TRANSPORT SERVICES AND NETWORKS: TERRITORIAL TRENDS AND BASIC SUPPLY OF INFRASTRUCTURE FOR TERRITORIAL COHESION

ESPON Project 1.2.1

Third interim report

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Summary

Summary 2

PART ONE 4

Introduction 4

1 Summary of main findings 5
- 1.1 Review of existing indicators 5
- 1.2 Indicators of transport services and networks 8
- 1.3 Typologies 16

2 Application of the ESPON Common Platform 18

3 Integration of comments to Second Interim Report 21
- 3.1 Co-operation with other ESPON projects 21
- 3.2 Indicators and data 21
- 3.3 Typologies of regions 22
- 3.4 Policy recommendations 22

4 Networking with other TPG 23
- 4.1 ESPON Project 1.1.1 The Role, Specific Situation and Potentials of Urban Areas as Nodes in a Polycentric Development 23
- 4.2 ESPON project 2.1.1 Territorial Impact of EU Transport and TEN Policies 24
- 4.3 ESPON project 3.1 Integrated Tools for European Spatial Development 24

PART TWO 25

1 Introduction 25

2 The concept of ESPON 121 25

3 Policy scope: key Issues 27
- 3.1 The general policy context 27
- 3.2 Major transport policy objectives 34
- 3.3 The spatial approach of transport 41
- 3.4 To bridge transport and spatial policies 44

4 State of the art on transport indicators 48
- 4.1 Supply of transport infrastructure and services 48
- 4.2 Use of transport networks and services 50
- 4.3 Accessibility indicators 50
- 4.4 Travel times and costs 59
- 4.5 Map-based indicators 67

4.6 Conclusions on existing indicators 67

5 Implemented indicators and maps 69

5.1 Transport infrastructure endowment 69
5.2 Network morphology 78
5.3 Travel times and costs 127
5.4 Daily accessibility 149
5.5 Potential accessibility 163
5.6 Traffic volumes and flows 174
5.7 Transport externalities 215
5.8 Network vulnerability 220

7 Typologies 230

7.1 Typology based on endowment 230
7.2 Accessibility and GDP 240

8 Conclusions 245

8.1 Main findings 245
8.2 Policy recommendations 249

Table of figures 254

References 257

References 257

Annex: Data request to Eurostat and/or other data providers 263

Table of contents 265

PART ONE

Introduction

The fundamental aim of the ESPON 1.2.1 project "Transport Services and Networks: Territorial Trends and Basic Supply of Infrastructure for Territorial Cohesion" can be developed in three questions: How the transport network may 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 objective?

These objectives of the project have to be seen for the background of the main challenge of the ESPON 2006 Programme:

- Identifying the decisive factors relevant for a more polycentric European territory, and the accessibility of a wide range of services in the context or enlargement.
- Developing territorial indicators and typologies capable of identifying and measuring development trends as well as monitoring the political aim of a better balanced and polycentric EU territory.
- Developing tools supporting diagnosis of principal difficulties as well as potentialities from infrastructure network in the field of transport…
- Investigating territorial impacts of sectoral and structural policies.
- Developing integrated tools in support of a balanced and polycentric territorial development.

This report is essentially an intermediary working document. It shows the present state of work, the available results whose form is related to the common ESPON platform and intermediary results, as well as examples on limited areas.

The originality and the essential of the group's work is focussed on indicators and new maps. In spite of the provisory nature of some methods, and so, of their results, we can see new point of view and tendencies that develop and complete classical analysis.

We have done this work with the aim of producing a result immediately understanding and interpretable. It is why this report is abundantly illustrated with maps, one for each indicator.

We have also wished to present new type of maps, some of which still at the experimental stage and subject to further developments.

These whole set of results show some convergences for phenomenon that are studied in different ways. If it is too soon to produce synthesis and propose recommendations at larger scales than that of certain countries, some maps indicate trends, and the subsequent recommendations can be envisaged.

1 Summary of main findings

1.1 Review of existing indicators

The report contains a brief review of existing indicators for transport networks and services. The review is structured 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 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 capacities of terminals such as airport, ports or intermodal terminals.
- *Transport service indicators*. There exist 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 issues such as statutory rest periods of drivers, safety or traffic regulations in 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 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.

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 which 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 detail 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 locational 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 network itself 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.

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 in a wide range of approaches with respect to dimensions of accessibility. They differ in many respects, but there are also some commonalties:

- More than half of the models use a potential type indicator, the remaining 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 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. 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 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 haven been already or can easily be calculated for the desired NUTS 3 level or for links or nodes.

1.2 Indicators of transport services and networks

1.2.1 Transport endowment indicators

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.

Motorway and expressways density shows two different groups of ESPON space NUTS3: central regions and peripherical regions, which are mostly in Accession Countries. It is a representation of the motorway and expressways map in 2001.

High-speed and upgraded rail lines density is a representation of this network in 2001, as it is calculated considering only length of network and not number of high-speed rail stations. It gives an idea of the lines that in future would define a European network (Planned high-speed lines of Trans-European Transport Network, horizon 2010).

1.2.2 Network morphology

The theory of Graph owns some indicators used to characterize transport networks as centrality, gap, accessibility, “circuity”(curve) etc. But The theory of Graph treats very little the problem of graph representation and its characteristics slowly lost interest in representation focusing instead on powerful algorithms of operational research ….

The problem of graph representation become recently again a field interest and research. Conditions of realisations of repetitive and verifiable graphs begin to be defined. But there is no morphological indicator to characterize the whole graph. The only clarification 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 except when there is an interchange.

The degree of vertex- One property of graphs allows a partial morphological description of the plan network and possibly planar graph: the degree of vertex, what is the number of road entering and coming out of a vertex. If the graph is homogenous, all the vertex are the same degree and for a planar graph this number is six.

The determination of vertex degree of network used by the CESA is obtained by a scanning of the adjacency matrix. This network is more complete than the one of NUTS2 and less heavy than NUTS3. The additing up of number of edges by column or line according to the existence of symmetry is the vertex degree.

The morphology of networks: Networks and cities are very bound in their development. Many studies show it. The « Rank Size Rule » of George Kingsley Zipf generalised by Benoit B. Mandelbrot apply also to the size of cities as Zipf quoted by Brian J.L. Berry shows it.He observes that the product ofthe city rank with its size (population) is constant :

This diagram log-log shows a straight line with a negative slope, that is a hyperbolic relation.

André Dauphiné after computation of the relations in comparative studies of networks cities of main European countries considers that the fractal dimension D of each network is equal to the value " –a" of the slope and at the scale of Europe it is 0.94.

The fractal analysis of cities and networks where developed by Pierre Frankhauser and Cyrille Genre-Grandpierre. The fractal analysis approach seems to us to complete and to qualify the density analysis and to be exactly adequate for the basic (essential) aim: measuring and reducing the spatial imbalance of EU 27.It has to be underlined that these two types of analysis are based on very different hypothesis.

The traditional approach: the indicators of density and their limits The density is defined by the ratio between a quantity or a statistical indicator (population, GDP, Kilometres of network…) and a surface of reference. The density is of such common use that its limits and its relevance are quite often forgotten by the users.

In others terms, each time there is hierarchical organisation and discontinuity, the density is not in theory a good indicator while in that case the fractal analysis seems more appropriate. An example is the use of graph theory for describing networks, because it is clearly defined by a finished collection of elements and relations between this elements.

In all networks there are zones of concentration and simultaneously empty spaces. The density is only in that case an approximation that hide this spatial distribution of networks

Morover, the density takes in account only one aspect as for example the length of network by surface unit: that is inadequate seeing that the quality of service depends simultaneously of distribution of elements and their interconnections.

There are three main approaches: analysis of square pattern, algorithm of expansion and dimension of spreading.

The hierarchical organization of the three indicators

1. The algorithm of square pattern with the fractal dimension characterize the networks morphology . This fractal dimension lies between 1 and 2 can demonstrate the self similarity the discontinuity and the hierarchy of networks
2. The algorithm of expansion or Minkovsky's algorithm describes the hierarchical and discontinuous occupation of the space and the empty organization
3. The "radial analysis" more punctual, unipolar, describes the expansion of the structure from a point in terms of network length and of covered surface if one uses the expansion of network, and consecutively the non covered surface. One can express this by the organisation of empty and full concerning one area bounded by isochronous. But the basic difference is that one do not presuppose the continuity even obtained with a mean, a density or a smoothing but on the contrary a discontinuity of the occupation area. That apply perfectly at the human localisation.

T*he algorithm of square pattern:* The algorithm of square pattern is the method the most used in the exact and social sciences One covers the structure with a square pattern with a varying area of gap. For each size of faces the number of faces that contains a part of the structure (here an element of network) is calculated.

The variation in fractal dimension in the space and to make a map possibly smoothed out.

The algorithm of expansion or Minkovsky's algorithm: It consists of expanding each point of the structure that takes the form of a circle with ε of radius or of a square with 2ε of side. This dilatation shows at each iteration a higher level of hierarchy of vacant spaces left empty and not served by the network. This way brings to the fore the non homogeneous arrangement of the structure and if it is hierarchical, its fractal characteristic.

The expansion can also be interpreted as the surface to serve from a network with a continuous speed. This is true for a network as national roads type but not from motorway or railway type. In this case it is a good indicator of servicing surfaces all things being equal otherwise. For motorway it is necessary to take only into account the connexions with other networks, the interchanges, and for railway the stations. This consideration restricts the analysis and the interpretation.

This analysis does not depend on the speed in and out the networks: it is purely geometrical.

The « radial analysis »: The last analysis is able to qualify this consideration because it tries to characterize the spatio-temporal relationship with the networks. This is an improvement of the " radial analysis" that measures the length of the structure content in a circle with a variable radius.

The « radial analysis » is adapted to the measure of possibly decrease of the network density with the distance of its local centre, but it does not take into account the topology of the network, and the connexity or not of bridges, and is ignorant of network functionalities.

The dimension of expansion of Cyrille Genre-Grandpierre takes into account this two information in raster mode: number of cells C(l) that may attain from a point with a maximum distance

It is then possible to consider, as the previously, a surface reachable from every side of bridge as far as a isochronous around the selected origin point or simply to consider a network length, a distance length or a isochronous network like Laurent Chapelon has computed it.

A good spreading indicator and a spreading homogeneity mapping are then obtained.

We use the two first ways in the order to define the European network morphology. The second way will use the Hausdorff's dimension that can to take in account unequal circles or surfaces and consecutively a specific splitting with irregular surfaces as NUTS in the first evaluation. The computing will be amply made easier and localisable and so verifiable. Moreover, space will be totally covered.

1.2.3 Travel times and costs

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 on 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 explain in the report). Due to the high proportion to 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 best connectivity than in Accession countries, but in some cases peripherical regions show best connectivity due to ports and airports infrastructure (coastal bulgarian regions, etc.).

Cost to motorways by car 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. The indicator illustrated the map of motorway and expressways network.

Cost to high-speed rail stations by car 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 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 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 high flow of passengers per year and its connectivity to the road network.

Cost to commercial ports by car shows the same concept of previous indicator but considering commercial ports. In this case it shows the minimum time to commercial ports with 0,5 Mtonnes/year.

1.2.4 Daily and potential accessibility

Indicators for two basic concepts of accessibility, potential accessibility and daily accessibility have been defined and are demonstrated for the ESPON space at NUTS 3 level.

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. Population or economic indicators such as GDP or income usually represent destination size. 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.

There are four potential accessibility indicators defined and demonstrated in maps for NUTS 3 regions of the ESPON space: potential accessibility by road, by rail, by air and multimodal accessibility aggregating over the three modes and thus expressing the combined effect of alternative modes for a location.

- *Potential 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.

- *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.

- *Potential accessibility by air* shows strong concentration of highest values 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 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 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.

- *Multimodal potential accessibility* 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. 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.

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.

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.

There is a daily accessibility indicator defined and demonstrated in maps for NUTS 3 regions of the ESPON space: daily accessibility by road.

- *Daily accessibility by road* 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), middle-south of England and north of Italy) and peripherical regions are clearly differentiated in the map.

- *'City network' daily accessibility by air* is based on timetables and on the possibility to do 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 decomposed in three levels of accessibility: no existing flight, existing flights but no possibility do business trips, business trips possible. The results show deeply asymmetrical situations that validate the method and illustrate dysfunctioning in the supply structure that can not 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 to reinforce some specific air or rail-air relations the weakness of which are revealed by this indicator.

1.2.5 Traffic volumes and flows

Traffic volume indicators capture the actual use of the transport infrastructure networks. Kma 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 (vacational). 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.

Generated trips have been calculated with KTEN, KTEN is a sequential 4-steps model able to generate flow matrices between NUTS2. They depend on: Trip rates work and study by group of age,

- Trip rates by Leisure + personal trips by GPD
- %Percent Personal/Leisure. Trips per distance depending on Type of Settelment (1,2,3,4,5,6) Based on Spatial Developement indicators (SPESP).
- Self Containing trips: Internal trips rates
- External Trips rates

Km per person by car in obligated trips is characterised by periphery and center of the ESPON space. Peripheric regions drive to regions with higher population and GDP, which are situated mostly in center ESPON space.

Km per person by car in leisure trips is characterised by eastern periphery and the rest of ESPON space. Regions in the periphery of the ESPON space drive to regions with high population and touristic attraction, mostly situated in the center and sourth of this space.

1.2.6 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.

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. 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 population 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, 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.

Three other indicators of transport externalities are proposed; methodologies to calculate the indicators have been developed and are described in the report:

- *Emission of greenhouse gases* addresses the contribution of transport emissions to climate change and will be calculated as CO_2 emissions of road transport.
- *Emission of air pollutants* addresses the regional and local impacts of transport emissions and will be calculated as NO_2 emissions of road transport.
- *Land fragmentation* addresses a major threat to habitats and species population due to major transport infrastructure and will be calculated as a land fragmentation index using GIS methodologies.

1.2.7 Network vulnerability

Theoretical background: The effectiveness of a network depends on its functionality durability and thus of its vulnerability to the risks.

Three types of risks can stop the functionality of a network, partially or totally, and more or less for a long time: the climatic risk ,the geological risk, the anthropic causes

But these various risks do not have the same effect according to the morphological characteristics of the networks. The observation is simple, the more the redundancy of a network is weak (unimodal or multimodal), the stronger is the risk, which shows the reliability theory.

As regards networks, the graph theory defined some morphological concepts allowing to locate the unimodal risk. The basic property of a transport network is to be strongly connected, i.e. from any point, one can go to any other point and can return from there.

The European multimodal network is naturally strongly connected, but it is not the case of unimodal networks

The aim of the morphological analysis of vulnerability is the determination of the arc vertex or a set of vertex or arcs whose removal would make the graph not connected. It is the point of view that is strictly contrasted with the military offensive which on the contrary, would tends to remove them.

A point of articulation or pivot is a point of articulation if, after its removal, the resulting under-graphs are not related.

Isthmus is an edge or an arc whose removal makes the resulting partial under-graphs not related.

Set of articulation by extension a set $UA \subset U$ is a set of articulation if its withdrawal involves the loss of the connexity of the resulting under-graphs G.

Set of Isthmus by extension a set of arcs will be known as a set of isthmus if its removal involves the loss of connexity of the resulting under-graphs.

The determination model of the sets of the graph articulation is under development and will be operational for August 2003.

Generalized, it will allow to measure the contribution of each arc to the effectiveness of a way, then to the whole network. It is then possible to go from the estimation of an arc contribution to the one of a way. This approach allows to qualify the analysis of the vulnerability because a way can have a weak primary contribution and a strong secondary contribution, i.e. when the minimum way is unusable.

This approach is all the more useful as the corridors are less "integrated", i.e. without precise calculation, the French network is even much more vulnerable than the German network which is a very closely-knit network.

Analysis of the climatic vulnerability

Great width floods that hit various countries during recent years well show the need for having quantitative forecasting studies to evaluate the availability of the transport systems during these events, 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) had not been evaluated yet. The CESA developed a software allowing to remove the arcs of the graph (portions of road and railway networks), of the flooded areas from a hydraulic model.

1.3 Typologies

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.
- 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.

Four types of regions can be distinguished:

- *Successful regions with high accessibility*. Regions with above-average accessibility and above-average GDP per capita confirm the theoretical expectation that the most central regions in the European core are also the most prosperous regions. Predominantly regions in central Europe and the UK fall into this category.

- *Successful peripheral regions*. These regions with below-average accessibility and above- average GDP per capita are regions which, for whatever reasons, have been able to be economically successful despite their peripheral location. Most regions in the Nordic countries fall into this category.
- *Lagging regions in the European core* These regions with above-average accessibility and below-average GDP per capita 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 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.

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 have below-average accessibility and below-average GDP per capita, whereas the regions with 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 with 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.

2 Application of the ESPON Common Platform

The success of ESPON depends largely on the possibility of a joint use of the analytical result of the single ESPON projects. Especially the integrated use of ESPON indicators and empirical data requires a coherent data structure both related to indicators and GIS.

The ESPON common platform accorded consists on that any data used in ESPON should have a documentation concerning origin of data, time reference, regional reference, author, source of data and variable description. Furthermore, related to indicators there must be a description of the calculation algorithm, the statistical computation. Concerning geo-data the kind of geo-processing and a description of data used should be indicated (see Figure 1 and Figure 2)

Table 2.1 Example for Data set NUTS level 3

NUTS_ID	NAT_ID	REG-NAM	POP_99_N3	DENS_99_N3
BE232	42000	DENDERMONDE	186,3	543,9

The metadata file includes all the information necessary for the identification of indicators and data.

Table 2.2 Example of Meta data set and documentation

		POP_99_N3	**DENS_99_N3**
S	ESPON Project	1.1.1	1.1.1
S	Source of data	Nordregio	Nordregio
S	Author	Kai Böhme	Kai Böhme
S	Regional reference	NUTS 3	NUTS 3
S	Time reference	1999	1999
S	Frequency of data	Yearly 1.January	Yearly 1.January
S	Origin of data	Eurostat - Regio	Eurostat - Regio
S	Variable name	Population 1999	Population Density 1999
S	Variable description	Annual average Population in 1000 (1999)	Inhabitants per km_ (1999)
S	In case: indication/ Source of use		
P	Theoretical Postulate	Indicator – Representation - Correspondence	Indicator – Representation - Correspondence
Q	Calculation algorithm	(Population 1.1.1999 + Population 1.1.2000) / 2 / 1000	Annual average population 1999 / Area 1999
R	Characterisation According DPSIR of the EEA		
R	Policy Relevance	Policy option relevant (i.e. ESDP)	Policy option relevant (i.e. ESDP)

SPQR

S: sample data description

P: theoretical postulate

Q: quantifiers used

R: policy relevance

see chapter 6.3

DPSIR

D: driving forces, adapt their behaviour to these more or less restrictive conditions,

P: pressures that may be positive or negative

S: state of the environmental components affected by pressures

I: impact on the environment as a whole in overall improvements or deterioration

R: society's response that is expressed by means of signals and reflected in political measures.

Data and metadata should be provided in separate files, saved under the same names with the related appendix, e.g. to indicators concerning polycentrism:

- Polycent_1_1_1_data
- Polycent_1_1_1_meta

To ensure data transfer between the projects, the potential use of different analytical software and to enable easy data integration a low technical standard would be the most appropriate. Therefore the "dbf" format should be used.

According to these standards ESPON 1.2.1 has defined these two files for each group of generated indicators (in Figure 3 and Figure 4 there is an example of the two files for transport infrastracture endowment indicators, metadata file and data file, respectively).

Following this example, data and metadata provided in separate files are saved under the same names with the related appendix:

- Transport endowment indicators_1_2_1_data
- Transport endowment indicators_1_2_1_meta

Table 2.3 Example of data set NUTS level 3

	A	B	C	D	E	F	G
1	NUTS_3	NUTS_0	REGION	DENSITY ROAD_KM_KM2	DENSITY ROAD>=85_KM_2	DENSITY RAIL_KM_KM2	DENSITY HST_KM_
2	AT111	AT	MITTELBURGENLAND	0.156746439	0	0	
3	AT112	AT	NORDBURGENLAND	0.147183737	0.02580145	0.01344841	0.0134
4	AT113	AT	SUEDBURGENLAND	0.13771584	0.009208381	0	
5	AT121	AT	MOSTVIERTEL-EISENWURZEN	0.168684946	0.024635469	0.017368107	0.01736
6	AT122	AT	NIEDEROESTERREICH-SUED	0.13522044	0.023706585	0.00338057	0.0033
7	AT123	AT	SANKT POELTEN	0.178371545	0.047425283	0.012265854	0.01226
8	AT124	AT	WALDVIERTEL	0.158761863	0.002552879	0	
9	AT125	AT	WEINVIERTEL	0.160160033	0	0	
10	AT126	AT	WIENER UMLAND/NORDTEIL	0.16622014	0.013329281	0	
11	AT127	AT	WIENER UMLAND/SUEDTEIL	0.281468792	0.065231343	0.048641791	0.04864
12	AT13	AT	WIEN	0.74888241	0.102301285	0.043893976	0.0408
13	AT211	AT	KLAGENFURT-VILLACH	0.208856087	0.053042287	0.018599803	0.0185
14	AT212	AT	OBERKAERNTEN	0.112458121	0.011968734	0.005894431	0.0058
15	AT213	AT	UNTERKAERNTEN	0.126332839	0.014973325	0	
16	AT221	AT	GRAZ	0.105860912	0.070702769	0	

Table 2.4 Example of Meta data set and documentation

	A	B	C	D	E	F
1		**Region**	DENSITY ROAD_KM_KM2	DENSITY ROAD>=85_KM_2	DENSITY RAIL_KM_KM2	DENSITY HST_KM_KM2
2	S	ESPON Project	1.2.1	1.2.1	1.2.1	1.2.1
3	S	Source of data	Mcrit	Mcrit	Mcrit	Mcrit
4	S	Author	A. Ulied/M. Font	A. Ulied/M. Font	A. Ulied/M. Font	A. Ulied/M. Font
5	S	Regional reference	NUTS 3	NUTS 3	NUTS 3	NUTS 3
6	S	Time reference	2001	2001	2001	2001
7	S	Frequency of data				
8	S	Origin of data	Mcrit	Mcrit	Mcrit	Mcrit
9	S	Variable name	Density of road and motorway network	Density of motorway and highspeed network	Density of rail network	Density of high speed and upgraded lines network
10	S	Variable description	Transport infrastructure endowment indicator	Transport infrastructure endowment indicator	Transport infrastructure endowment indicator	Transport infrastructure endowment indicator
11	S	In case indication/ Source of use				
12	P	Theoretical Postulate				
13	Q	Calculation algorithm	[total length road(km)]/[area nuts (km2)]	[total length motorways and highways (km)]/[area nuts (km2)]	[total length rail lines(km)]/[area nuts (km2)]	[total length high speed and upgraded lines(km)]/[area nuts (km2)]
14	R	Characterization According DPSIR of the EEA				
15	R	Policy Relevance	ESDP Policy Option 25.	ESDP Policy Option 25.	ESDP Policy Option 25.	ESDP Policy Option 25.

3 Integration of comments to Second Interim Report

The comments made by the Coordination Unit to our Interim Reports focused the relations with the other ESPON projects, on the level of detail in the decription of indicators, on the typologies to be developped, on the policy recommendations. The comments also insisted on a series of expectationn concenring the present Third Intrerim Report.

All the comments and questions raised have been taken into account in the development of this Third Intrerim Report.

3.1 Co-operation with other ESPON projects

The relations with other ESPON groups are developped in the chapter 4. Nevertheless, a list of key elements can be precised here, in relations with the comments to the First Interim Report.

The project 111 on polycentrism having not succeeded in proposing a stabilised list of poles, we have already started working on a specific list of cities on the ESPON space.

On the question of the combined impacts of transportation and telecommunications on the territorial cohesion, the relationships with projects 122 and 211 have to be carried. As the SPESP stated, accessibility and connectivity should be assessed simultaneously. Accessibility should not be reduced to "physical accessibility", but integrate the use of information and communication technologies to overcome physical transport barriers. The networks and flows of passengers, goods and informations have not been considered together in the ESPON architecture, and it is the role of networking between research teams to adress this crucial question.

The themes of vulnerability of networks in relation with hazards and risks has to share information, methods and results with other ESPON groups, especially projects 131 and 132. nevertheless, at the present stage, we are still missing important data, especially dealing with flooding risk analysis. The data requirements chapter relates this demand.

3.2 Indicators and data

The First Interim Report report gives an overview on the the kind of supply indicators and transport infrastructure capacity indicators used. However, more detail have been requested in the comments received especially on availability and comparability of these indicators (spatial scope, origins) as it is provided for accessibility indicators. Such developments and precisions are detailed in chapter 5.1 to 5.8.

3.3 Typologies of regions

According with the addendum to the contract, one of the aims of the ESPON is to provide a typology of regions with respect to transport infrastructure and services in the third interim report (August 2003). Nevertheless the comments to the First Interim Report questionned the comitment of the group to provide these typologies. A first set of elements dealing with territorial typologies is present in thios report (section 7 of part II).

In addition, integration and co-operation with the typologies used in the ongoing ESPON project 1.1.1 on polycentrism, as expressed before, and with typologies of regions in ESPON project 2.1.1 are discussed in the following chapter.

3.4 Policy recommendations

The comments to First Interim Report recognised a good understanding of the need for recommendations in the field of transport and planning policy with clear political scope. However, interrogations concerning the timetable for delivering these policy recommendations are mentionned. The first part of policy recommendations is included in chapter 8.3. These are the first results of our work but no definitive results. In the present report we can’t anticipate the future results as they will be produced in August 2003.

4 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. This chapter describes the networking at the various levels in more detail.

The project coordinator of 1.2.1 attended all ESPON coordinator meetings and participated in the discussions. The events provided also an opportunity to approach selected other 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 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 to relevant other 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. These cooperations will be described for the most relevant projects in more detail below.

4.1 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 are dealing from very different viewpoints and to a different degree with the concept of polycentrism. 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 main 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.

One of the results of the cooperation is that the concept of accessibility potential developed in 1.2.1 and applied here to NUTS 3 regions will be used in 1.1.1 and will be applied there to describe one feature of the European urban system.

4.2 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 main 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 as those being developed in 1.2.1. In addition, both projects will contribute to the core-periphery typology.

4.3 ESPON project 3.1 Integrated Tools for European Spatial Development

To ensure data transfer between the projects, the potential use of different analytical software and to enable easy data integration ESPON 1.2.1 has applied the ESPON common platform: all data used and calculated indicators in ESPON 1.2.1 have two files attached:

- Data set file
- Metadata file with the documentation concerning origin of data, time reference, regional reference, author, source of data and variable description. All metadata files of the calculated indicators have a description of the calculation algorithm and the statistical computation and also all the information necessary for the identification of indicators and data.

Mcrit, as partner of ESPON 3.1, has co-operated in the development and first testing of this data format with transport indicators data.

Following the same concept, ESPON 1.2.1 has recieved all information on the map layout to represent the transport indicators.

To calculate transport indicators concerning NUTS levels, ESPON 1.2.1 has used integrated databases proportioned by ESPON 3.1 on population, GDP, area and employment. Apart from this data, this group has made a data request to ESPON 3.1 of information on hands of EUROSTAT or other institutions (to be explored) that could complement works of this group in data assembling (some are already delivered).

PART TWO

1 Introduction

This part presents the essential of undergoing work after an update of First Interim Report's elements (sections 1, 2, 3 and 4).

The core contribution is presented in the section 5 "Indicators of transport services and networks", section 6 "New maps types" and the section 7 "Typologies".

As requested, each indicator (classical or new) is illustrated by an associated map. To make the reading easier, the layout is the same for each of these indicators.

It constitutes an important work a part of which is still provisory or incomplete, especially for the new indicators, reflecting the short delay since the last Interim Report but also the potential of our work's evolution.

2 The concept of ESPON 121

The research questions of ESPON 1.2.1 cover issues 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 should be 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. Compilation of national studies with European focus should be undertaken.
- 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 (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 ongoing ESPON project 1.1.1 on polycentrism and to typologies of regions in other ESPON projects.

- 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 (structurally weak areas, islands and mountain areas).
- The role of services of general interest as vectors for territorial cohesion: constitution of trans-European networks of services of general interest (in particular, in rural areas).
- The different kinds of complementarity and exchange processes (level of multi-modality) 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, including identification of an operational benchmarking system that could be applicable with regard to the data and indicators available.
- 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 will have a strategic and territorial approach. Therefore, it relays in data and knowledge to be obtained from studies and researches mostly developed in the transport field. More than deepening transport specialised questions, the aim is integrating in them the still missing territorial dimension.

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. The proposed concept will result in tangible and innovative results. The concept for the development and implementation of indicators consists of five steps which correspond to five different work packages:

- Review of the state-of-the-art and existing indicators (WP1)
- Demonstration of existing indicators (WP2)
- Definition of advanced indicators (WP4)
- Implementation of advanced indicators (WP5)
- Integration of indicators (WP6)

3 Policy scope: key Issues

3.1 The general policy context

ESPON project 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 stage 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 interfere with many other policy objectives so that it is difficult to present a consistent framework for transport policy objective 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 sector 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 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 way 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 cooperation at national, international and local level, with more and more often participation of citizens. All these elements must be parts 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 which 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 on going project which considered 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 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 has 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 have been prepared by DG TREN and is mainly focusing 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 help in this mobilisation and new ten guidelines in 2004 should be a new step towards European spatial development. 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 and regional and spatial policy:

- because ESPD Scheme become 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 tried: and ESPD is clearly related to TEN development and consequently to TEN operating system and therefore to general transport policy regulation
- because the EU enlargement put forward 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 were a first scheme of Mediterranean corridors which will now analysed in depth in the new MEDA programme ; for these operations there will be a clear mobilisation of all financial means of EU.
- Because of the necessary renewal of structural funds policy 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 3.1.1 *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 3.1.2 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
Maximaze 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 cost 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	Indigeneous 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 3.1.3 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 3.1.4 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 center 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 difussion to larger landlocked areas through regional capilarity	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 3.1.5 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 of GPD. Aggregation: CBA including the cost of externalities. Muticriteria analysis for non-monetary elements (...)

3.2 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 subsidiarity 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 point 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 pointed 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.

3.2.1 Liberalisation and harmonisation: the market regulation

Liberalisation has been the “master word” for the implementation of the single market in transport. Liberalisation 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 was probably the most difficult mode to liberalise: because there is a closed 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 has 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 way 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. Specially 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. The spatial dimension was not stressed in the White paper, as mentioned before, but the consequences of market regulation on the spatial development will be an important point of analysis of this ESPON project.

3.2.2 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 care, 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 then 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 to 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. Till 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 to favour 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 revitalised rail and promote intermodal transfer
- to promote short sea shipping and inland waterways

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, 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 when the container are distributed (or collected).

The combined transport

The combined transport is 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 tunnel might be difficult to build and operate, or might create important nuisances to the environment.

The use of intermodal techniques require investments in terminals, maritime terminals 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 road 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.

Short sea shipping

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 fare 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.

3.2.3 The implementation of TEN network

Implementation of TEN network 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 be 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 an European space.

Two types of European network were prepared :

- a HST 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 when 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 including also energy and telecommunication networks.

From the transport policy this gave rise to:

- different modal TEN European networks for road, rail, inland waterways with for rail a conventional rail network in addition to the HST network.

Such rail network should irrigate the European regions. Concerning the air transport a network of airports was defined including different levels according to the role of the airport in international, European and national services. However it was not possible to introduce such a typology for ports because of the competition existing between them and the ports mentioned were more a list of ports than a structured definition

of a network of European ports. For inland terminals the same type of difficulties arose and the TEN proposals for infrastructures tended to be more a juxtaposition of national schemes than a genuine European network.

- an effort to build an European intermodal network stressing intermodal solutions and including basic principles relative to efficient use of such network from an economic but also an environmental point of view
- 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 network 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 are stressed including with 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 are 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 forwards.

The question of funding this project 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 which privileged the spatial dimension from regional or European spatial development point of view.

3.3 The spatial approach of transport

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

At local level such approach does exist for a long time and in particular in urban planning although a clear understanding between land use pattern and mobility was not always obvious: progresses are made in this direction.

At national level, infrastructure scheme does 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 privileged 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 an 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 was refined including redeployment of old industrial places and stimulate 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 network 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 strengthen.

3.3.1 European spatial development perspectives and the polycentric development

The polycentric development concept is central in the ESPD. 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 "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.

Starting from this "bottom up" scheme of socio and economic relations, identified in the space the polycentric framework will include:

- settlement structure of urban places offering different levels of public services: pointing major growth points and development axis
- location of infrastructures and routes as well as nodal points, distribution centres, logistic facilities
- economic structure of the region with location of different types of accessibility
- the open space structure which will allow expansion but also point relations with neighbouring regions ; EU market and world economy.

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.

3.3.2 Structural funds policies

Structural funds policies have developed progressively in a process of "deepening" a 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 policy programme 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 also 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 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.

3.3.3 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 will 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 which 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 ESPD as well as in the regional development policies, the importance of European 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 network 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 specific context and European diversity requires at the same time more complex transport analysis in terms of multimodality and intermodal solutions. Infrastructures are not the unique answer to this problem of accessibility and the availability of services, the quality of services must also be considered.

From now the interrelations between regional development, spatial analysis and transport are strong and both approaches, the spatial and transport opposite, must be combined in a more efficient way.

It is on this interrelation that the task network and services will concentrate in order to adapt the decision making tool and the use of GIS.

3.4 To bridge transport and spatial policies

Although the international organisation of institutions always introduce 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 progressed on both fronts towards a better understanding of the role of transport in spatial scheme.

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.

3.4.1 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 which 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 opportunity to adapt to a diversity of regional context.

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 open within 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.

3.4.2 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 become essential. In a world where the logistics policy 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.

3.4.3. A multilevel governance

The bridging of transport and spatial policies is obviously a long term objective which calls for a new definition of long term decision process. This process 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 for CBA techniques have been privileged for the choice of priorities. These techniques are able to take into account external efforts through monetarisation. But this techniques 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 their 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.

4 State of the art on transport indicators

This chapter provides a brief review on existing indicators for transport networks and services. It commences with the supply side of transport infrastructure and services. Then, indicators for the actual use of transport infrastructure and services are summarised. After that, the concept of accessibility as 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 kind of shopping list for the next phase in ESPON 1.2.1, namely the demonstration of existing indicators to the territory of EU15 plus the candidate countries plus Norway, Liechtenstein and Switzerland.

4.1 Supply of transport infrastructure and services

This section gives a very brief overview which kind of supply indicators are used in relevant documents and studies. Indicator groups 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 list form.

4.1.1 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 4.1 gives an overview on these types of indicators.

Table 4.1 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

4.1.2 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 which are not independent from the kind of service supplied, Table 4.2 can give only broad classes of capacity indicators.

Table 4.2 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 airport by category Capacity of port by category Capacity of intermodal terminals

4.1.3 Indicators of transport services

Existing indicators of transport services can be grouped in five 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 issues such as statutory rest periods of drivers, safety or traffic regulations in form of aircraft grounding or traffic banning during night time.

Table 4.3 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

4.1.4 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 (see Table 4.4).

Table 4.4 Existing indicators of transport vulnerabilities

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

4.2 Use of transport networks and services

This section provides a brief overview 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.

4.2.1 Traffic volume indicators

The actual use of the transport infrastructure networks and services is captured by traffic indicators. 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 resources and pollution as well as indicators describing transport safety.

Table 4.5 Existing traffic volume indicators

Indicator type	**Sample indicator**
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

4.2.2 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 (see Table 4.6).

Table 4.6 Existing traffic flow indicators

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

4.3 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 locational 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 network itself 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. Then, new accessibility models at the regional scale are briefly presented. Finally, pan-European accessibility models are reviewed in terms of their dimensions.

4.3.1 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:

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. The functions g(W_{ij}) and f(c_{ij}) are called *activity functions* and *impedance functions*, respectively. They are associated multiplicatively, i.e. are weights to each other. That is, 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.

These 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; see Table 1):

- 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 (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 4.7 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. Or, 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.

4.3.2 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 region, 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 top 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 were 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 scenarios. Results were presented in maps showing the outcome of the different indicators and scenarios.

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 which 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 time table 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.

4.3.3 Accessibility models for Europe

Over the last decades a vast number of accessibility studies addressing European core-periphery issues have been published. This 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 often not 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-peripherality 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 in map form 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 time table information. Indicators are presented in numbers and map form 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 fastest mode. Results are presented in tables and map form 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 which 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 capable to include European or national regulations in form of constraints, example 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 that 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.

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 offered 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.

The 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 commonalties:

- More than half of the models use a potential type indicator, the remaining 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 4.8 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	Fastest 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 agglomerations (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 multimodel	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 agglomerations	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	EU15
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

4.4 Travel times and costs

4.4.1 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.*

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 succesive applications, as well as for the technologic evolution of communication networks during the last decade, few aspects of the earlier mathematical formulation need to 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.

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 can 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 locational 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 locational decisions and induce spatial development, in the context of current economic and technological changes.

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 intutively 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 sistematic 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, depite 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 exercice 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 conectivity approach in classic forecasting models goes beyond the aim of this paper, but is an extremely interesting research area.

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 dimmensionally 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 contribution 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 minimun 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:

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

$$tax_i \geq taj_i \geq tam_i \, , j = 1 \ldots N$$

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 ordre to reduce the importance of most extreme values:

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

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 ($\delta_i = 0$) 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 ($\delta_i = 1$) 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 assigment 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 countings (the same service can be considered in all terminals where there is a stop). In this case a good aproximation 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 succesive alternatives until the connection providing Sxi at taxi is reached.

Pl is the probablity 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).

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.

4.5 Map-based indicators

Existing indicators of transport infrastructure and services are either presented in tabular form, in diagrams or, mainly, in cartographic representations. Maps do show transport infrastructure, transport services, transport volumes and flows, and accessibility either for transport links, nodes or regions. Some maps do show quasi-continuous surfaces of indicators based on a raster representation of space (Spiekermann and Wegener, 1996; MCRIT, 1999).

In addition, there are some methodologies developed in cartography which 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 maps* 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. 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. This change of the metric results in distortions of the map compared to physical maps. Network sections with low travel speed lead to an enlargement of that area on the map, sections with high travel speed lead to contractions and shrinking of that area on the time-space map. 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 (Cauvin, 1994, Spiekermann and Wegener, 1994b).
- *Crumpled time-space maps* and costmaps go a step further in that they are able to show more than one transport mode in a map. Here, the location of nodes and cities will not be changed. The distortion due to different travel speeds or costs is introduced through the distortion of the surface in the third dimension. The length of an arc represents the travel time or cost on that link. If then, for instance, the travel time is slower than the physical distance, the arc is divided into two arcs of equal length, the middle point of the two arcs is pushed down until the length of the two arcs corresponds to the travel time. This results in a three-dimensional representation 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 also to compare the emerging European high-speed rail network in Europe with other modes (L'Hostis, 1996).

4.6 Conclusions on existing indicators

The chapter has provided an overview on existing indicators describing transport infrastructure and services. Indicators do range from transport infrastructure and service supply via their use in form of traffic volume and flow indicators towards territorial indicators in form of accessibility indicators.

Existing indicators can 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 haven been already or can easily be calculated for the desired NUTS 3 level or for links or nodes.

Any indicator presents just a simplified model of understanding and explaining reality; by definition, they just “indicate” certain aspects of the problem or the concept being studied while other aspects remain dark. Successful indicators, rather than trying to explain everything, have to be focused on key aspects, illuminating those aspects more relevant to the problem under scrutiny. Therefore, multiple indicators, as scientifically consistent and policy-meaningful as feasible, are needed to get useful insights.

To be policy-relevant, indicators have to be defined to measure the accomplishment of policy aims, and discriminate properly between different places and between different moments in time, in order to assess the potential impacts of a given policy.

The purpose of the study is one the one hand updating existing indicators and advancing in new indicators scientifically consistent and relevant to contemporary trends on transport, and on the other, gathering a policy-meaningful set of them, in the sense already mentioned. The conclusion for ESPON 1.2.1 is that it should be tried to take advantage of the variety of existing approaches and models and should try to fill indicator gaps in relevant fields. In addition, raster-based maps, time-space maps and crumpled time-space maps may be considered as a starting point to develop innovative cartographic methodologies in ESPON 1.2.1.

5 Implemented indicators and maps

5.1 Transport infrastructure endowment

5.1.1 Density of motorways and expressways by population

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 and results

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. Red 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 greens 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.

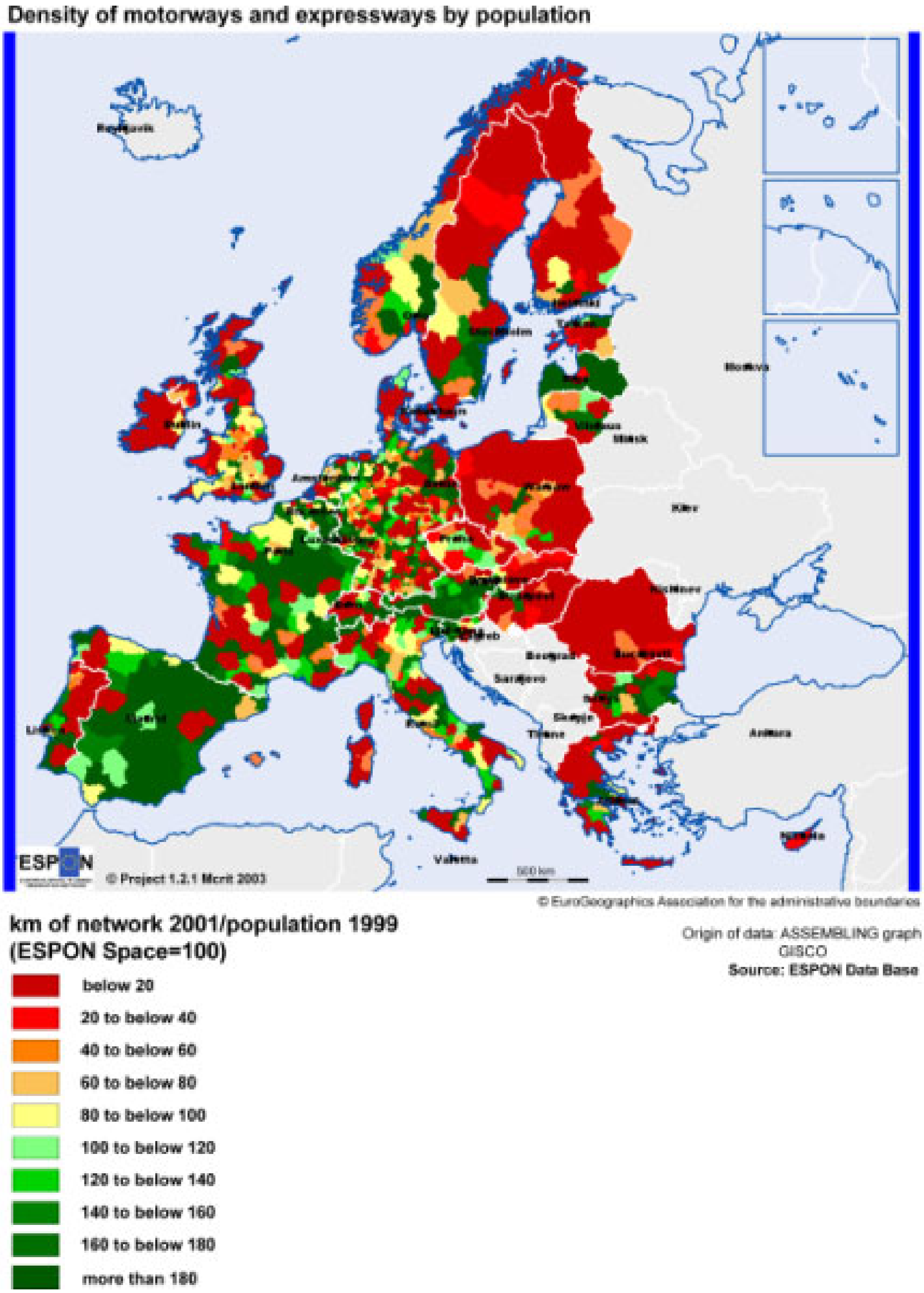


Figure 5.1.1 Density of expressways by population

5.1.2 Density of rail lines by population

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 first sections 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 the previous section.

Application and results

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. Red 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 greens 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.

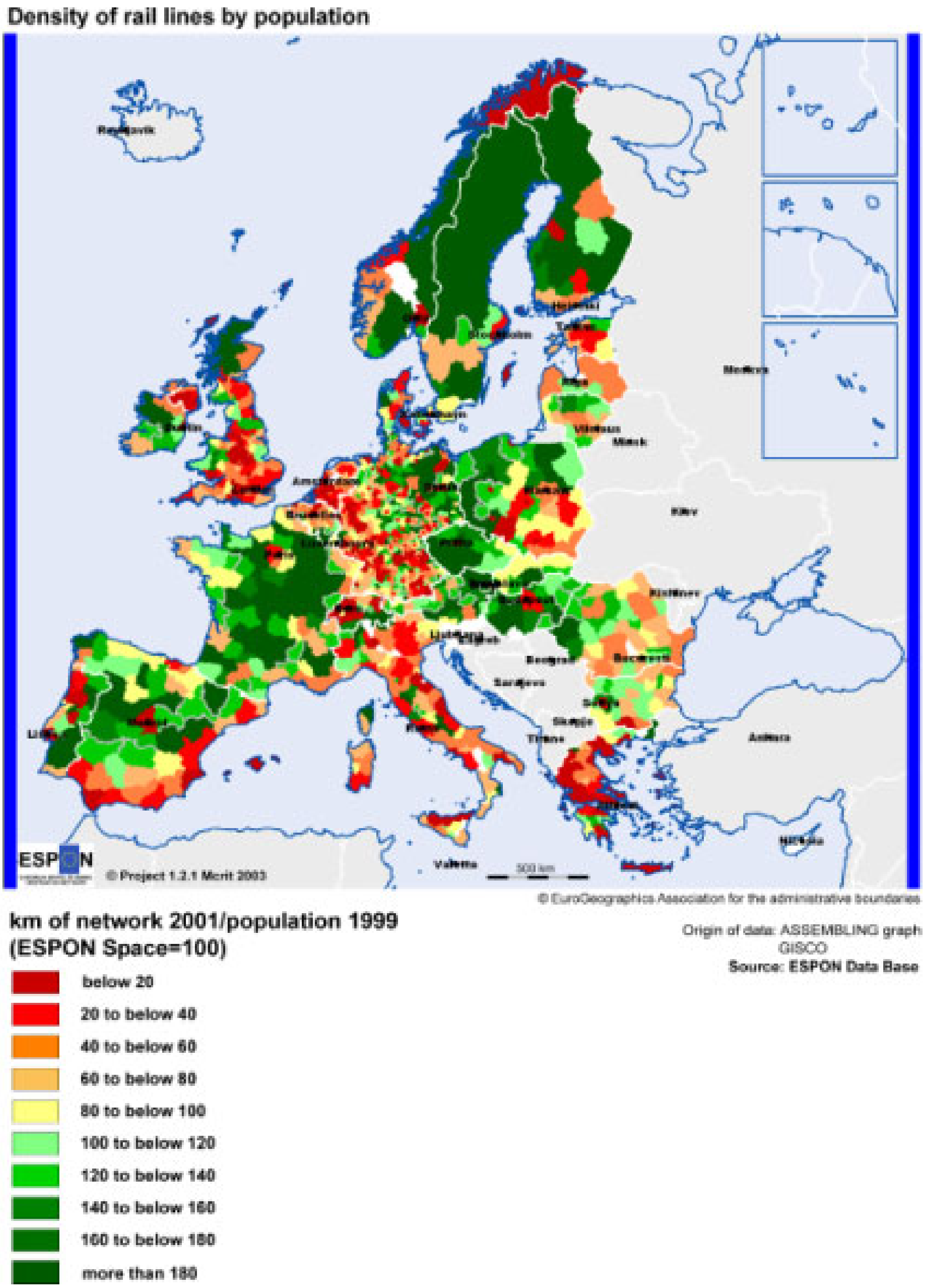


Figure 5.1.2 Density of rail lines by population

5.1.3 Commercial seaports infrastructure

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 section.

For each region the traffic volume of all the seaports has been aggregated.

Data requirements

The data requirements are the ASSEMBLING graph and the capacity of the seaports from the EC seaports classification.

Application and results

The commercial seaports infrastructure (seaports with a traffic volume higher or equal to 0,5 Mtonnes/year) has been calculated for all NUTS 3 regions of the ESPON space. The seaports with the highest volumes are the ones located in the North Sea. Rotterdam is by far largest port in Europe, followed by other major hubs like Antwerp, Hamburg and Bremen. In many ways, the Benelux countries could be called the gateway or “main port” of Europe. Regions with seaports in Great Britain and the Netherlands dominate seaport handing in Europe followed by Germany, Belgium, Spain, Italy and France. Islands and some peripheral regions, like the ones from the Scandinavian countries, are dependent on maritime transport. As seen in chapter 5.1.4, these regions have the highest number of ports, although they are small due to their natural locations, which implicates restricted accessibility and therefore less activity.

Other alternative measures such as traffic in terms of containers may also provide for useful indications.

