inland waterways (5.1.6)								
Seaports (5.1.7)								
Airports (5.1.8)								
MORPHOLOGY								
Fractal dimension (5.1.9)								
Cartogram (5.1.10)								
Minkowski's algorithm (part 5.2)								
Radial analysis (part 5.2)								

	Accessibility	Imbalance	Polycentrism	cohesion	Sustenable spatial devlopment	Modal transfert	consequences of enlargement	Missing links
TRAVEL TIMES AND COSTS								
GENERALIZED ACCESSIBILITY								
Average accessibility by truck (part 5.3.6)								
Average accessibility by rail for truck								
Cities within given travel time (5.3.8)								
Average time to reach MEGAS								
Potential accessibility by road (5.5.1)								
Potential accessibility by rail (5.5.2)								
Potential accessibility by air (5.5.3)								
Potential accessibility, multimodal (5.5.4)								
Daily accessibility by car (5.4.1)								
Daily accessibility by rail (5.4.2)								
Daily accessibility by surfaces (5.4.1)								
ACCESSIBILITY TO TRANSPORT INFRASTRUCTURES								
Access to motorway entrances (5.3.1)								
Access to rail stations (5.3.2)								
Access to seaports (5.3.3)								
Access to airports (5.3.4)								

	Accessibility	Imbalance	Polycentrism	cohesion	Sustenable spatial devlopment	Modal transfert	consequences of enlargement	Missing links
TRAVEL TIMES AND COSTS								
ACCESSIBILITY TO A TERRITORIAL SERVICE								
Average time to reach the 3 nearest cities of 100 000 h (part 5.1.3)								
Travel time to reach a city of 200 000 h								
Travel time to reach the nearest MEGA by truck (part 5.3.7)								
Travel times by air between MEGAs (5.3.7)								
Daily accessibility between MEGAs(5.4.3)								

	Accessibility	Imbalance	Polycentrism	cohesion	Sustenable spatial devlopment	Modal transfert	consequences of enlargement	Missing links
TRAFFIC VOLUMES AND FLOWS								
Hierarchy of the road network (part 5.1.3)								
DEMAND OF TRANSPORT								
Personal trips generated (5.6.1)								
Personal trips attracted (5.6.2)								
Car km generated (5.6.3)								
Freight volume generated (5.6.4)								
Port traffic (5.6.8)								
Airport traffic (5.6.9)								
FLOWS ON LINKS								
Car traffic on road (5.6.5)								
Freight traffic on road (5.6.6)								
Freight traffic on rail (5.6.7)								
Flows between MEGAs								
Potential freight corridors from maritime gateways (part 5.6.8)								
Potential relations between MEGAs								

	Accessibility	Imbalance	Polycentrism	cohesion	Sustenable spatial devlopment	Modal transfert	consequences of enlargement	Missing links
TRANSPORT EXTERNALITIES								
Road traffic deaths		■			■	■	■	
Emission of greenhouse gases					■	■	■	
Emission of air pollutants					■	■	■	
Transit flow per area		■			■	■	■	
Number of tons going through nodes by road for freight		■			■	■	■	
Potential territorial externalities of road network for freight		■			■	■	■	
VULNERABILITY								
Suppression of edges				■	■			■
Suprression of nodes				■	■			■
Daily accessibility surfaces (5.3.4)	■	■		■				
Tme-space maps (5.3.8)	■	■		■			■	
Transport corridor relief maps (5.3.9)		■						■

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