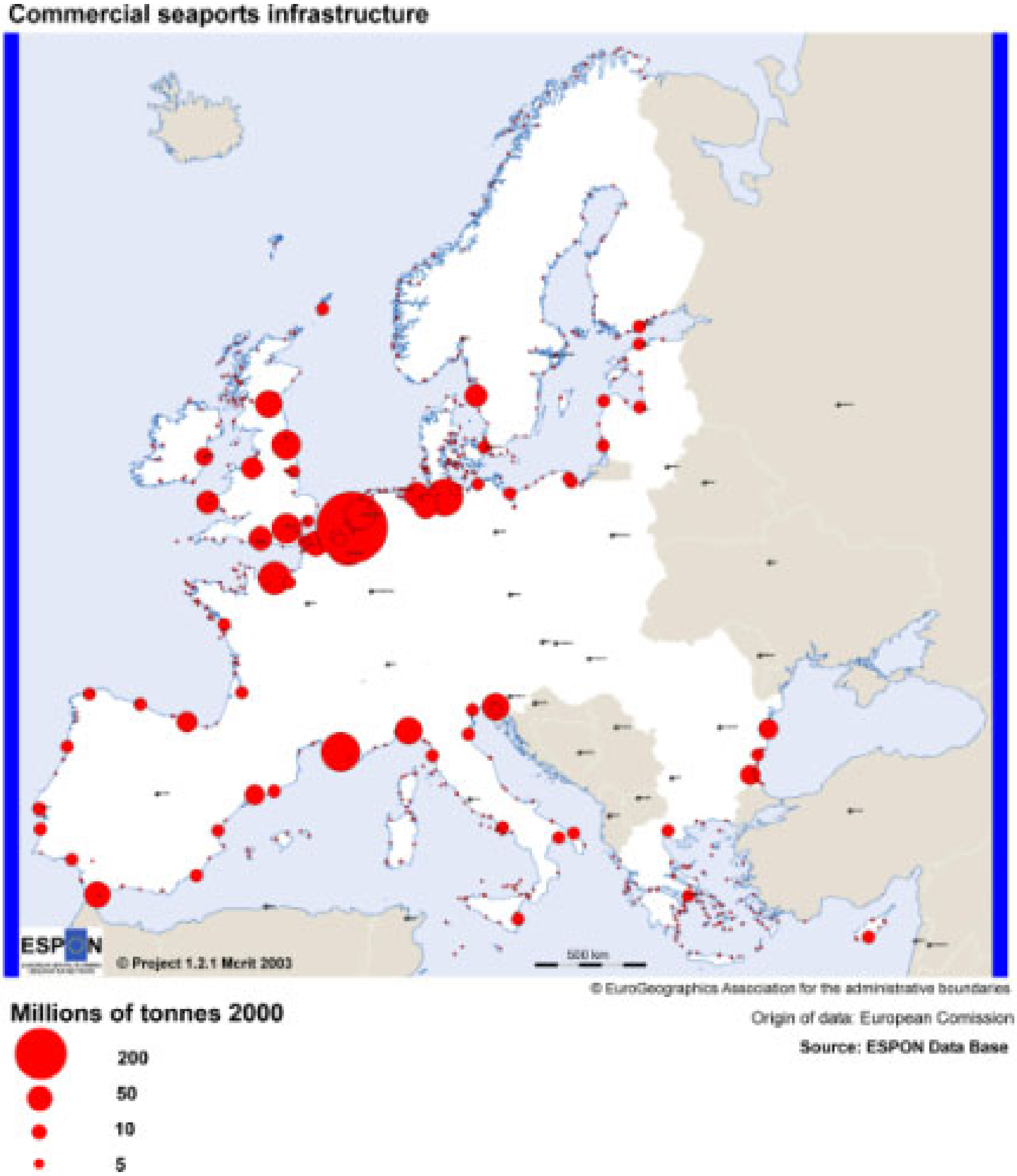


Figure 5.1.3. Commercial seaports infrastructure

5.1.4 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 and the traffic volumes of each commercial airports (Mpassengers/year of 2000) from the EC airport classification.

Application and results

The commercial airports infrastructure (with a traffic volume higher or equal to 0,5 Mpassenger/year in 2001) has been calculated 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. 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 is 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).

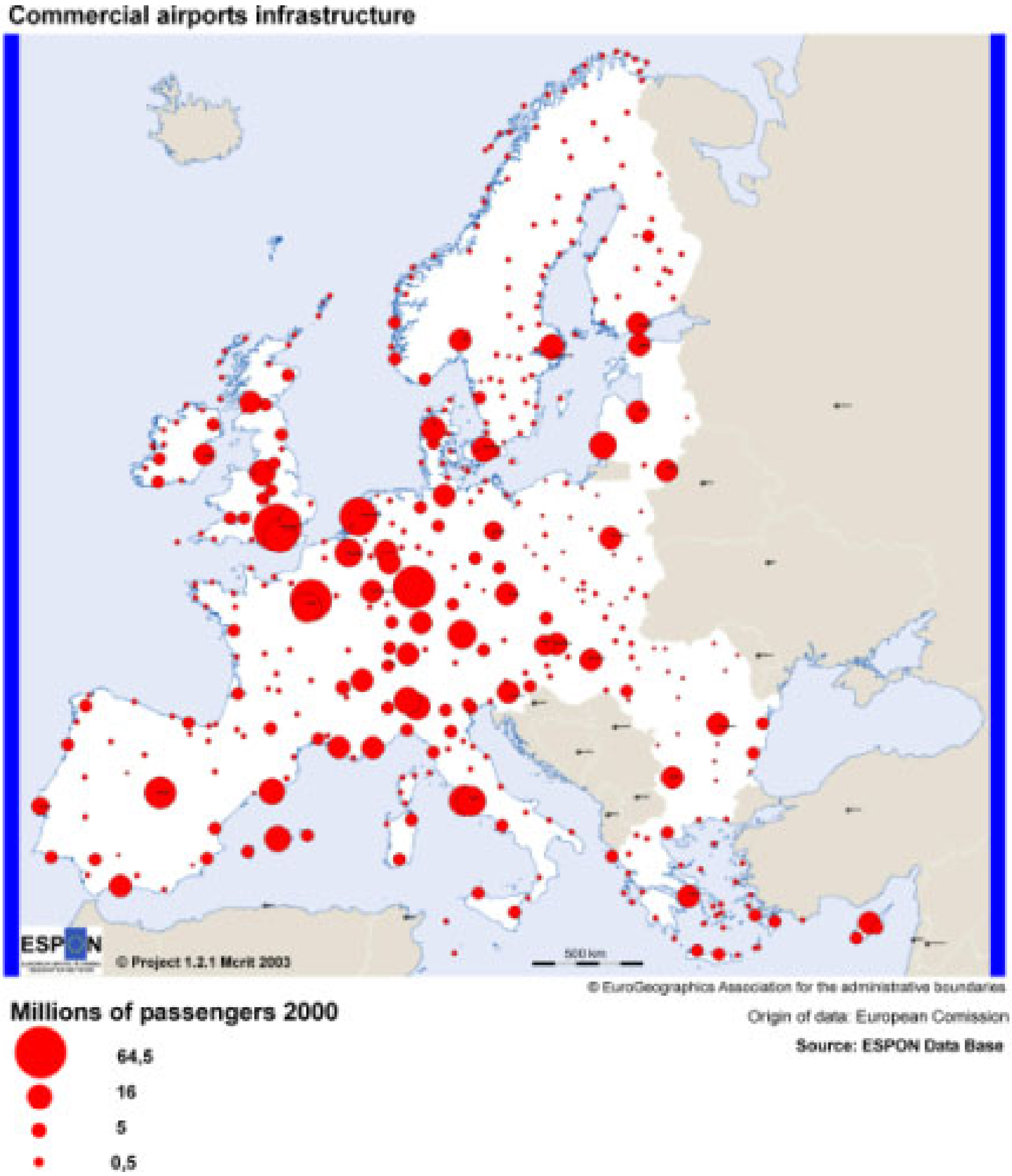


Figure 5.1.4. Commercial aiports infrastructure

5.2 Network morphology

The morphology of transport networks reveals the structure of a space from a geographic, economic and political perspective. It is the inheritance of the past : if France and Spain have a centralized network and Germany a meshed network, it is not by chance.

However the morphology of networks also partially determines at least the future evolution of a territory and a certain number of its potentialities.

Independently of these general aspects, transport networks undergo the constraints of their morphology as they benefit from specific potentialities.

The morphological analysis will begin with a classic analysis; the properties of the vertex of the network with the road example, then the analysis of the shape of the network will follow as a consequence of the degrees of the axes and of the physical properties of space.

This classic analysis inspired by geometry and by the physical geography will be qualified by another perspective, on the one hand by the consideration of the distribution of the population and the GDP in European space and on the other hand by the use of a more unusual cartographic shape: the cartogrammme, that is the distorted map according to the importance of a particular attribute of the zones under consideration.

Secondlyas a supplement to the density analysis of the previous section, we will develop a fractale analysis intended to underline the dual aspect of the density that is to say its discontinuities, its imbalances.

With the " square pattern " algorithm, we will calculate the fractale dimension of the considered networks, which characterizes them globally and by country, then by using the expansion algorithm of Minkovski we will study the spaces cover by networks, then we will propose an example of radial analysis allowing us to approach the same phenomenon from points or from places but also and simultaneously the spreading and the local polarization.

Lastly we will present a view in relief of the European corridors by means of "creased" maps or chronocartes, underlining the consecutive deformation of the speed of the transport networks of the various speeds used on various networks by various modes.

5.2.1 The degree of vertices

Rationale

One property of graphs is that it allows a partial morphological description of the plan network and possible planar graph : the degree of vertices, which is the number of road entering in and coming out of a vertex.

Method

The determination of thevertex degree of network used by the CESA is obtained by a scanning of the adjacency matrix that describe the graph in the computer.

The graph does not has a spatial shape. The aim is forthe graph to represent the network and each node to have its spatial coordinates

Data requirement

This CESA network is more complete than the one of NUTS2 and less heavy than NUTS3. But each node correspond to a city and it is signifiant.

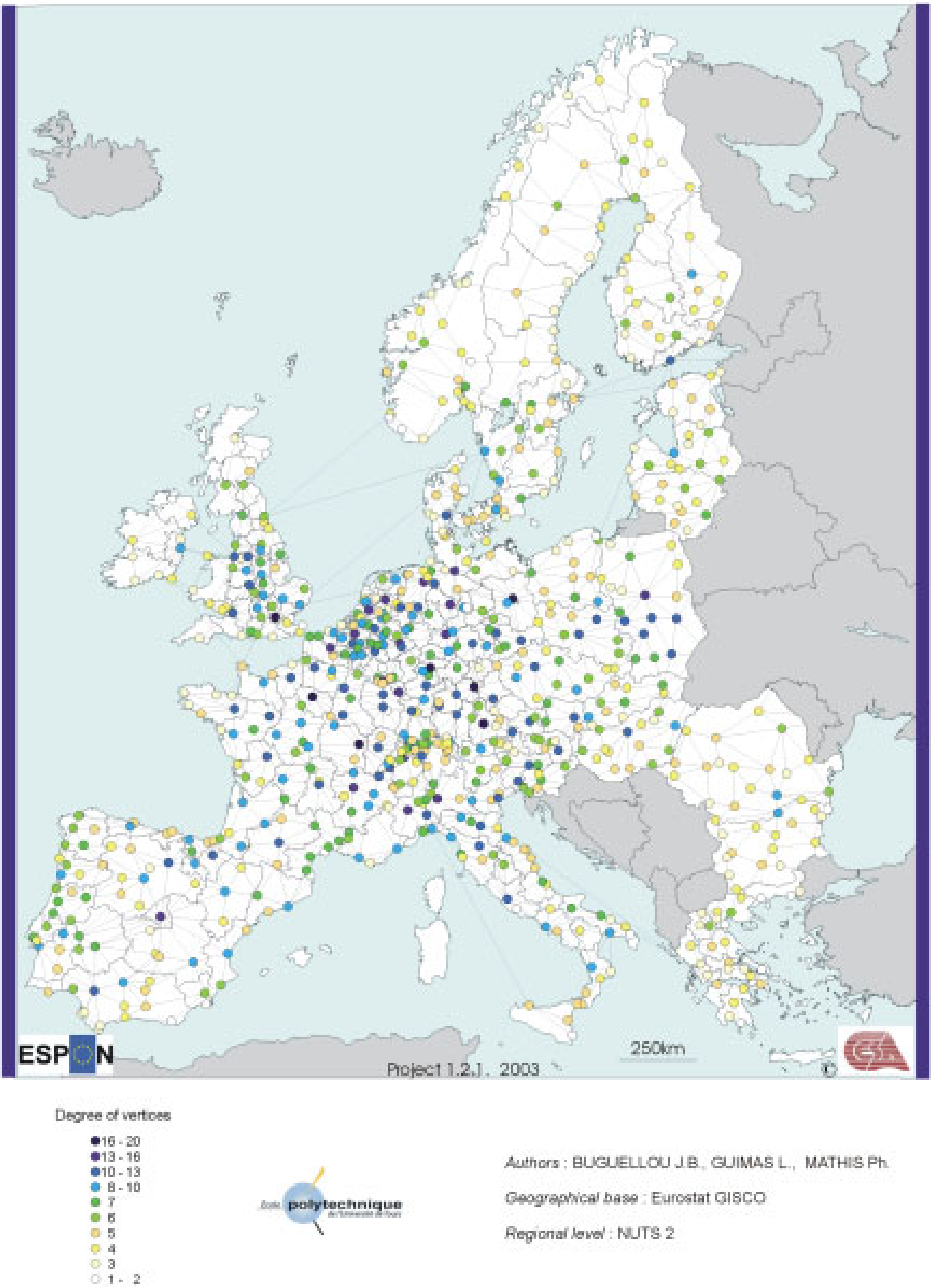
The vertex degree is determined by adding the number of edges by column or line according to the existence of symmetry.

Demonstration example

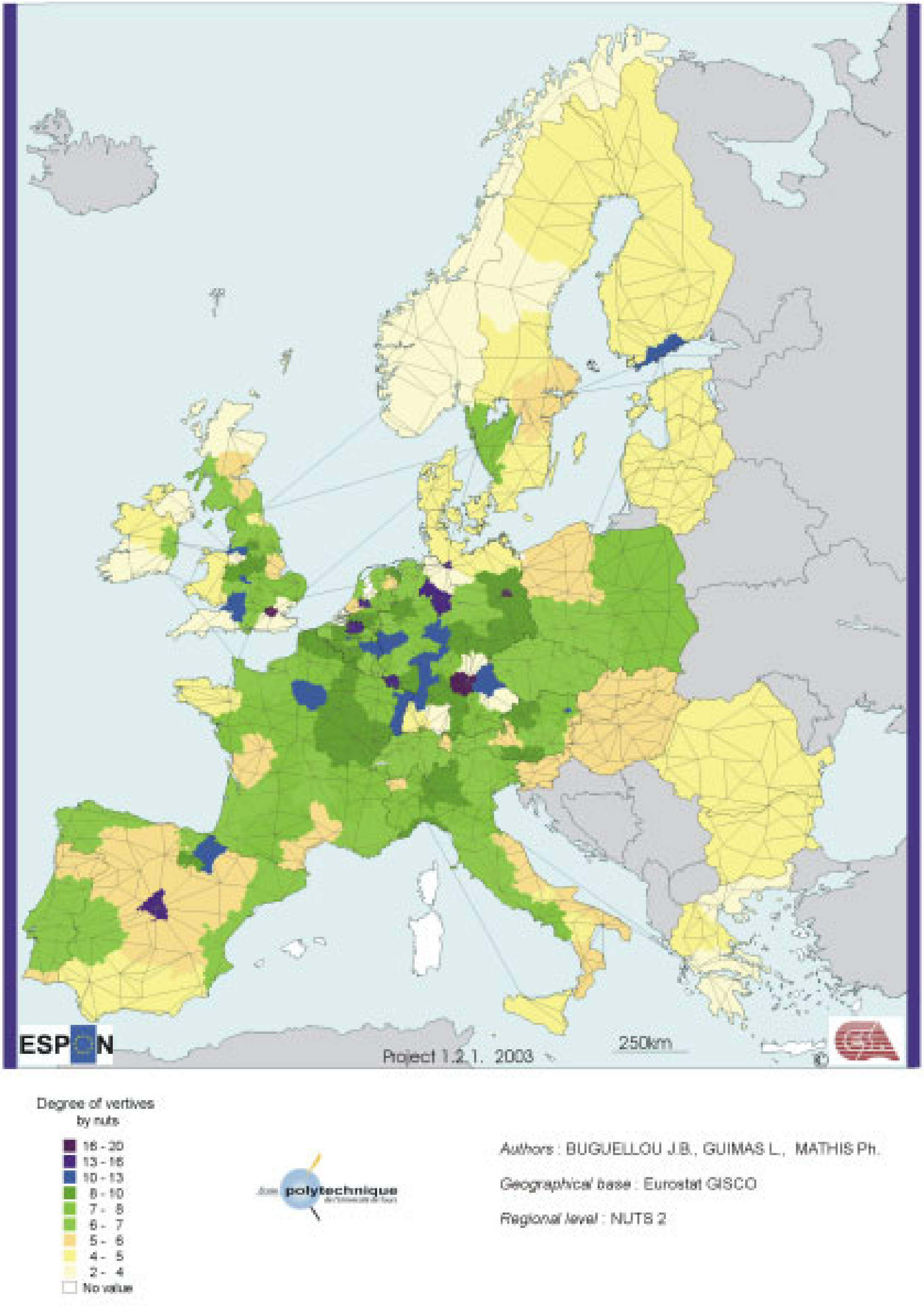
The nodal map below shows that the considered network being studied is not regular and that some cities have higher degree than others. These are often the biggest cities.

Another map present these values in the NUTS2 ESPON form.

We may observe that the degrees of vertices in Germany are more higher than in the peripheral regions. This remark will be corroborated by many others observations.



Degree of vertices of the European transport network



Average of vertices' degree of the European transport network by Nuts 2

5.2.2 The morphology of networks

Rationale

The aim is to determine the principal ways, the corridors of different modal network and mainly the corridors used by the heavy trucks that are the most important mode of freight transport at the present time.

Method

We used the modal networks and the most significant flows. Two methods are possible : the traffic counting or the traffic models of goods. We take into account the shortest paths and the potential flows for the projection and futurology;

Data requirement

The data used are the network GISCO and for the nodal modelling the CESA Network that is nodal. In this report we also used the data of traffic volumes and flows, see section 5.6.: Freight transport and assignment

Demonstration example

We show the European road network of GISCO, the bimodal road and ferries network and the synthesis, the European corridors and the principle of national network.

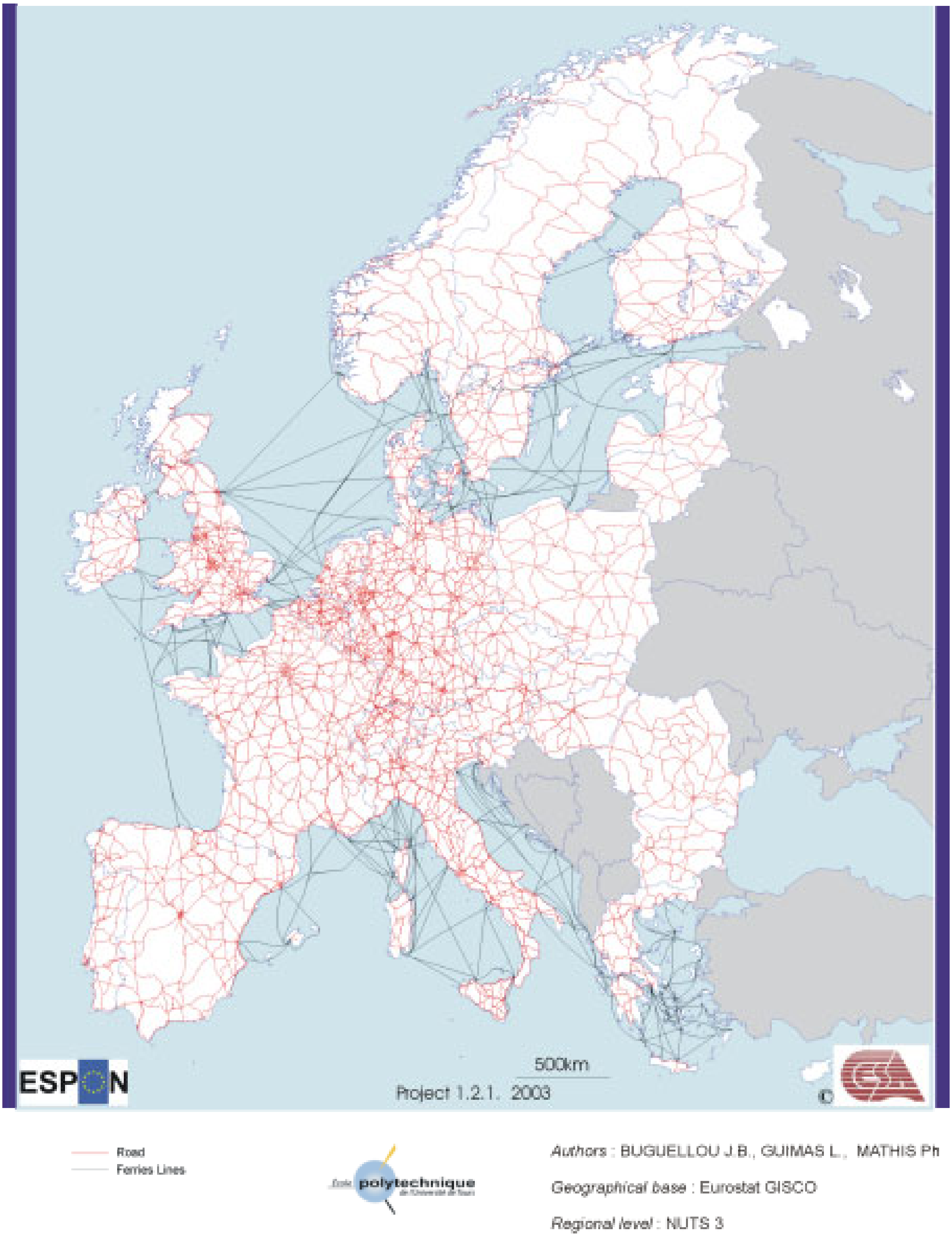
Comments

We have three principal types of network corridors:

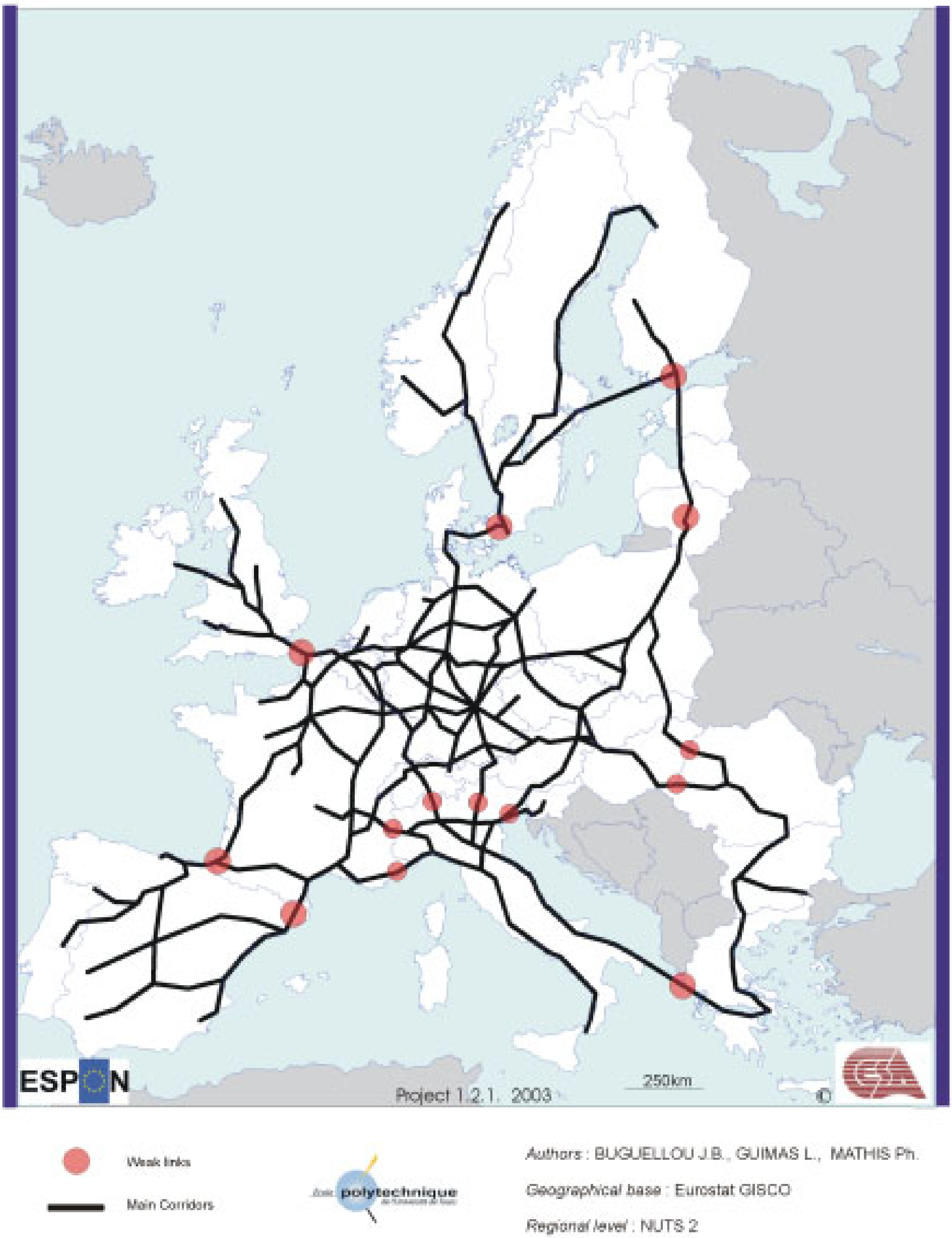
- The centralized network with a peripheral way for instance the Iberian Peninsula,
- The parallel network like France, Italia and United Kingdom, Sweden, Finland…
- The square pattern network for example the Germany.

The others are mixed networks from the three principals types

The third type is the most connected network, the least vulnerable because it has many possible paths. The vulnerability of the others is greater.



Multimodal European network



Main European corridors and weak links

5.2.3 Evolution of the motorway network

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 in the countries of the ESPON space, with the colour code indicating the evolution of the motorway network in the last decades. In addition, dual-carriageway roads without the status of a motorway are indicated as they existed in 2001.

Data requirements

The motorway network data presented in the map were extracted from the European network database complied and maintained at the Institute of Spatial Planning of the University of Dortmund (IRPUD, 2002).

Demonstration example

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 – the Benelux countries have the highest density of motorways in Europe. 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 is now in progress in the accession countries in eastern Europe through the TINA projects. Nevertheless, there remains a large gap in motorway provision between central and peripheral countries. Whereas the accession countries in eastern Europe account for about 21 percent of the population of the total ESPON space, they have only 5 percent of all motorway kilometres on their territory (Eurostat, 2002). And this gap is still widening. In the 1990s, about 1,000 km of motorway per year was built in the member states of the European Union; the corresponding figure for all CEC countries together was 100 km.

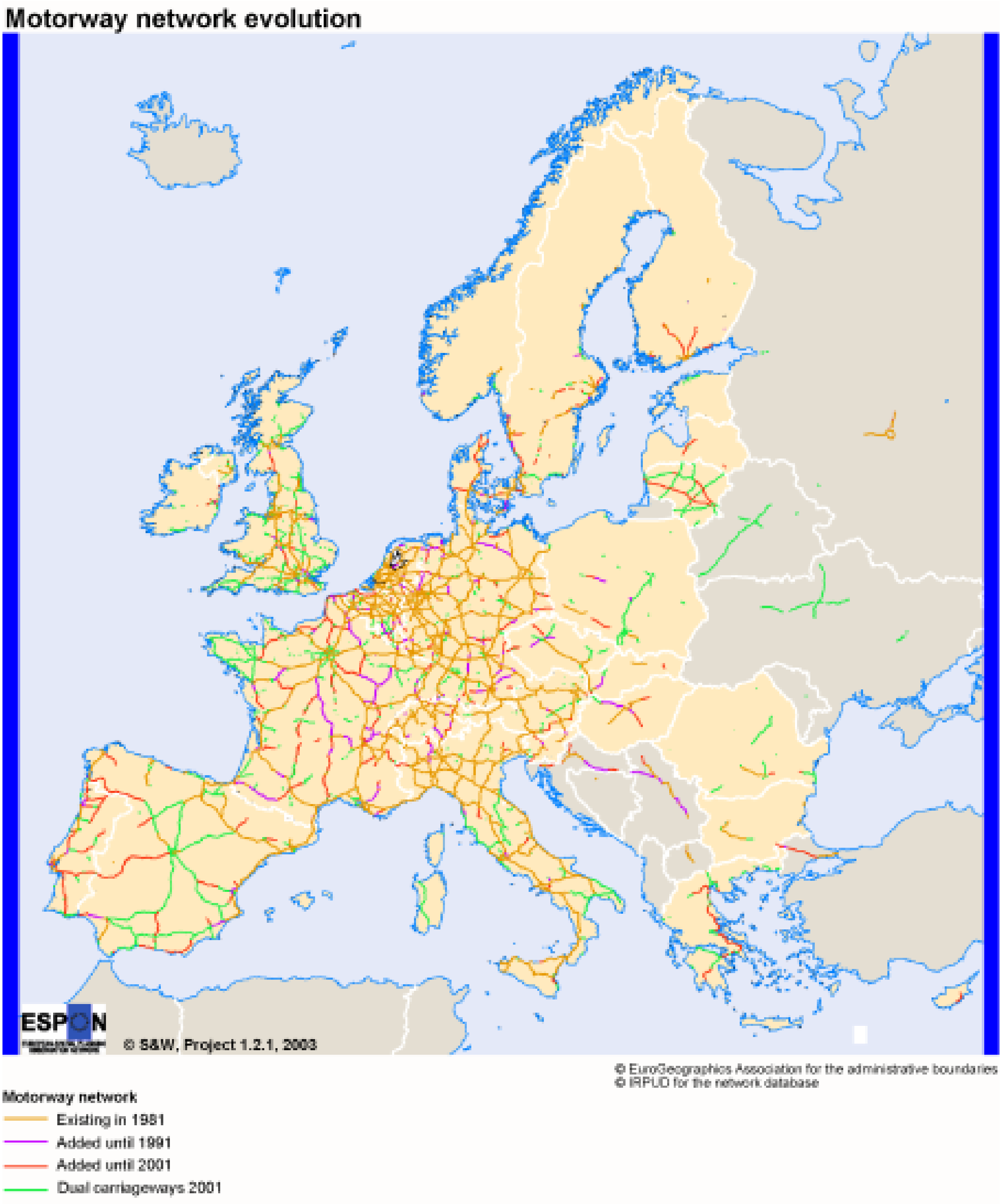


Figure 5.2.3.1. Evolution of the motorway network

5.2.4 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 a 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 in the map were extracted from the European network database complied and maintained at the Institute of Spatial Planning of the University of Dortmund (IRPUD, 2002).

Demonstration example

For historical reasons, the European railway network is most developed in the countries of north-western Europe. However, in these countries many rail lines in rural areas are today 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, 2001). However, high-speed rail lines are still concentrated in western Europe, i.e. in France, Germany, Spain, the United Kingdom and Sweden.

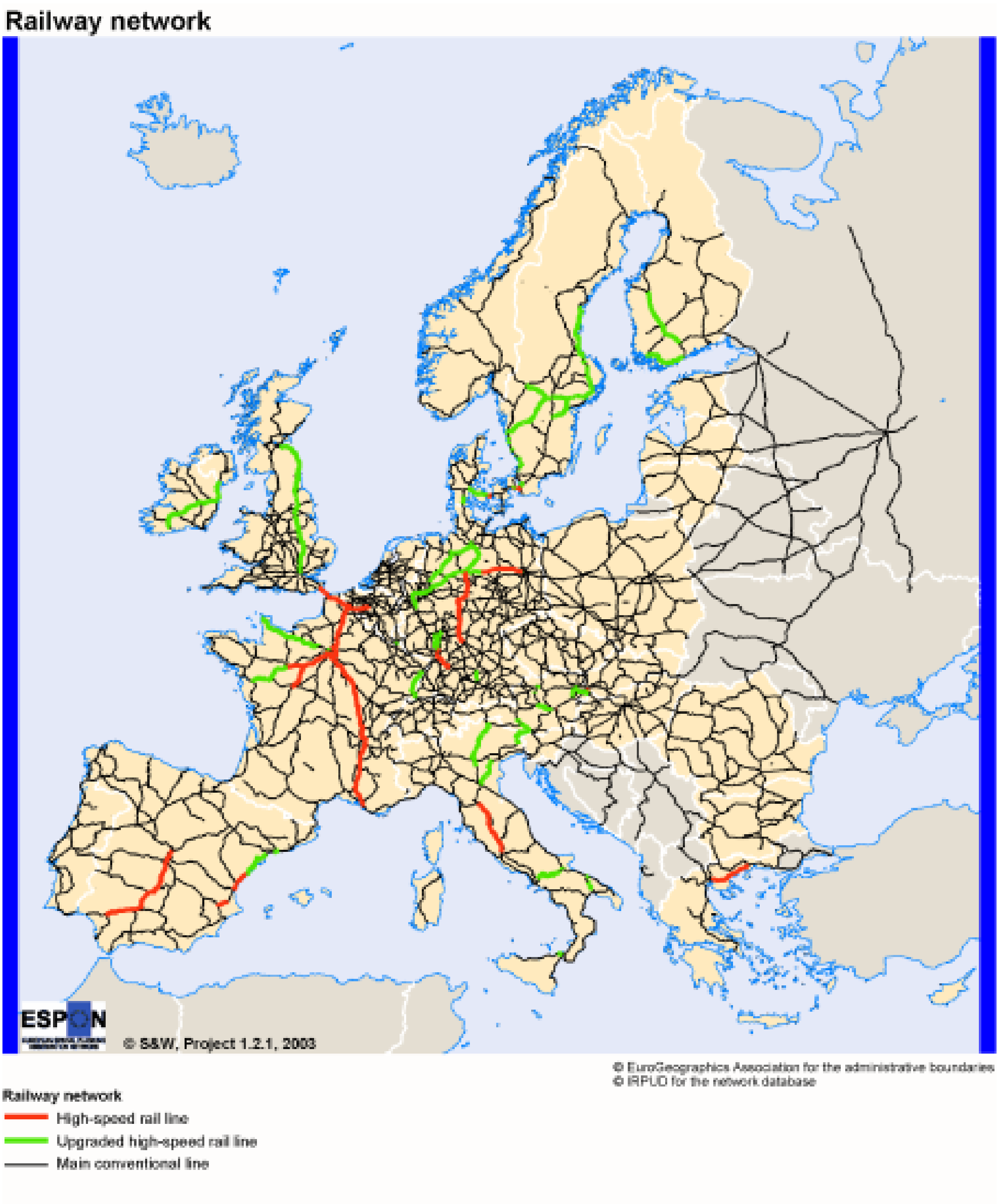


Figure 5.2.3.2. Main railway network

5.2.5 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 in the map were extracted from the European network database compiled and maintained at the Institute of Spatial Planning of the University of Dortmund (IRPUD, 2002).

Demonstration example

The first inland waterways were rivers, but already in the Middle Ages the Netherland hat 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).

Figure 5.2.3.3 Inland waterway network

5.2.6 Cartograms and network morphology

Rationale

The principle of cartogram is simple: to represent a political or an administrative division, not according to the surface as in classic maps but according to another characteristic of the considered areas such as the population, the GDP etc... The cartogram is both easier to interpret than the geometrical representations of these variables and more strikingly because of its resemblance to a caricature of the original.

Method

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 was different: it was a question of showing the network with regard to the population and to the GDP and of giving a representation of the densities. 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

The NUTS2 level and the CESA network has 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 730), it is practically a subset of the whole ESPON 1.1.1. list.

The number of cities is halfway between the one of NUTS2 and NUTS3 areas and is a function of their sizes as a city in the considered NUTS2 areas and also in terms of road, air, rail and maritime transport networks structure : every airport is represented.

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 at present.

Demonstration examples

The first cartogram represent the NUTS2.Their surfaces are function of the population, and the main road corridors are shown on the cartogram. The corridors connect the regions with a very large population. The others cartograms visualize the indicators of areas and the population density of motorway and high speed network and densities of road network by NUTS from another perspective than the classical maps.

This representation allows us to show the importance of the adopted factor and in the case of the presented maps the imbalance in terms of populating appears clearly as well as the imbalance in terms of GDP between the Europe Union and the PECOS.

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 have the advantage of proposing another aspect even if it can be considered as rough or more exactly disturbing.

These four maps selected among ten iterations show the process of cartogram algorithm.

The distortion is strongly accelerated at the beginning, then there is convergence of the process.

The distortion of population cartogram is very important for the Scandinavian countries but their populations are small .

The GDP cartogram is surprising but the GDP also : the picture, here the map is more strong that the number.

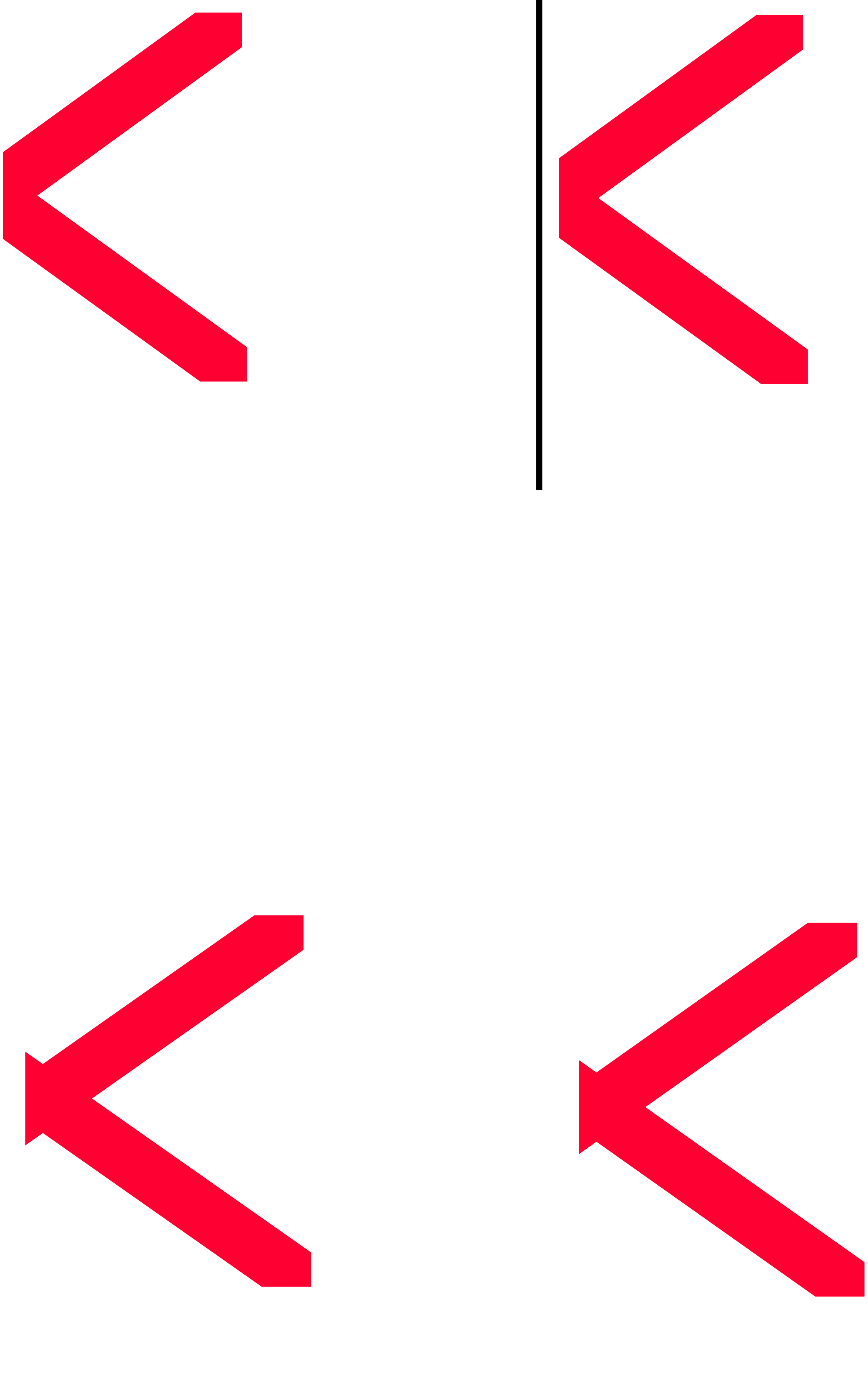


Figure 5.2.6.5 Cartogram of population in Europe 27 with main transport corridors

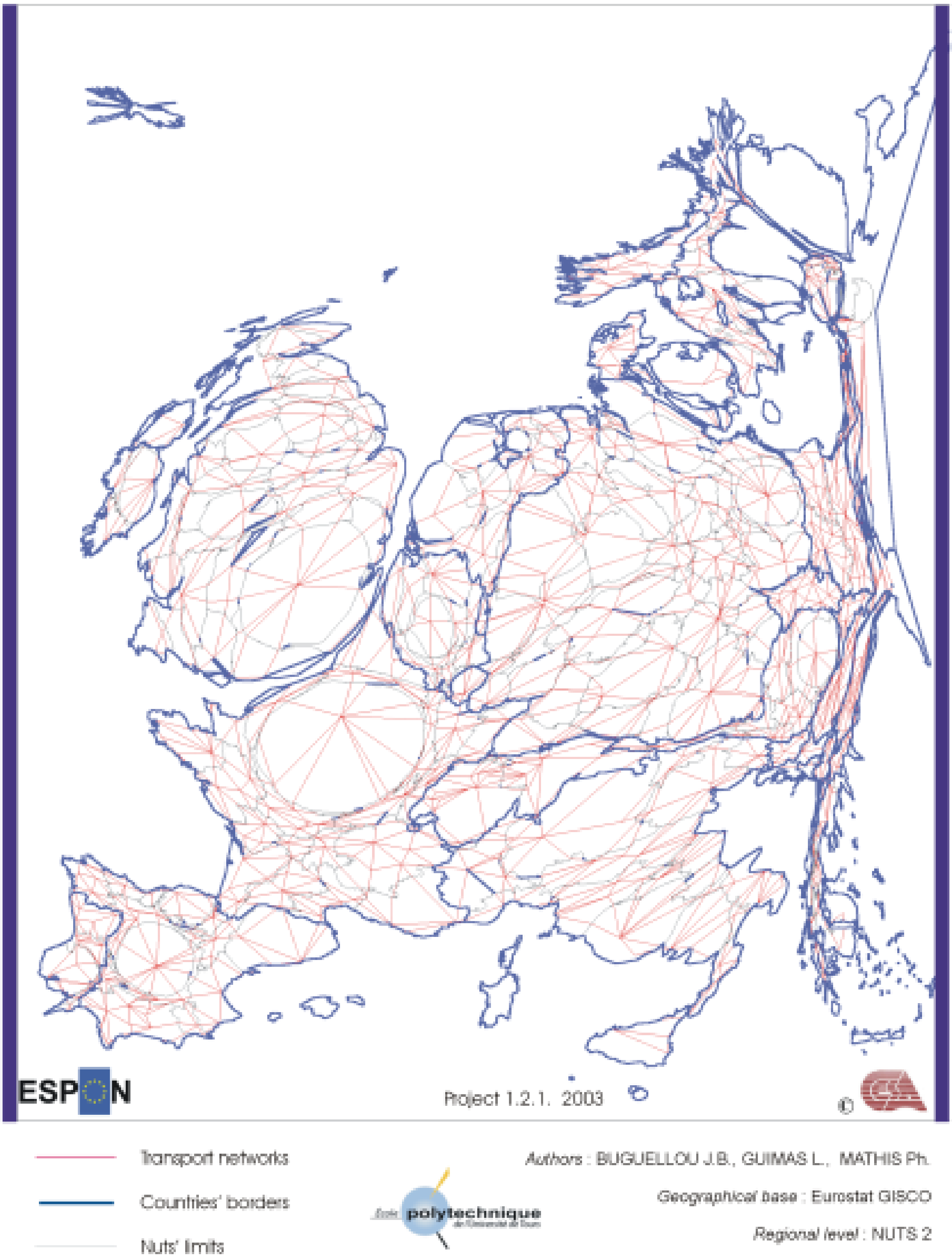


Figure 5.2.6.6 Cartogram of GDP in europe 27 with main transport corridors

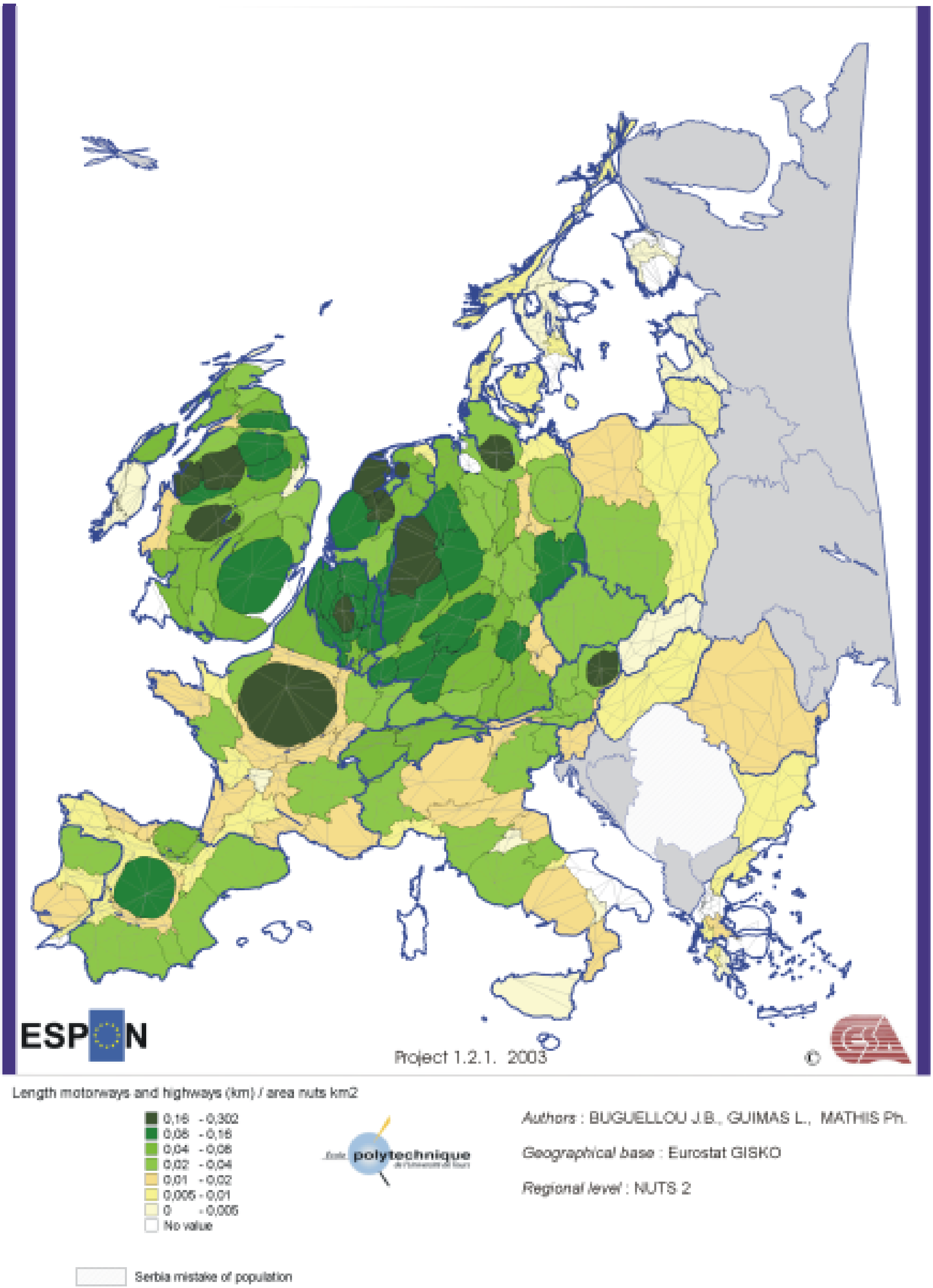


Figure 5.2.6.7 Cartogram of density of motorway by surfaces of NUTS 2 in Europe

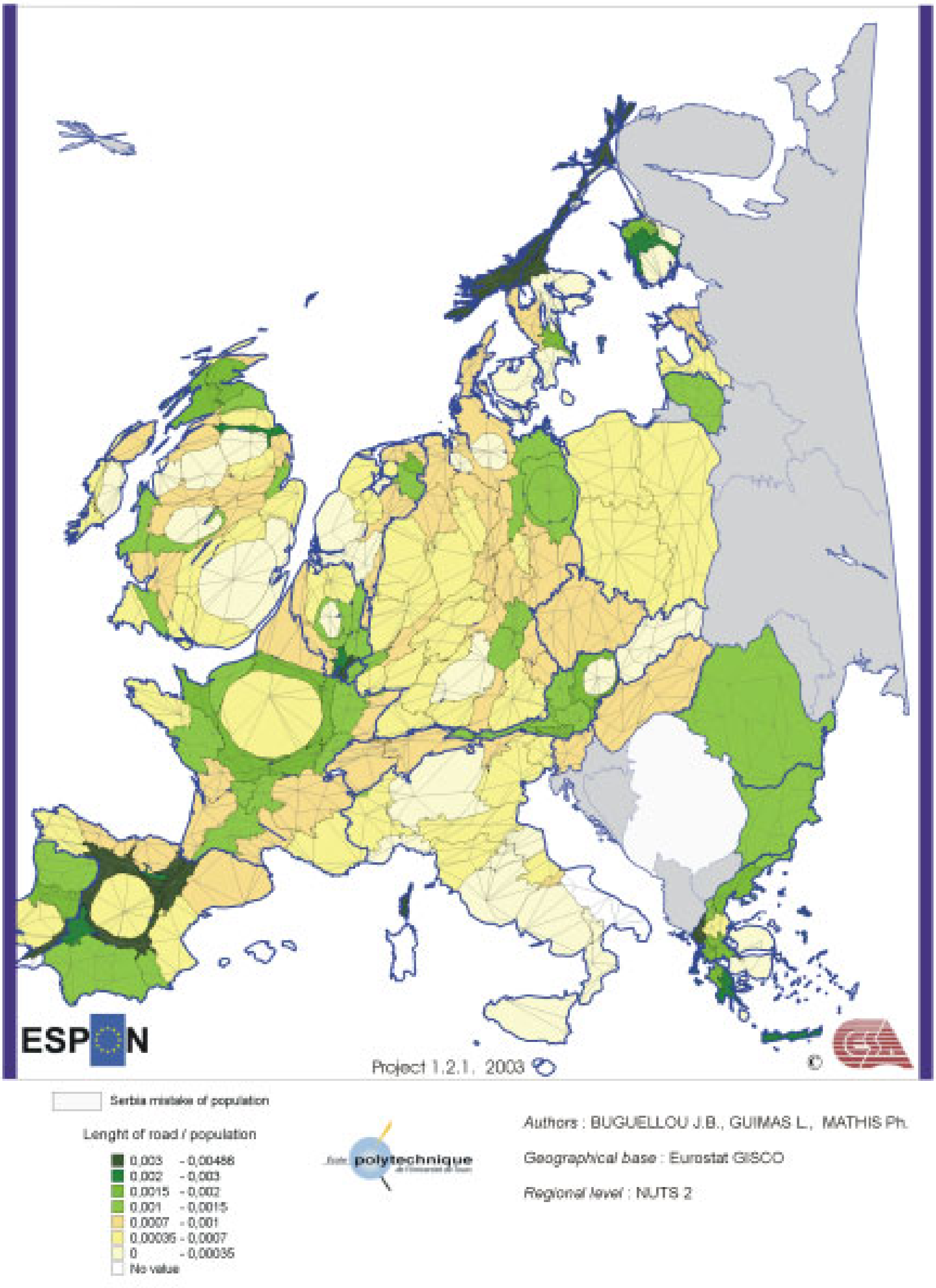


Figure 5.2.6.8 Cartogram of density of road by population of NUTS 2 in Europe (km/inhabitants)

Both maps are complementary. The length motorway and highway length by km_ is high in the NUTS with many people and in the nuts with a small rural and agricultural population, the length of road is geater important for example Spain and France around the region of the capital.

5.2.7 The algorithm of square pattern

Principle

The fractal is a discontinuous processes. The most large definition of fractal dimension is the ratio of full and empty space in logarithms.

The fractal dimension : 1 < Ds < 2

Ds=1 is a line Ds : s self similarity correspond to Hausdorff's dimension

Ds=2 is a surface

$$DF = - \text{Log } N / \text{Log } R$$

Method

A square pattern is defined on the map and the algorithm compute the number of network elements content in each square. The dimension of square is reduced and the computation is make again

Data

Only the network. Or the network map. The computation of fractal dimension do not depend of the size of NUTS. That is a objective indicator of characteristic of scale network.

Demonstration example

On the map below, the dimension fractal has been computed for each countries.

We have **three groups**

First : the countries with a network fractal dimension *DF < 1.2*

Second : the countries with a network fractal dimension *1.2< DF<1.35*

Third : the countries with a network fractal dimension *1.35< DF*

But this analysis do not take in account the population or the GDP, only the surface.

It is possible to extend this analysis and take in account the population or the GDP with the catogram (see 5.2.3)

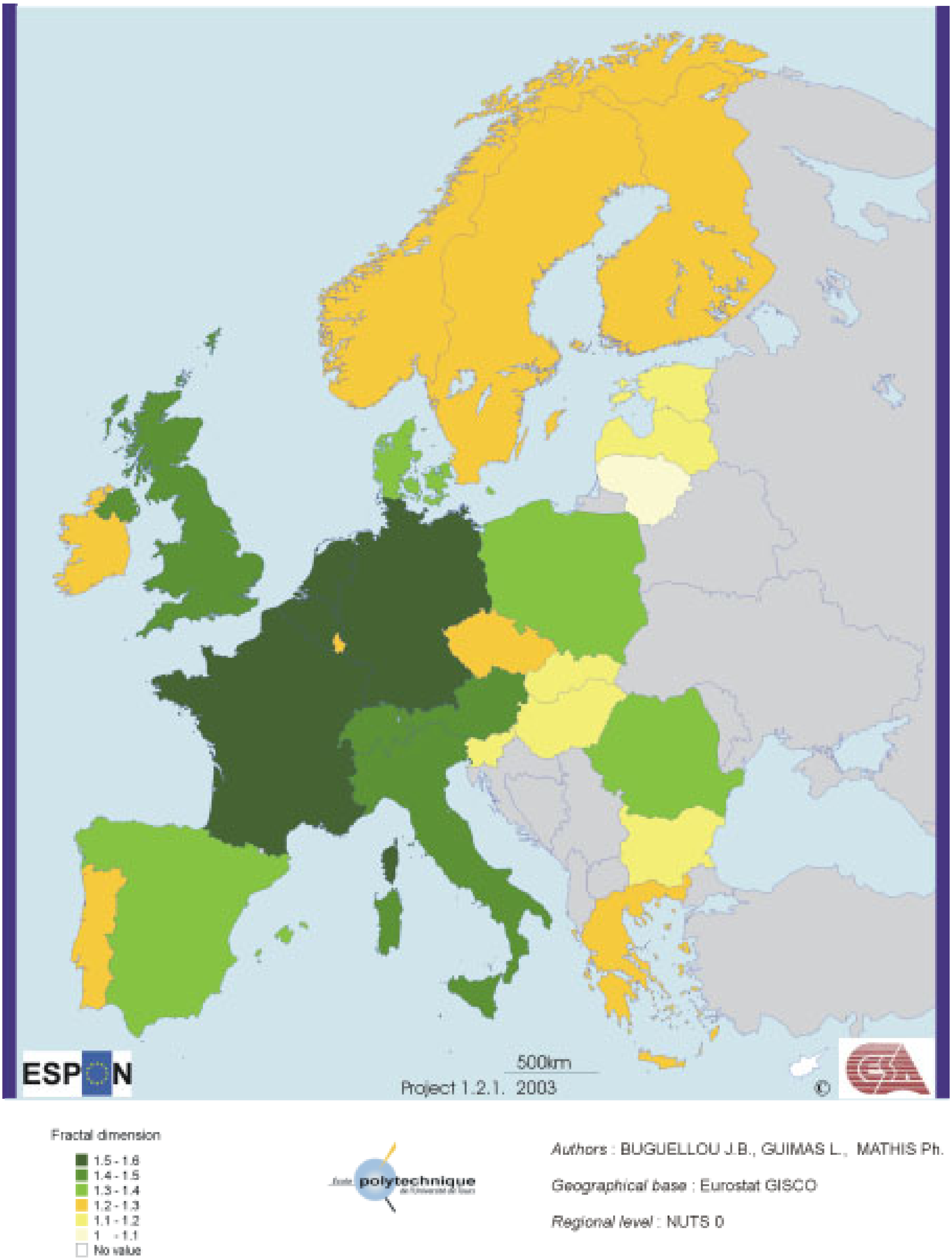


Figure 5.2.7 Fractal dimension of European countries

5.2.8 The algorithm of expansion or Minkovsky's algorithm

Principle of the Minkovski indicator

It consists in calculating the surface which is less than x km from one or several networks and to make the connection with the surface of every zone.

We thus have an indicator of network coverage, of proximity of the specific network to every zone and which could characterize the zone in a more precise way than a simple calculation of classic density. In fact, this fractal indicator allows to calculate the non-covered surface of every zone and thus to give thus an initial evaluation of the distribution or the concentration of networks by comparing this value with an indicator of classic density. Obviously the distance to the network is variable and it allows us to define a threshold from which all the zone is covered.

Method

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

Data

In an initial approach in the second intermediate report we had used the CESA network and the NUTS2 level. The CESA network being simplified in its representation (every arc being linear between two poles), it makes the calculation of the surface easier.

For the third intermediate report we used the GISCO network and the NUTS3 level which implied the finalization of a different method of calculation because GISCO is made of polylines.

Development of the method for ESPON 1.2.1.

Considering the complexity of the GISCO network we used a different method. A square pattern of variable width was defined on the European zone then for every part of a zone the test algorithm test whether it contains or not a part of the network or not.

We can thus "fit together" the network in a set of the surface of which we know.

Obviously this calculation is only an approximation of a surface of constant width but it avoids double account and there is globally a compensation of the errors.

The cartography is automatic and the calculation of indicators is very simple.

The method is the same as the network, either continuous as the road network or discontinuous as the railroad, air and motorway networks. 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

Demonstration

On the road network, we have computed the expanded surfaces – 2.5, 5, 7.5, 10, 15, and 20km of side square and the percentage of NUTS3 surface and we display the maps for va

Example

We show for example a map of expansion around motorways but the Gisco data are old and the computation not significant.

For example, a expansion maps around airport cities are being implementing for circle radius value of 25, 50, 75 and 100km.

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 analysis depend either on population or GDP : see also cartograms (5.2.3) for example.

The data for each country are readeable in the annex of this report.

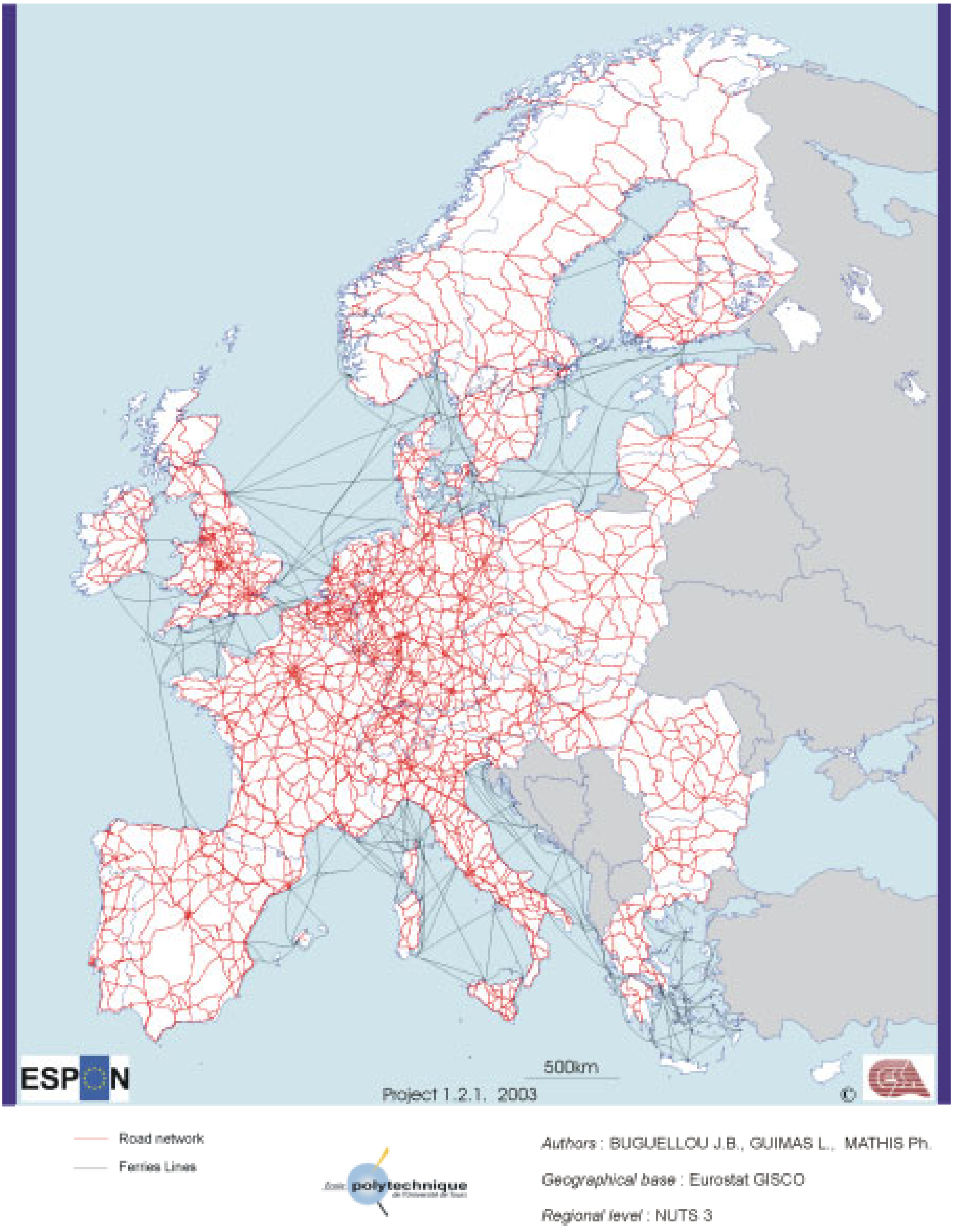


Figure 5.2.8.1 *European road network with a square grid of 2.5 Km*

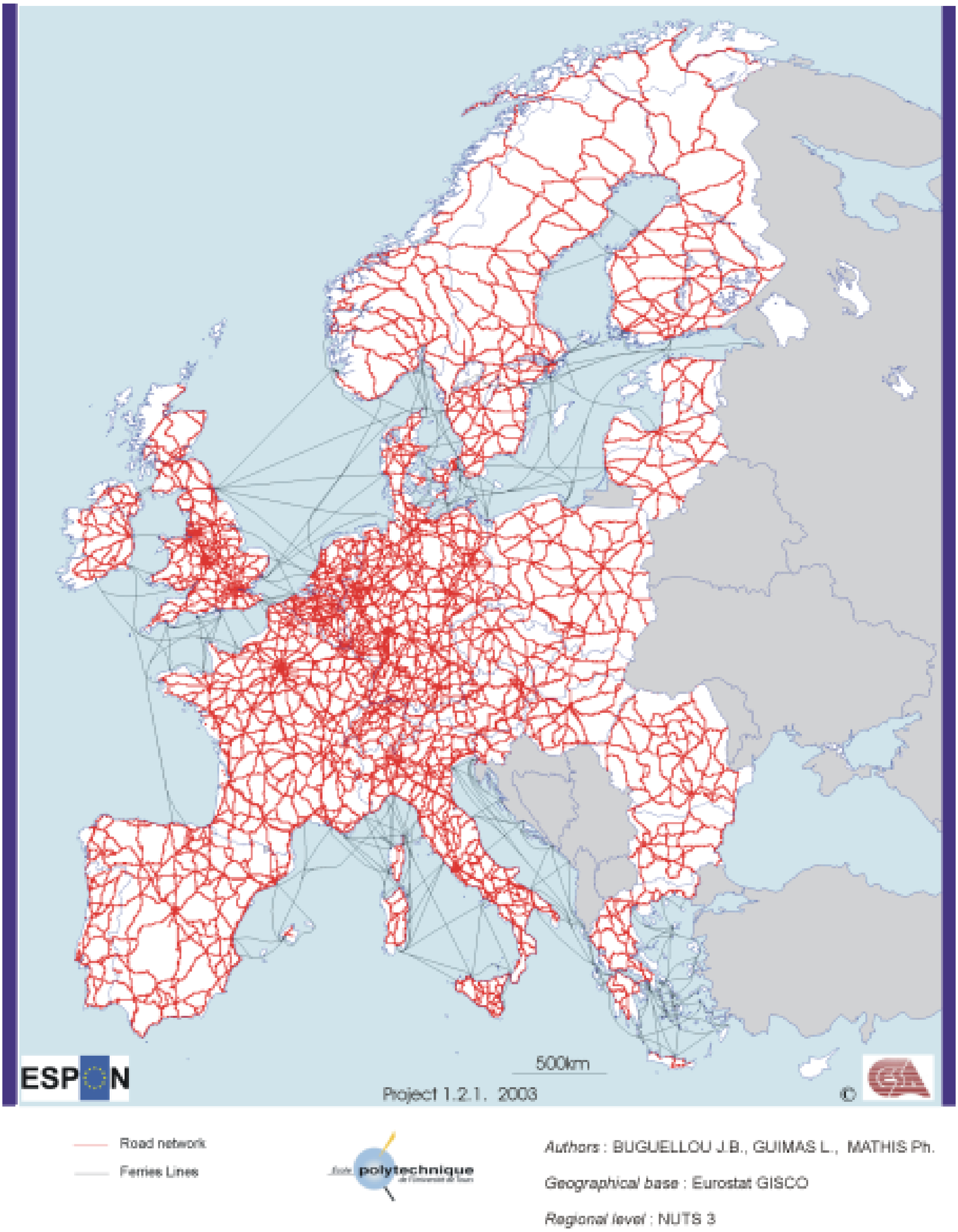


Figure 5.2.8.2 *European road network with a square grid of 5 Km*

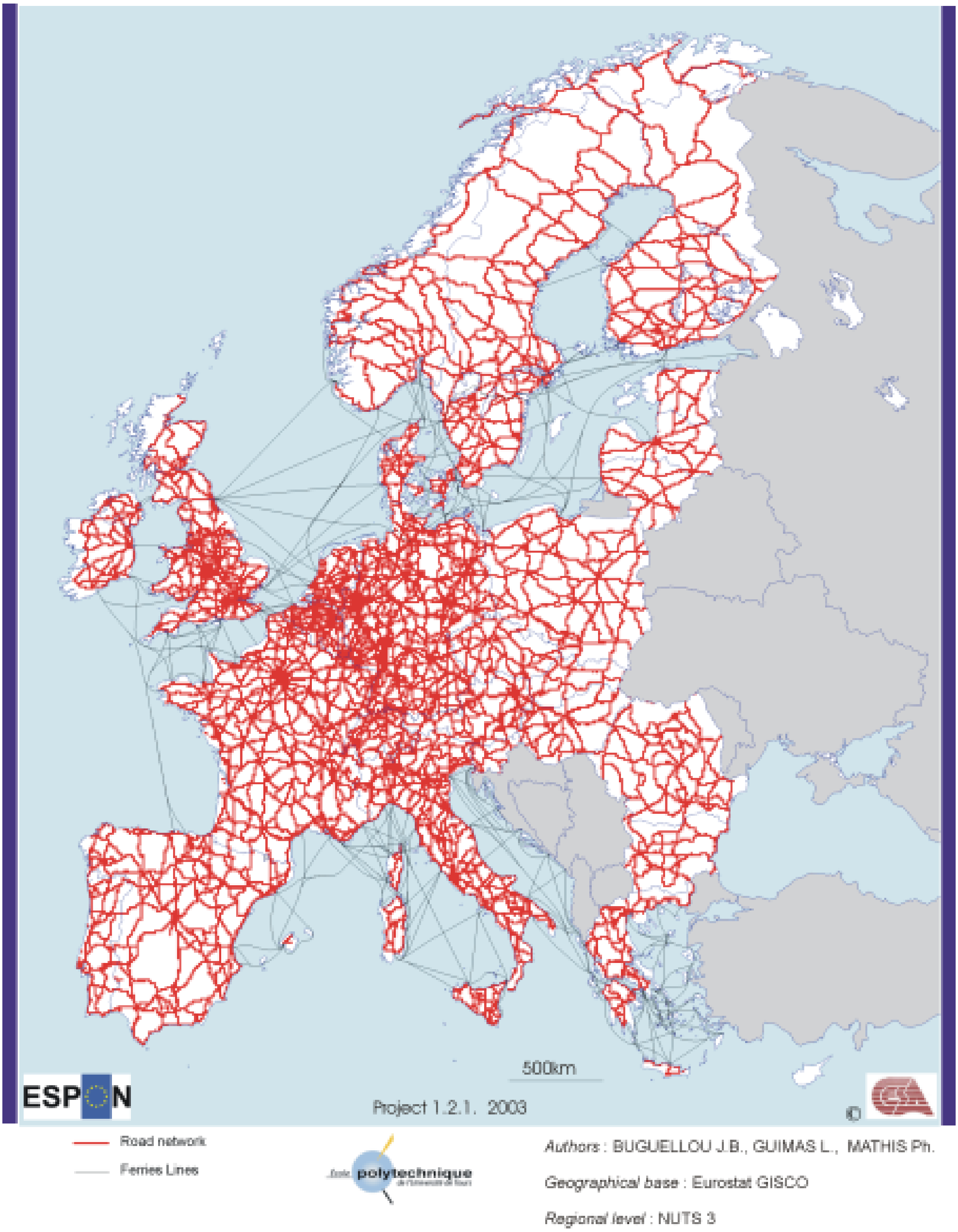


Figure 5.2.8.3 *European road network with a square grid of 7.5 Km*

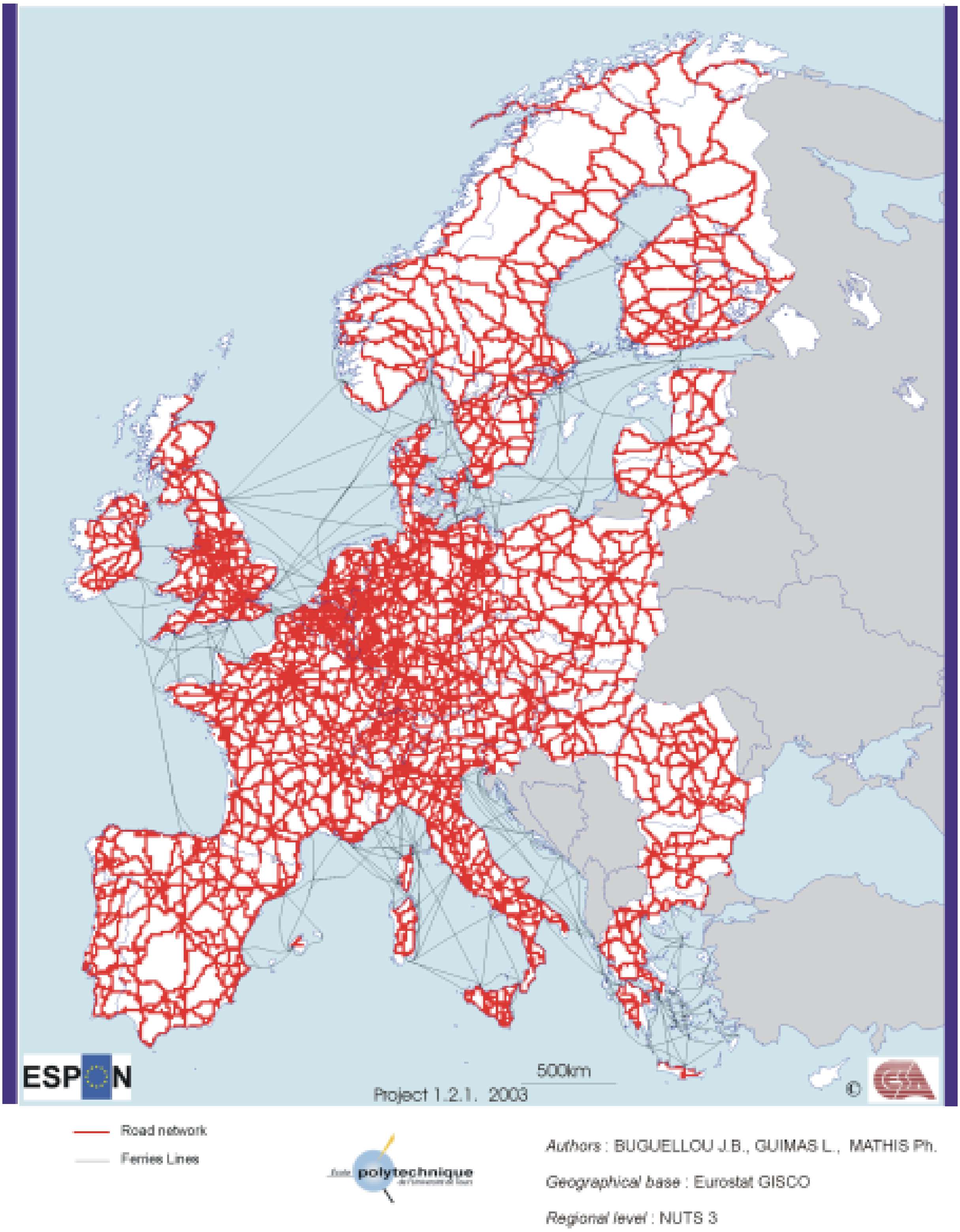


Figure 5.2.8.4 *European road network with a square grid of 10 Km*

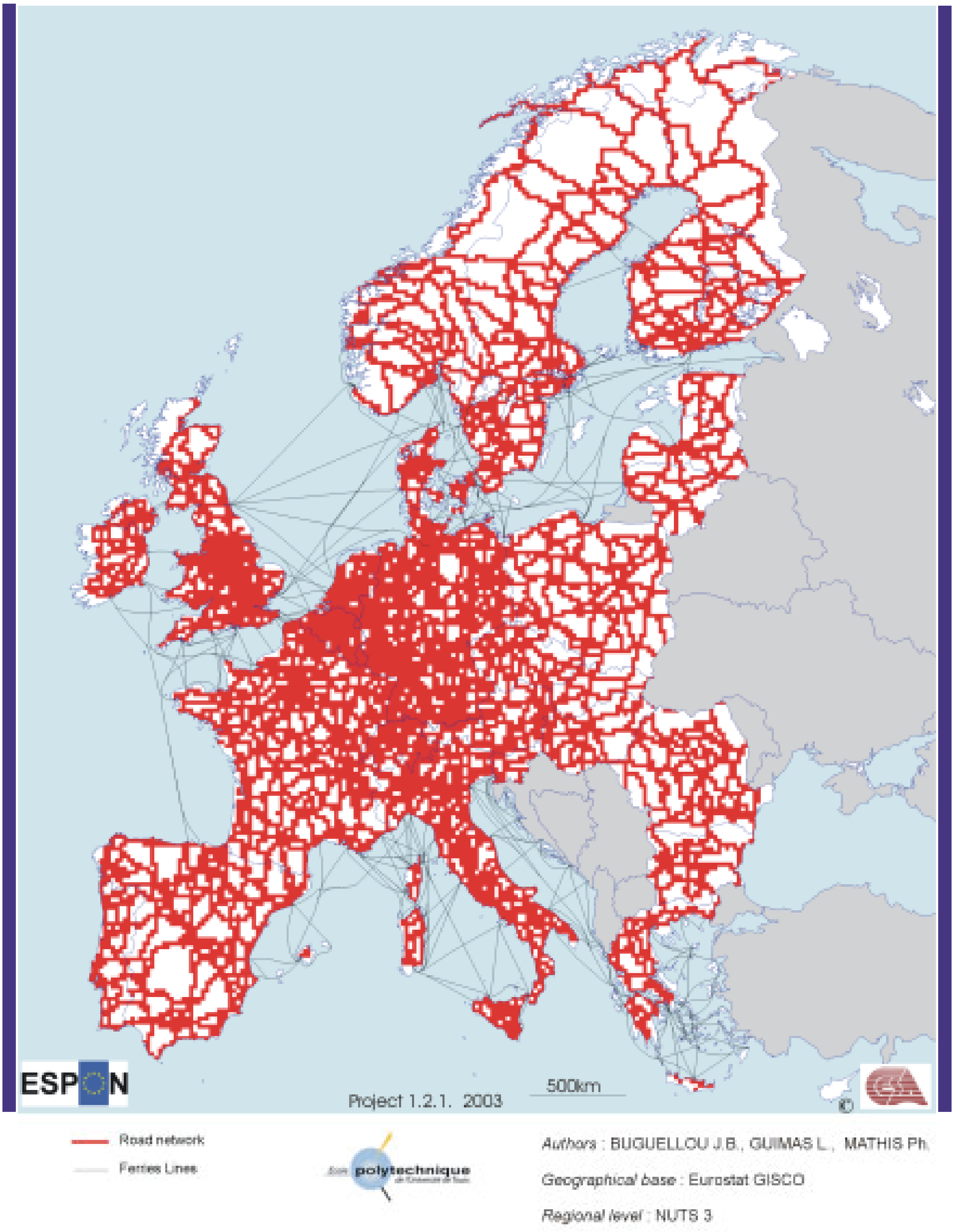


***Figure 5.2.8.5** European road network with a square grid of 15 Km*

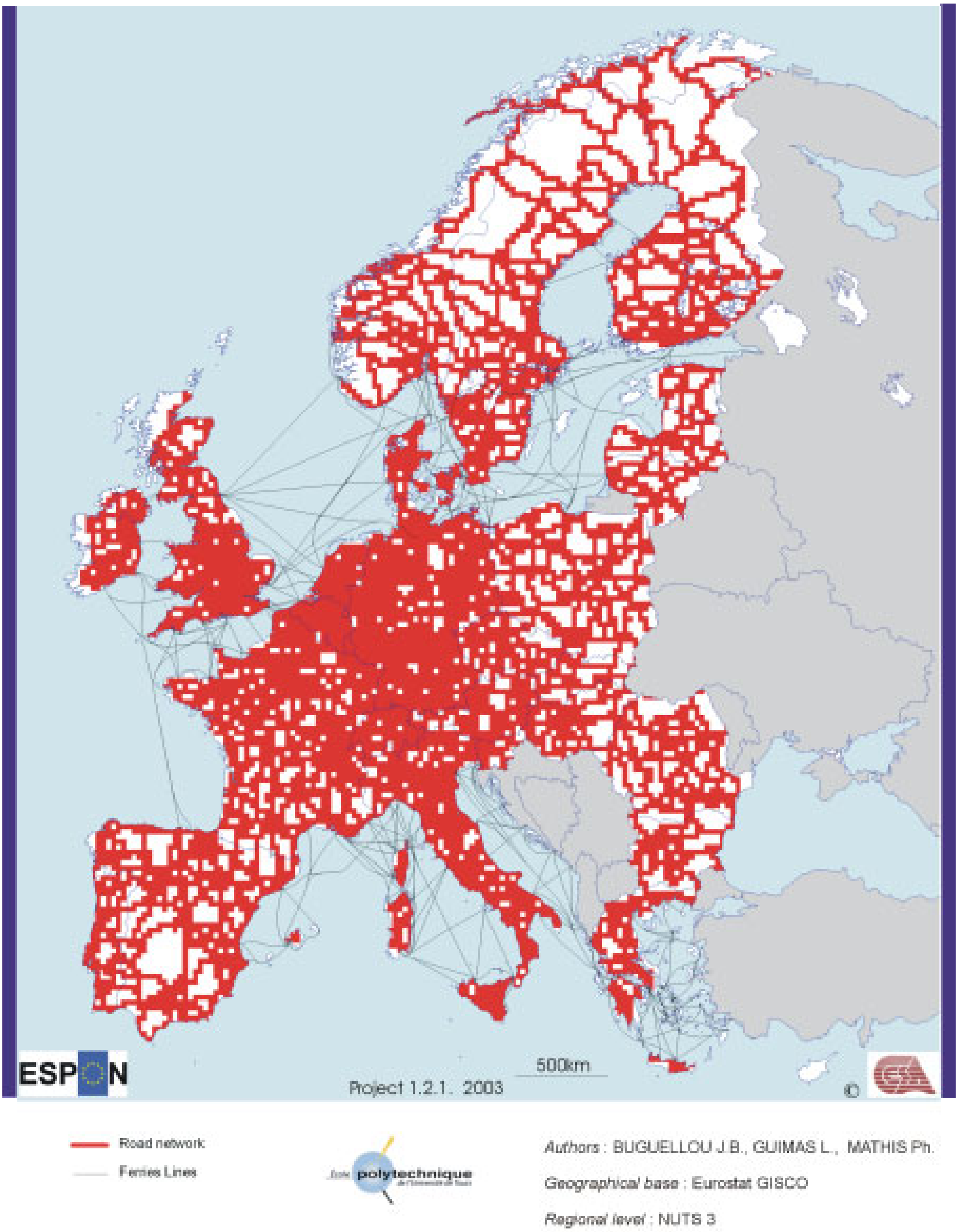


Figure 5.2.8.6 *European road network with a square grid of 20 Km*

The spatial imbalance is very clear and the computing specifies these values. The following maps show these data in their spatial position.

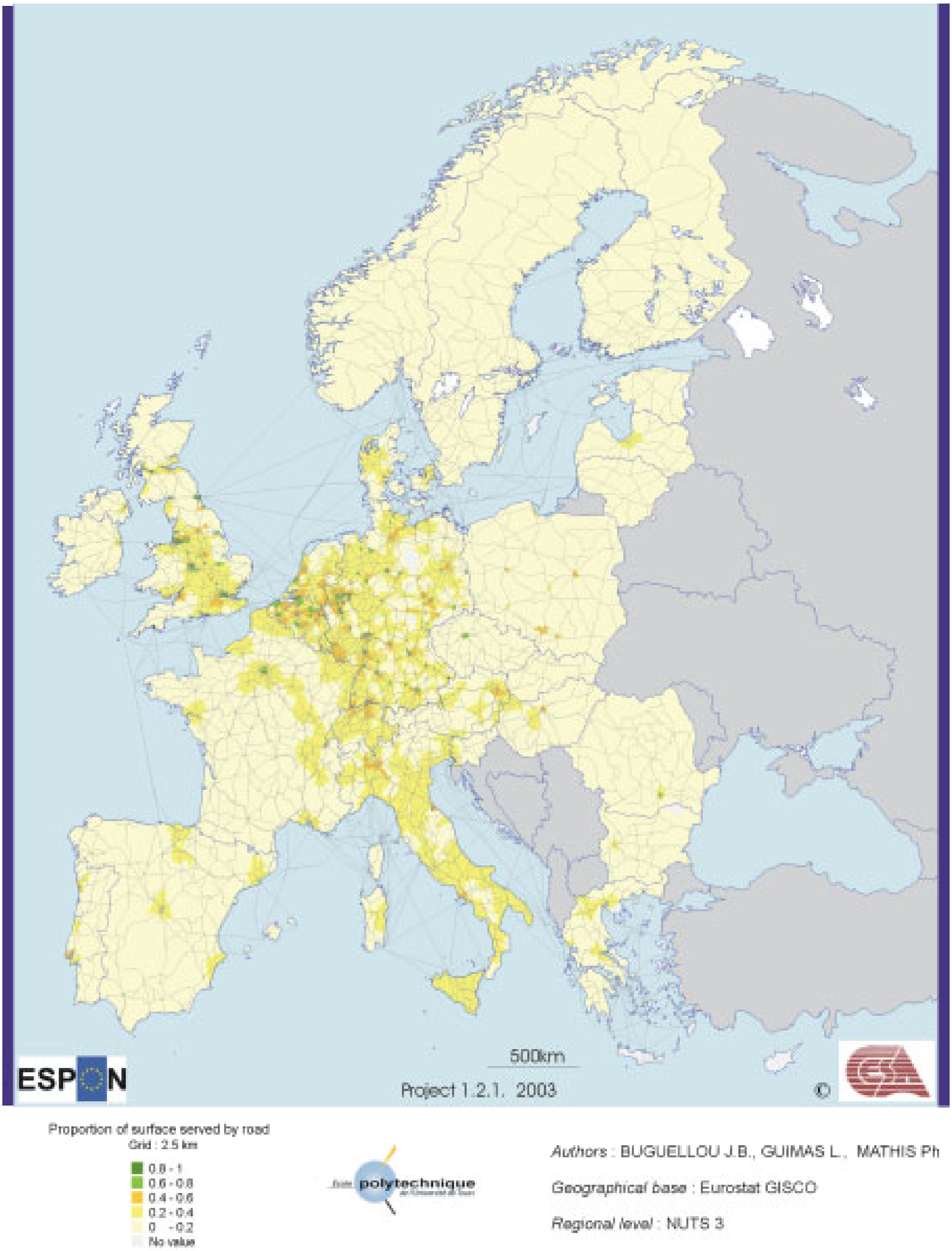


Figure 5.2.8.7 *Surface served by a road in Europe with a square grid of 2.5 Km*

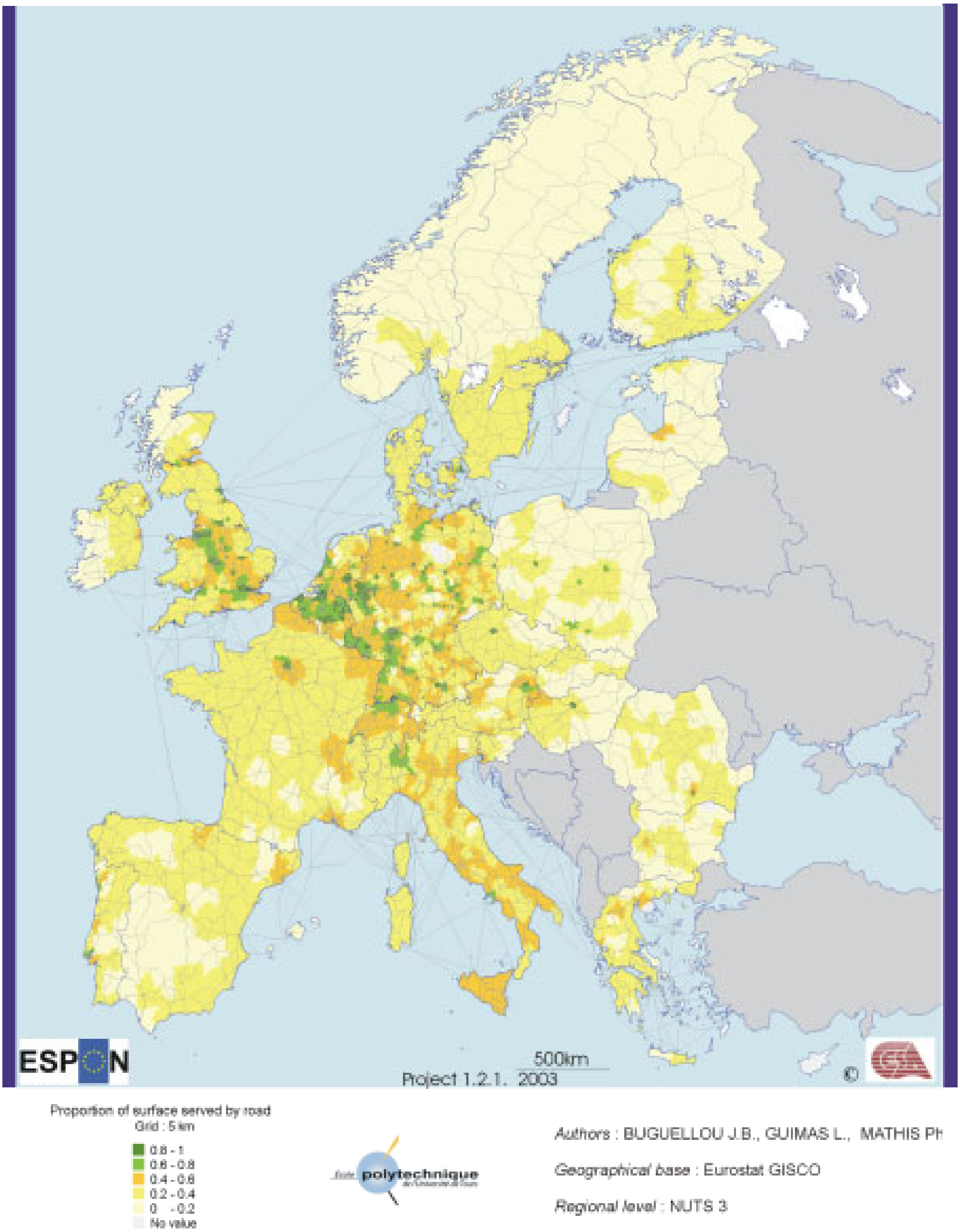


Figure 5.2.8.8 *Surface served by a road in Europe with a square grid of 5 Km*

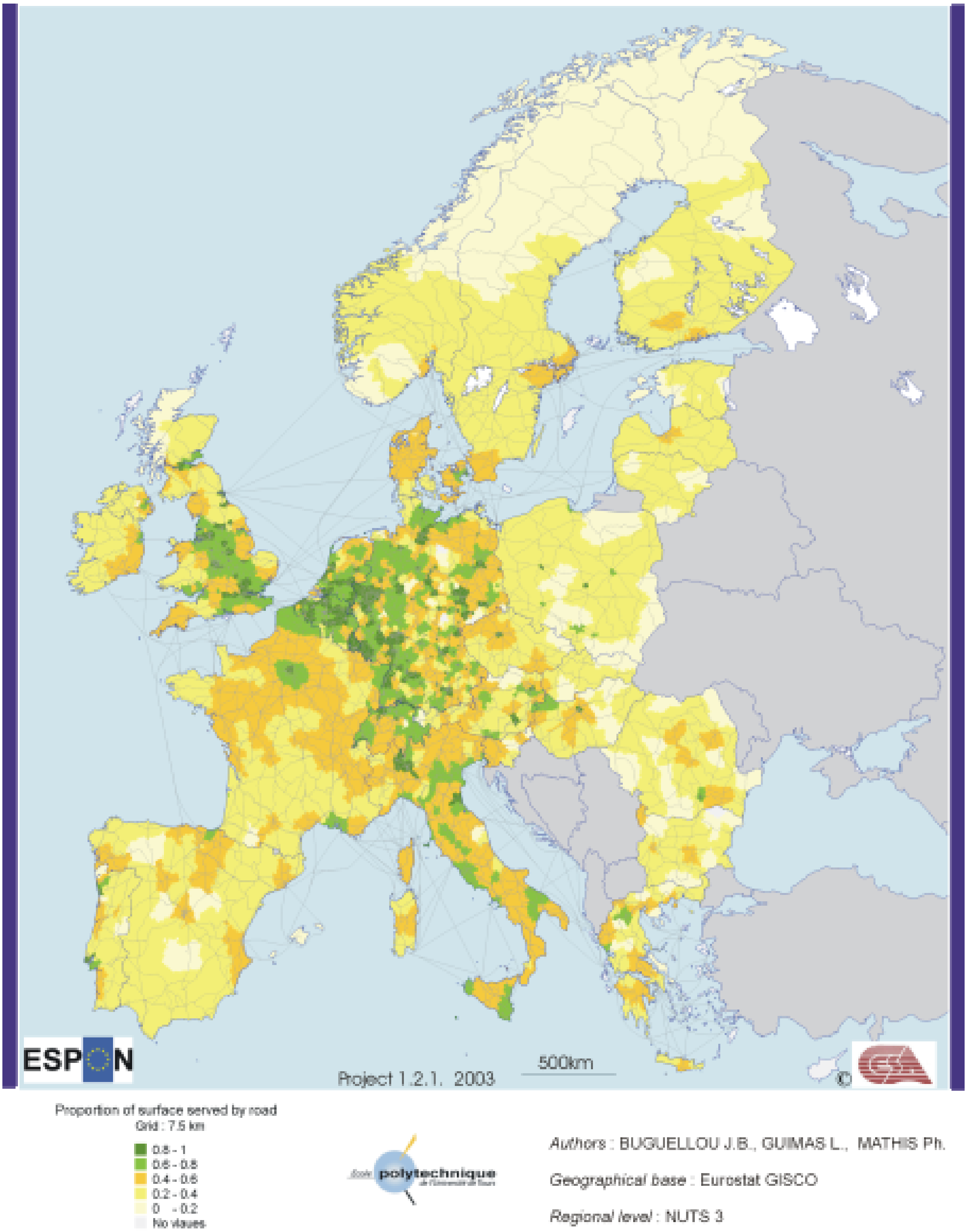


***Figure 5.2.8.9** Surface served by a road in Europe with a square grid of 7.5 Km*

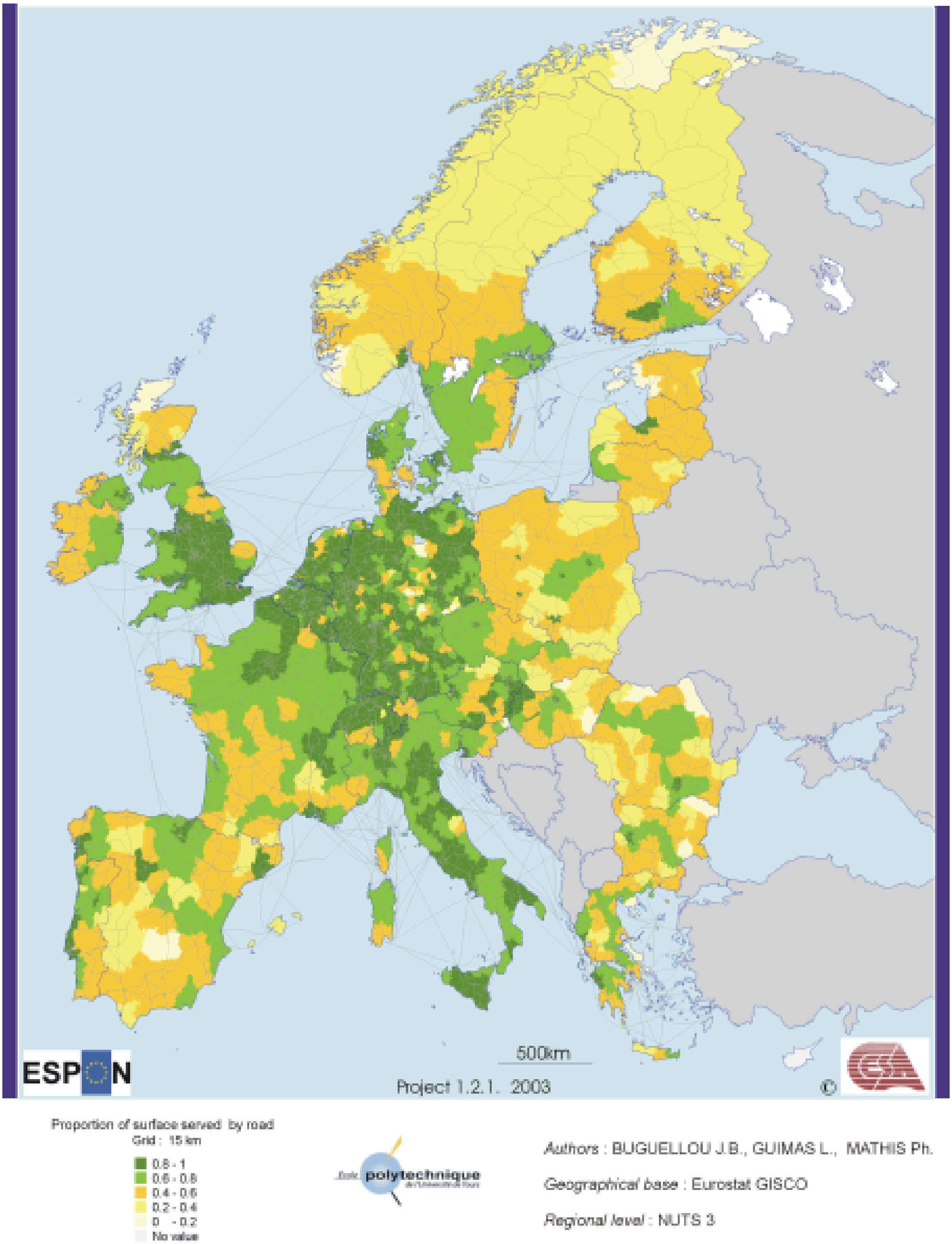


Figure 5.2.8.10 *Surface served by a road in Europe with a square grid of 10 Km*

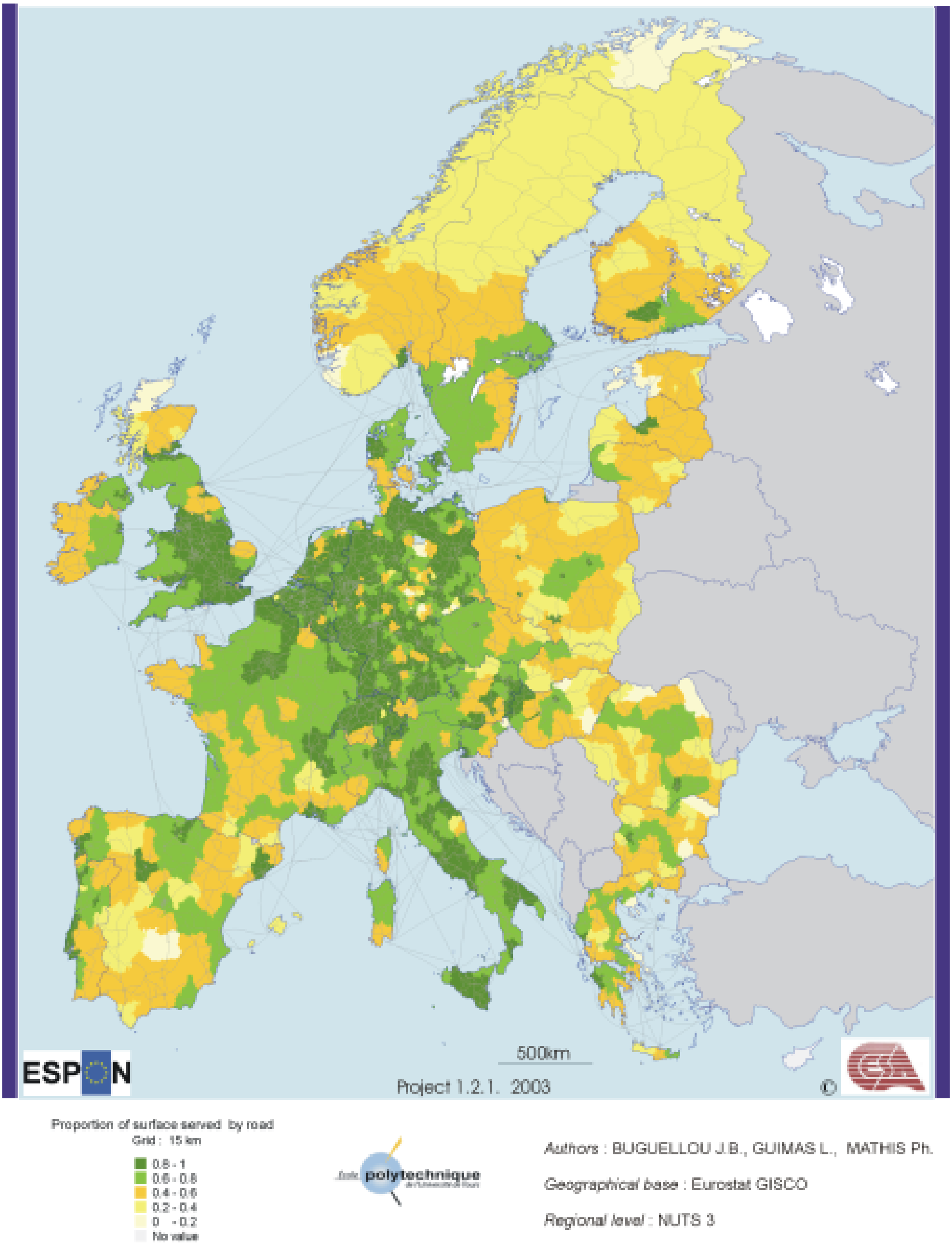


Figure 5.2.8.11 *Surface served by a road in Europe with a square grid of 15 Km*

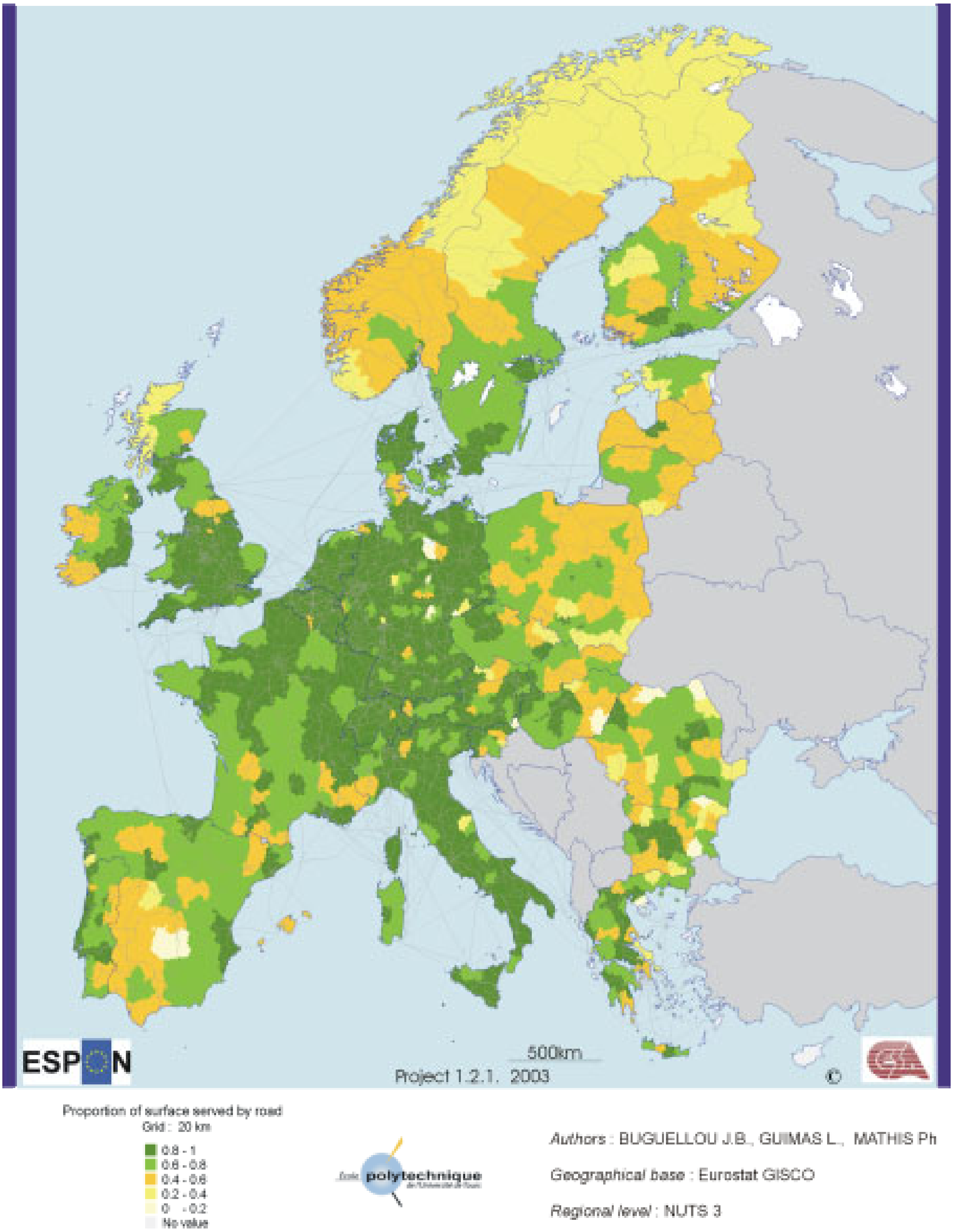


Figure 5.2.8.12 *Surface served by a road in Europe with a square grid of 20 Km*

5.2.9 The « radial analysis »

Rationale

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.

Data requirement

For this application we use the CESA network that makes computing the length in the circles easier.

Method

With the degree of vertices, we know the number of bridges from each city and the length or circle radius. The network length of each city is the sum of each bridge length. The data are readeable in the annex.

Comments

These maps and results are not according to surfaces of Nuts. In these cases, the nodal analysis is more significant and relevant.

We can see the "density" of cities but no yet the including population. This aspect will be feasible with coloured circles.

An others perspective is shown by the number of accessible cities in less of so much time. It is not any the length but the time, it is more realistic. It is not the same scale of moving.

The change of scale, here the scale is the travel time show a transfer of centres : for up to a travel time of one hour there are two clear centres, for six hour there is one centre.

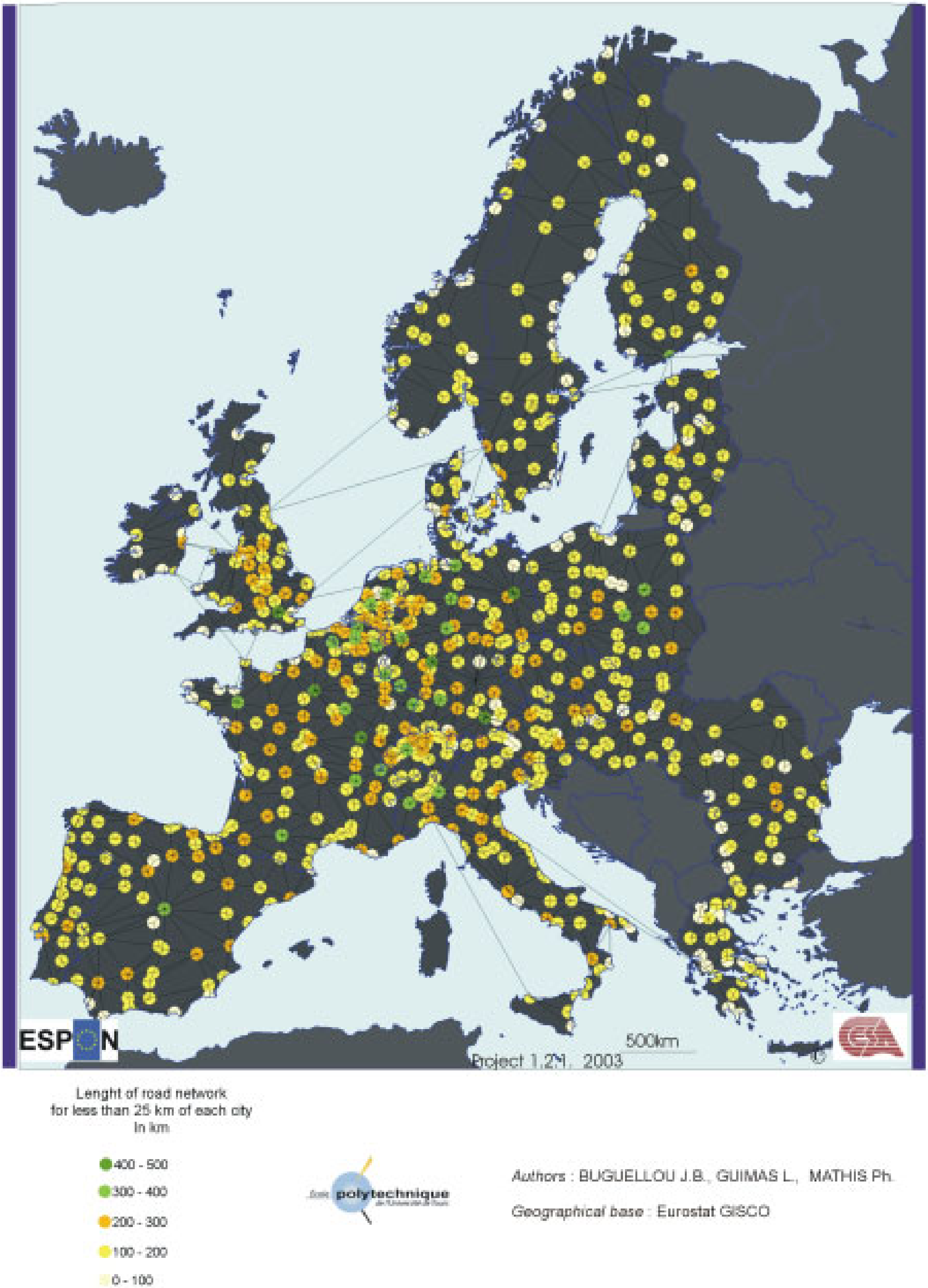


Figure 5.2.9.1. *Example of radial analysis on main European cities(circle of 25 Km of radius)*

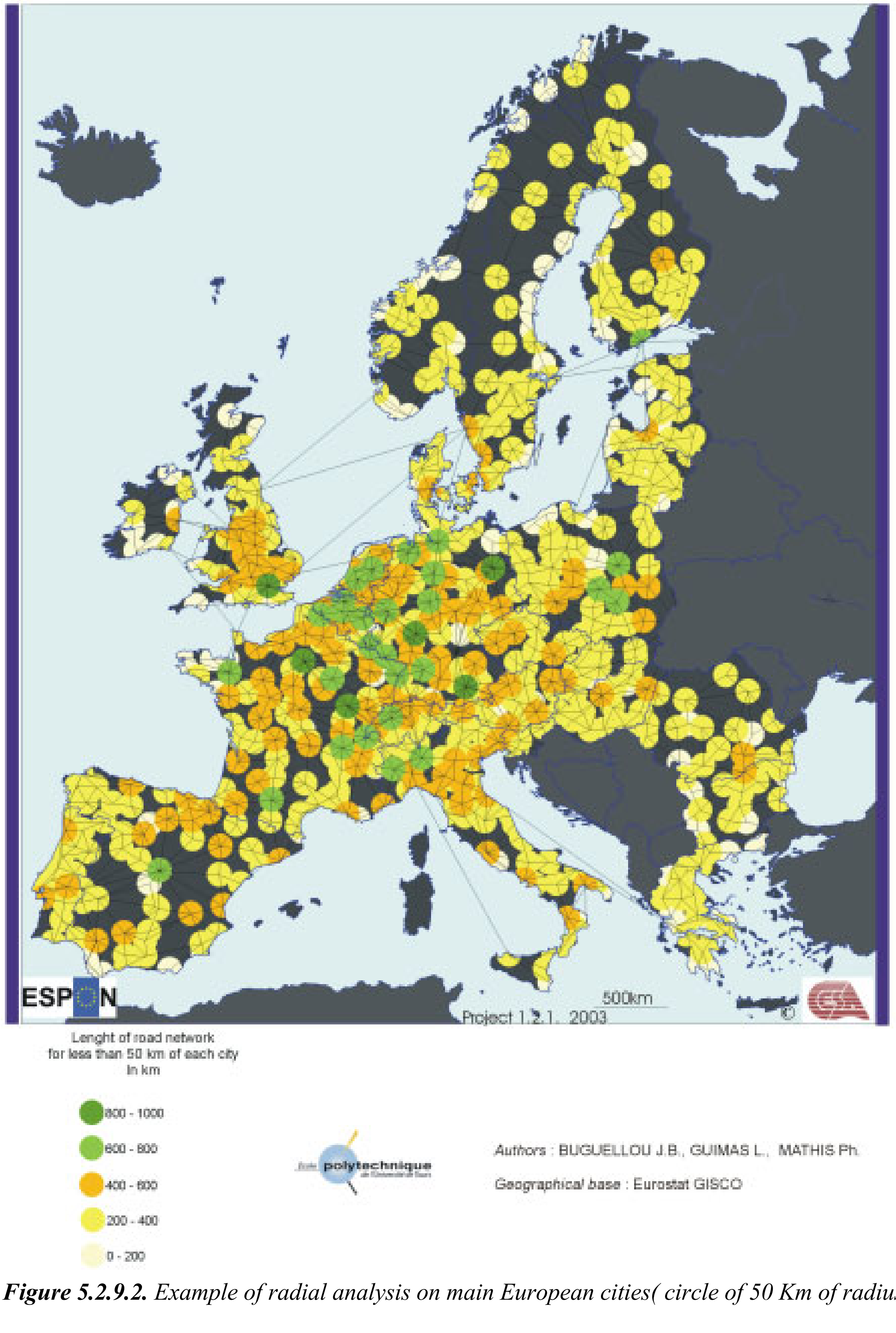


Figure 5.2.9.2. *Example of radial analysis on main European cities(circle of 50 Km of radius)*

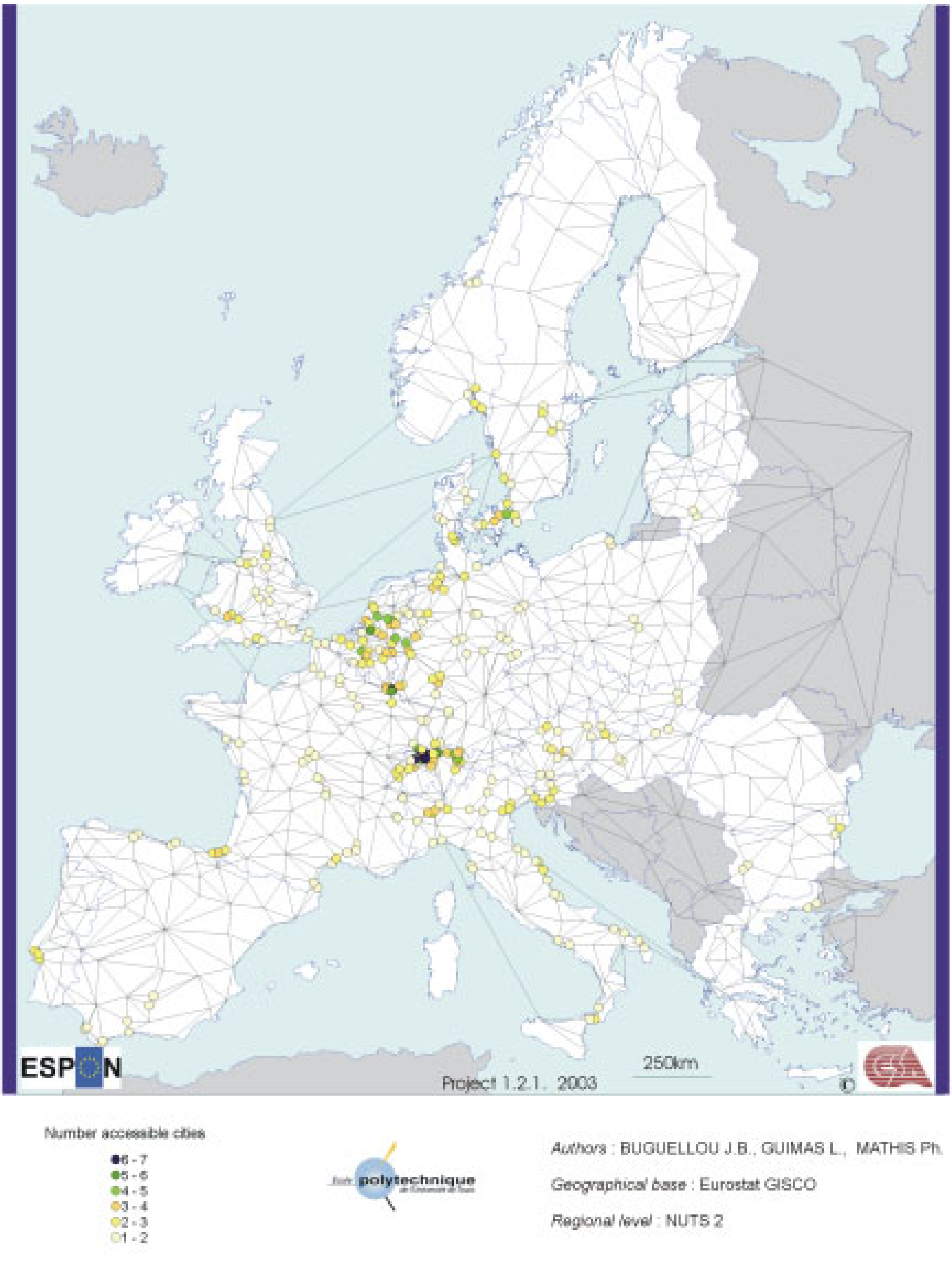


Figure 5.2.9.3. *Number of cities accessible from each city in less than 30 minutes*

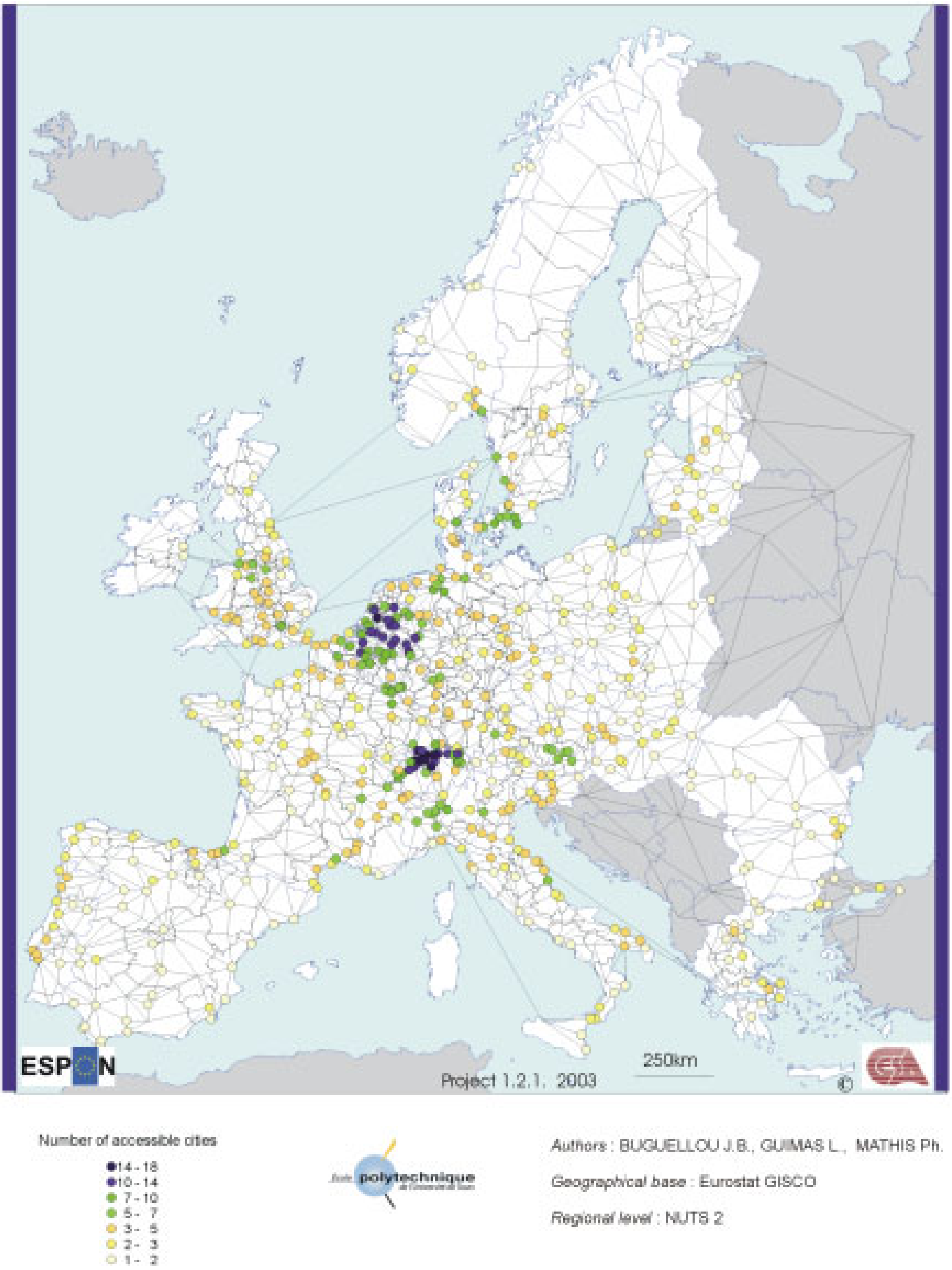


Figure 5.2.9.4. Number of cities accessible from each city in less than 60 minutes

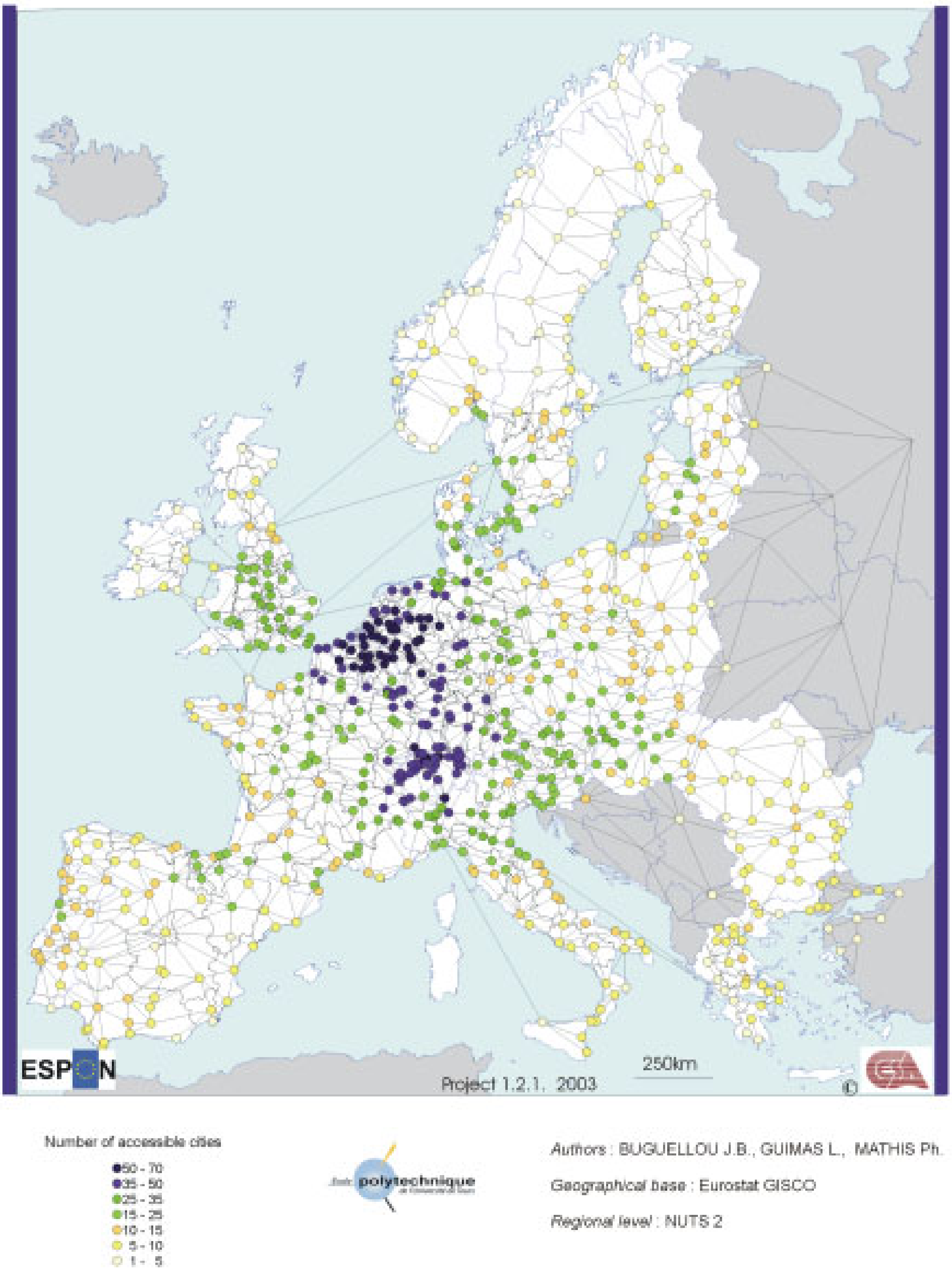


Figure 5.2.9.5. Number of cities accessible from each city in less than 180 minutes

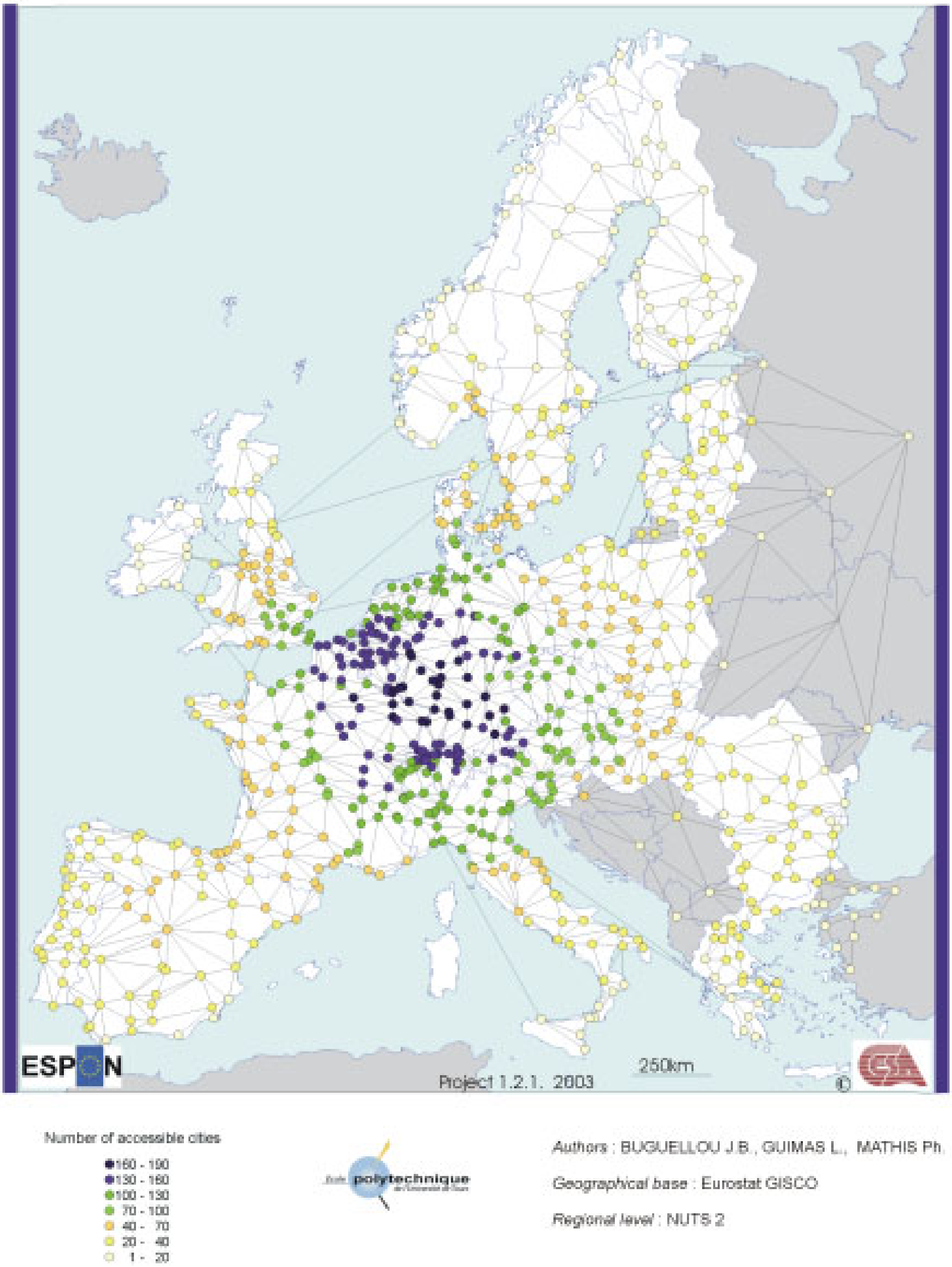


Figure 5.2.9.6. Number of cities accessible from each city in less than 360 minutes

5.2.10 Summary of morphology indicators

The three indicators can be sorted in a hierarchical organization:

- The algorithm of square pattern with the fractal dimension characterize the networks morphology . This fractal dimension which lies between 1 and 2 can demonstrate the self similarity the discontinuity and the hierarchy of networks
- The algorithm of expansion or Minkovsky's algorithm describes the hierarchical and discontinuous occupation of the space and the empty organization
- The " radial analysis " more intermittent, unipolar, describes the expansion of the structure from a point in terms of network length and of covered surface if one uses the expansion of network, and consecutively the non covered surface. One can express this by the organisation of empty and full concerning one area bounded by isochronous. One concurs with indicators(M. Wegener, Cl Grasland). But the basic difference is that one do not presuppose the continuity even through obtained with a mean, a density or a smoothing ("lissage") but on the contrary a discontinuity of the occupation area. This applies to at the human localisation perfectly.

We use the two first ways in the order to define the European network morphology. The second way will use the Hausdorff's dimension that can to take in account unequal circles or surfaces and consecutively a specific splitting with irregular surfaces as NUTS in the first evaluation.

The NUTS are relatively consistent in Europe with the exception of Germany.

The computing will be amply made significantly and localisable and so verifiable. Moreover, space will be totally covered.

5.2.11 European transport corridors in relief

Rationale

The idea of the transport corridor relief is that, between two locations, a 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.

Method

The principle of the relief transport corridor map is very similar to that of the crumpled time-space maps. The easiest links, *id est* 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

Data requirements

Like any other flow thematic mapping technique this type of map needs flow data through a graph. A weighted graph is used: nodes, arcs, and a value associated to each arc.

Demonstration example

The data presented in the example come from the simulation of computed minimum path through the European road network. The European corridors appears 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, *id est* it will tend follow the main transport corridors.

Figure 5.2.11 Relief map of the main european transport corridors

5.3 Travel times and costs

5.3.1 Connectivity to transport terminals

Rationale and policy relevance

The ICON (Connectivity to transport terminals) evaluates the connectivity of any place as their minimum access time by road to the closest transportation nodes (e.g., the closest motorway entrance, the closest railway station, and the closest commercial port...) and the utility that the node provides in terms of service provision (facility to get access to 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 Chapter 4.3 for the detailed formulation).

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

The model used to calculate the ICON (Bridges/NIS) uses centroids of NUTS3 as origins and transport terminals (road access, seaports, airports and rail stations) as destinations. It calculates the time to reach the transport node with a minim and a maximum service already defined as a parameter (see Table no. 5.3.1) using 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.

Table no. 5.3.1: Services and weights

Transport networks	So	Sx	Pi
Road network	85 km/h	100 km/h	55
Rail network	75 trains/day	100 trains/day	15
Comercial airports	0,5 Mpass/year	15 Mpass/year	20
Comercial Seaports	0,5 Mtonnes/year	10 Mtonnes/year	10

Source: ESPON Project 1.2.1, Mcrit

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 5.1.1) 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 transport terminals 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.

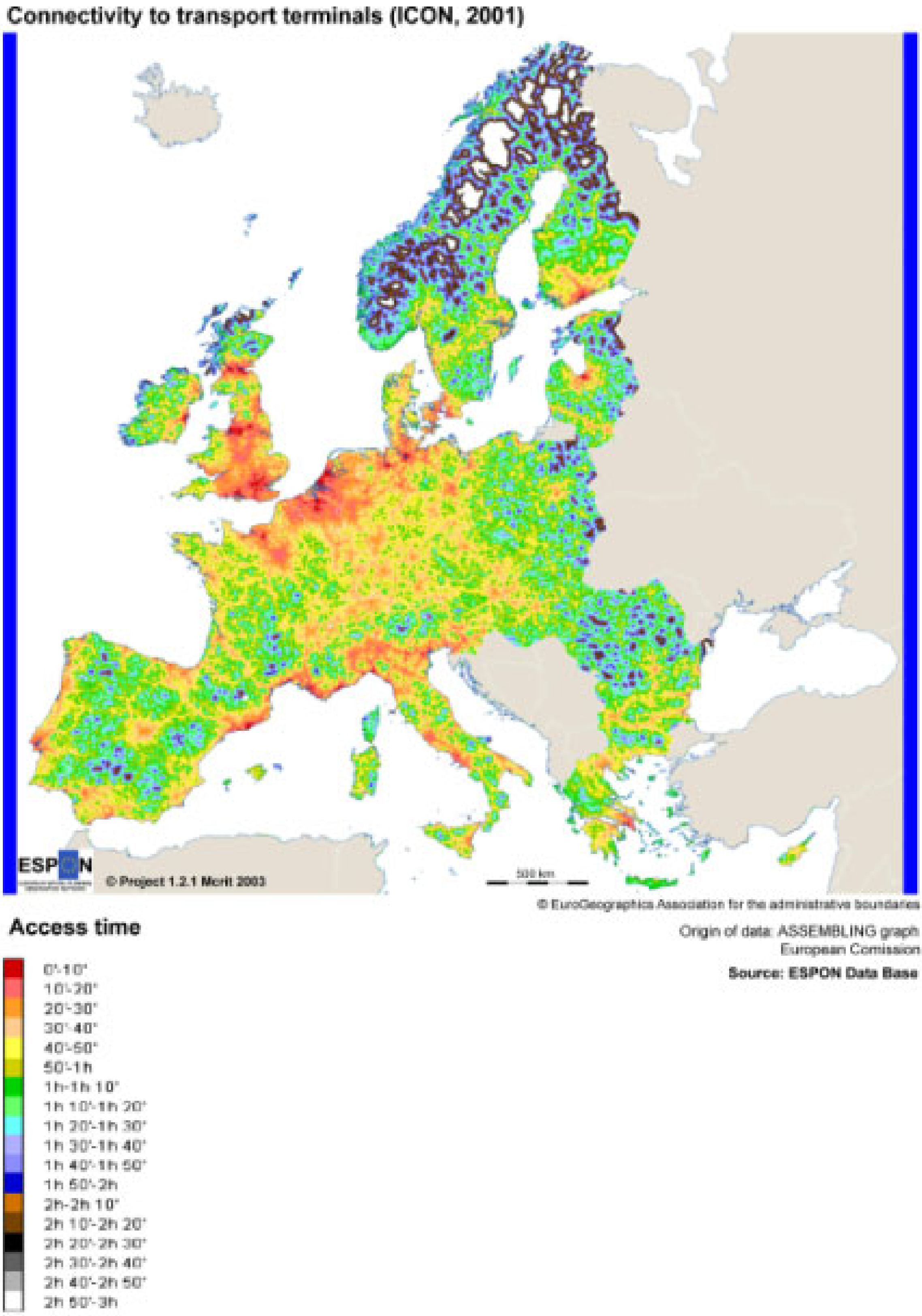


Figure 5.3.1. Connectivity to transport terminals

5.3.2 Cost 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, which is the maximum level adopted for road entrances services (see table no. 5.3.1).

Data requirements

The data requirements are the same to the previous requirements, but only considering as transport nodes the rail stations. The services of each rail station depends on the category of the rail link

Application and results

The cost to motorway access has been calculated for all NUTS3 regions of the ESPON space and it gives an alternative representation of the motorway network, 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 doesn’t 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.

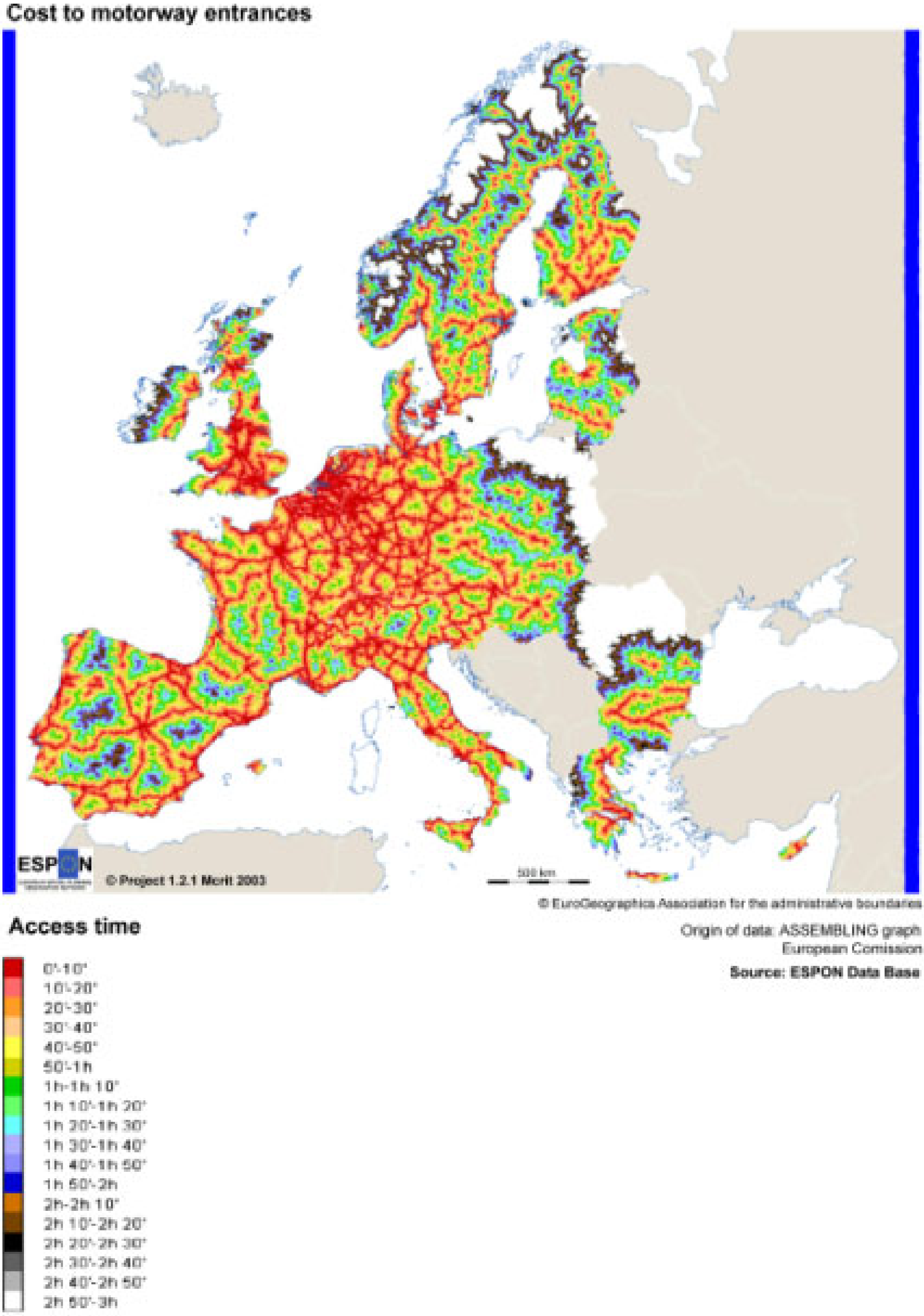


Figure 5.3.2. Cost to motorway entrances

5.3.3 Connectivity 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.

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, and like in the cost to motorway entrances, it gives an alternative representation of the conventional, upgraded and high-speed rail network. In this case, all ESPON space is well served by rail stations with a service of 75 interregional trains per day.

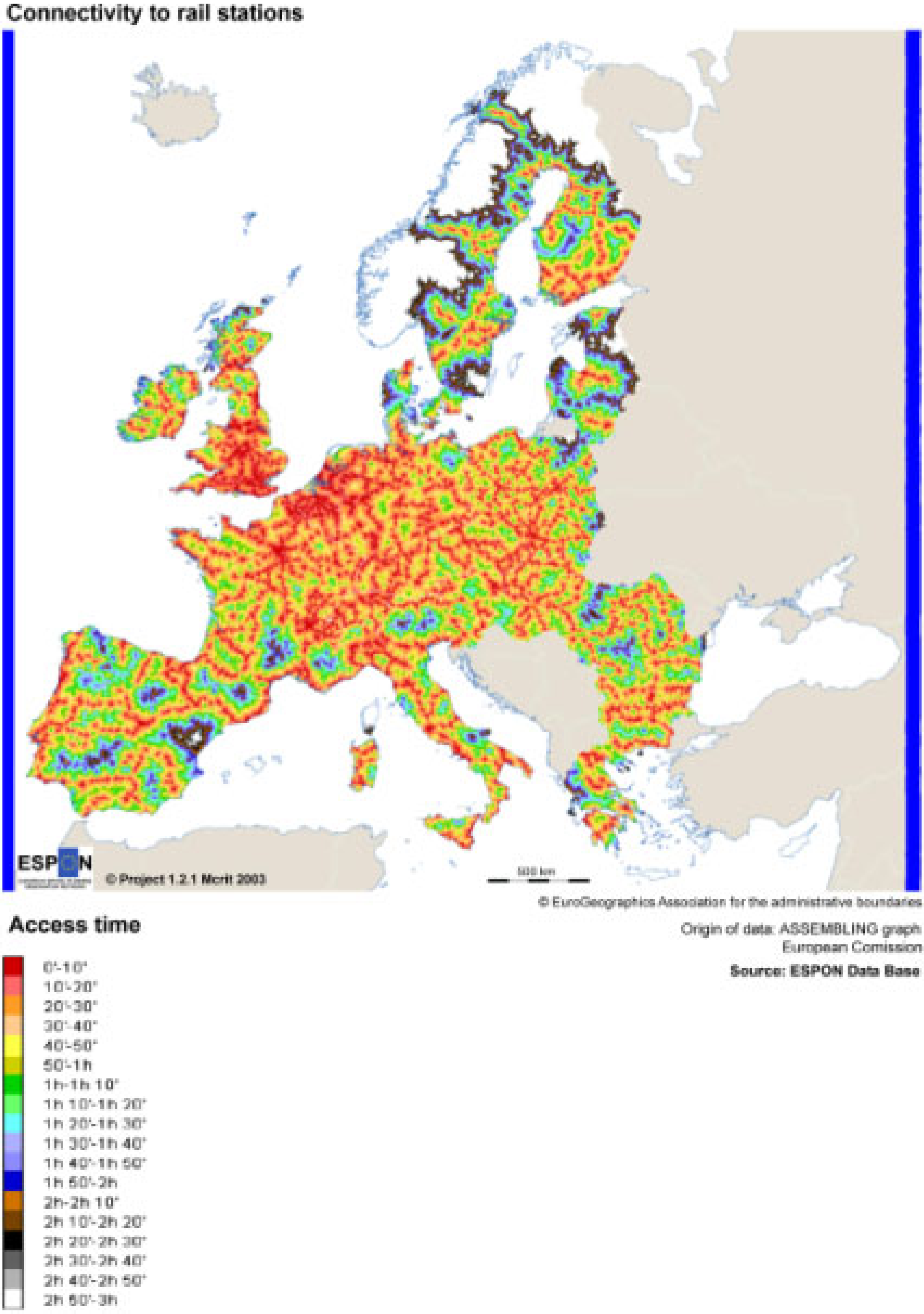


Figure 5.3.3. Connectivity to rail stations

5.3.4 Connectivity to commercial 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 from Scandinavian ones (with small fishing seaports), have good seaport infrastructure, although the hinterland changes depending on the road network to access to it.

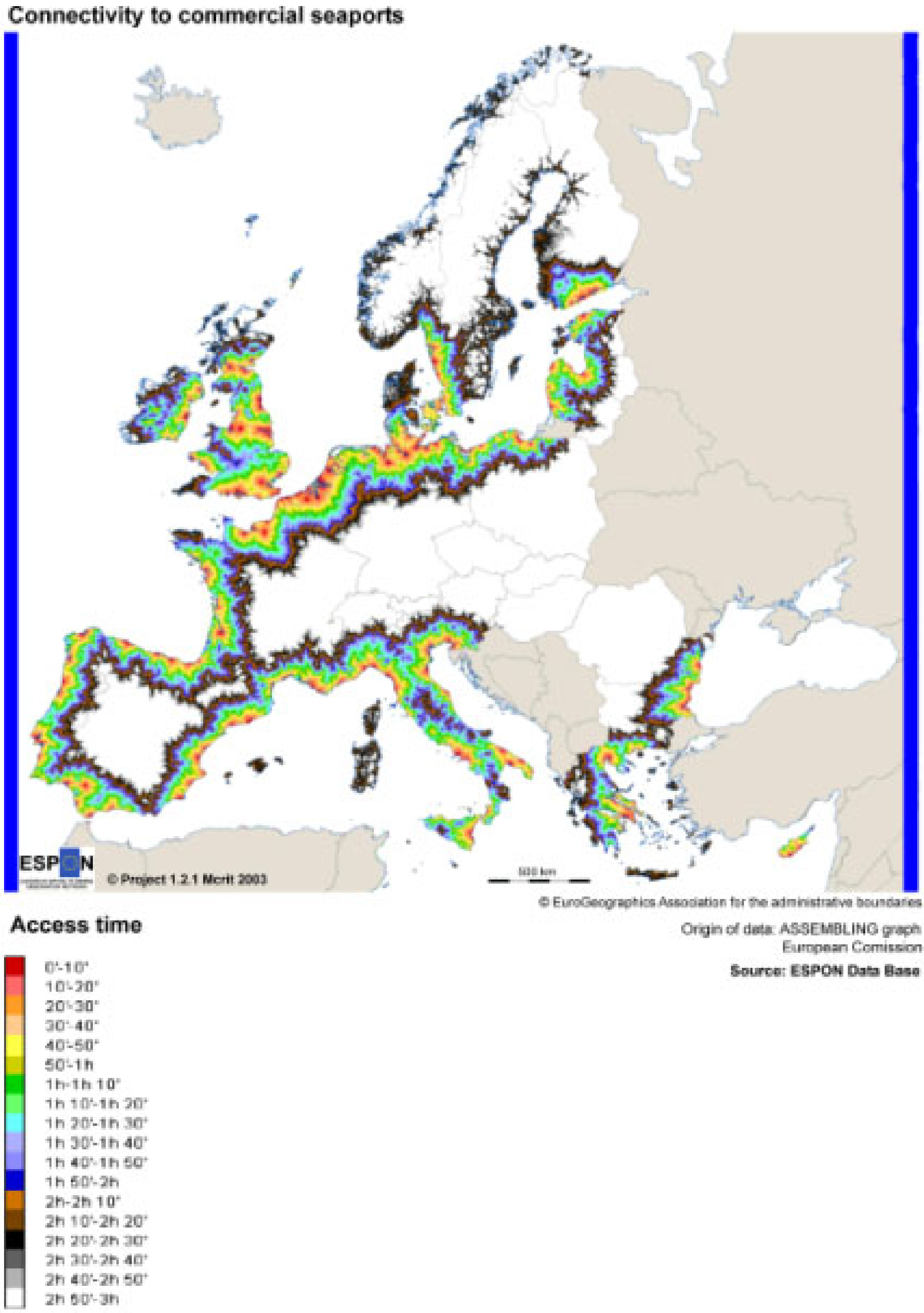


Figure 5.3.4. Connectivity to commercial seaports

5.3.5 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. 5.3.5). The maximum time that a truck driver can drive and the rest time have not been considered.

Table no. 5.3.5: Speed by car and truck in road links

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

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 chapter 5.1.4 there is 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 Sardenya, 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 Letonia to the Riga port, have a high cost to port due to the lack of motorways and expressways network.

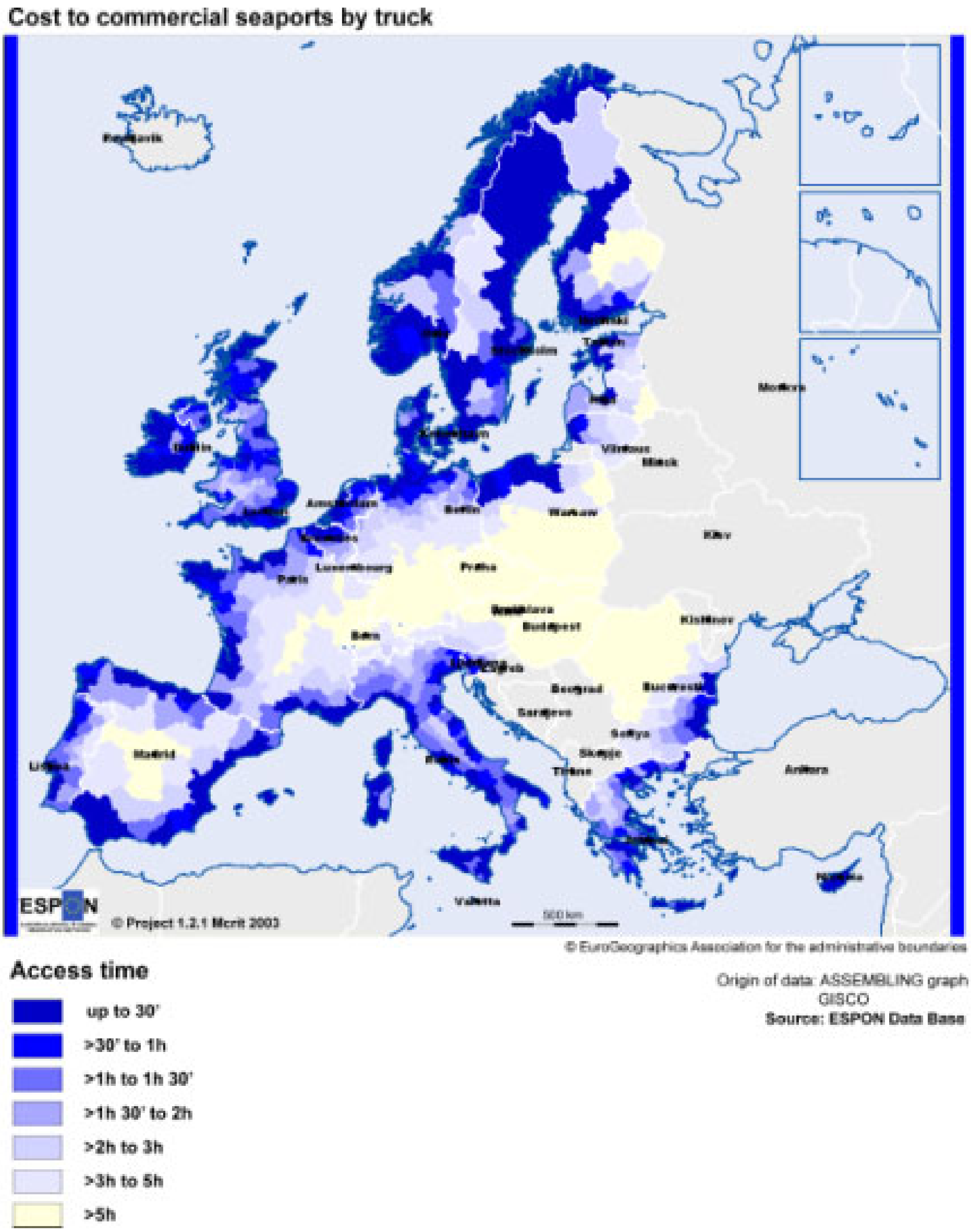


Figure 5.3.5. Cost to commercial airports by truck

5.3.6 Connectivity to commercial 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 don’t act as hubs of secondary hubs spread around the rest of the territory.

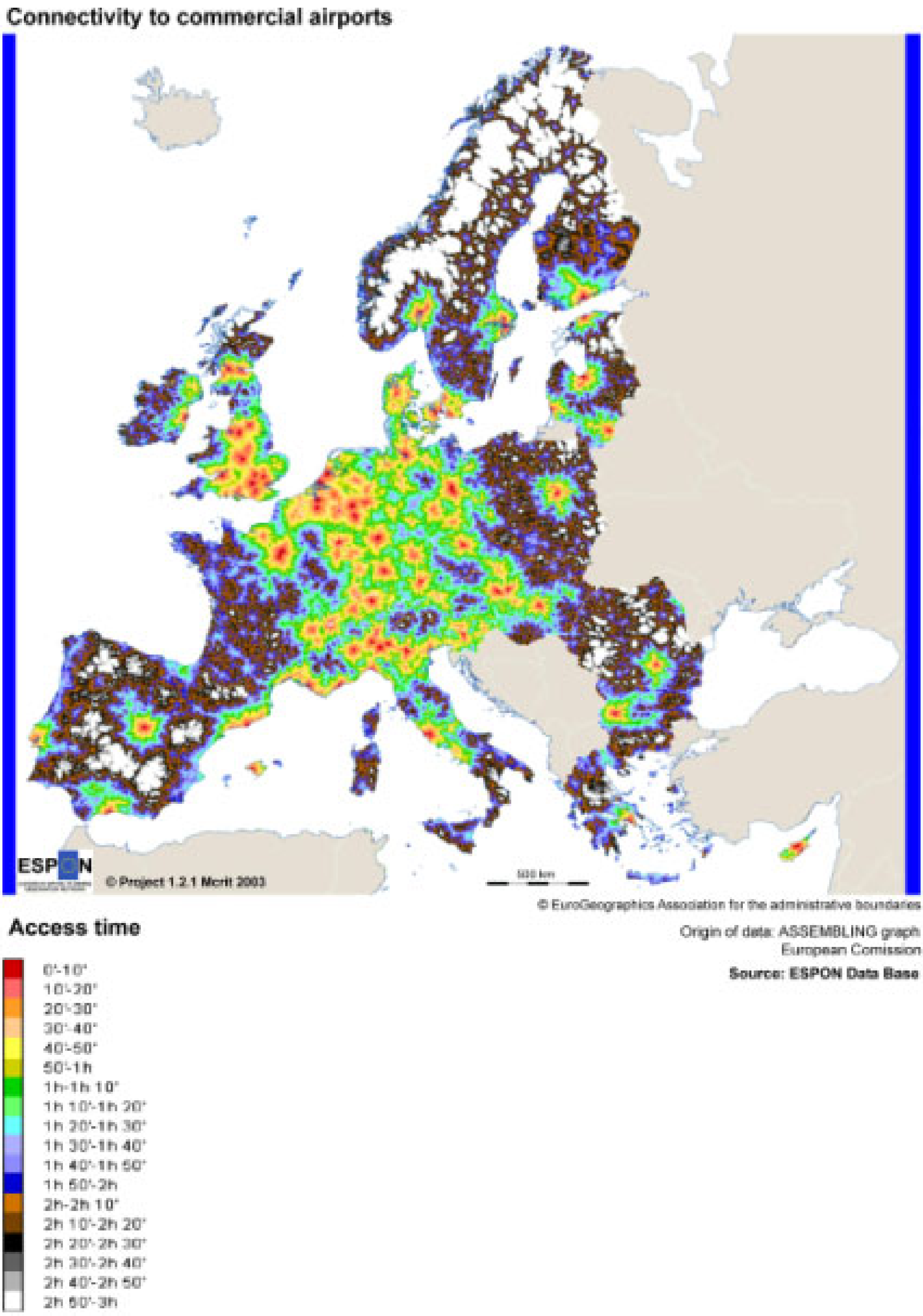


Figure 5.3.6. Connectivity to commercial airports

5.3.7 Time for freight road transport

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 of 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 45 min	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 doesn't 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.

Demonstration example.

This map show the average travel time for trucks from candidates to members and from members to candidates. The results are aggregated by Nuts level 3. We consider that the European legislation is the same for all countries (members and 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.

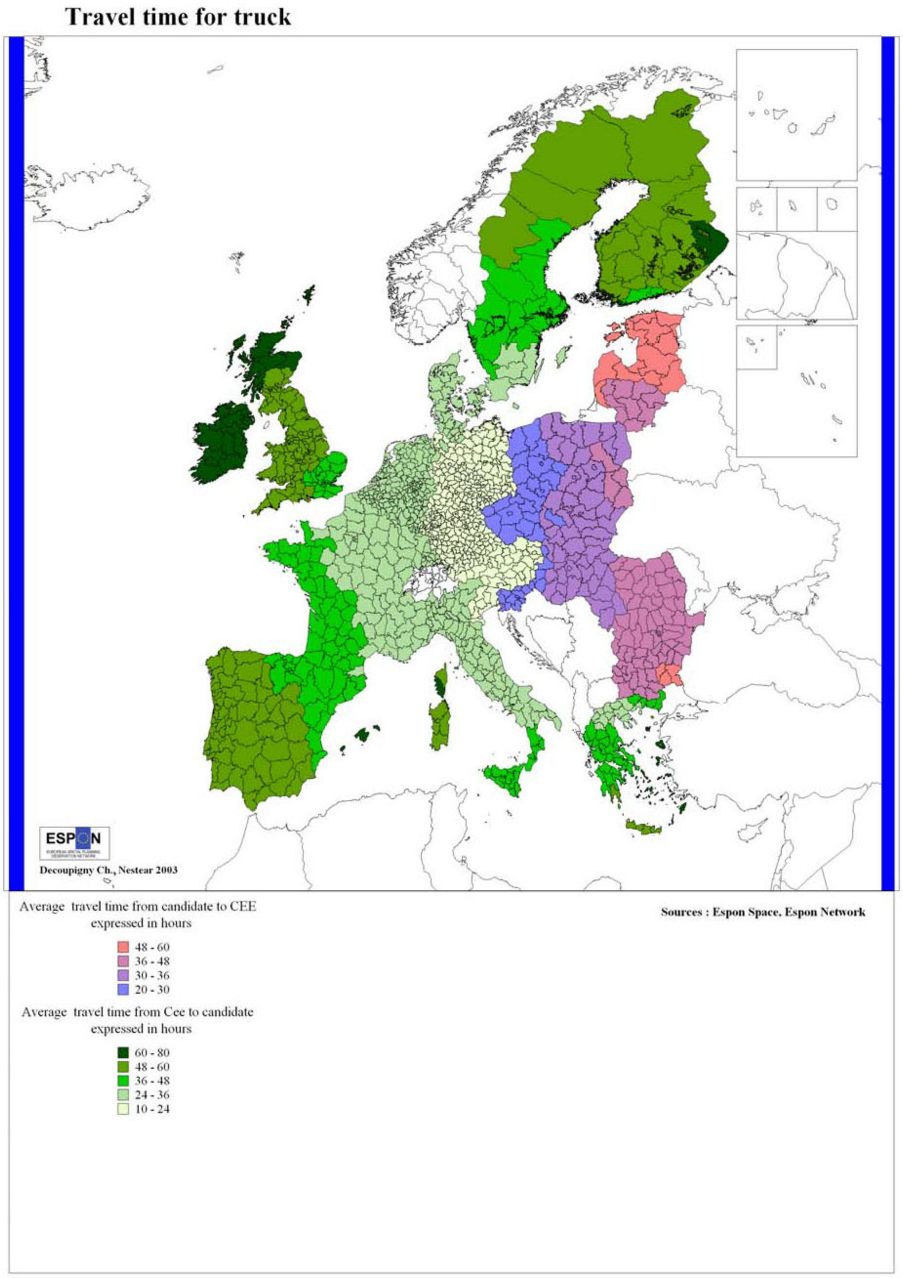


Figure 5.3.7 Travel times for trucks

5.3.8 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:

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 Nuts 2. It is a representation of the cost of the truck travel time.

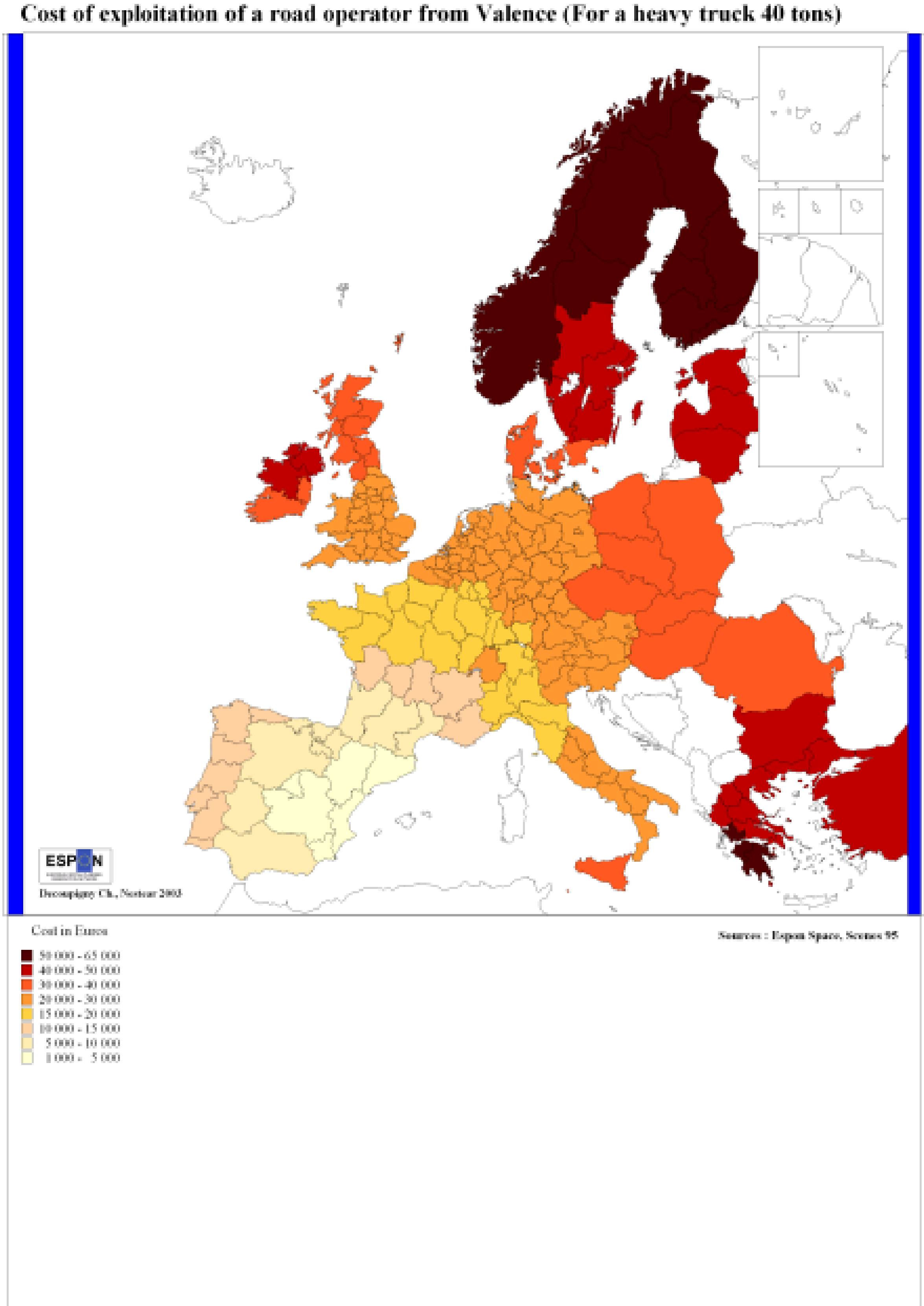


Figure 5.3.8 Exploitation cost of a road operator from Valencia

5.3.9 The rail operating techniques

The rail operating techniques are probably the ones which offer 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 which affect all the rail operating systems has been recalled the following distinction can be made between :

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

5.3.9.1 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 which 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 introduce 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.

5.3.9.2 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.

5.3.9.3 Intermodal technique

The intermodal technique is already well developed on certain market and corridors and should develop quickly on these 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 transpyrenean markets since more freight has to be transferred to rail for the crossing of these mountains because of reduced capacity od 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.

5.3.10 Short sea shipping operations

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.

5.4 Daily accessibility

5.4.1 Daily population accessible by car

Rationale and policy relevance

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 hinterland of 3 hours using road 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 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 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 and results

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 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).

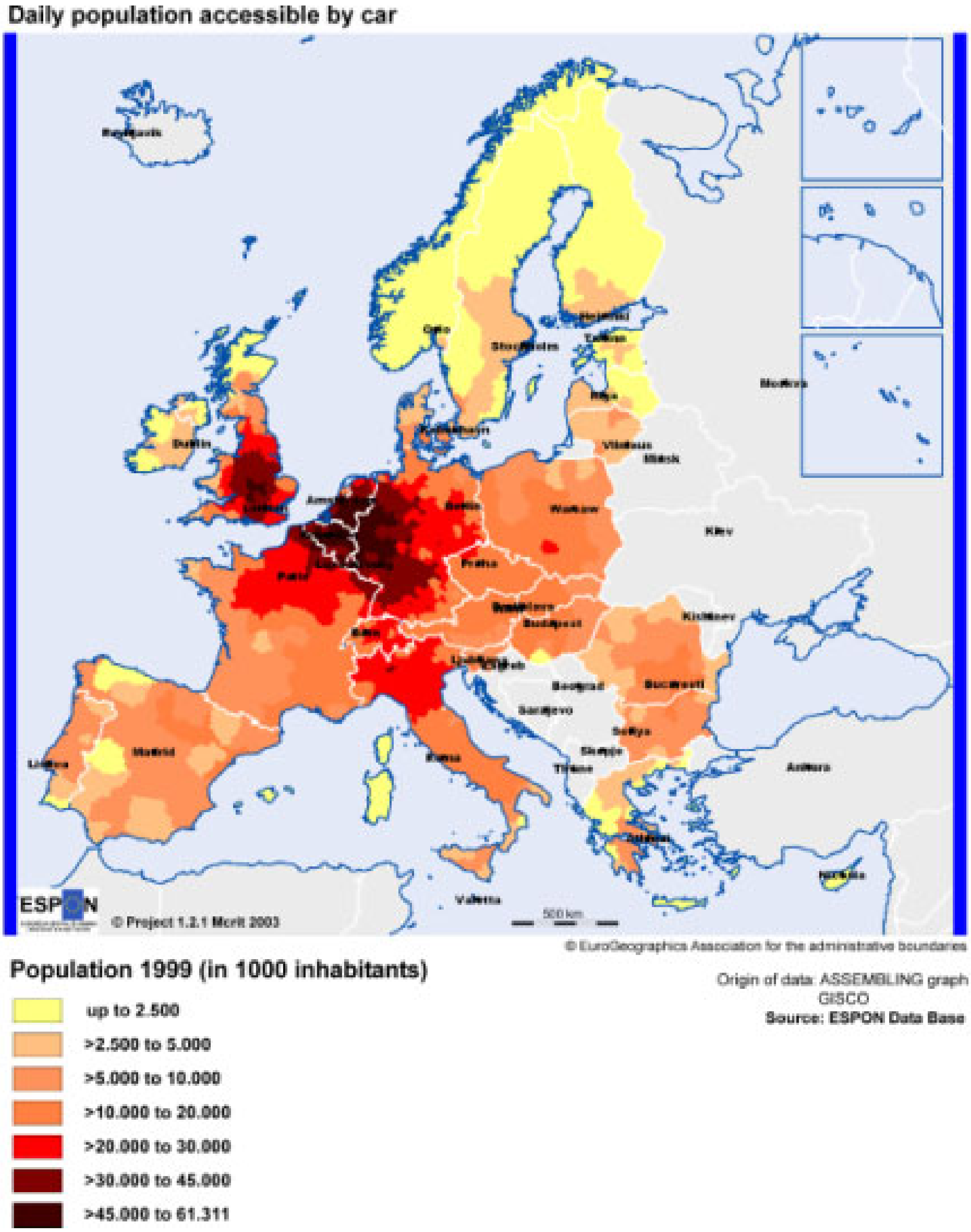


Figure 5.4.1. Daily population accessible, 1999

5.4.2 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 and results

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

Comparing with the previous indicator, the recentralisation of European geography in Germany becomes more clear.

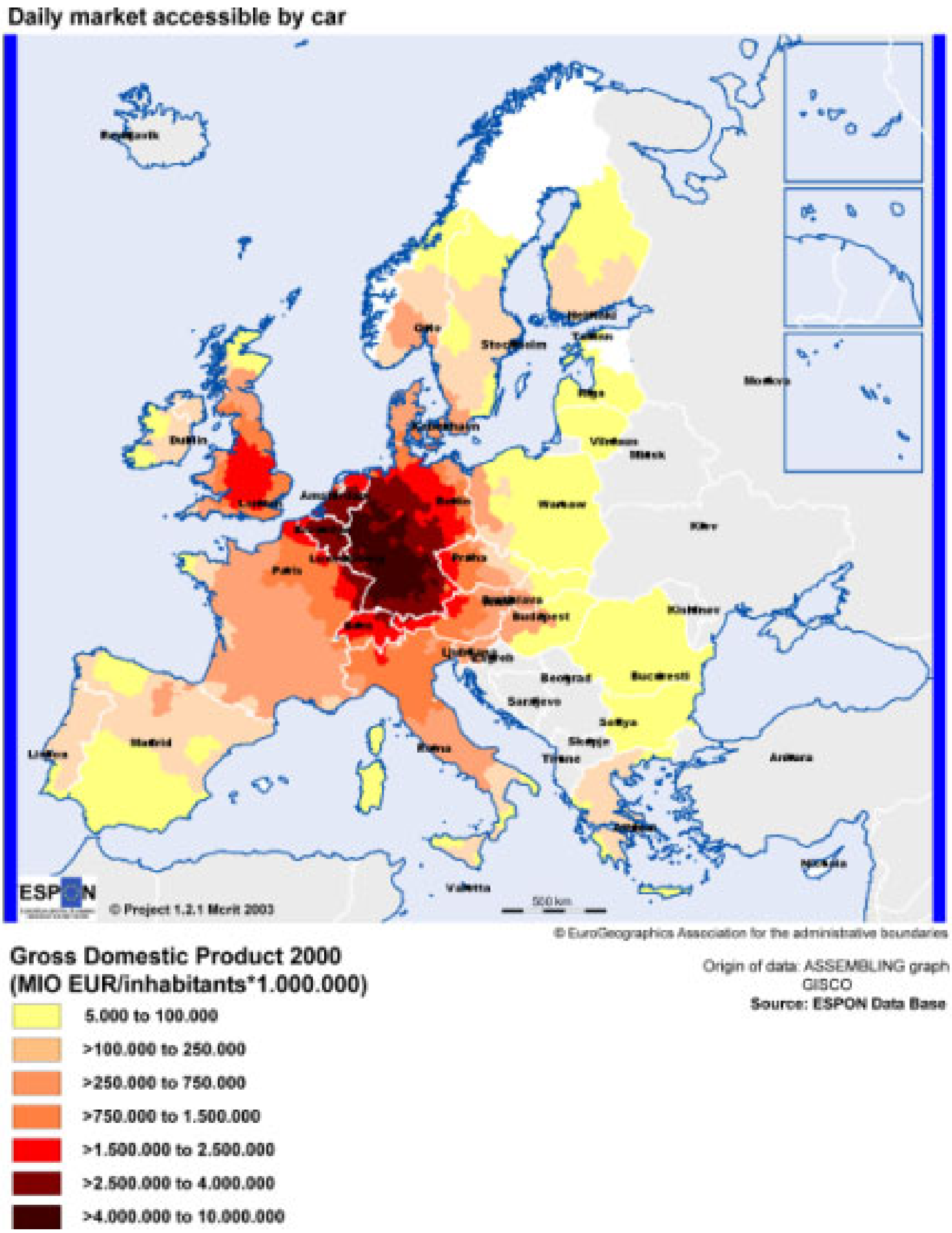


Figure 5.4.2 Daily market accessible by car, 2001

5.4.3 'City network' air relations for 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

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 comes from the work done in the ESPON theme 111 on polycentrism.

At the continental scale, two systems of mobility can be identified: firstly the sphere of daily mobility articulated around the trips between homes and to workplace 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 functionning 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.

Data requirements

The data sources on the minimum flight time between the MEGAs is provided through a seach on the major transport websites such as Amadeus.

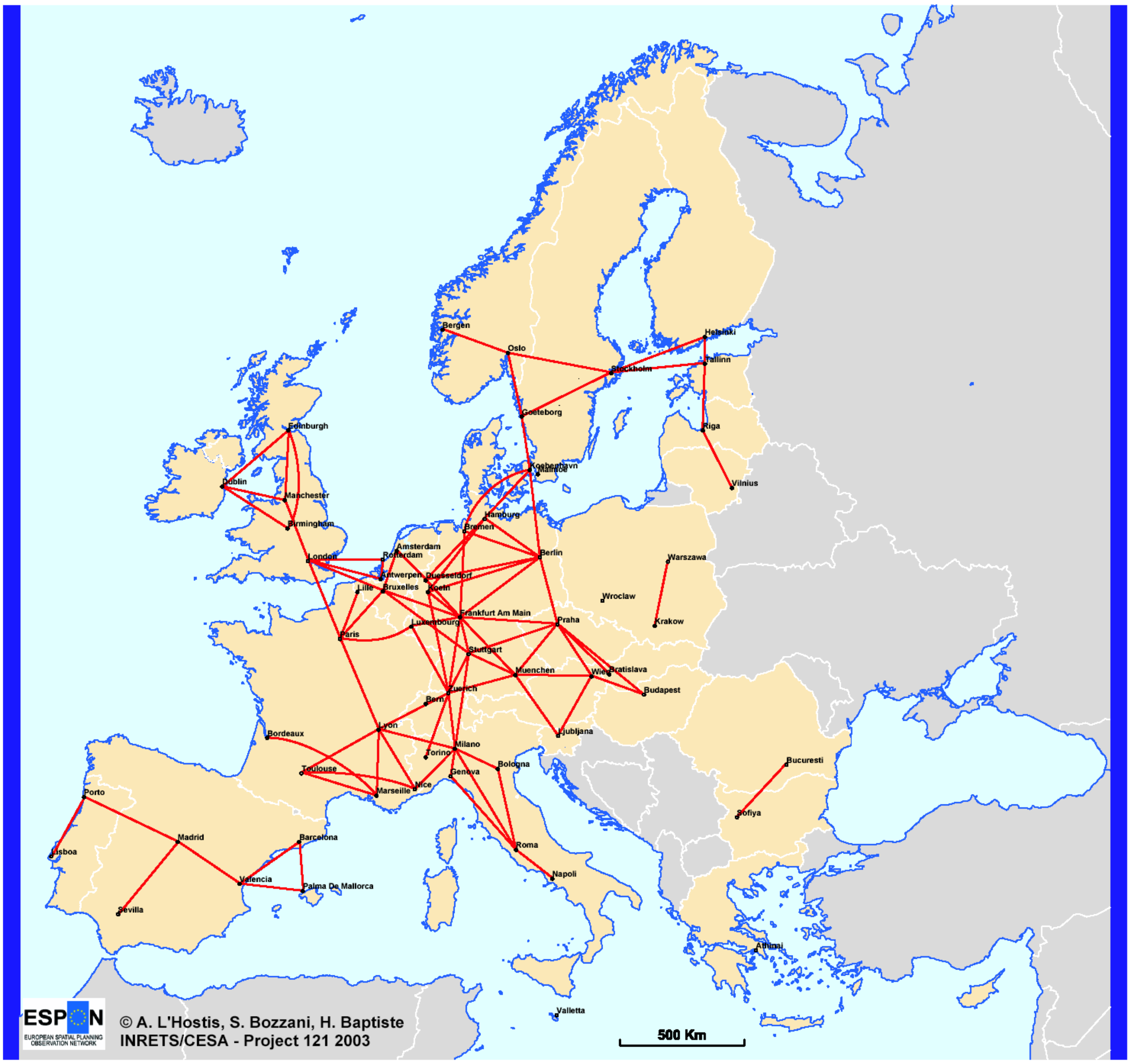
Application to ESPON space

The map figures the existence of a minimum time flight of one hour or less between the 62 MEGAs identified by the 111 ESPON group.

This map expresses a factor of integration of the European territorry. The connexity of the system of relations allows the continuity of one hour realtions in the core of the continent from Rome to Edinburgh and from Bordeaux to Helsinki. Tha Baltic states are linked to the Union through relations between Tallinn, Helsinki and Stockholm.

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

Travel times of one hour or less by air
between the 62 Metropololitan European Growth Areas (MEGA)



Geographical Base: Eurostat GISCO

Time distance of 1 hour or less by air

Figure 5.4.3 Travel times of one hour or less by air between MEGAs 2003

5.4.4 'City network' daily accessibility

Rationale

The minimum time approach assumes the short 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 has been based on:

- the political role of cities (capitals of countries of the ESPON space and neigbouring countries).
- the mass criterion (at least 200 000 inhabitants based on GISCO data)
- under 200 000 inhabitants, the importance of the airport to have a correct image of the air transport system
- under 200 000 inhabitants, a spatial covering criterion

Data requirements

This family indicators deal 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 resides 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.

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The data sources on the collective transport systems services resides 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.

Application to the ESPON space

The map presented show the possibility to do daily business trips between 236 cities on the ESPON.

Firstly, the hub function of the major Europen nodes is expressed through the convergence of bilateral relations with neighbouring cities, as can be observed in London, Paris, Frankfurt, Muenchen, but also in Madrid and Rome.

Nevertheless, the high level of service in the integated Europe contrasts with the generally poor levels in the eastern and accessing countries. In these parts, the bilateral links can only be observed in intra-national relations.

Considering the European Union countries, the main crossborder gap occurs between the Iberic peninsula and the rest of the continent with with no symetric relation, confirming the result observed with the one hour relations.

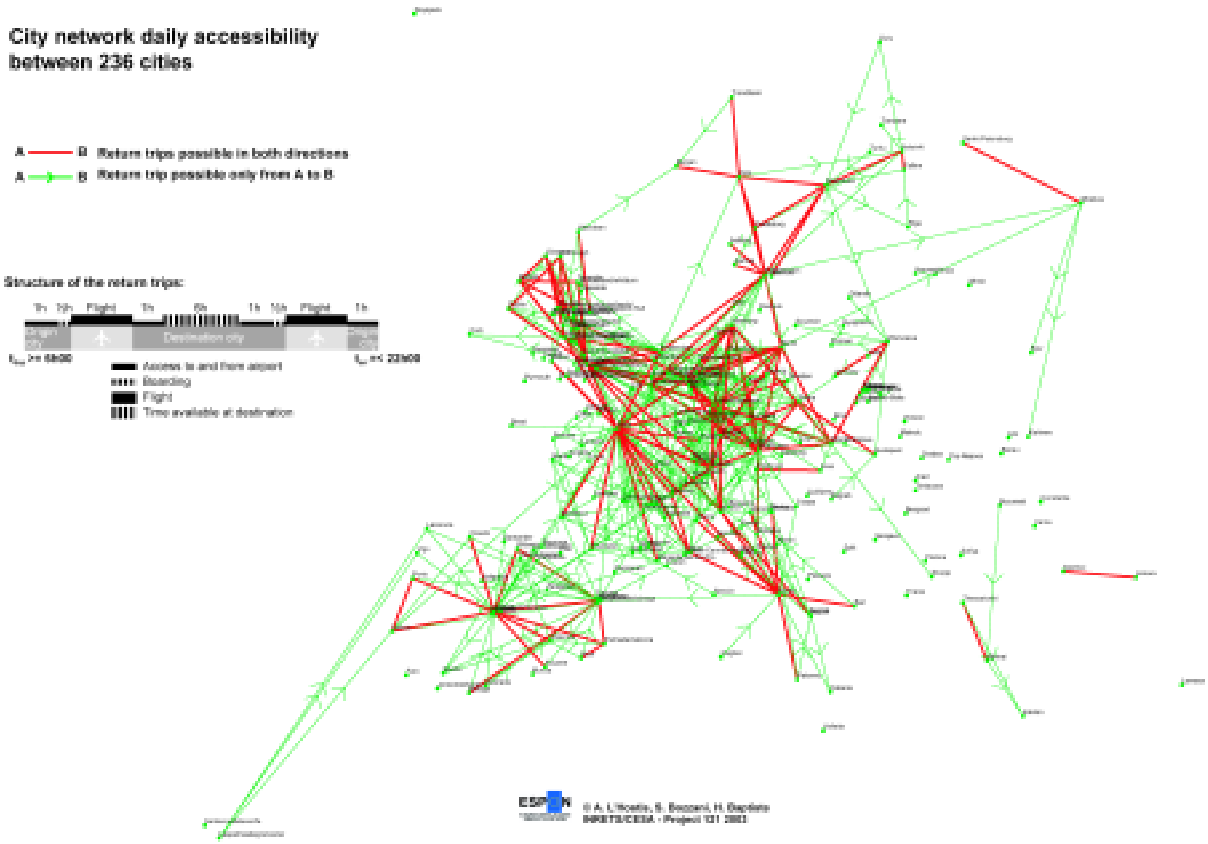


Figure 5.4.4 Travel times of one hour or less by air between MEGAs 2003

5.4.5 'City network' daily accessibility for MEGAs

Rationale

See city network daily accessibility

Method

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 comes from the work done in the ESPON theme 111 on polycentrism.

Data requirements

See city network daily accessibility

Application to the ESPON space

The map presented shows the possibility to do daily business trips between the 62 MEGAs provided by the 111 ESPON group on polycentrism.

Firstly, the pentagon pattern 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, at the exception of Praha.

The coherence of the Nordic network appears clearly with the role of gateway for Kobenhavn.

In the Iberic peninsula a high level of integration is reached between Madrid and the major Spanish and Portuguese cities, but the gap with the continental Europe is still there

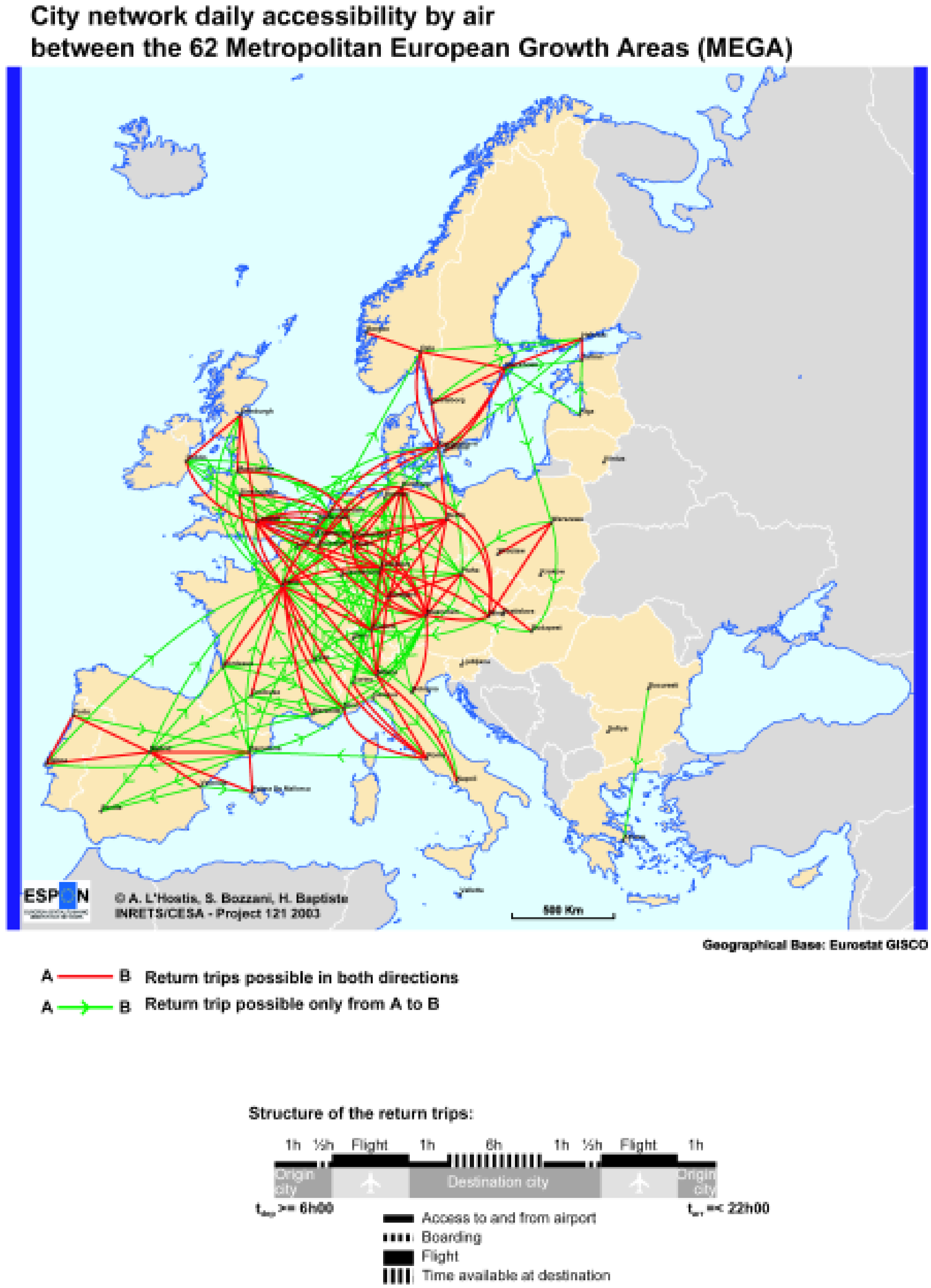


Figure 5.4.5 Travel times of one hour or less by air between MEGAs 2003

5.4.6 'City network' daily accessibility for modified MEGAs list

Rationale

Based on the indicator of daily accessibility but also with reference to previous studies, especiallly the CRPM works, 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 make 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 Bruxelles
- Duesseldorf associated to Koeln

MEGAs introduced according to CRPM analysis:

- Bilbao
- Nantes
- Belfast
- Bristol
- Nottingham
- Leeds
- Newcastle
- Thessaloniki
- Genève
- Lodz
- Palermo
- Venezia
- Firenze

Method

See city network daily accessibility

Data requirements

See city network daily accessibility

Application to the ESPON space

The accessibility levels with 13 added MEGAs as compared to the initial list 62 cities can be seen on the following map. Improvements can be observed with apparition of a bilateral relation in Greece between Thessaloniki 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 improvement 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 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.

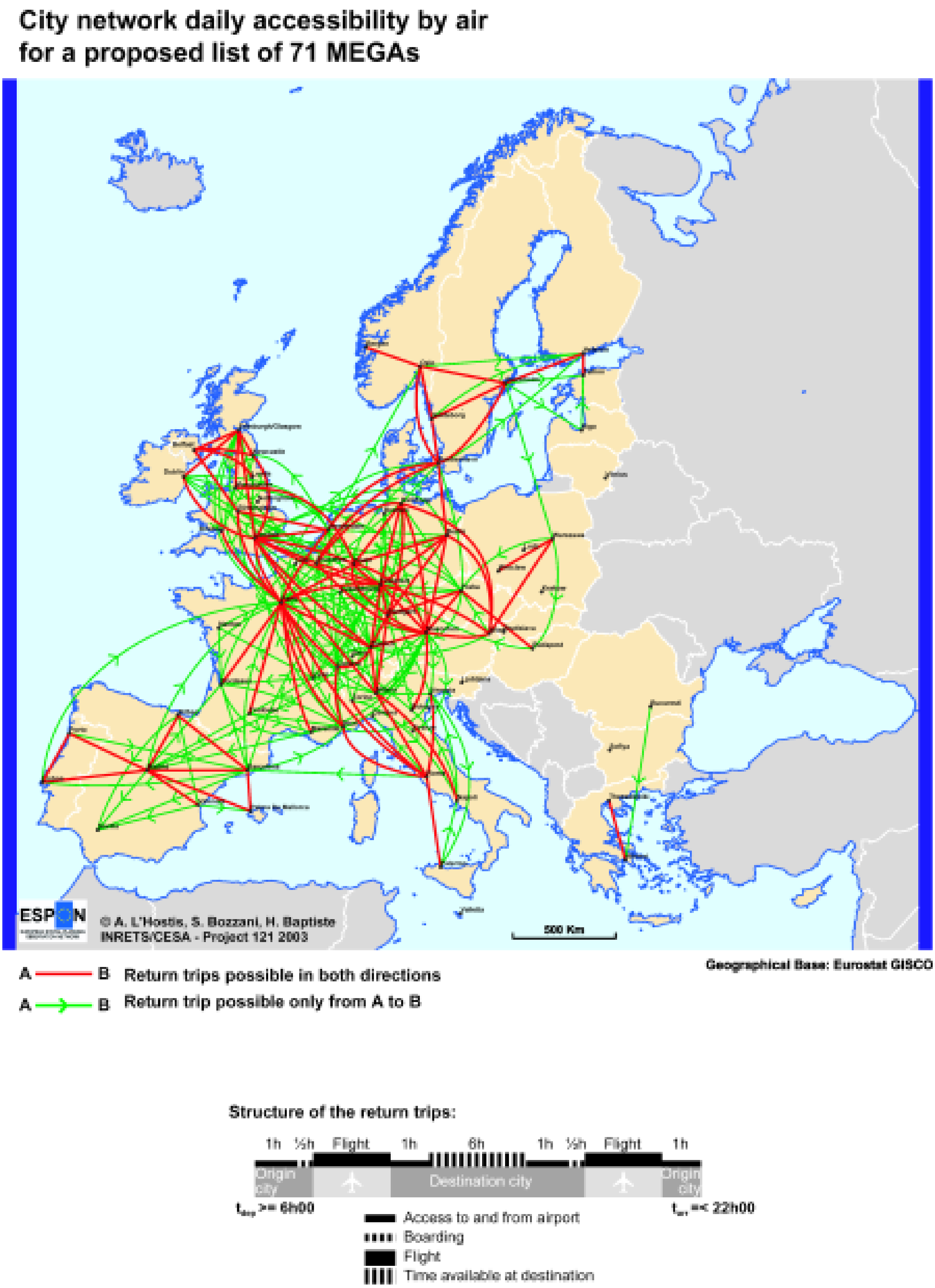


Figure 5.4.6 Travel times of one hour or less by air between MEGAs 2003

5.5 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.

5.5.1 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 (see Chapter 4).

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, one representing the activities or opportunities to be reached and one representing the effort, time, distance or cost needed to reach them (Wegener et al., 2002):

$$A_i = \sum_j g(W_j)\, f(c_{ij})$$

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*. The functions $g(W_{ij})$ and $f(c_{ij})$ are called *activity functions* and *impedance functions*, respectively. They are associated multiplicatively, i.e. are weights to each other. That is, 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*.

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*. This definition of accessibility is referred to as destination-oriented accessibility. In a similar way an origin-oriented accessibility can be defined: The more people live in areas *j* and the easier they can visit area i, the greater is the accessibility of area i. Because of the symmetry of most transport connections, destination-oriented and origin-oriented accessibility tend to be highly correlated.

The activity function may be linear or nonlinear. Occasionally the attraction term W_j is weighted by an exponent α greater than one to take account of agglomeration effects, i.e. the fact that larger facilities may be disproportionally more attractive than smaller ones. One example is the attractiveness of large shopping centres which attract more customers than several smaller ones that together match the large centre in size. 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.

$$A_i = \sum_j W_j^{\alpha} \exp(-\beta \, c_{ij})$$

The accessibility model used here (based on Spiekermann and Wegener, 1996) uses centroids of NUTS 3 regions as origins and 70,000 raster cells of 10 x 10 km as destination zones. Destination activities are disaggretated from NUTS 3 regions to raster cells. The accessibility model calculates the minimum paths for the road network, i.e. minimum travel times between the centroids of the NUTS 3 regions and all raster cells. For each NUTS 3 region the value of the potential accessibility indicator is calculated by summing up the population in all 70,000 raster cells 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. The road network database contains information on the type of road, inclusion in the TEN and TINA programmes, 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-Eurpean network database developed by the Institute of Spatial Planning of the University of Dortmund (IRPUD, 2001).
- The regional data consists of population data to be used as destination activity.

Demonstration example

The potential accessibility by road indicator has been calculated for all NUTS 3 regions of the ESPON space (see Figure 5.5.1). 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.

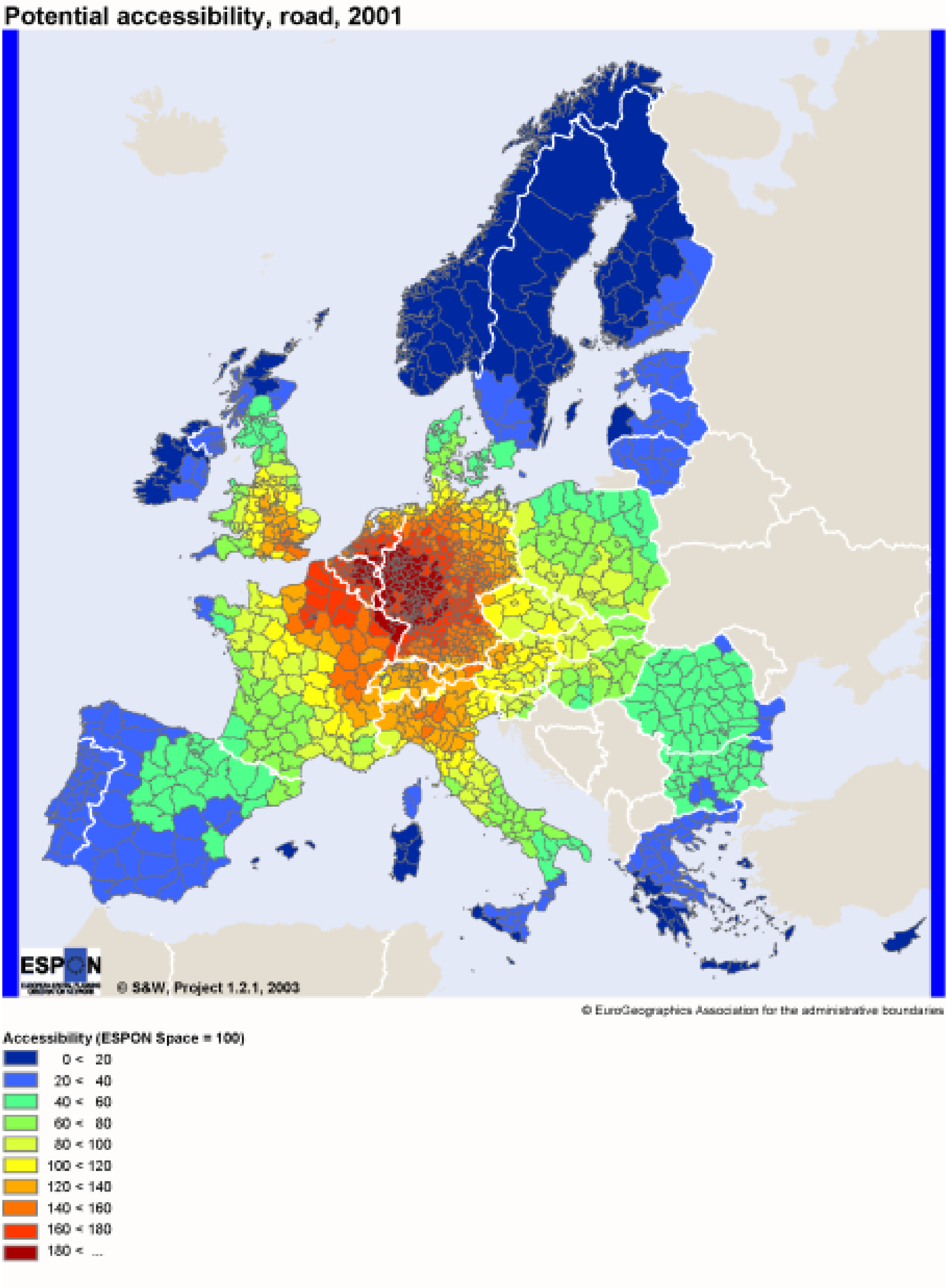


Figure 5.5.1 Potential accessibility by road, 2001.

5.5.2 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 the road network is replaced by a rail 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 time tables. 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, 2001).

Demonstration example

The potential accessibility by rail indicator has been calculated for all NUTS 3 regions of the ESPON space (see Figure 5.5.2). 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.

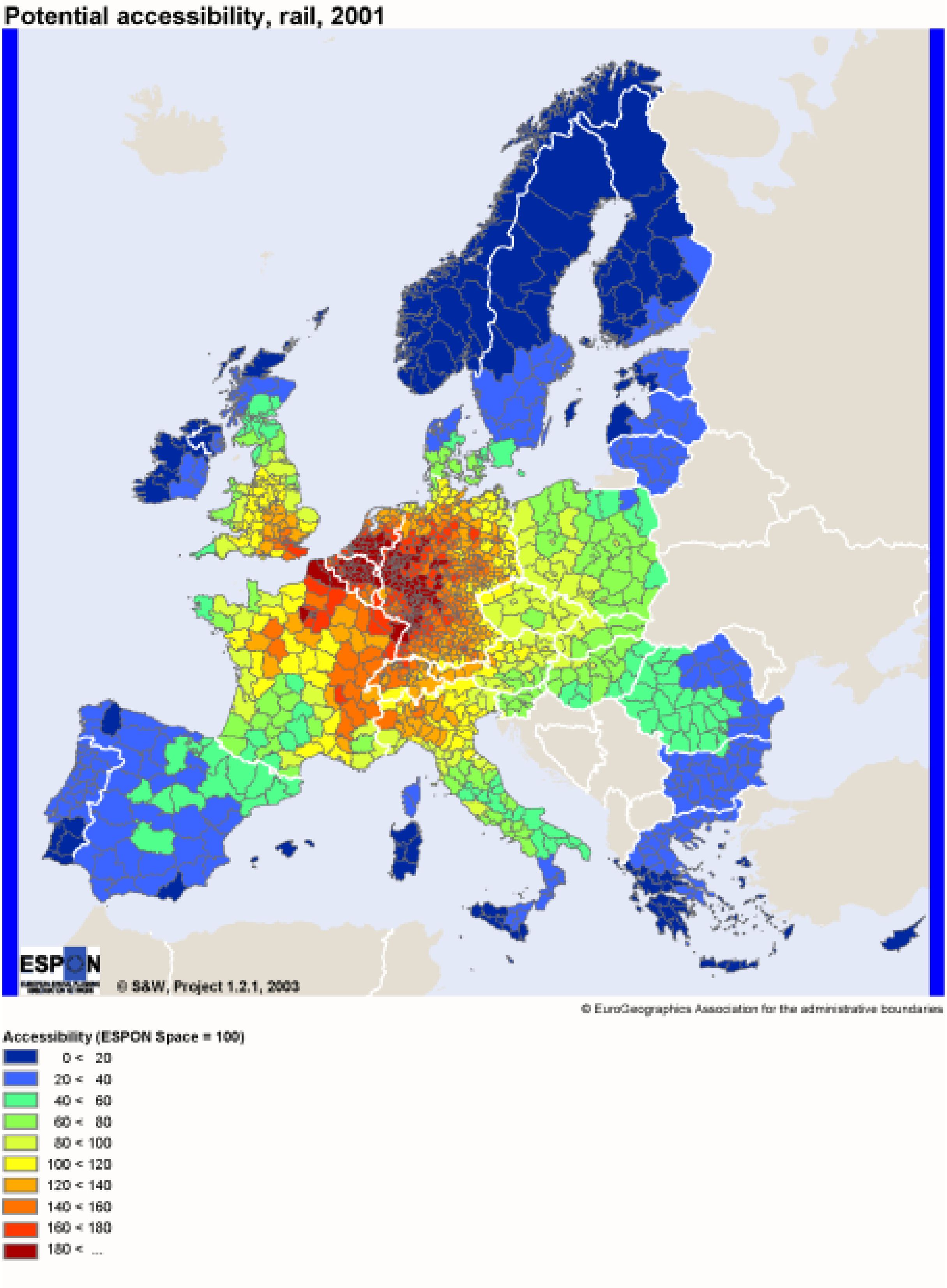


Figure 5.5.2 Potential accessibility by rail, 2001.

5.5.3 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 described in Section 5.5.1 applies here.

Method

The same 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. charter flights and other non-regular flights are not included. For each relation, the average flight time based on flight time table 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.

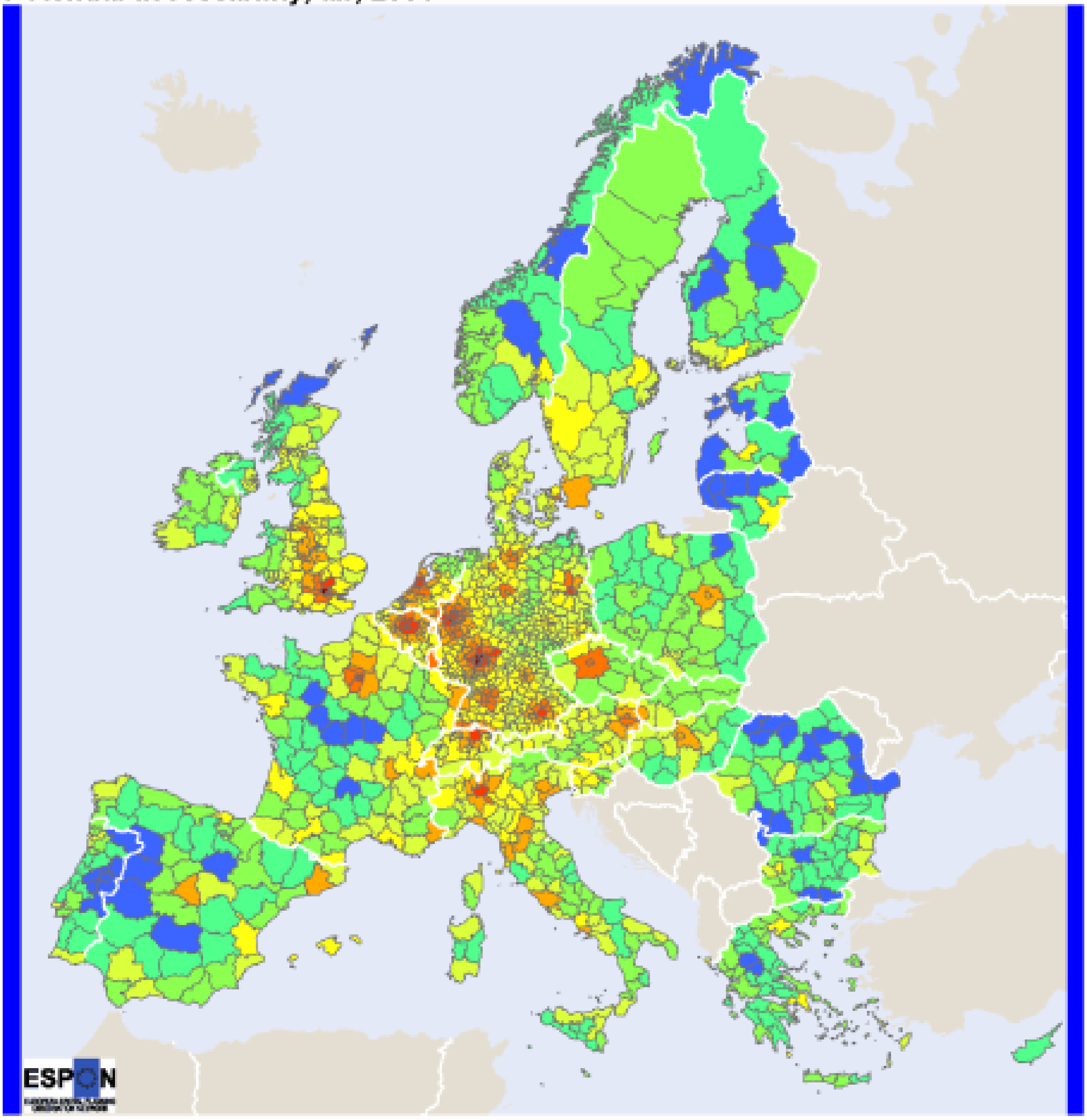
Demonstration example

The potential accessibility by air indicator has been calculated for all NUTS 3 regions of the ESPON space (see Figure 5.4.3). 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 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 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.

Potential accessibility, air, 2001



© EuroGeographics Association for the administrative boundaries

Accessibility (ESPON Space = 100)

0 < 20
20 < 40
40 < 60
60 < 80
80 < 100
100 < 120
120 < 140
140 < 160
160 < 180
180 < ...

Figure 5.5.3 Potential accessibility by air, 2001.

5.5.4 Multimodal potential accessibility

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 advantages 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.

Demonstration example

The multimodal potential accessibility indicator has been calculated for all NUTS 3 regions of the ESPON space (see Figure 5.5.4). 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, 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.

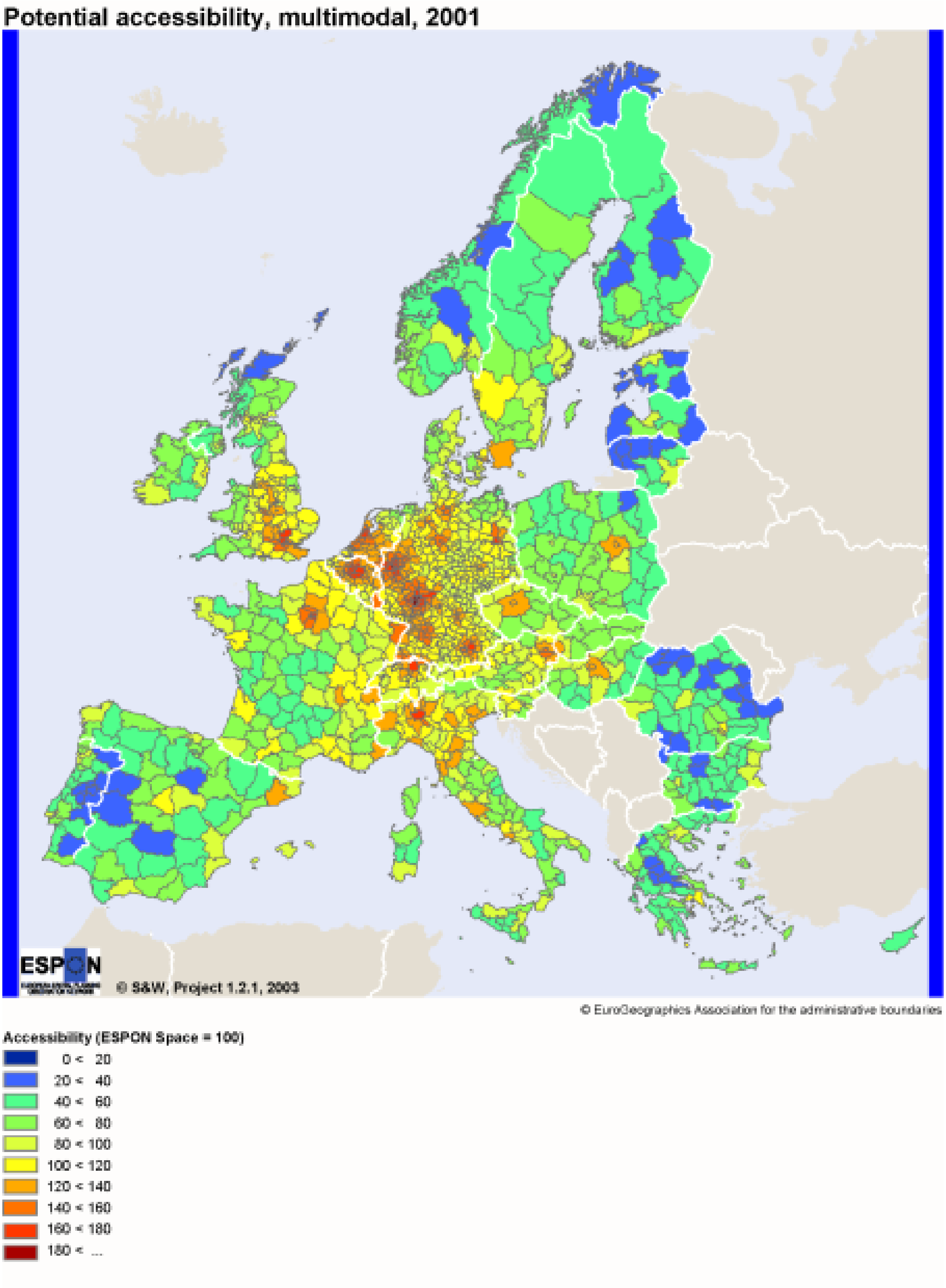


Figure 5.5.4 Multimodal potential accessibility, 2001.

5.6 Traffic volumes and flows

5.6.1 Trips generated / Purpose: business

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; also, it is important that forecast models be efficient sofware tools allowing for relative easy and fast simulation to test multiple scenarios and validate results.

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

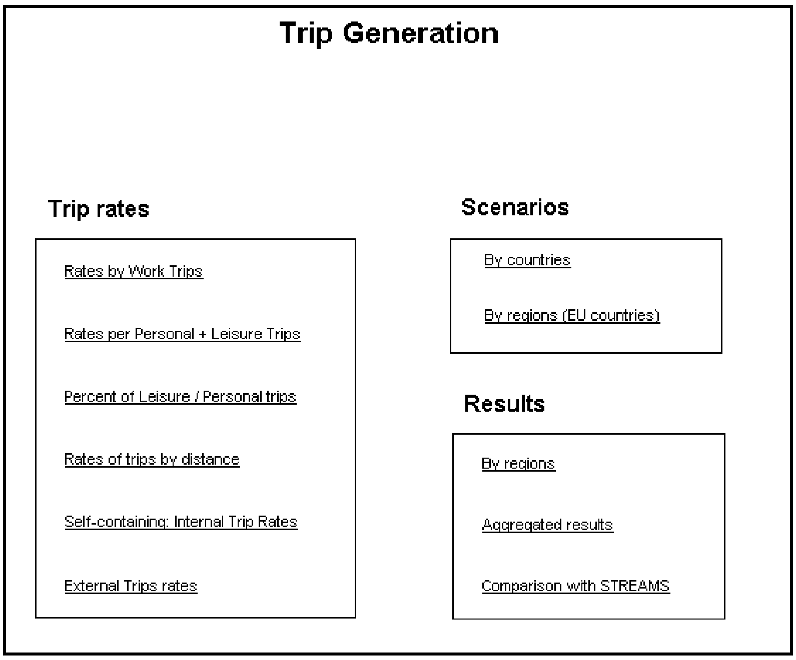
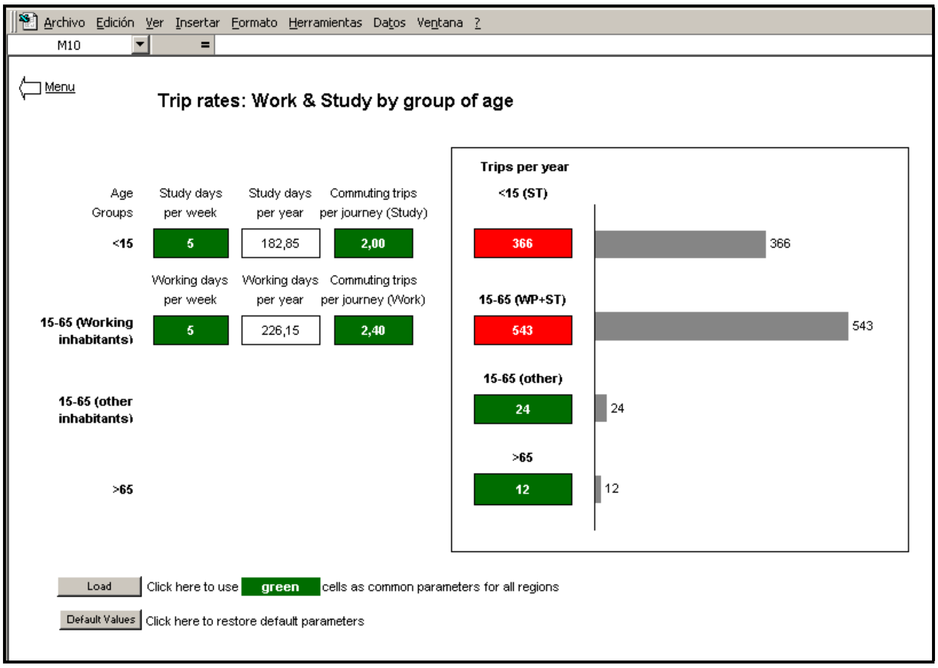


Figure 5.6.1.2: KTEN: Trip rates interface of the Trip generation module



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.

Data requirements

The regional data needed is the population and the active population of each NUTS2 to determine the work and study rates.

Application and results

Business trips generated 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 and with a high external trip rate.

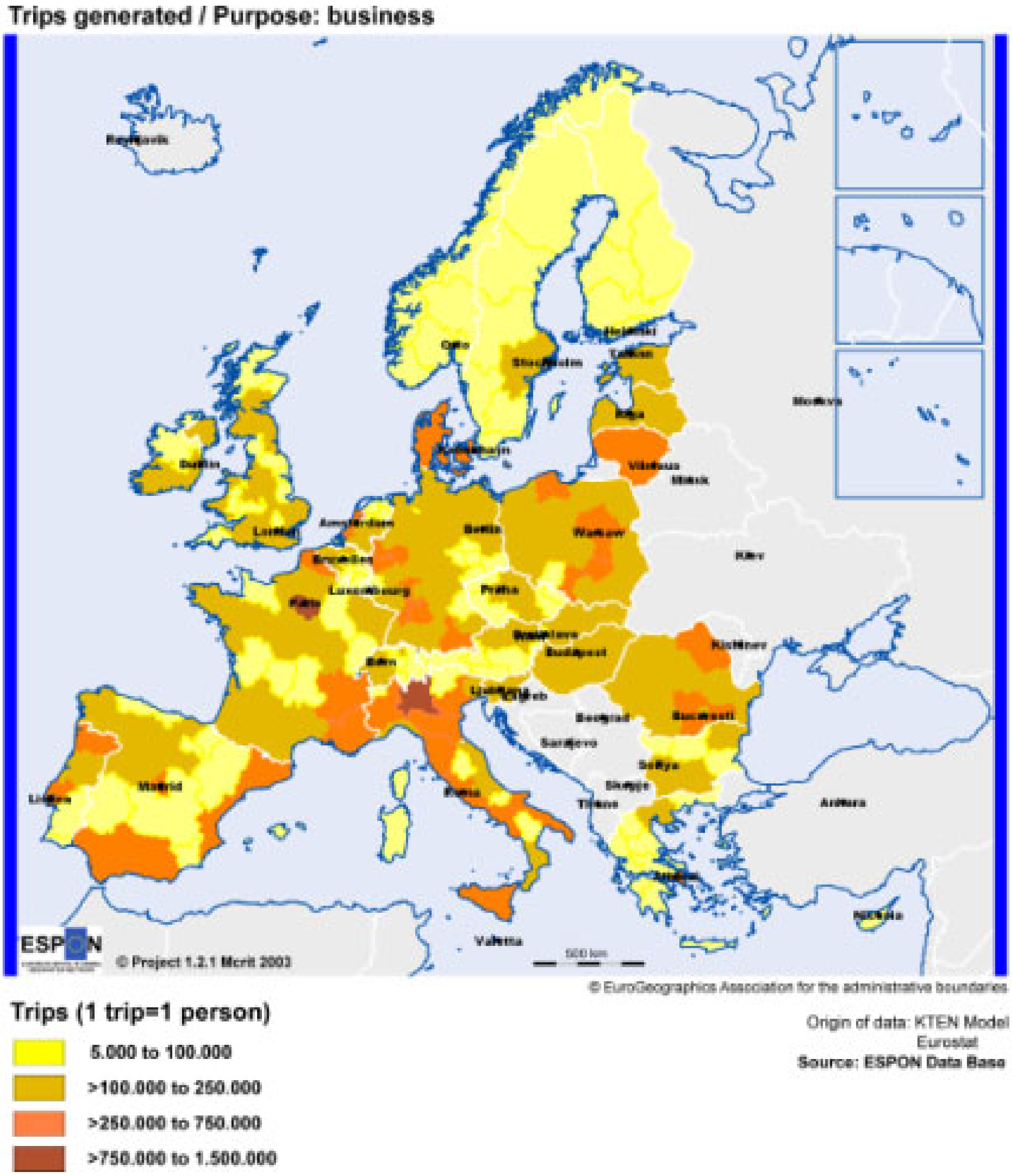


Figure 5.6.1.3. Trips generated for business purpose.

5.6.2 Trips generated / Purpose: leisure

Rationale and policy relevance

Leisure trips generated follows the same rationale as the previous section.

Methodology

The same model as described in the previous section has been applied here.

Figure 5.6.2.1: KTEN: Leisure and Personal trips by GDP of the Trip generation module

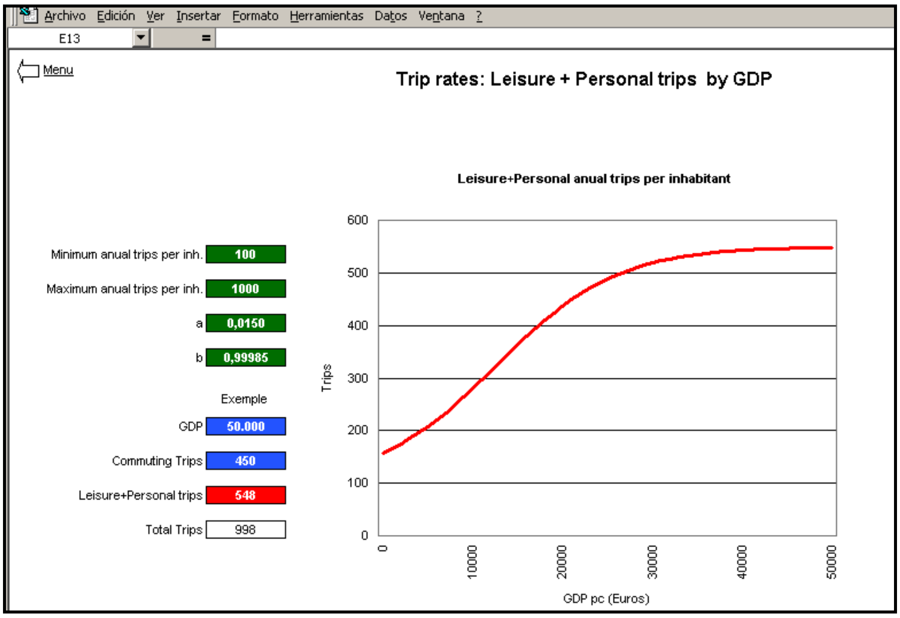
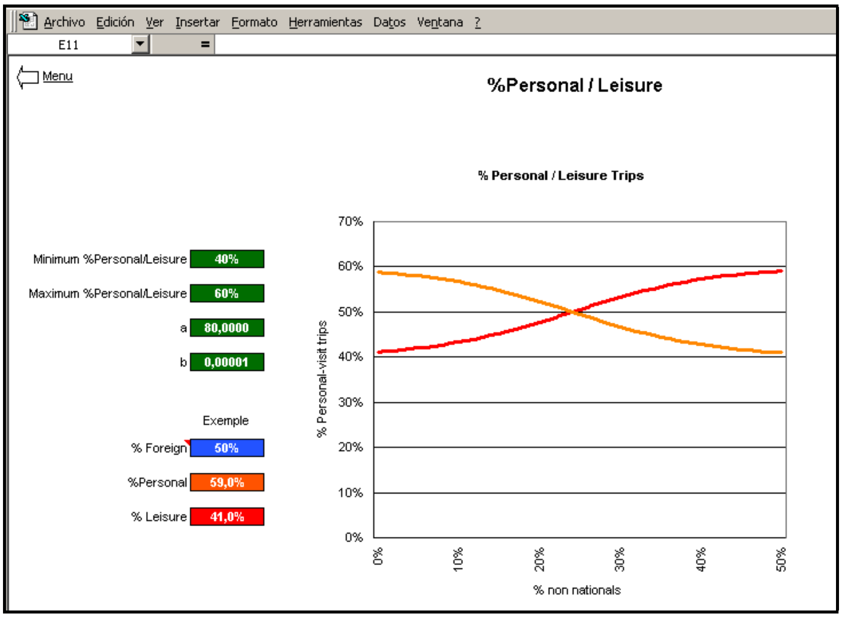


Figure. 5.6.2.2: KTEN: Relation between Leisure and Personal trips of the Trip generation module



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. The percentage of leisure trips regarding total leisure and personal trips is calculated with the same function. In this case x is the percentage of non-national inhabitants and A_s and A_i are the superior and inferior asynptotes of the percentage of leisure and personal to total anual trips. The percentage of personal trips is the complementary of the leisure trips.

Data requirements

The data required are the GDP per capita of each NUTS2 (from Eurostat), and Spatial Indicators (SPESP).

Application and results

Leisure trips generated by a zone (i) have been calculated for all NUTS2 in ESPON space. NUTS2 with higher generation of leisure trips are those with high GDP and population, and low percentage of non-national inhabitants (those with a high non-national population have higher visit trips due to their family situation). This is the case of most capitals and Mediterranean regions.

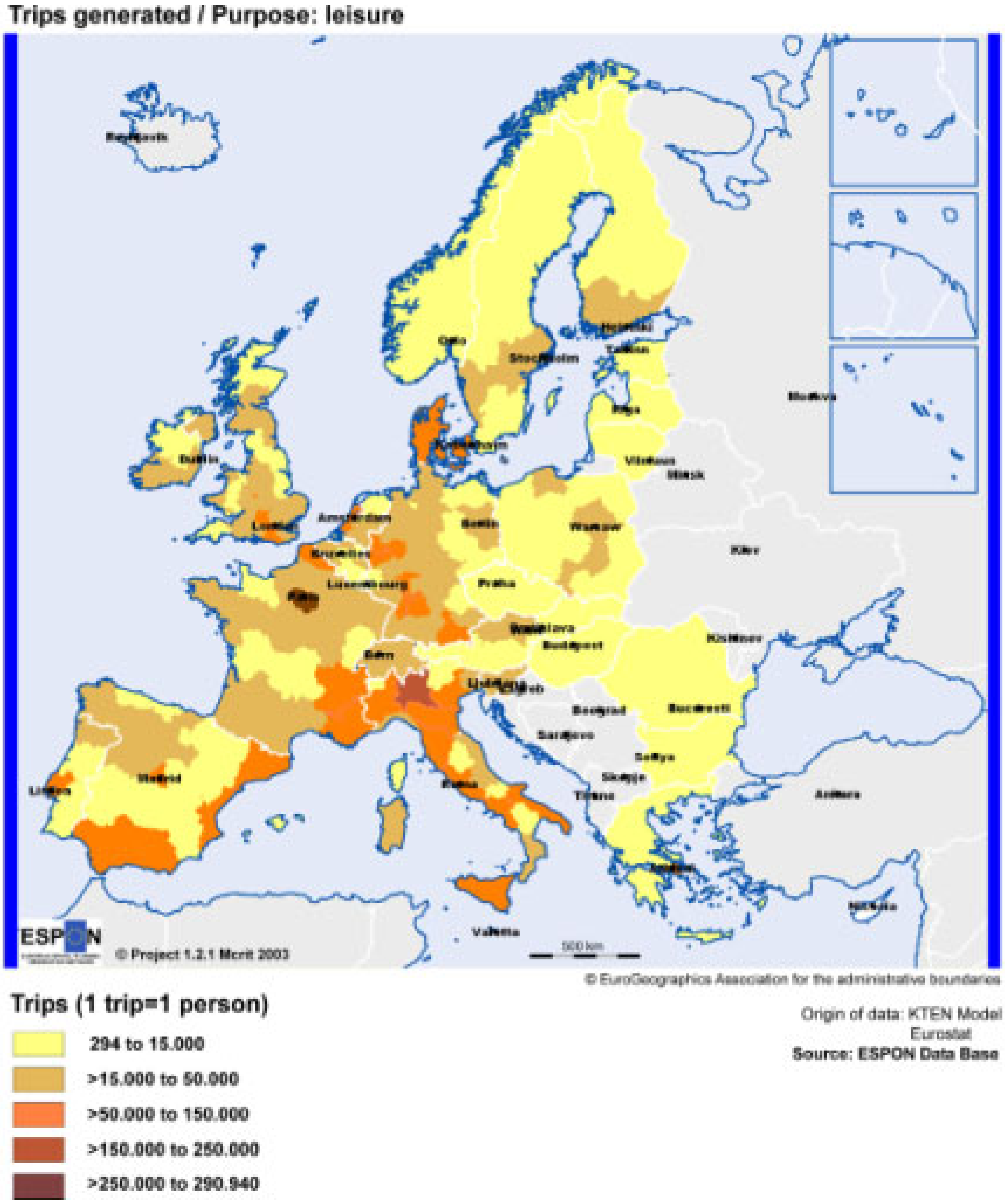


Figure. 5.6.2.3: Trips generated for Leisure purpose

5.6.3 Trips generated / Purpose: visits

Rationale and policy relevance

Visit trips generated follow 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

Visit trips generated by a zone (i) have been calculated for all NUTS2 in ESPON space. Like in leisure trips generation, NUTS2 with higher generation of visit trips are those with high GDP and population, but in this case with high percentage of non-national inhabitants as they travel to visit their relatives. This is the case of most capitals and Mediterranean regions.

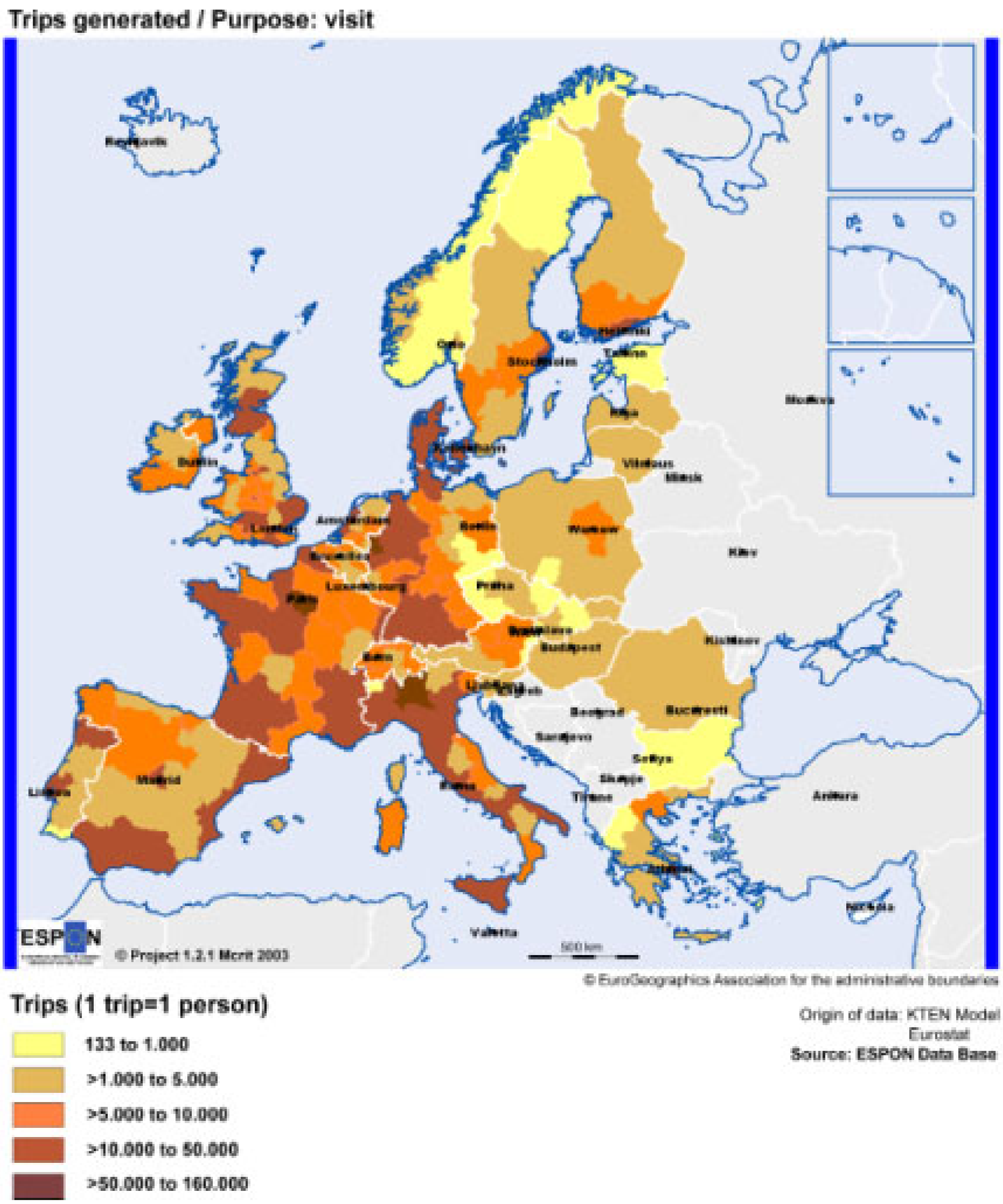


Figure. 5.6.3: Trips generated for visit purpose

5.6.4 Trips attracted / Purpose: business

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 business trip distribution, KTEN 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)

The business trips attracted by zone (j) are all the trips with origin zone (i) to destination zone (j). The expression is as follows:

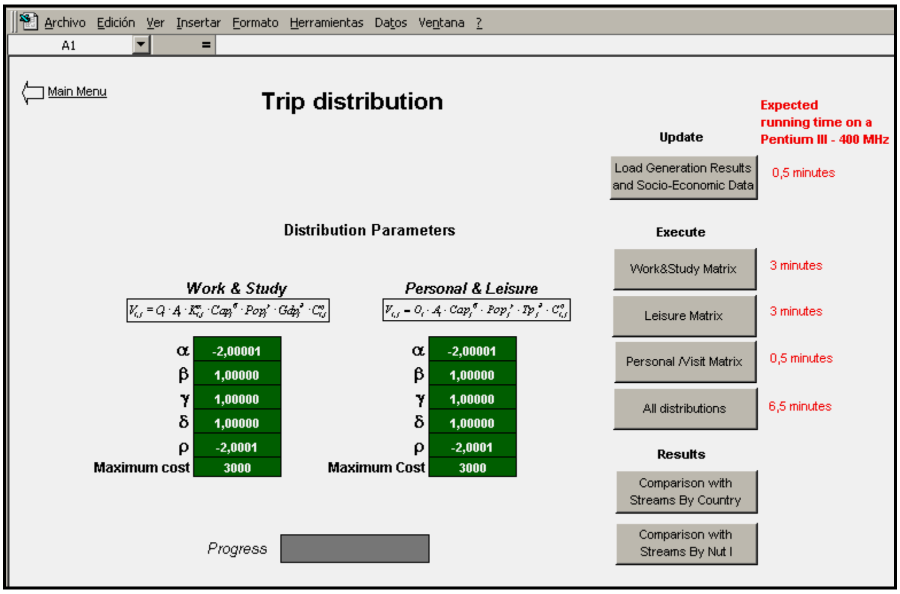
$$V_j = \sum_i V_{i,j}$$

where,

V_j trips attracted by zone (j)

$V_{i,j}$ trips between zone (i) and zone (j)

Figure 5.6.4.1: KTEN: Interface of the Trip distribution module



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) from Eurostat.

Application and results

Business 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 European, 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.

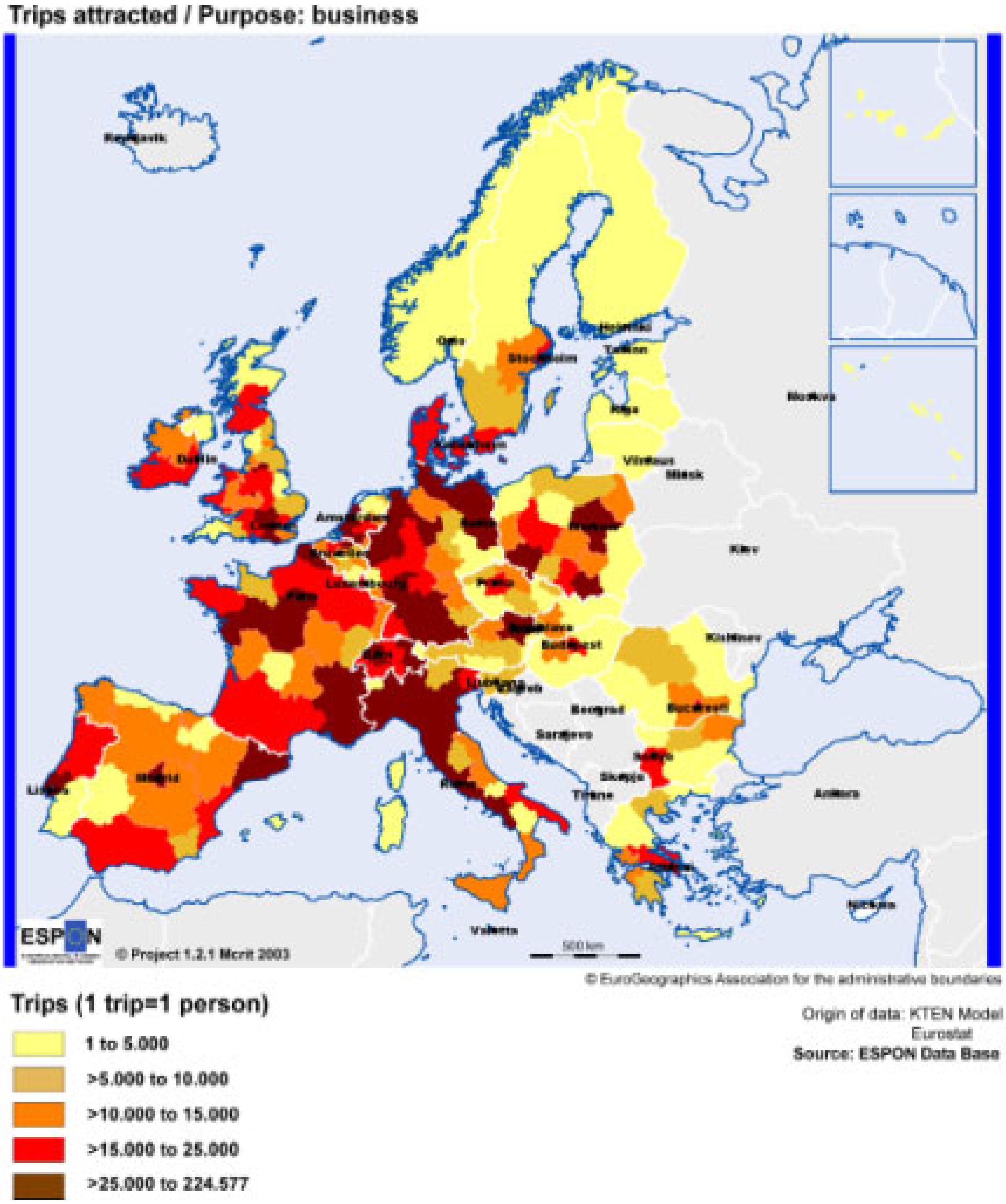


Figure. 5.6.4.2: Trips generated for business purpose

5.6.5 Trips attracted / Purpose: leisure

Rationale and policy relevance

Leisure trips attracted follow the same rationale and policy relevance as explained in the previous section.

Methodology

The model and method used are explained in the previous section. In this case, 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 preasure on site of zone (j)

$C_{i,j}^{\rho}$ cost to travel from zone (i) to zone (j)

Once the distribution between zones of leisure trips is calculated, the leisure trips attracted in a zone (i) is the aggregation of trips with destination the zone (i).

Data requirements

The data used is the same as the one used at the previous section, adding the tourist pressure of zone destination, taken from the World Tourism Organisation statistics. It has to be remarked that there's no data of this parameter for non-EU countries, and therefore, no trips attracted for the regions of these countries have been calculated.

Application and results

Leisure trips attracted by a zone (j) have been calculated for all NUTS2 in ESPON space. NUTS2 with higher attractiveness are those highly populated and tourist attractiveness, like in most regions of the Mediterranean Coast.

Note that there are leisure trips attracted mapped in non-EU countries, Switzerland and Norway, due to the lack of data on tourist pressure.

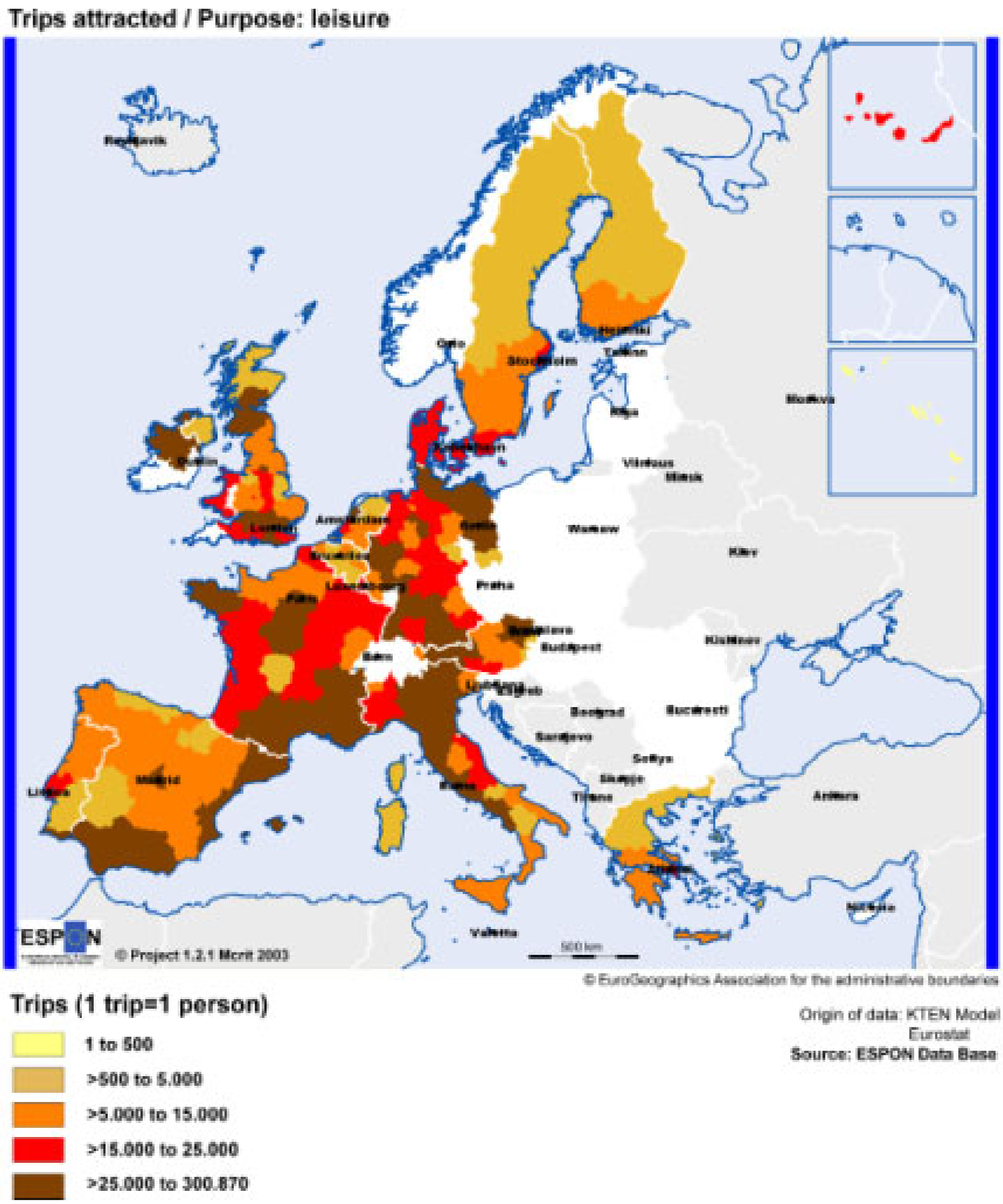


Figure. 5.6.5: Trips attracted for leisure purpose

Note: no data is available for Eastern European countries, Switzerland and Norway.

5.6.6 Trips attracted / Purpose: visits

Rationale and policy relevance

Visit trips attracted 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

Like in the previous, that there are no personal attracted trips mapped in non-EU countries, Switzerland and Norway, due to the lack of data on tourist pressure. As the distribution in KTEN for visit trip follows the same methodology of the distribution for leisure trips, the map shows the same relation of attracted trips between regions.

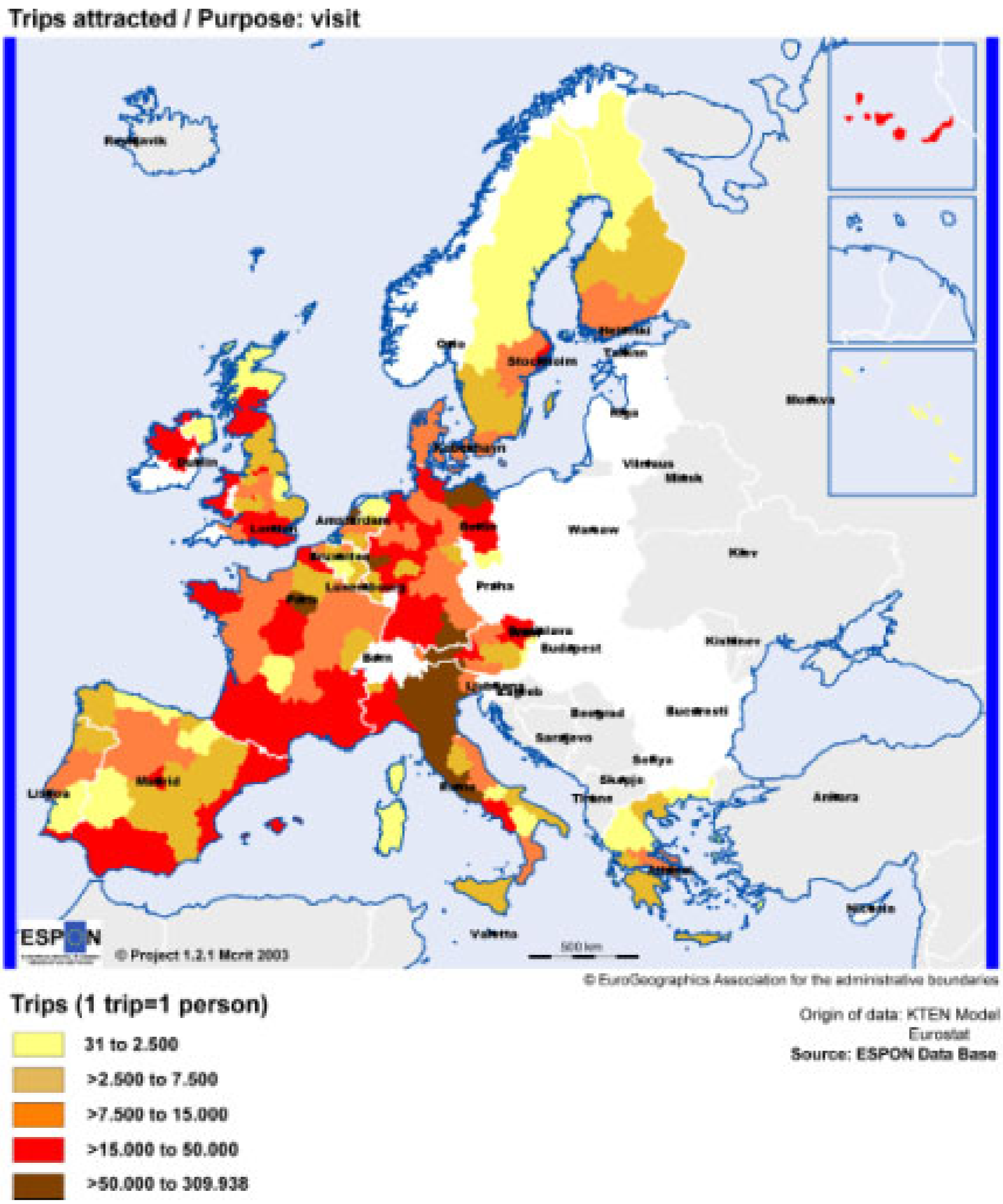


Figure. 5.6.6: Trips attracted for visit purpose

Note: no data is available for Eastern European countries, Switzerland and Norway.

5.6.7 km per person in trips generated by car / Purpose: business

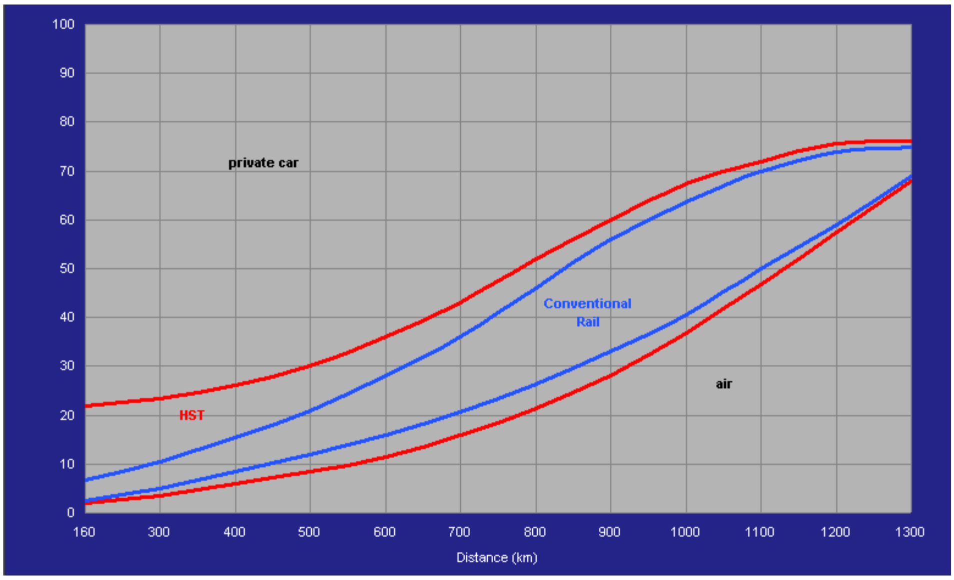
Rationale and policy relevance:

The issue of the mode choice is provably the single most important element in transport planing 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.

Methodology:

The modal split has been calculated considering the following percentages for every mode (see Figure no. 5.5.7). The distance in km is from zone (i) to zone (j) using road network and ferry lines.

Figure 5.6.7.1 : modal split for interregional trips



Source: ESPON Project 1.2.1, Mcrit

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

K_{ijk} km per person per mode *j* by purpose *k* in NUTS3 *i*

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 chapter 5.5.4) and the transport network to calculate distance between NUTS2. The transport network used is from ASSEMBLING multimodal graph, which is explained in chapter 5.1.1.

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.

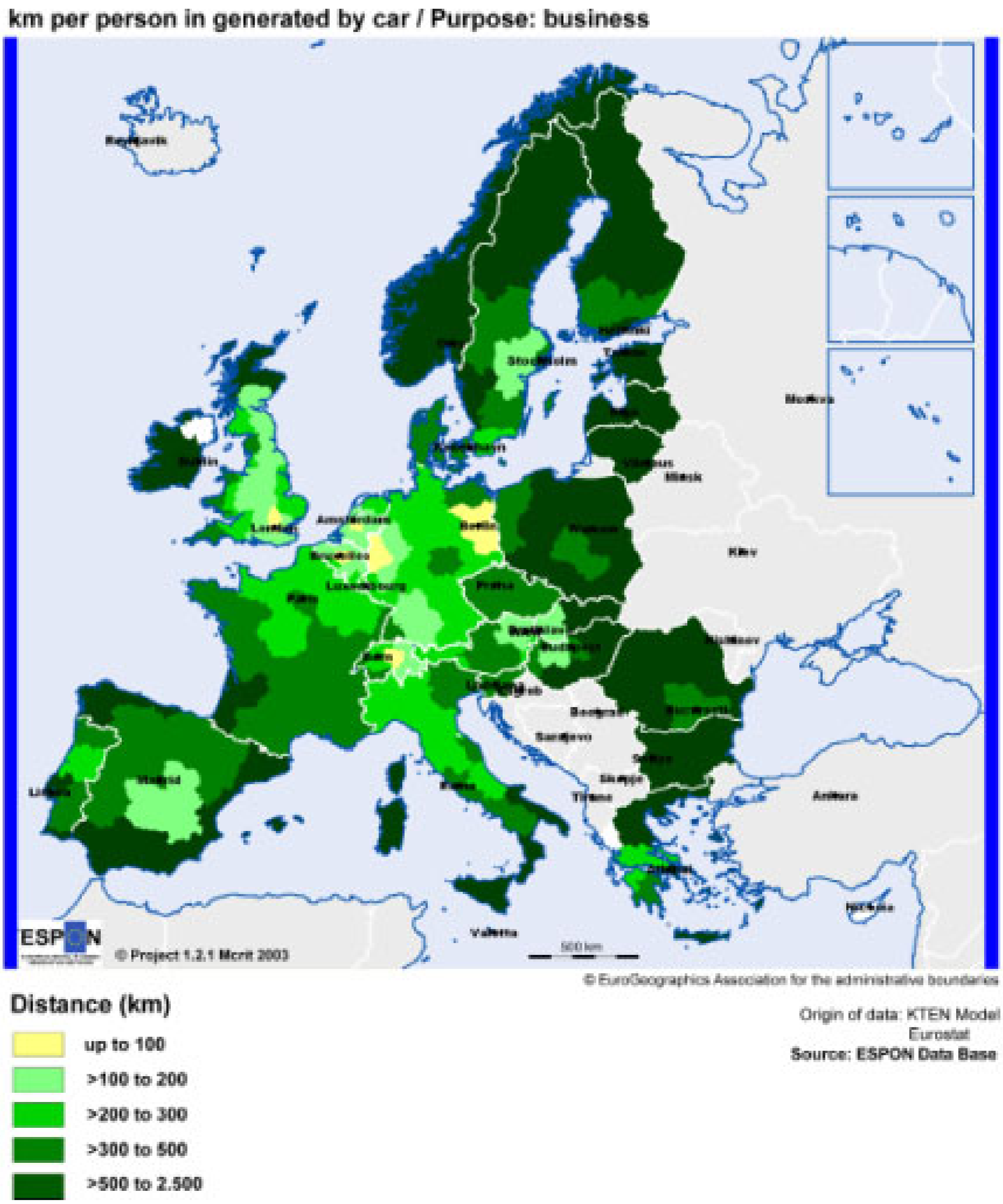


Figure. 5.6.7.2: km per person in trips generated by car for leisure purpose

5.6.8 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 has 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.

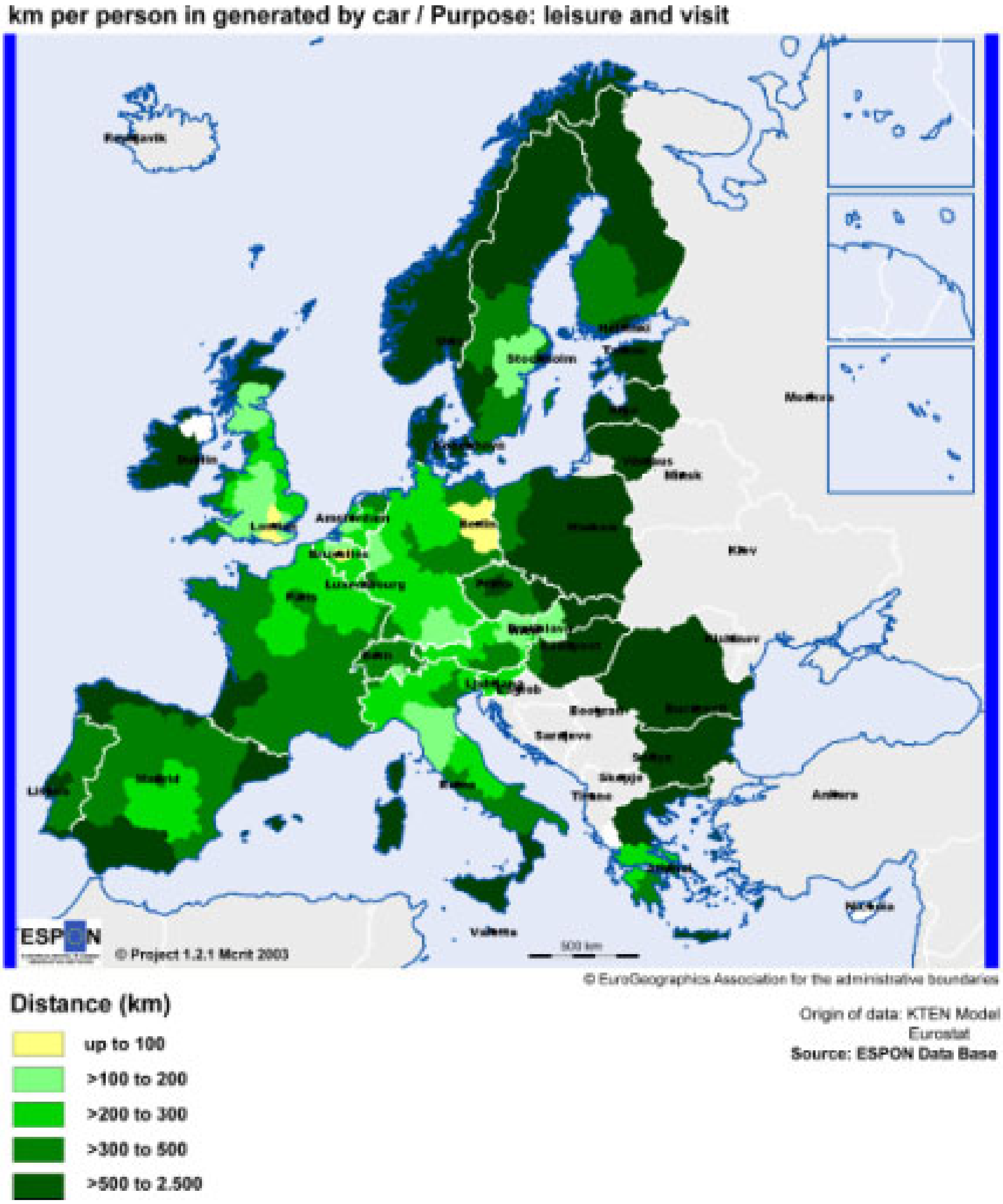


Figure. 5.6.8: km per person in trips generated by car for leisure and visit purpose

5.6.9 Traffic on road links / 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 (see chapter 5.5 and 5.6) 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 allow 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 (see chapter 5.5.4). 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 chapter 5.1.1.

Application and results

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's 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 chapter 5.5.4). For this geographical reason, road networks in peripheral regions haven't such a high traffic on their links, in some cases reaching values 100 times lower.

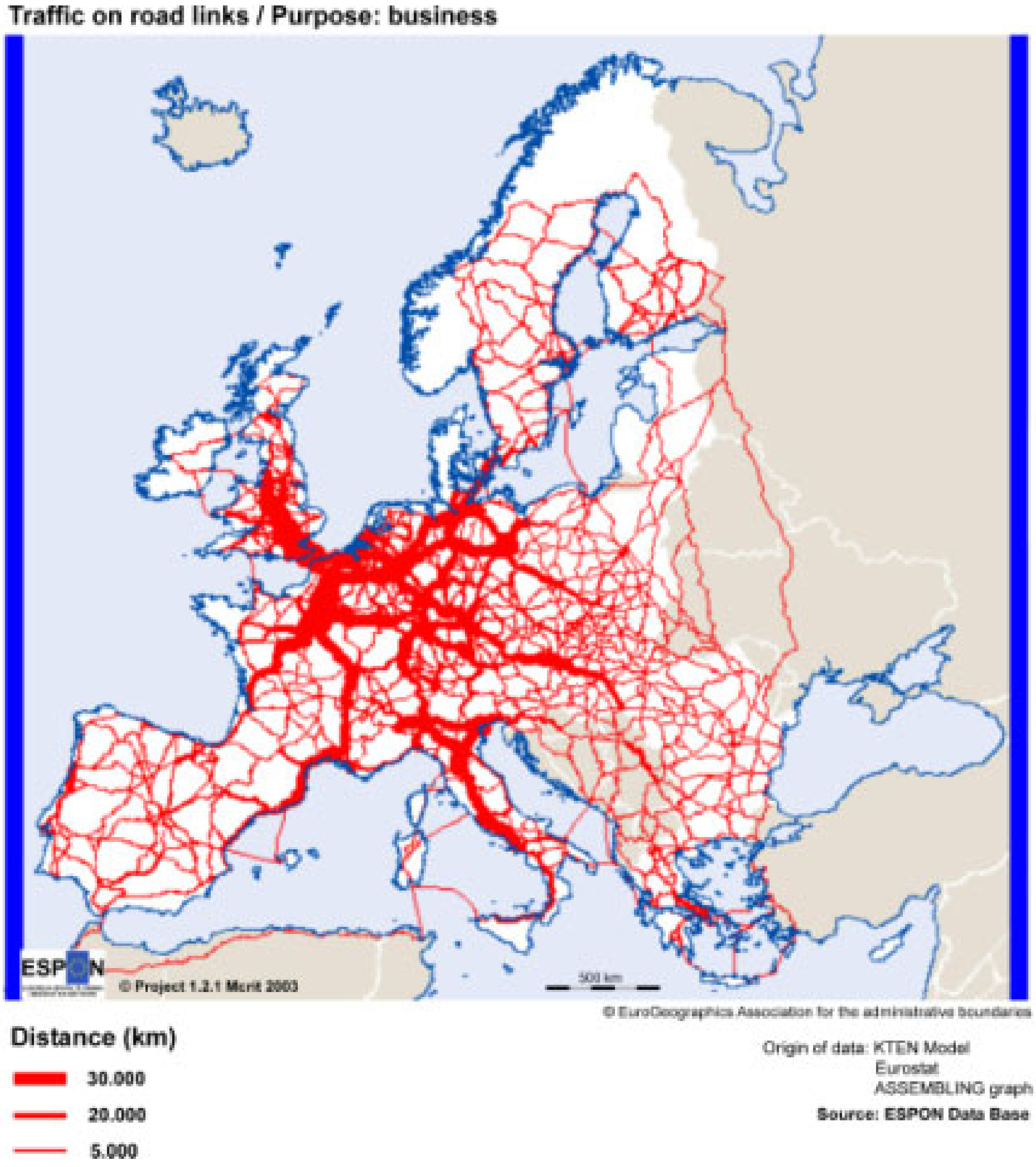


Figure. 5.6.9: traffic on roads for business purpose

5.6.10 Freight transport quantities

Rationale

In the first point concerning freight 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 fairly poor mainly for passenger traffic; this mean is particular that there is no O/D statistics at regional level (Nuts 2 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 introduced in mere global data base because of lack of harmonization of presentation.

Among the existing sources one must however mentioned 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 provide 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 stile 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 nuts 2 level, two major type of tool have been used.

- a gravity model developed by NEA at nuts 2 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 is 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 interim report the SCENES data base 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.

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 (Nuts 2 or Nuts 3 according to cases) or from country to country, by type of product (13 to the total) and by mode.

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 product manufactured (Groups of goods number 13) between two Austrian regions.

Knowing accessibilities region / region, we calculate the quantities in tons kilometers for each region by mode and by groups of goods.

Demonstration example

The following map gives an example of use of these data bases. This 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 Nuts 2 level without Bulgaria and Romania.

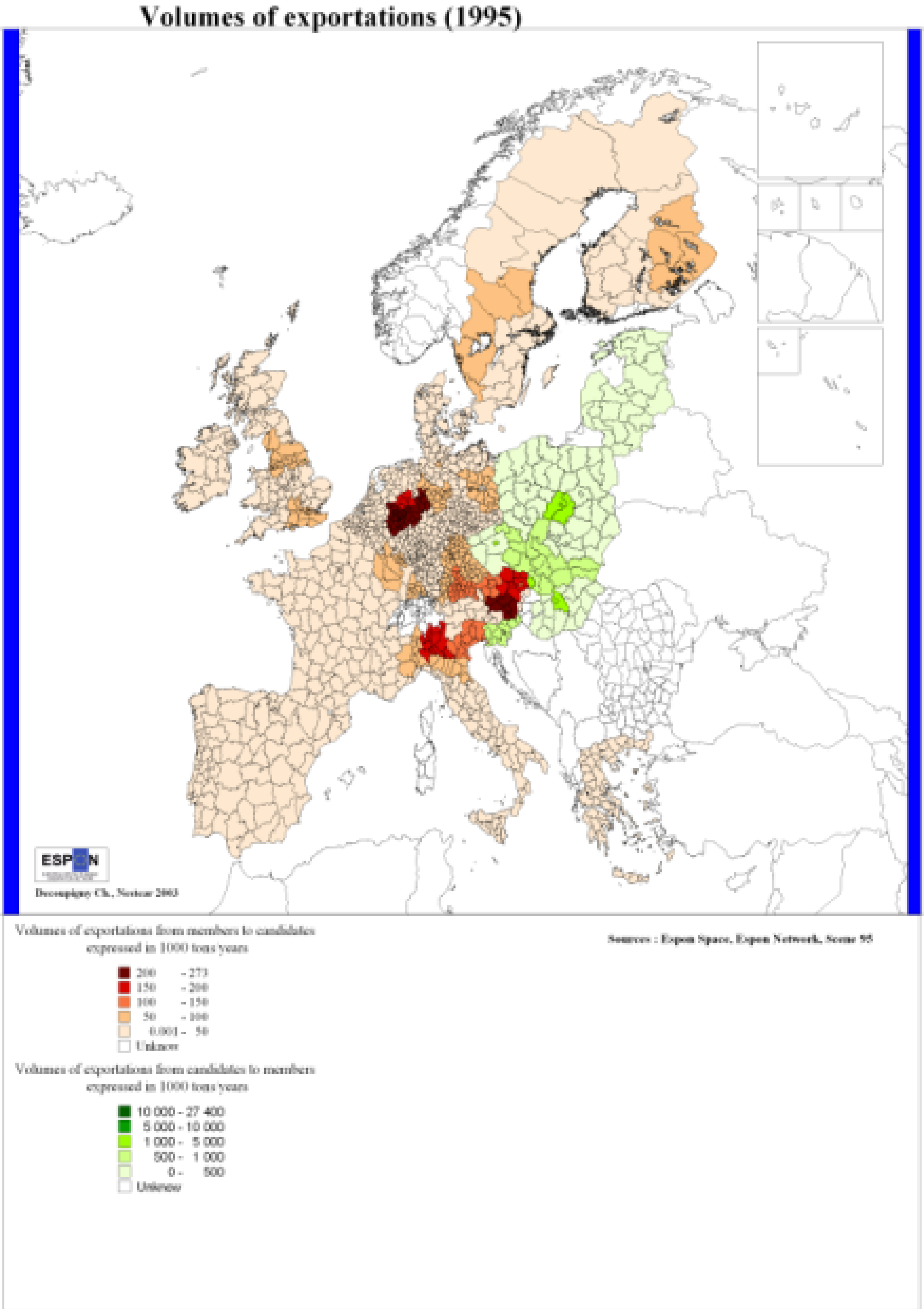


Figure. 5.6.10: volumes of exportations

5.6.11 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 bottle necks 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 data bases, 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 used.

Demonstration example

The map shows an assessment of the volumes of freight on the minimal paths with a difference between the flows from origin to destination of the candidates and the members. We used the data from country to country. It's why the peripheries area volumes (as the Sicilia) are very important in this example. We prepare an assessment of the volumes according to the population or to the GDP.

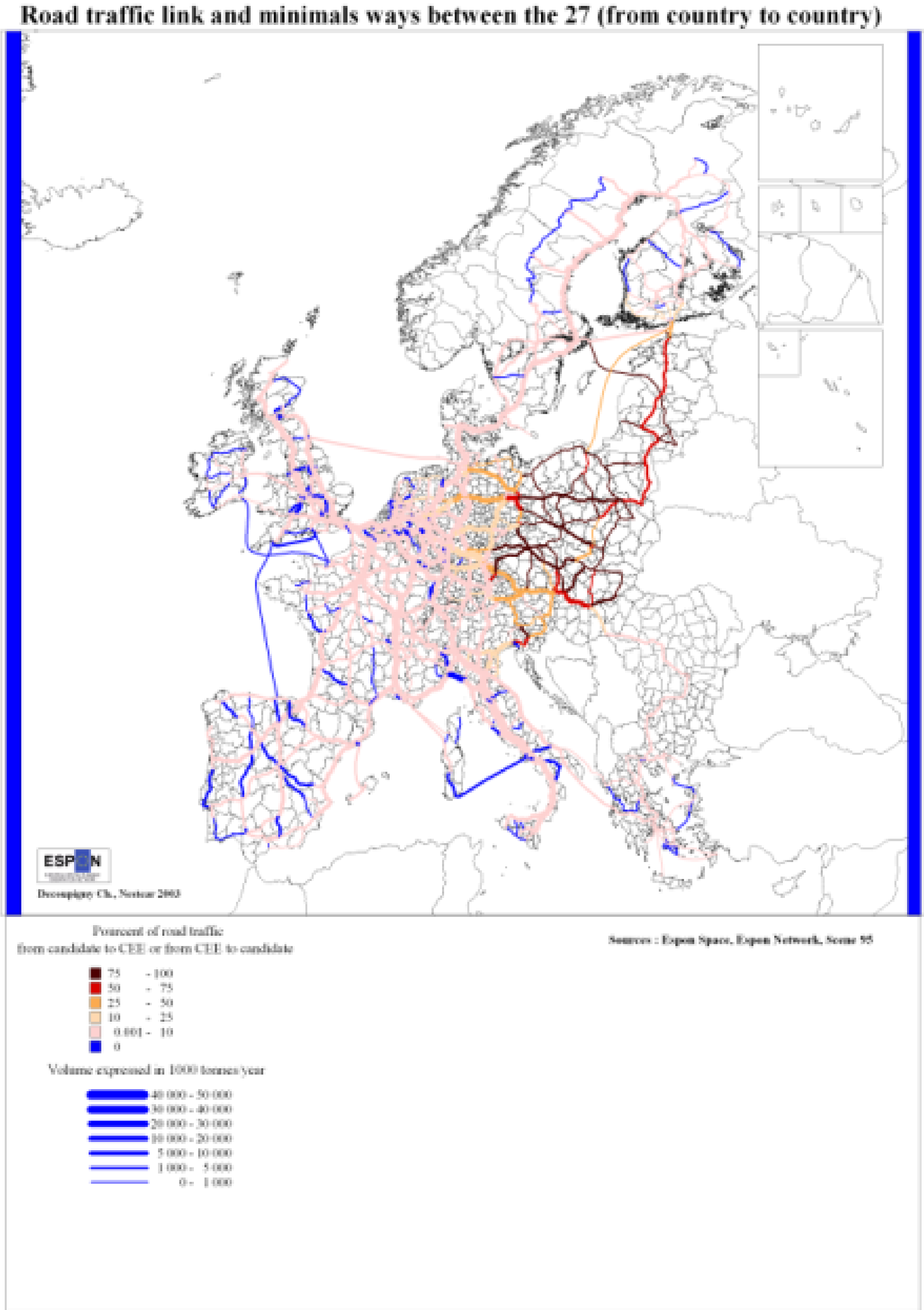


Figure. 5.6.11: road traffic link and minimal path between the 27 (country by country)

5.6.12 Freight road assignment : Number of lorries

Rationale

This indicator permits to complete the freight road assignment. The calculation of the number of vehicle participle to the same reasoning that previously. It consists to complete information of tons transported while offering 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 region by the rate of middle replenishment of trucks (about 20 tons by truck). After we use the same method that the volume assignment.

Demonstration example

The first map shows an assessment of the number of truck 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’s why we have only one way for this 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.

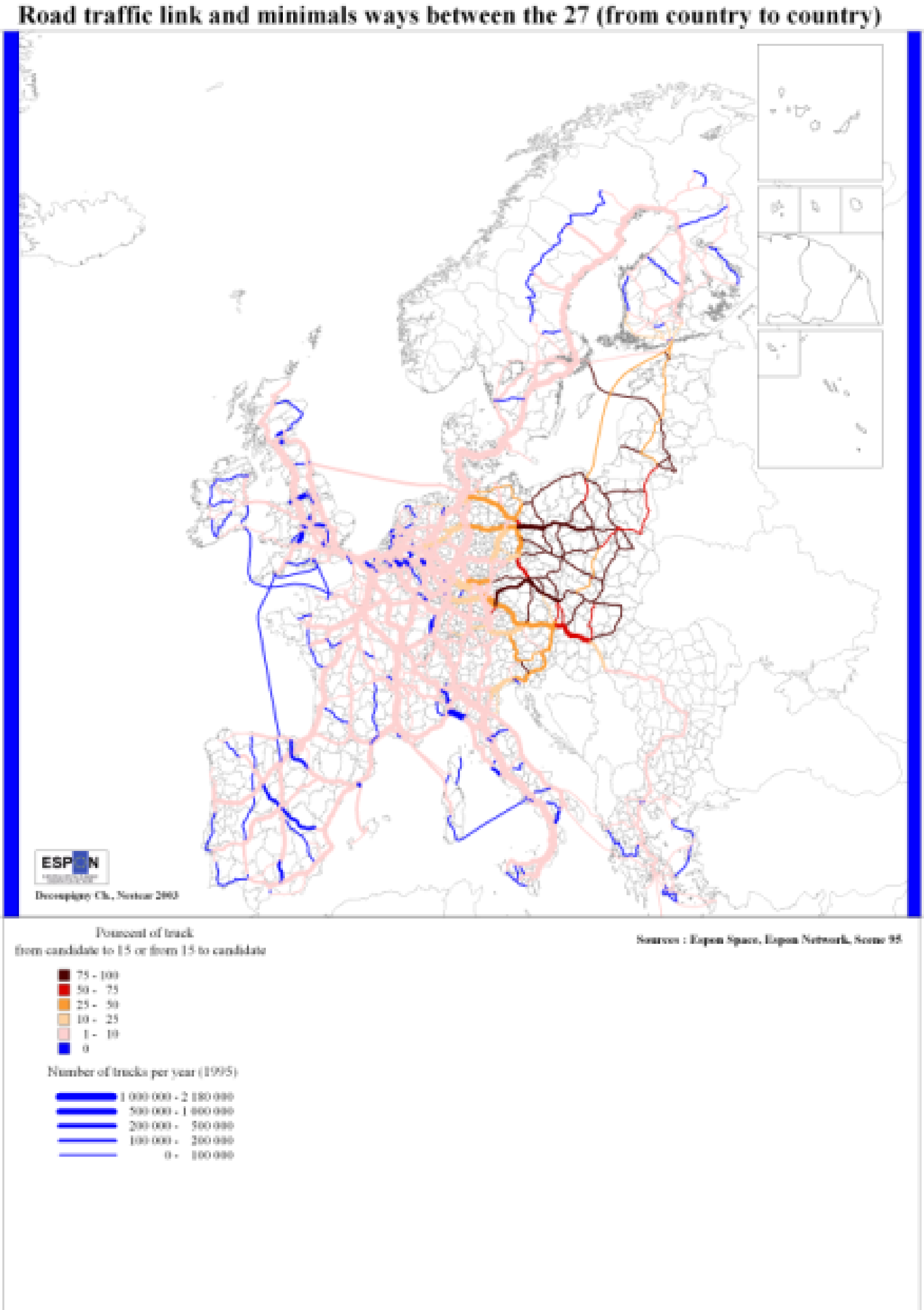


Figure. 5.6.12.1: road traffic link and minimal path between the 27 (country by country)

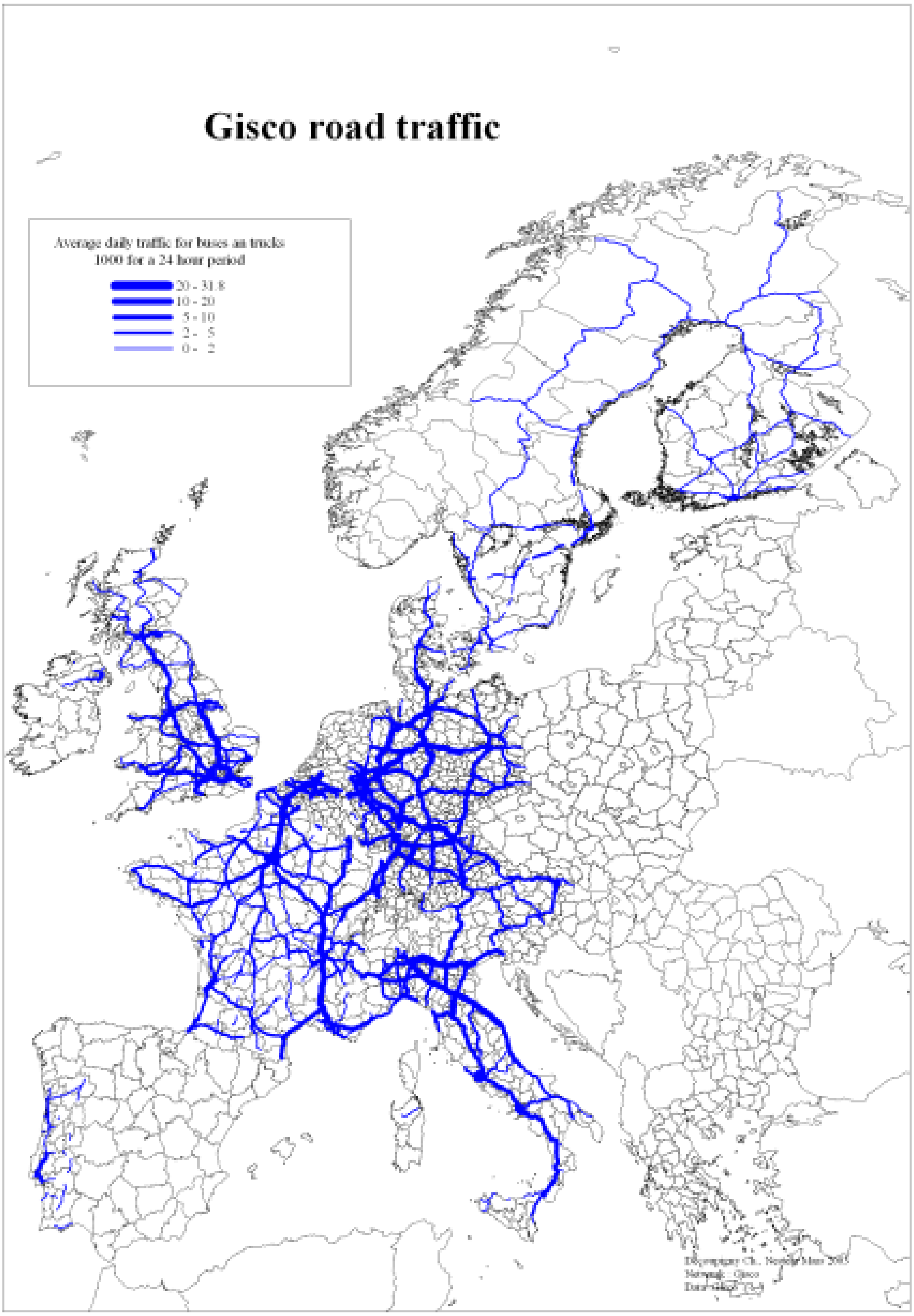


Figure. 5.6.12.2:GISCO road traffic

5.6.13 Freight rail assignment : volumes

Rationale

The assignment of goods by direct train follows a similar reasoning of 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 account 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 assignment volumes on the rail network according to the minimal travel time. We take 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

We need, if possible, the time of waiting some nodes for a main rail network. We need the real freight trains speeds, not per O/D but per segment.

Demonstration example

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. The third is the same than the second but the datas 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 don't 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 to disappear the importance of the structure and the relation of a transport network. We can't see on this map the structure of the relations between the regions.

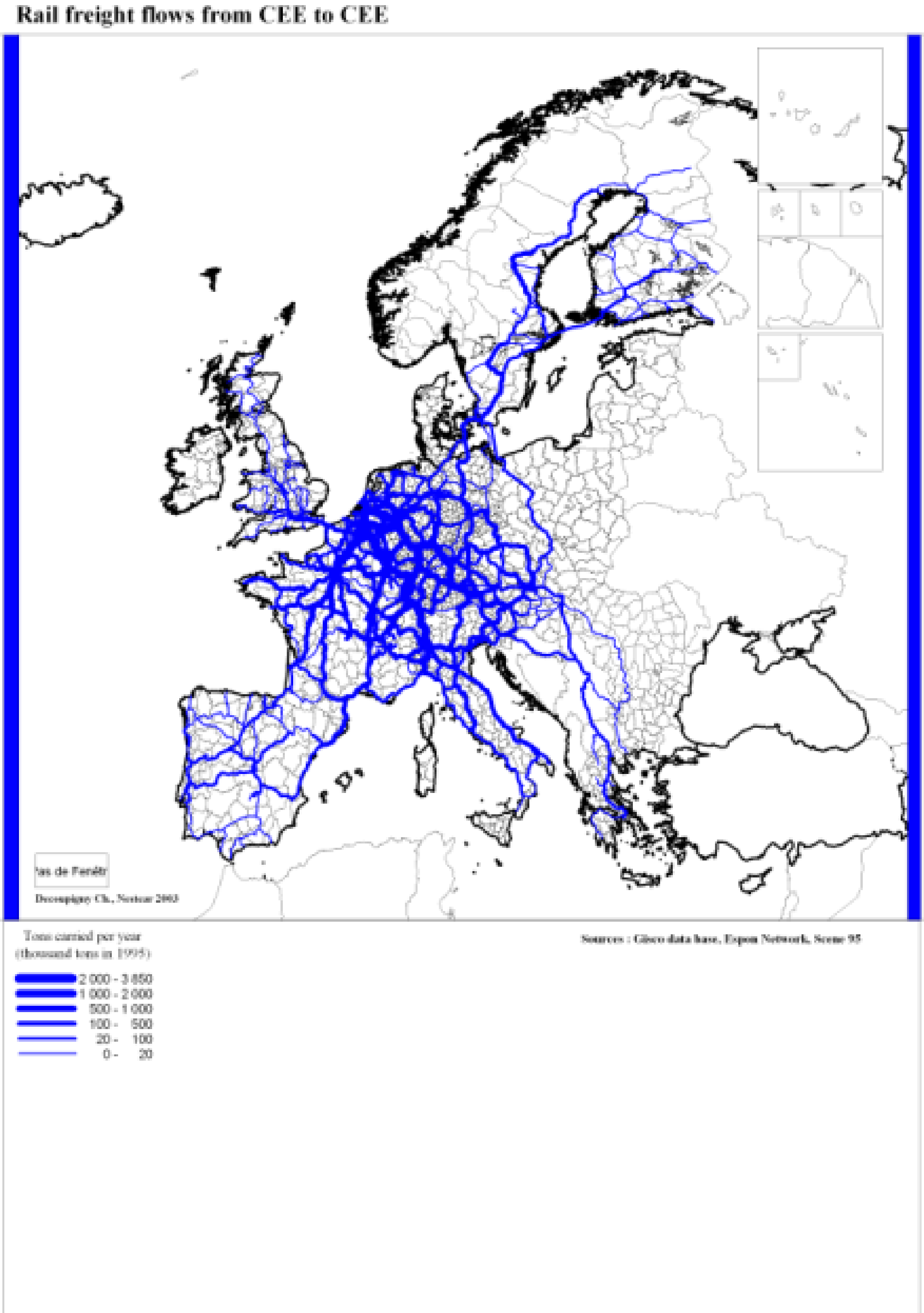


Figure. 5.6.13.1: rail freight flows in the CEE

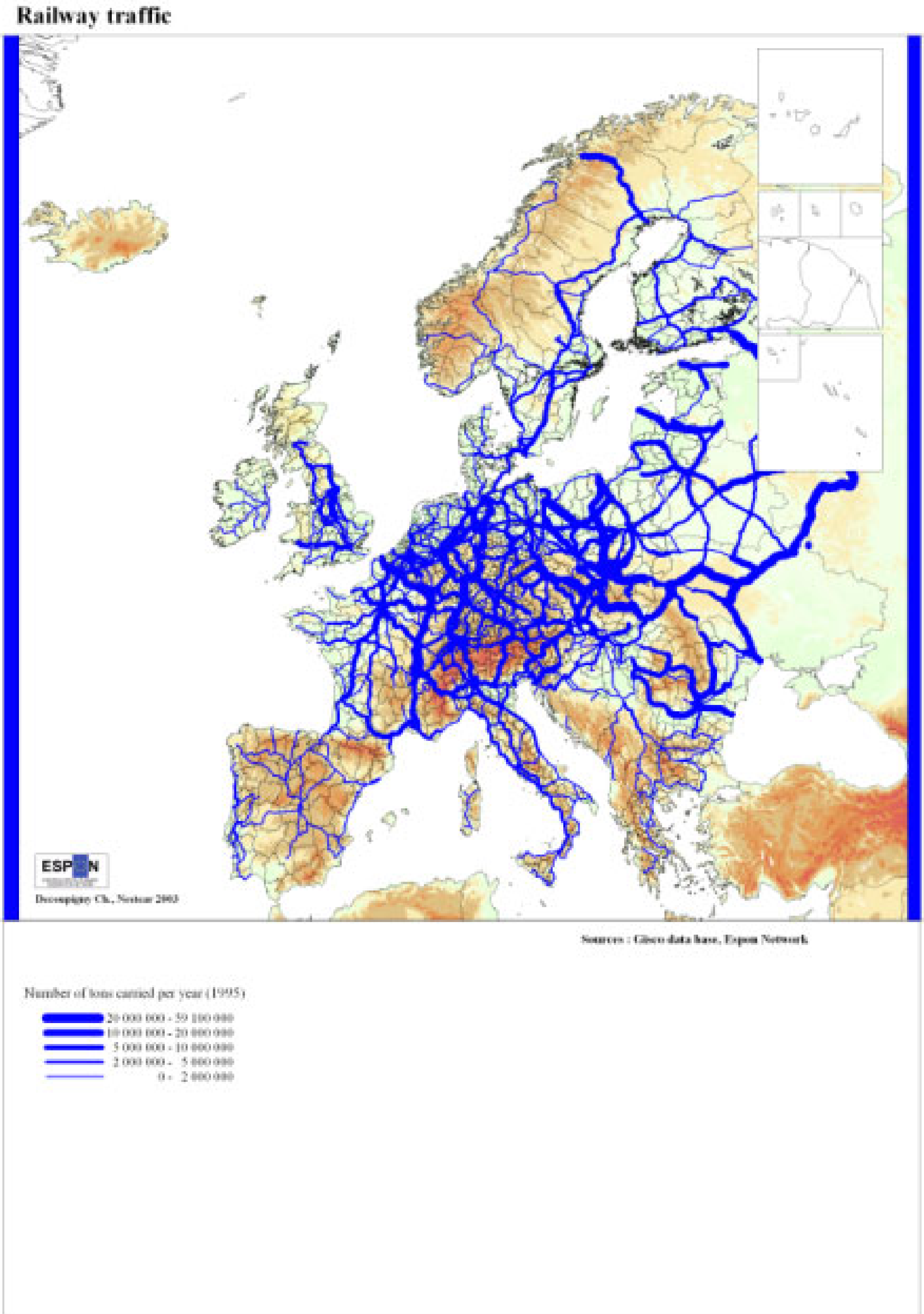


Figure. 5.6.13.2: railway traffic in Europe

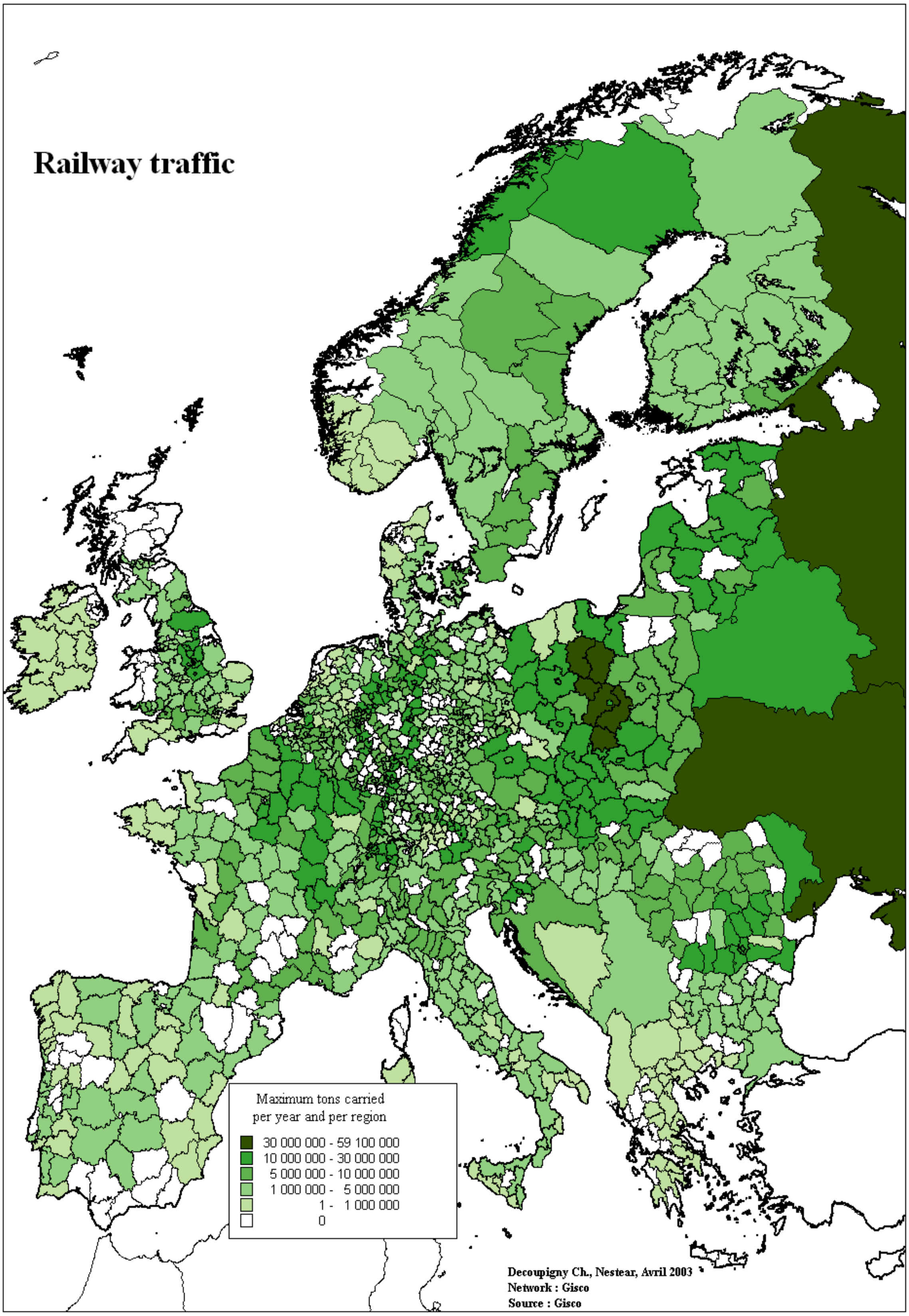


Figure. 5.6.13.3: railway traffic in Europe per NUTS zone

5.6.14 Freight rail assignment : Number of freight trains

Raisonnement

The number of train (passenger and freight) running is important because it permits to value the load of the network according to the capacity. It will permit to value the bottlenecks of the rail network.

Method

Data provided by the railway companies being incomplete, we make an approximation of the number of train according to the volume of goods.

Demonstration example

The following maps show the traffic railway in train per day. The first is the number of train running per workday. The second is the railway line capacity; it is expressed as the number of trains per day in both directions together who can to run. The third is a compilation between the number of train running (passenger and freight) and the capacity (number of train/ capacity). It shows the railway saturation.
Gisco provides this data, but the data are incomplete.

Railway traffic : number of train

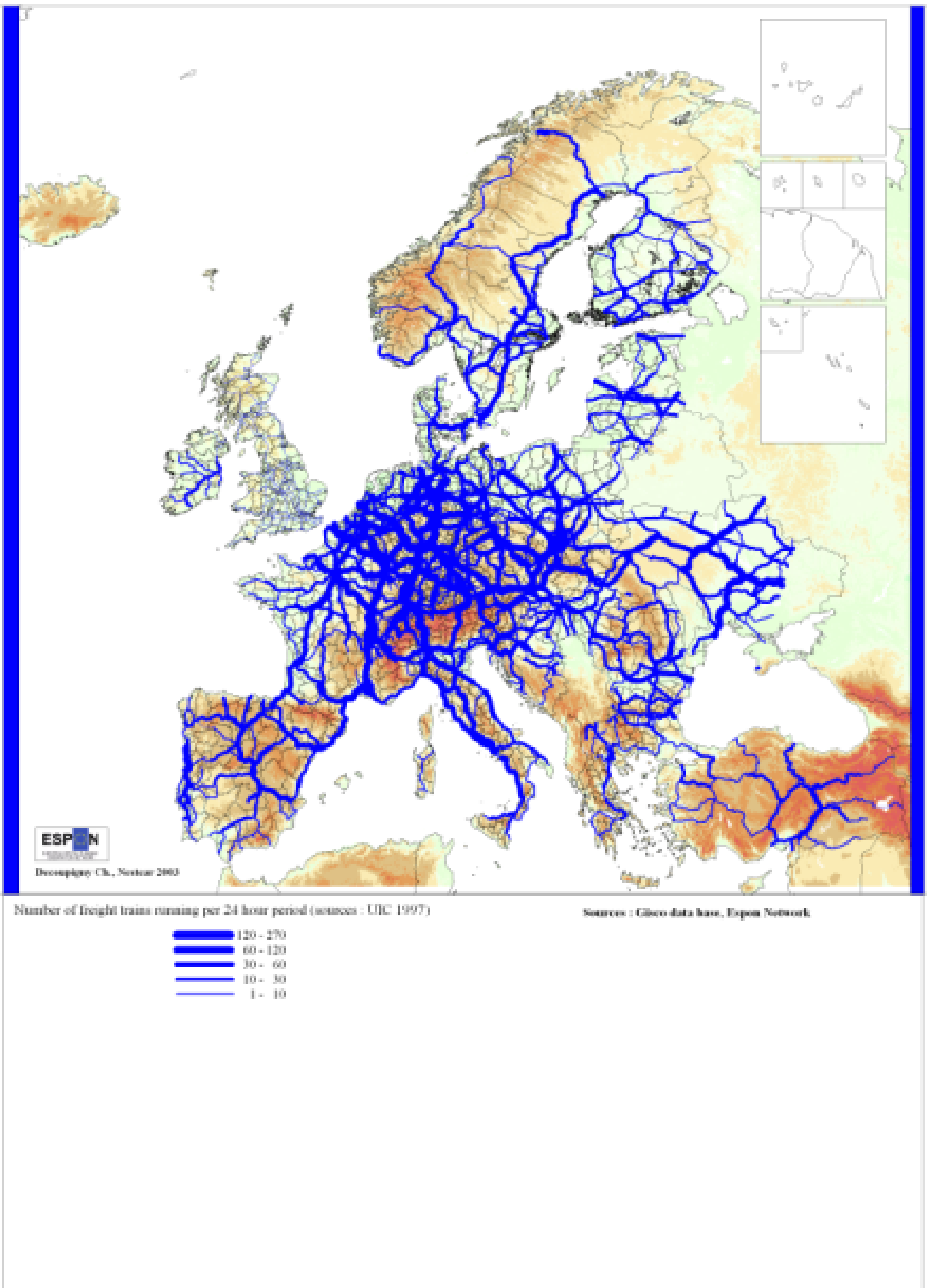


Figure. 5.6.14.1: railway traffic number of trains

Railway line capacity

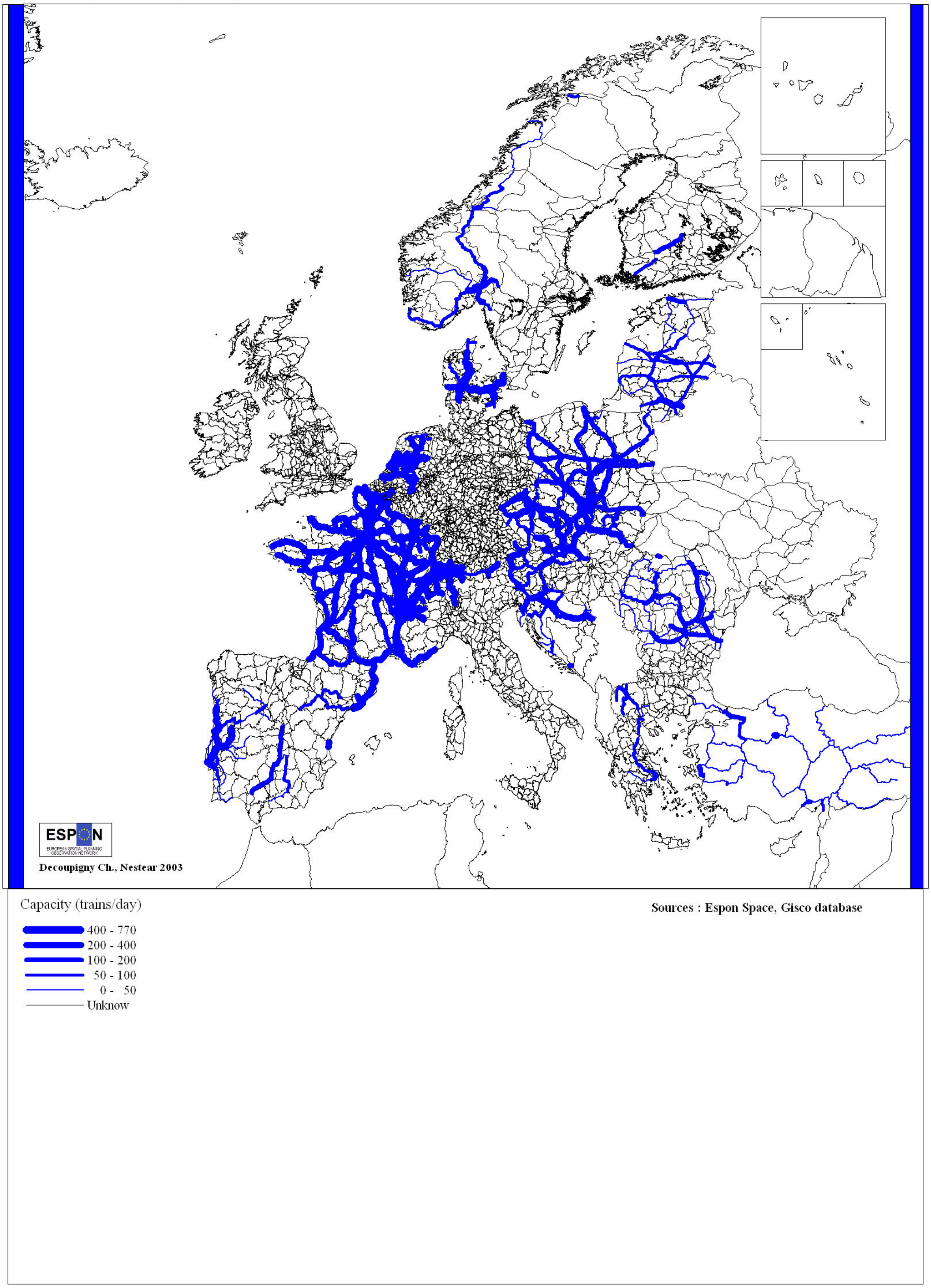


Figure. 5.6.14.2: railway line capacity

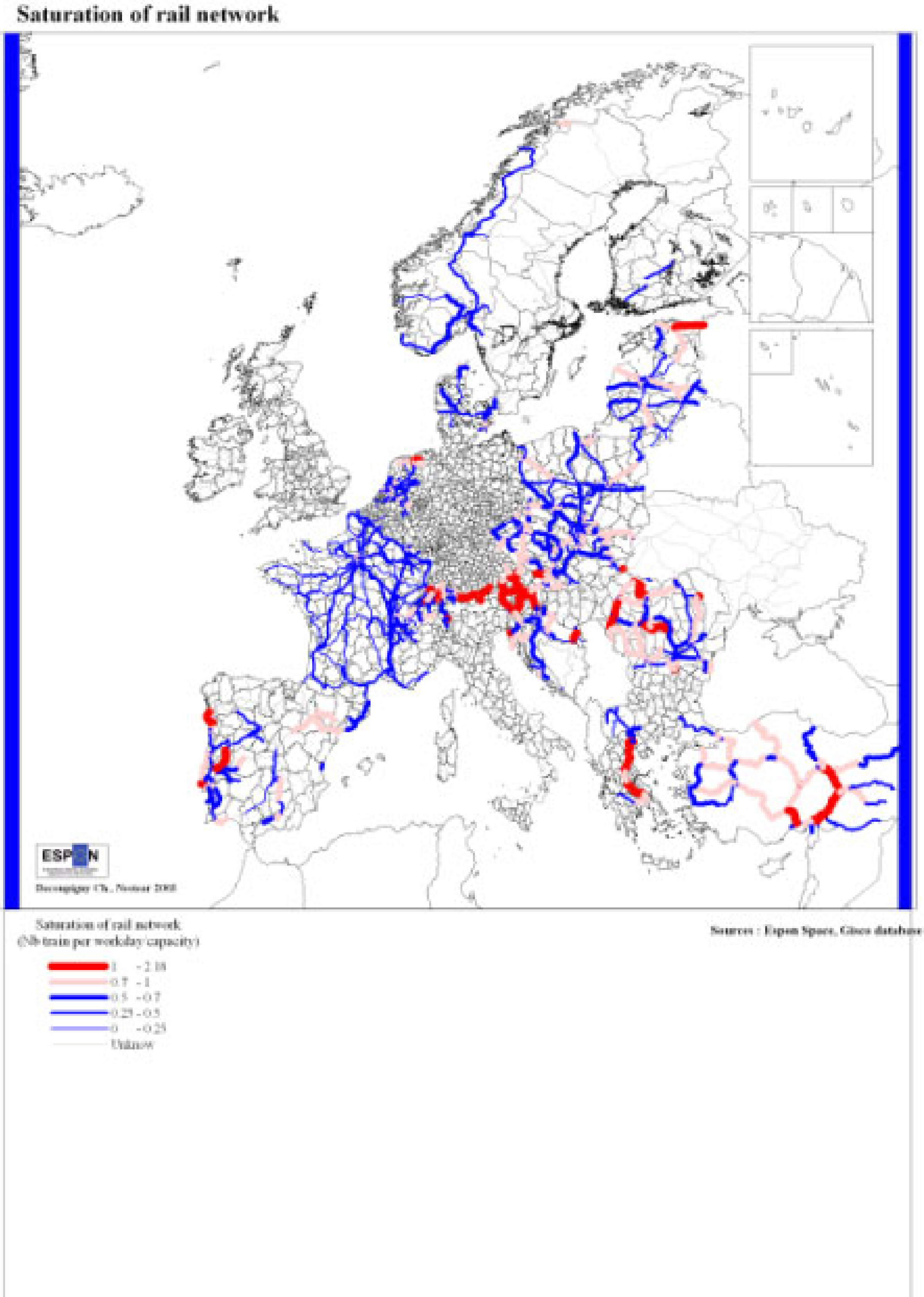


Figure. 5.6.14.3: saturation of rail network

5.7 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 calculation of such impacts at regional level based partly on estimates and ratios from existing studies will complement the previously described transport-based indicators.

5.7.1 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

Demonstration examples

Figure 5.7.1 maps 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 population 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, 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.

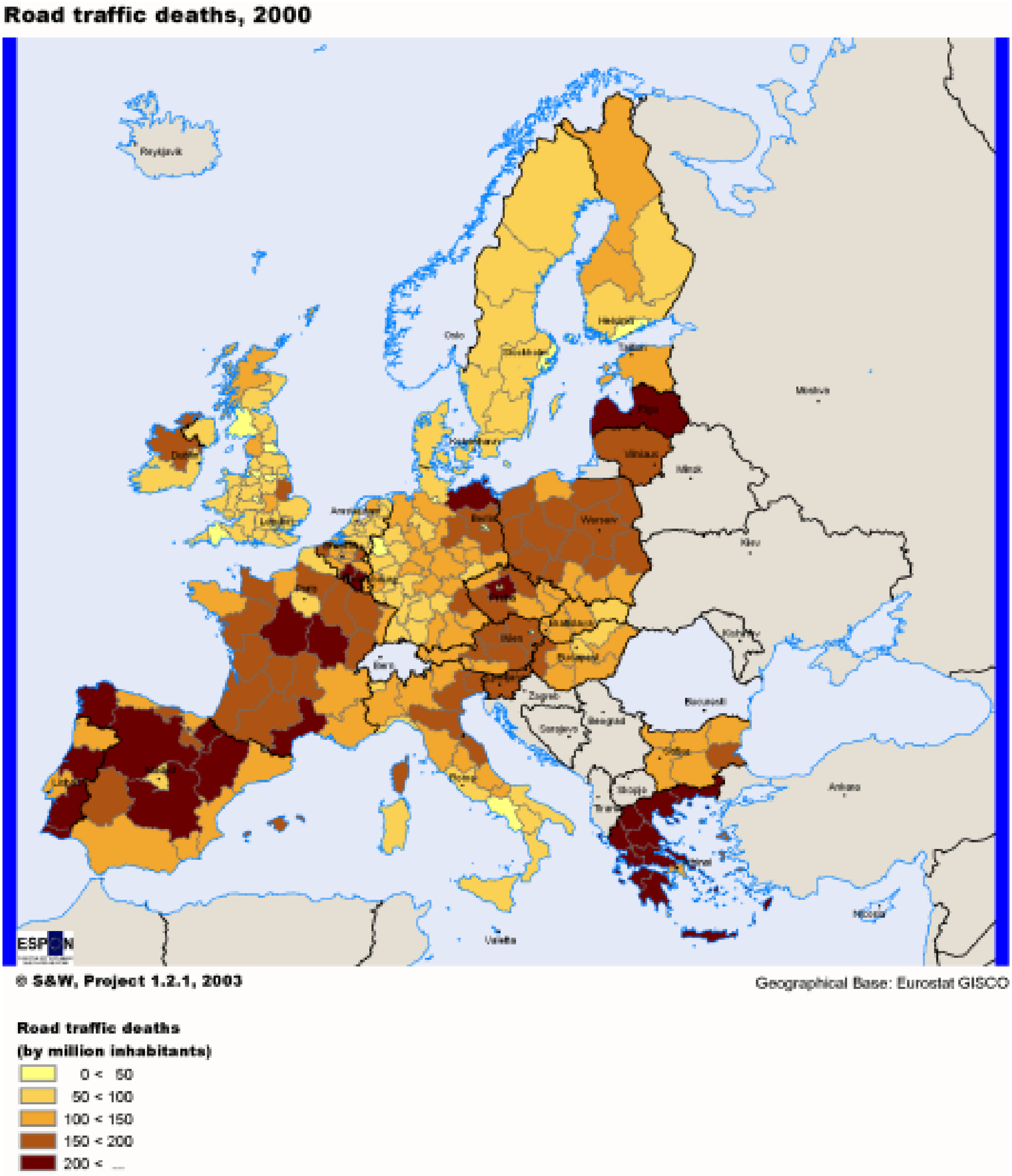


Figure 5.7.1 Road traffic deaths, 2000.

5.7.2 Emission of greenhouse gases

Rationale

Emissions from transport contribute significantly to climate change. CO_2 emission is one of the most important factors contributing to 97 % of all transport greenhouse emissions. CO_2 emission of transport has increased by 20 % in the European Union during the last decade, thus acting against the reduction targets agreed at international conferences. Road transport accounted for 92 % of all transport CO_2 emissions in the European Union in 2000. In the candidate countries CO_2 emission dropped in the early 1990s but is now growing again with the increase in traffic volumes (EEA, 2000; 2001; 2002).

Method

CO_2 emissions will be calculated for road transport. The location of CO_2 emission is not important for its impact on climate change. However, in order to get a differentiation of the contribution of the different regions, road transport emissions will be localised, i.e. they are modelled along the transport links and will then be aggregated to regional emissions. To do this, two models will be combined, a transport model and an emission model.

The transport model will be the European transport model of MCRIT, which is applied also for some of the indicators described in Section 5.3. The transport model will provide transport volumes on the links of the European road network. For each link the number of cars, lorries and the average link speed will be produced.

The emission model is based on state-of-the-art emission models developed in the MEET project and the COST 319 action. (Hickman et al., 1999; Joumard, 1999). The speed-related emission functions have been transferred into a sustainability indicator model applied at the urban scale, the emission part of that model will be linked here to the European transport model (Spiekermann, 1999; 2003).

Data requirements

Basically, the modelling system to calculate CO_2 emissions has the same data requirements for the transport model as described in Section 5.5. Most data required by the emission model, i.e. mainly parameters and data on the composition of the vehicle fleets are already available with the exception of vehicle fleet data for the candidate countries.

Demonstration example

The indicator will be calculated for all NUTS-3 regions of the ESPON space and will be demonstrated in the final report of the project.

5.7.3 Emission of air pollutants

Rationale

There exists a range of pollutants emitted by traffic that have mainly regional and local impacts. Emissions of acidifying substances and tropospheric ozone precursors from the transport sector decreased by 20 % and 25 % during the 1990s, mainly as a result of the introduction of catalytic converters and stricter emission regulations for new cars. However, population in Europe, mainly the urban population, is still exposed to air pollution exceeding EU urban air quality standards (EEA, 2000; 2001; 2002). Nitrogen oxide (NO_2) emissions can be seen as lead indicator for these developments, also the share of transport-generated NO_2 to the total exposure of population to NO_2 is important for this pollutant.

Method

NO_2 emissions will be calculated for road transport. The same combination of transport and emission model as described in the previous section for CO_2 emission will be applied. That means road transport emissions will be localised, i.e. they will be modelled along the transport links and aggregated to regional emission figures.

Data requirements

Basically, the modelling system to calculate CO_2 emissions has the same data requirements for the transport model as described in Section 5.5. Most data required by the emission model, i.e. mainly data on the composition of the vehicle fleets are already available with the exception of vehicle fleet data for the candidate countries.

Demonstration example

The indicator will be calculated for all NUTS-3 regions of the ESPON space and will be demonstrated in the final report of the project.

5.7.4 Fragmentation

Rationale

Land fragmentation is considered a major threat to habitats and species population by the UN Convention on Biological Diversity. Today the average size of contiguous land units in the European Union is about 130 km_ and is still 175 km_ in the candidate countries (EEE, 2000; 2002). However, there are great disparities in land fragmentation reaching from average sizes of non-fragmented land of only 20 km_ in Belgium to about 600 km_ in Finland. The development of major transport infrastructure according to the TEN and TINA programmes brings the risk that land fragmentation of territories will increase, in particular in the candidate countries.

Method

In the literature, there have been numerous land fragmentation indicators developed, of which one that is meaningful and easy to understand will be selected. The indicator will be calculated by analysing a database on transport infrastructure with GIS methodologies.

Data requirements

A representation of major European transport infrastructure in a GIS database is available already.

Demonstration example

The fragmentation indicator will be calculated for all NUTS-3 regions of the ESPON space and will be demonstrated in the final report of the project.

5.8 Network vulnerability

5.8.1 Analysis of the vulnerability :

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.

Theoretical background

The effectiveness of a network depends on its functionality durability and thus of its vulnerability to the risks.

Three types of risks can stop the functionality of a network, partially or totally, and more or less for a long period : the climatic risk from flooding, snow, ice, storm… the geological risk : landslide… the anthropic causes : from the technical, technological or human error to the will/impulse to temporarily or definitively stop this functionality, whatever the reason or the means are.

These various risks have the same effect : a disconnected network and a discontinuity or impossibility of the use. The duration of this effect, the cost dependent on the geomorphologic characteristics of the networks. The observation is simple, the more the redundancy of a network is weak (unimodal or multimodal), the stronger is the risk, which shows the reliability theory.

The European multimodal network is naturally strongly connected, but it is not the case of unimodal networks. For example, England is not related to the continent by the road and the connexity of Scandinavia and Finland is due to the bridge of OSLOW and the passage through St Petersbourg, there is no territorial continuity.

The localisation of the surface transport network vulnerabilities is know : between the Netherlands and Sweden, United Kingdom and France, Poland and Lithuania, Hungary and Romania, Spain and France, Italy and France, Switzerland, Austria… Between Finland and Estonia, the connexity is not available. The morph geographical map illustrate this phenomena like the traffic maps (see 5.6).

If generalized, it will allow us to measure the contribution of each arc to the effectiveness of a way, then to the whole network. It is then possible to go from the estimation of an arc contribution to that of a way. This approach allows us to qualify the analysis of the vulnerability because a way can have a weak primary contribution and a strong secondary contribution, i.e. when the minimum way is unusable.

This approach is all the more useful because the corridors are less “integrated”, i.e. without precise calculation, the French network is even much more vulnerable than the German network which is a very closely-knit network.

Methodology

The transport model determines the shortest paths and the distances between all couple of cities with the whole network. One cancels one or more arc and computes the new shortest paths.

The indicator in the difference value the disconnection between the two situations : before and after the cancel of arc.

The indicator is able to weight by the flow or the traffic volume in tonnes per year or in value. The local flow is preserved only in the transit (from regions to regions non connected) is diverted.

The map shows the paths before and after.

Data requirement

For this demonstration we have used the CESA network better adapted.

Demonstration example of the disconnection of networks

We show three examples of cancel : Frejus, Hendaye-Irun, Brenner;

Comments

The result of disconnection is specifically that tha redundancy is limited and the arcs are distant.

This is the situation today. For the futurology we must take into account the development of production and trade. The differential map of potential flows between EU15 and EU27 show the potential most important corridors like the map of potential South-East transit across Europe.

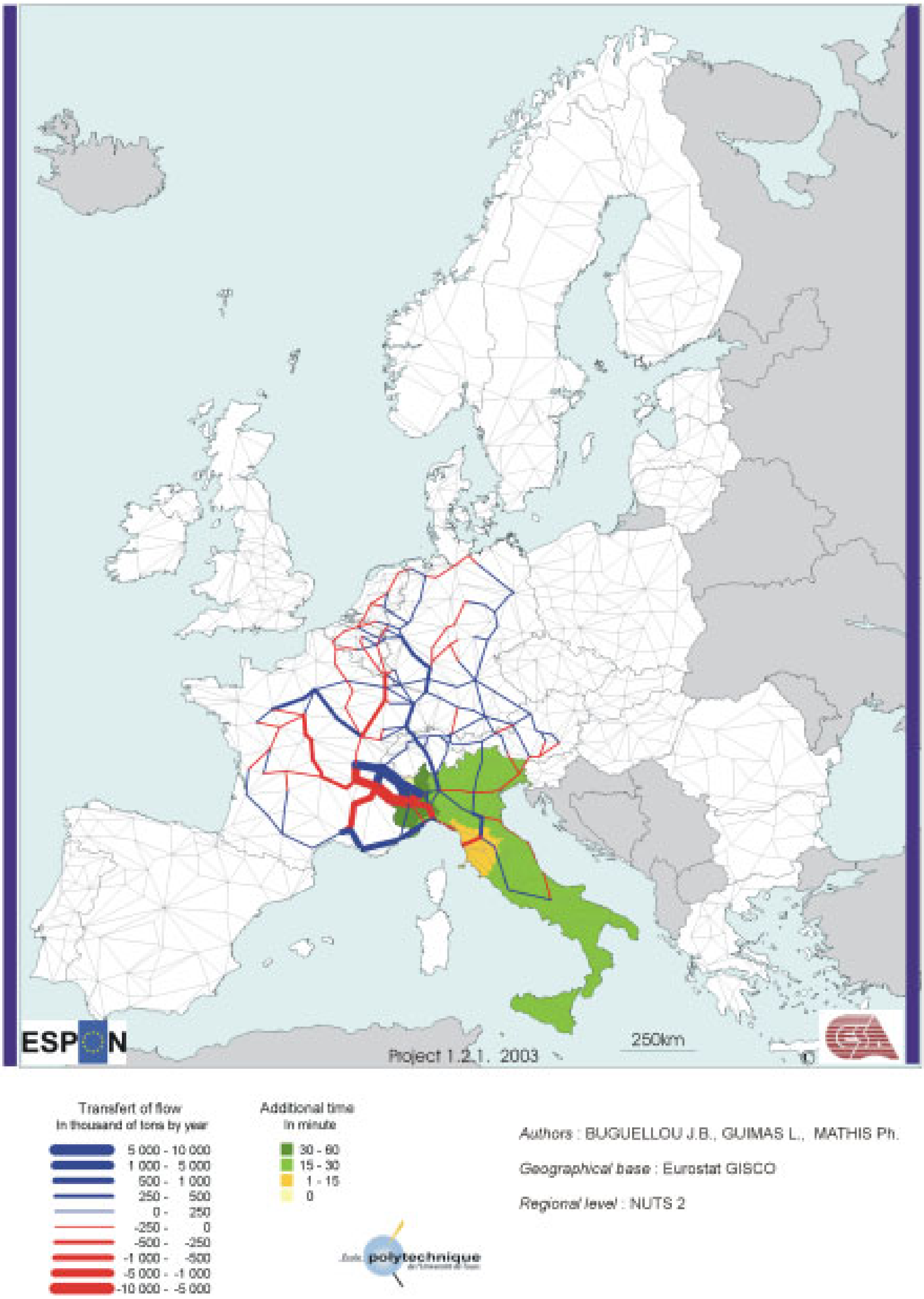


Figure 5.8.1.1 Transfer of flows in freight transportation and additional time after the suppression of the "Tunnel de Frejus"

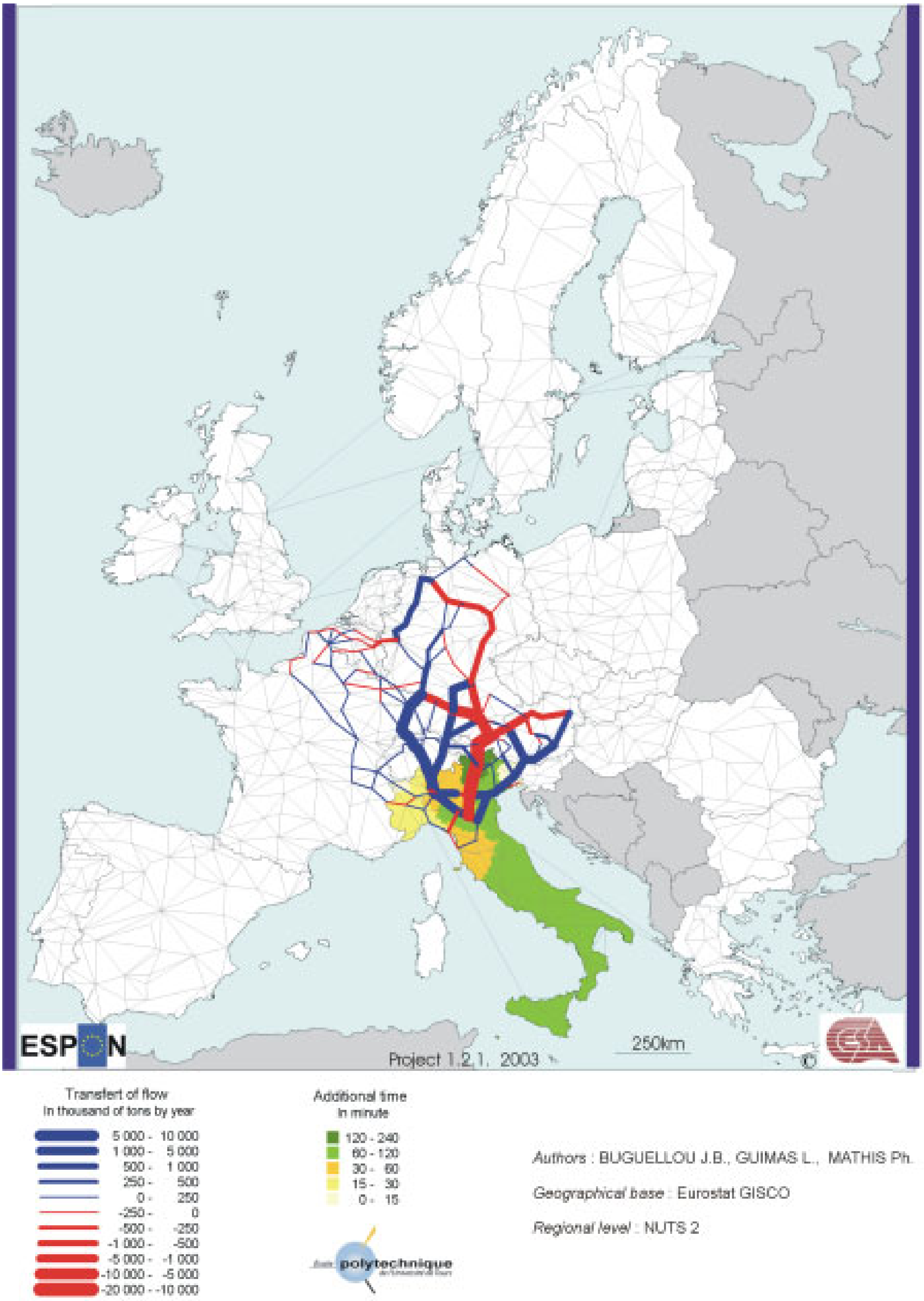


Figure 5.8.1.2 Transfer of flows in freight transportation and additional time after the suppression of the link Bolzano-Innsbruck

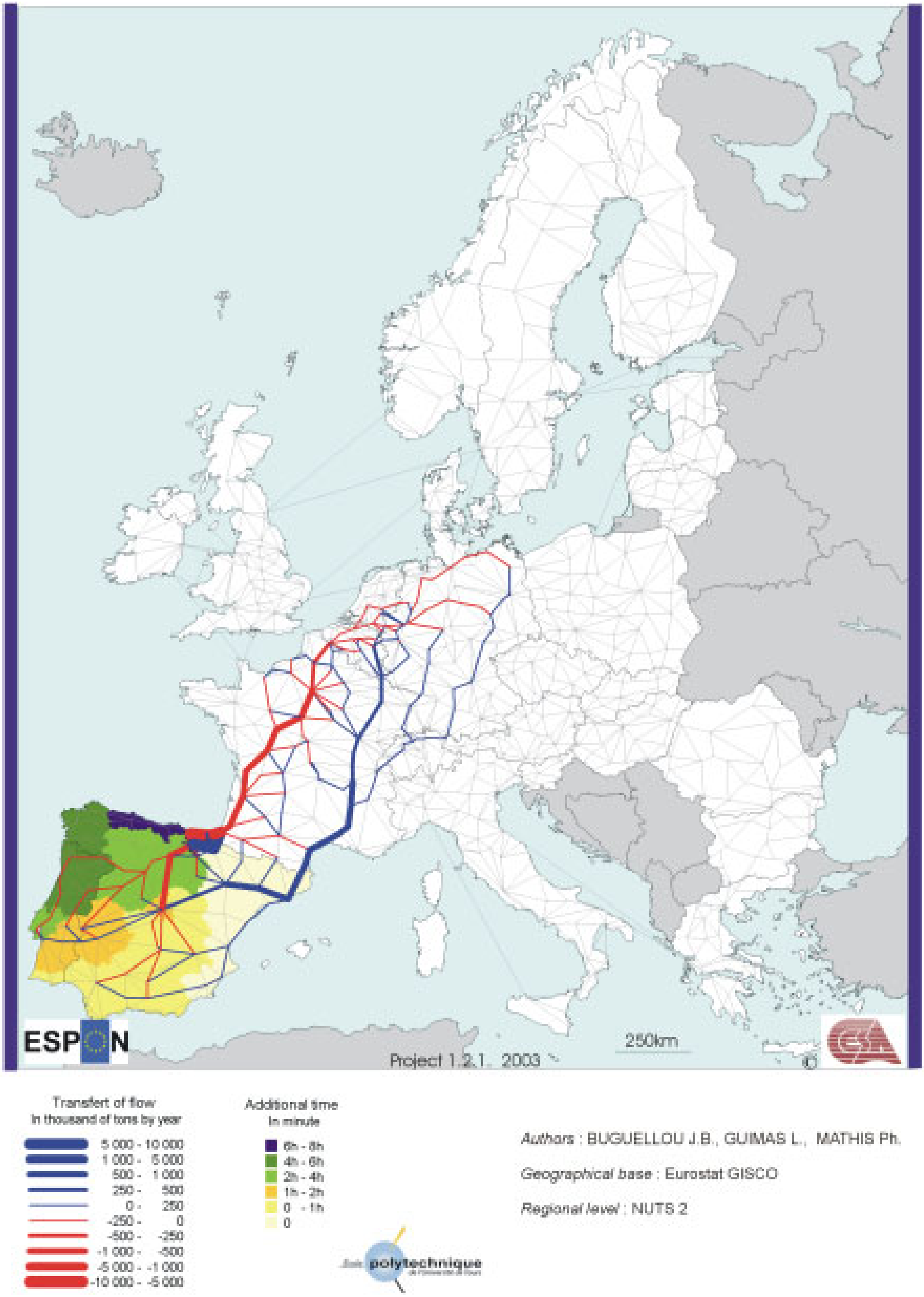


Figure 5.8.1.3 Transfer of flows in freight transportation and additional time after the suppression of the link Irun-Hendaye

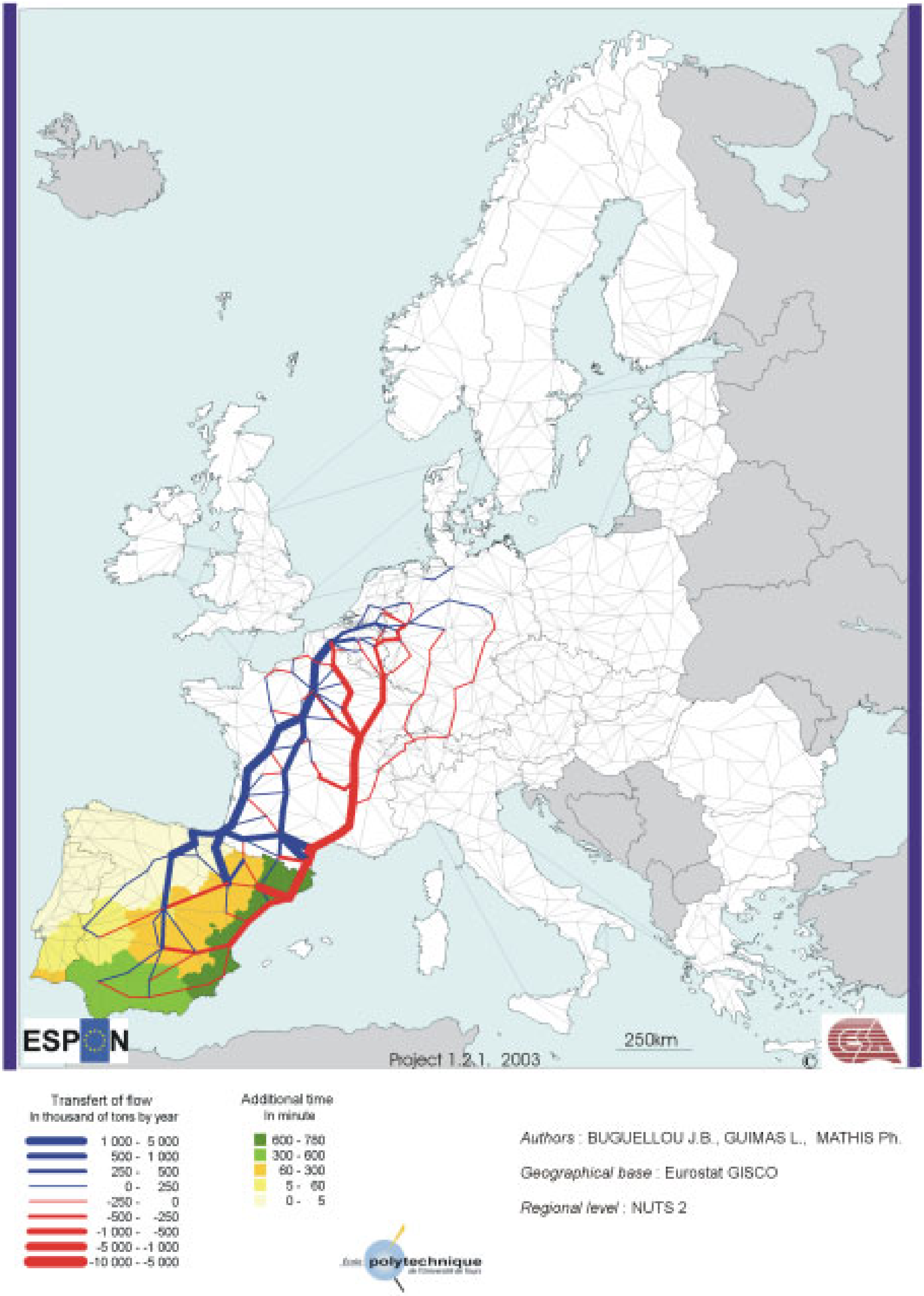


Figure 5.8.1.4 Transfer of flows in freight transportation and additional time after the suppression of the link Narbonne-Perpignan

5.8.2 The new corridors of enlargement

Rationale

The aim is to define and show the change of main transport corridor for the international transit between EU15 and EU27.

The forecast of the future economic evolution of PECOS is unpredictable.

But it is possible to express the hypothesis that the evolution of flows would be similar as the evolution of traffic with the Iberian Peninsula.

The transit uses the shortest travel time paths. The enlargement of Europe change the potential importance of main transport corridors

Method

We compute the shortest travel time of EU 15 and these of EU 27 with NOD- MAP Model that use the FLOYD’s algorithm. On a map we superimpose the results of two computations.

With this method, we can see the two results with two colours and the differential appears automatically.

Data requirement

We used the CESA motorway and road network between the 730 node cities of graph.

Application and result

The map shows the results of this modelling

This potential map shows the evolution of main corridors with the enlargement of Europe.

The growth of diagonals is clear : two corridors South-West - North-East and one North-West - South-East, and Mediterranean arc and Nordic arc.

We must balance the shortest paths with the volume of goods for the next phases.

The growth of usual North-South corridors will be less fast that the new corridors but at the present time their flows are already important.

This map corresponds to an hypothesis of internal European growth with an hypothesis of new members growth similar to the Iberian Peninsula situation.

We can evaluate some consequence of that hypothesis as emissions of air pollutants, of greenhouse gases, and other externalities.

The new corridors strengthen the problem of vulnerability, disconnection of networks in Pyrenees that we have computed and showed on maps Irun-Hendaye and Narbonne-Perpignan.

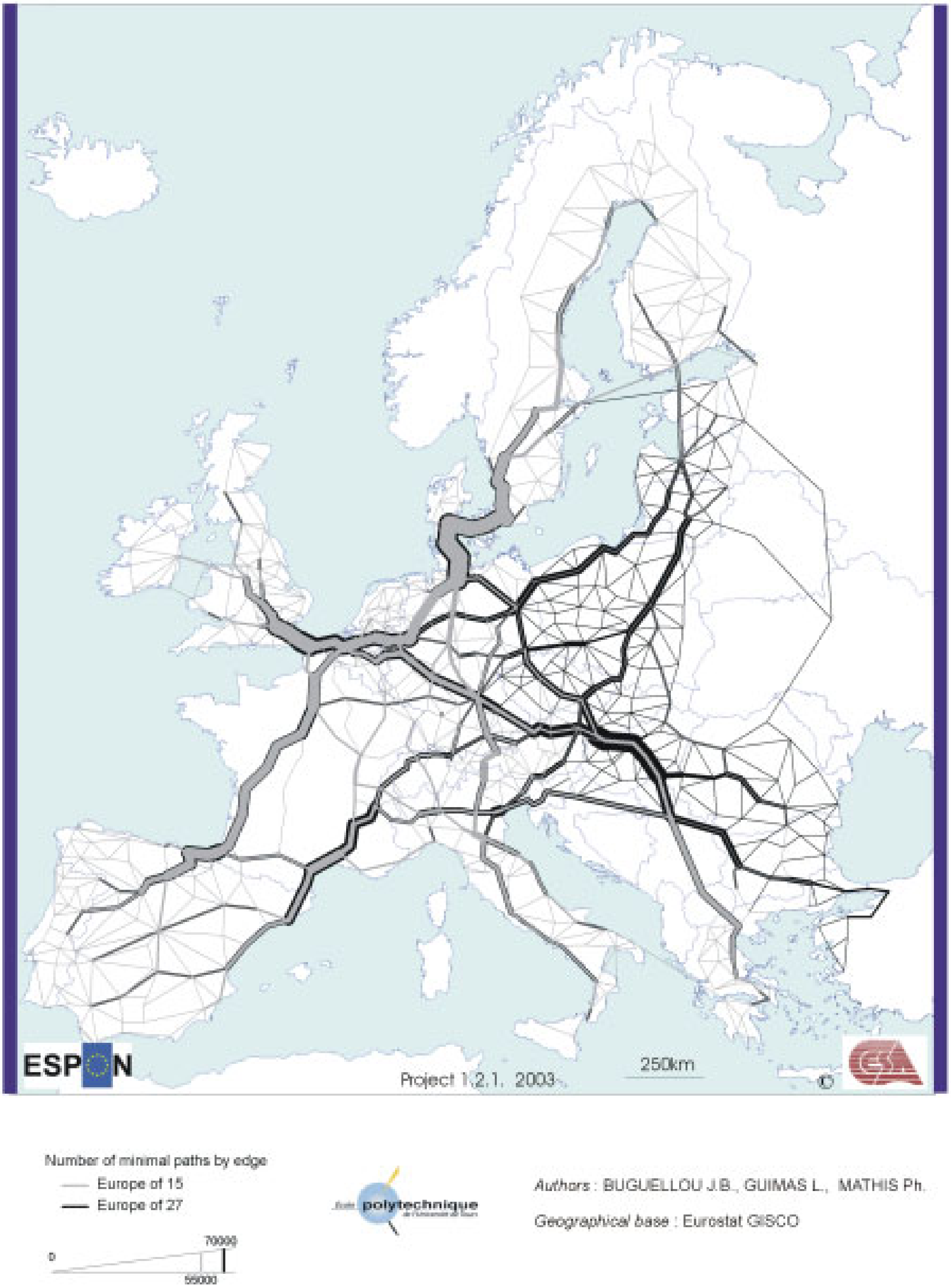


Figure 5.8.2 *Superposition of main transport corridors for the transit through France in Europe 15 and Europe 27*

5.8.3 The new corridors between Maghreb and Eastern countries

Rationale

The aim is to define and show the effect of main international transport corridor for the European transit of goods between the Maghreb and the Eastern countries.

The forecast of the future economic evolution of the zones is unpredictable.

But is possible to express the hypothesis that the evolution of flows would be significant, and that the transit will mainly use the shortest travel time paths.

Method

We compute the shortest travel time trough the EU 27 between the main cities of South and East with NOD- MAP Model that use the FLOYD's algorithm. On a map we show the results of the computation.

Data requirement

We used the extended CESA motorway and road network.

Application and result

The map shows the results of this modelling

The result is clear : one corridor South-West - North-East appears strongly. This simulation reinforce the importance of the South diagonal through a congested area (in France and Germany, etc.).

This maps corresponds to an hypothesis of external growth but it is very difficult to forecast the rate of growth.

We can evaluate some consequence of that hypothesis as emissions of air pollutants, of greenhouse gases, noises etc..

The new corridors strengthen the problem of vulnerability, disconnection of networks in Pyrenees that we have computed and showed on maps Irun-Hendaye and link Bolzano-Innsbruck.

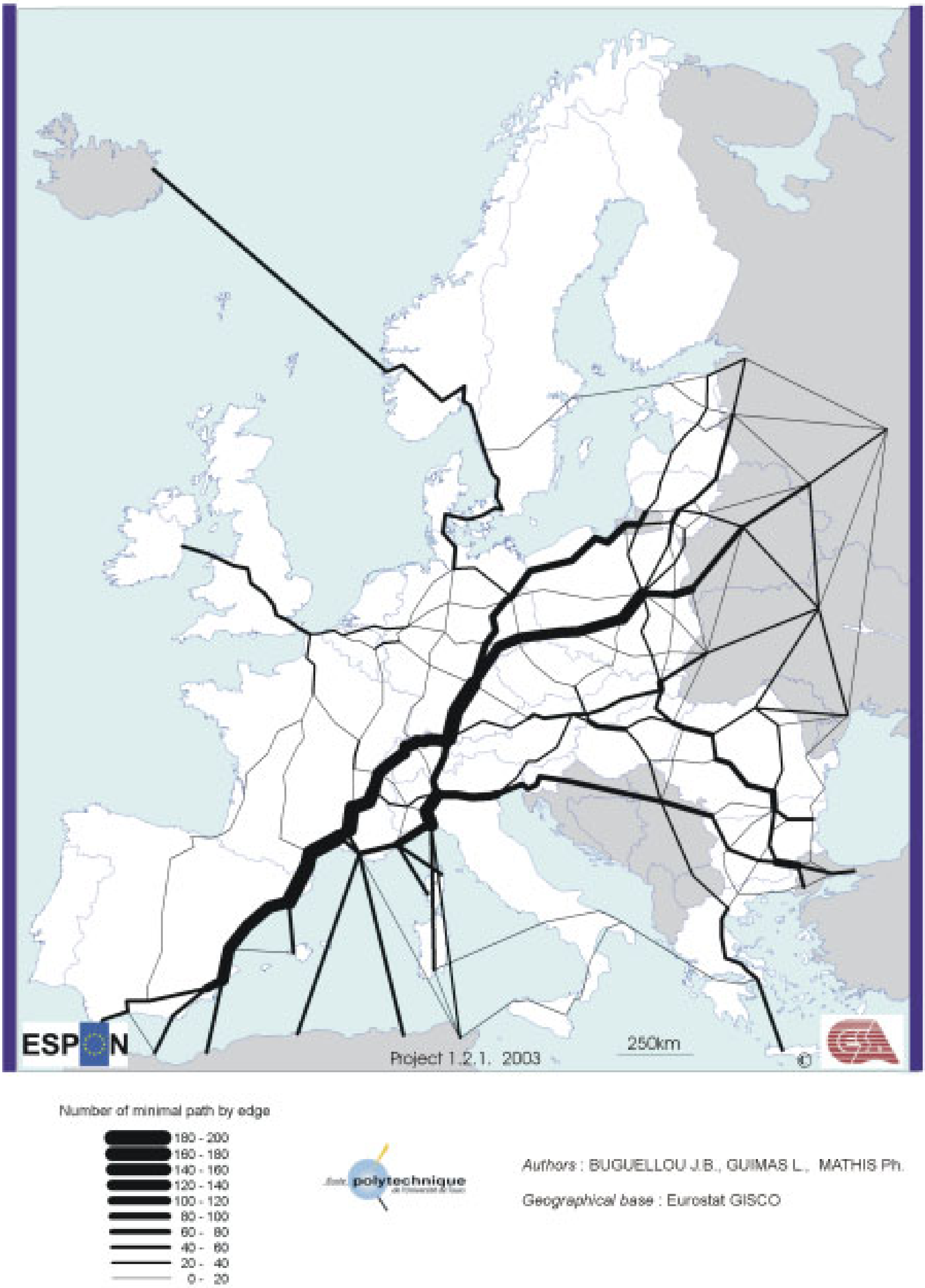


Figure 5.8.3 Main transport corridors for transit through Europe 27

7 Typologies

Typologies are proposed through the combination of at least two different indicators.

7.1 Typology based on endowment

The comparison between the intrastructural 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 Nuts 3 surfaces. The potential request of infrastructures is simplified dividing the Nuts 3 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:

- Nuts 3 with a high population density and with a rural[1] profile;
- Nuts 3 with a high population density and with a composite profile;
- Nuts 3 with a high density and with a urban profile(HD-urban);
- Nuts 3 with a medium and low population density and with a rural profile;
- Nuts 3 with a medium and low density and with a composite profile;
- Nuts 3 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 km^2) in the different Nuts 3 area, singles out four idealtypical situations which ascribe to take policies for integration between land use and transport offer.

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.

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[1] Relative rurality: share of rural population, index country average=100, < 90 low (urban), 90-110 medium (composite), >110 high (rural).

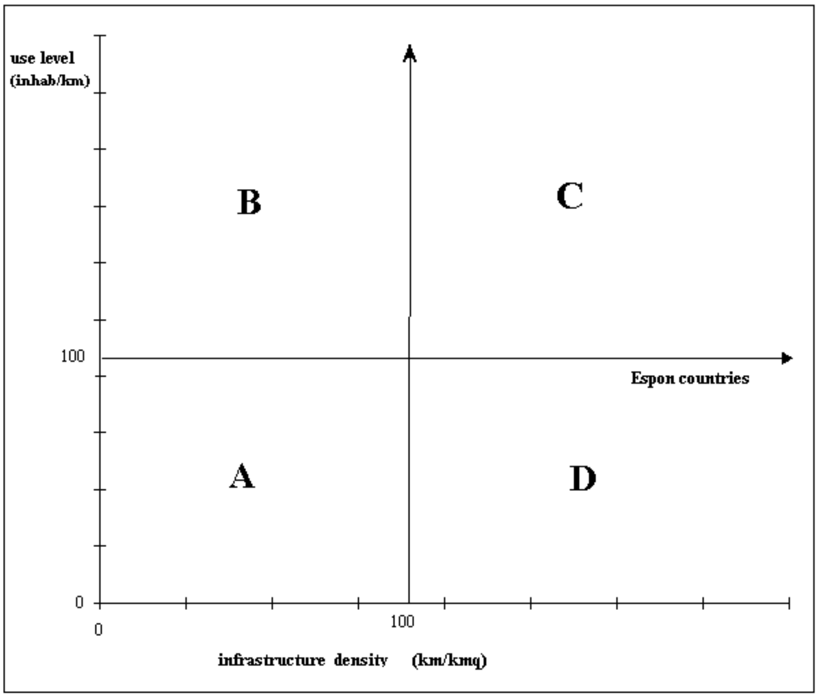

Figure 7.1.1 Diagram of the comparative study on infrastructures endowment

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 offer, 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's 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 Nuts 3 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 infrastructrural endowments, introducing as reference the average Espon countries data. The red lines in the following diagrams refer to the Espon average data.

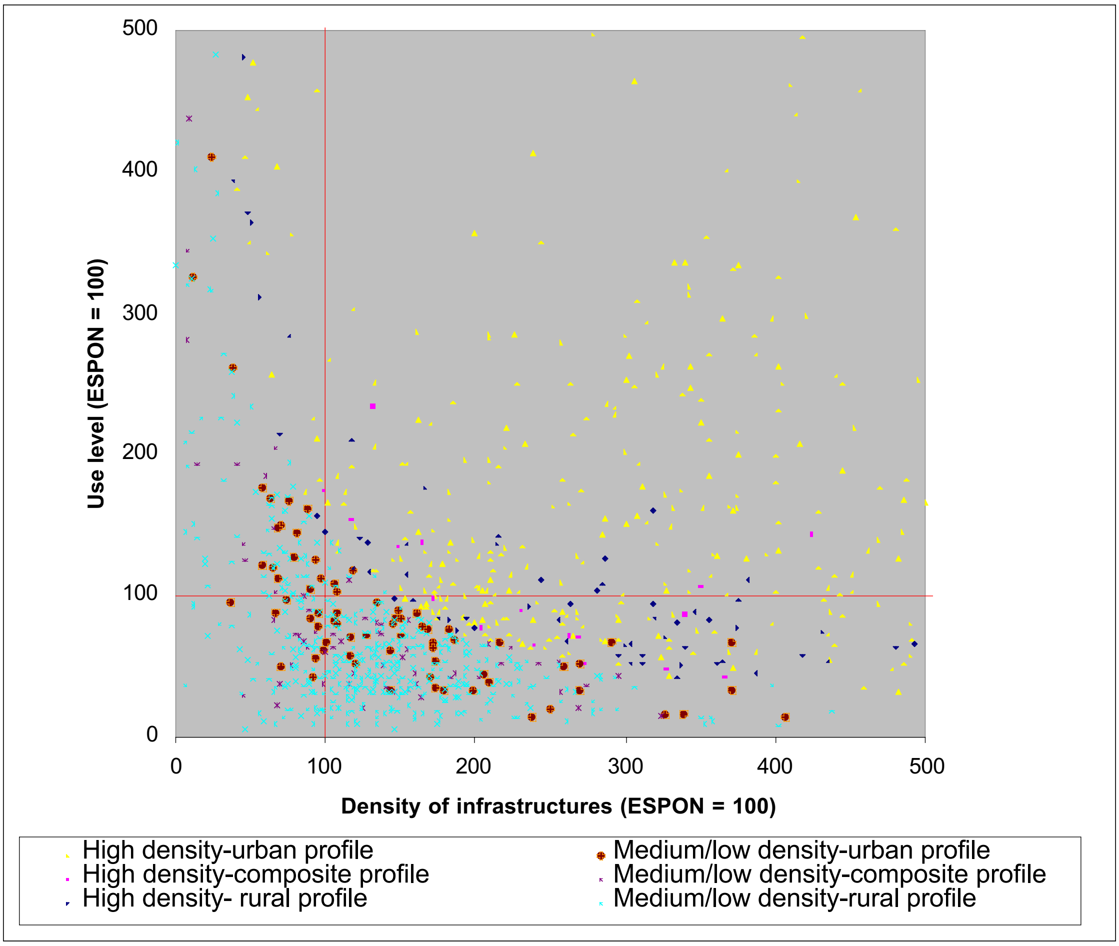

Figure 7.1.2 Diagram of use level and density of infrastructures in Nuts 3 regions. Colours refer to urban-rural profile

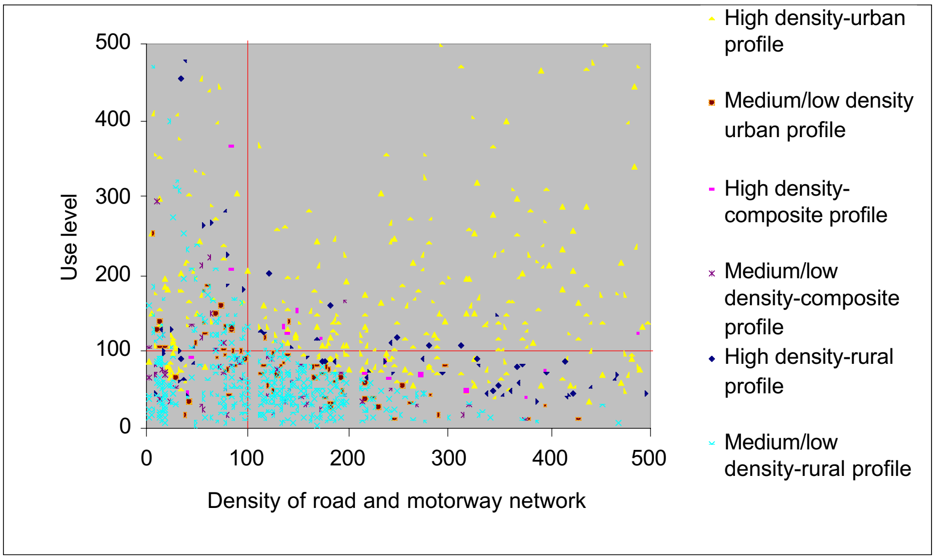

Figure 7.1.3 Diagram of use level and density of road and motorway network in Nuts 3 regions

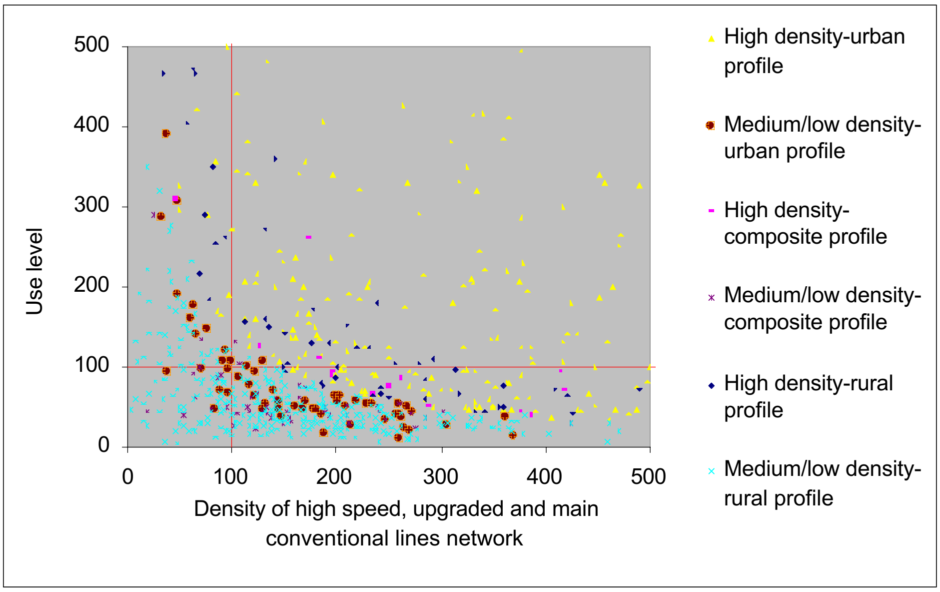

Figure 7.1.4 Diagram of use level and density of motorway and high speed network in Nuts 3 regions

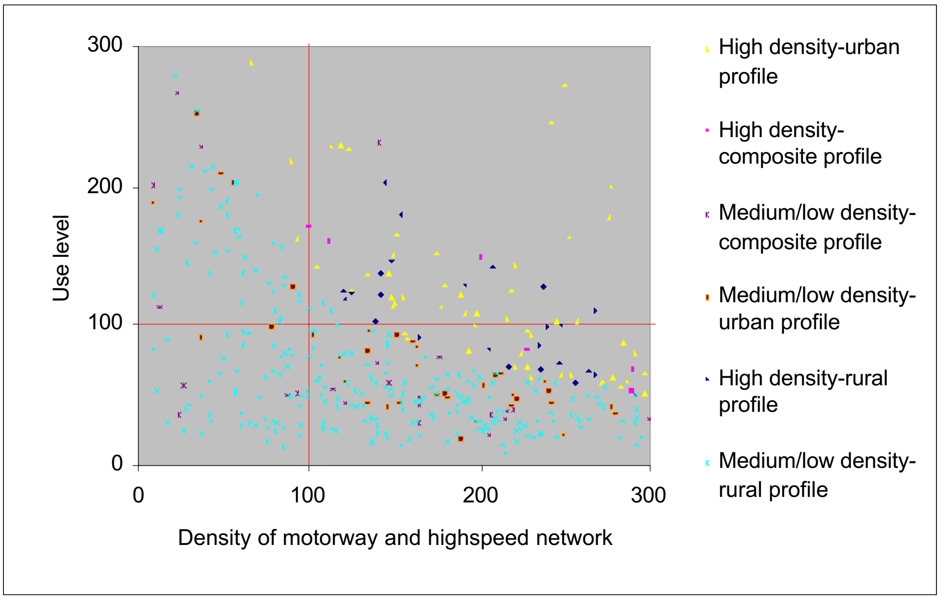

Figure 7.1.5 Diagram of use level and density of high speed trains, upgraded and main lines network in Nuts 3 regions

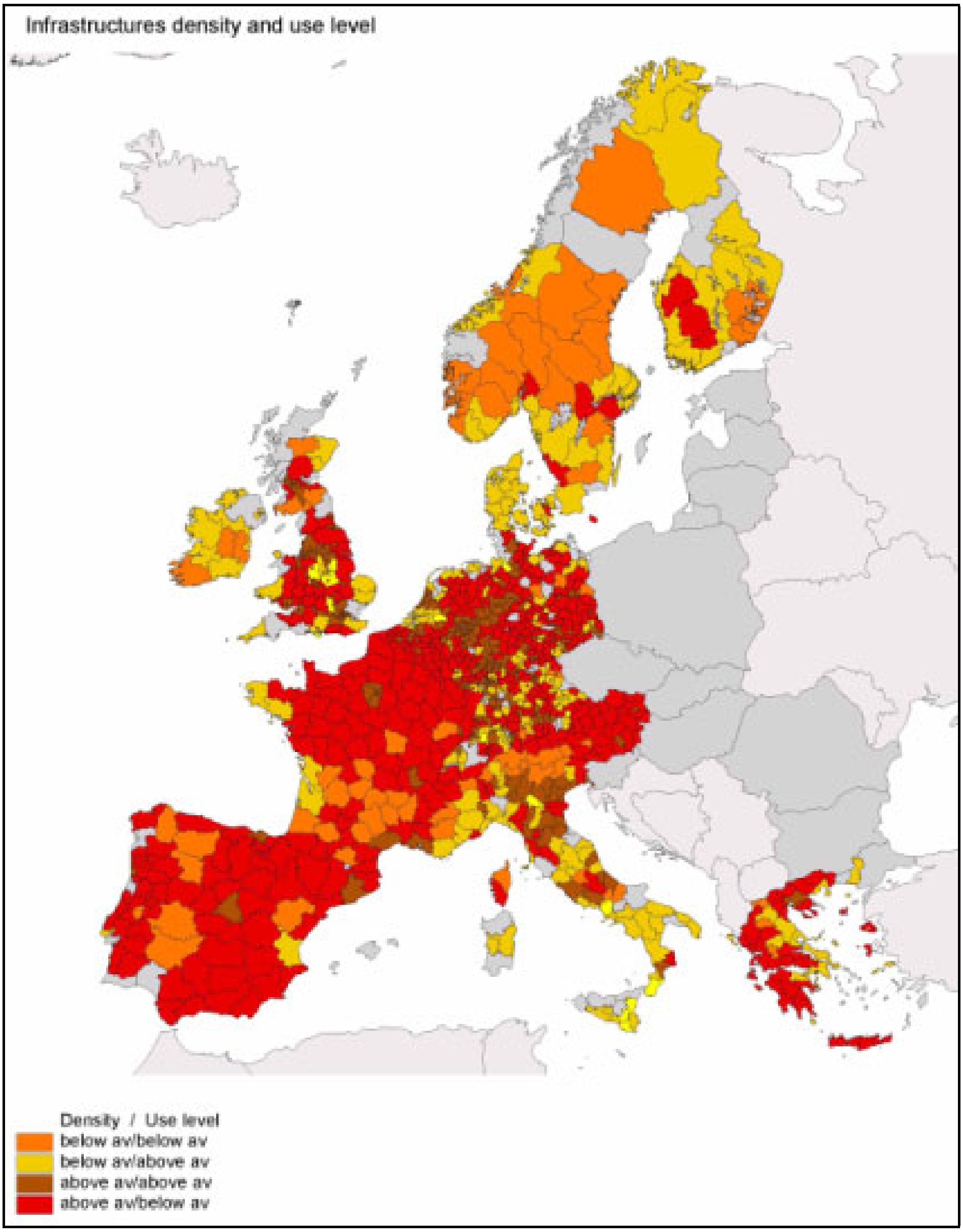

Figure 7.1.6 Map of use level and density of infrastructures in Nuts 3 regions

Reading the results on the round of administrative subdivision for the Nuts 3, 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 Nuts 3 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 Nuts 3 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 offer (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 Denmark 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.

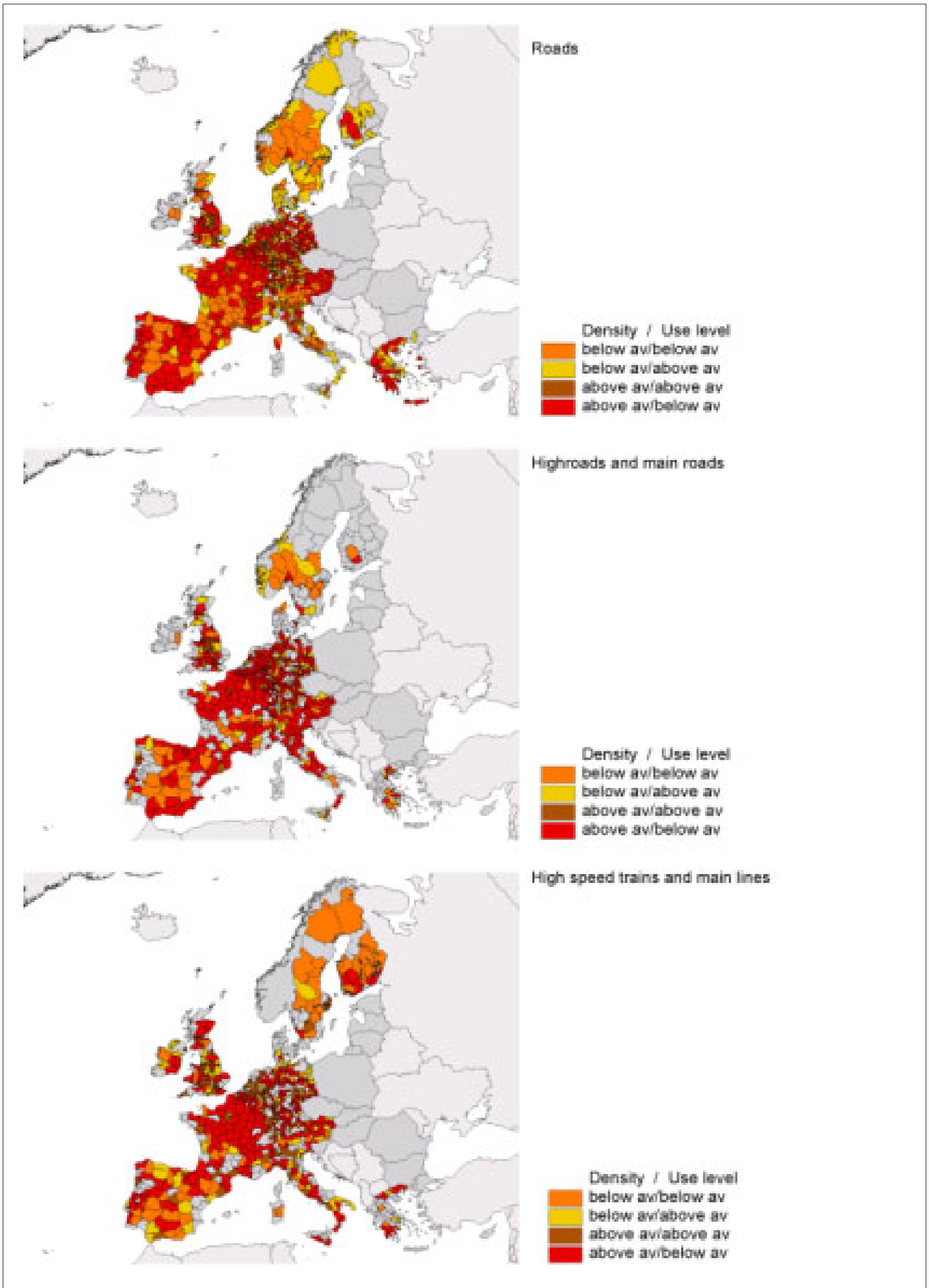

Figure 7.1.7 Maps of use level and density of road, main roads and high speed trains in Nuts 3 regions.

Analyzing the infrastructures endowments in reference to the **geographical position** of the Nuts 3 regions, we can find:

- an high presence of the Nuts3 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”** tipology (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)

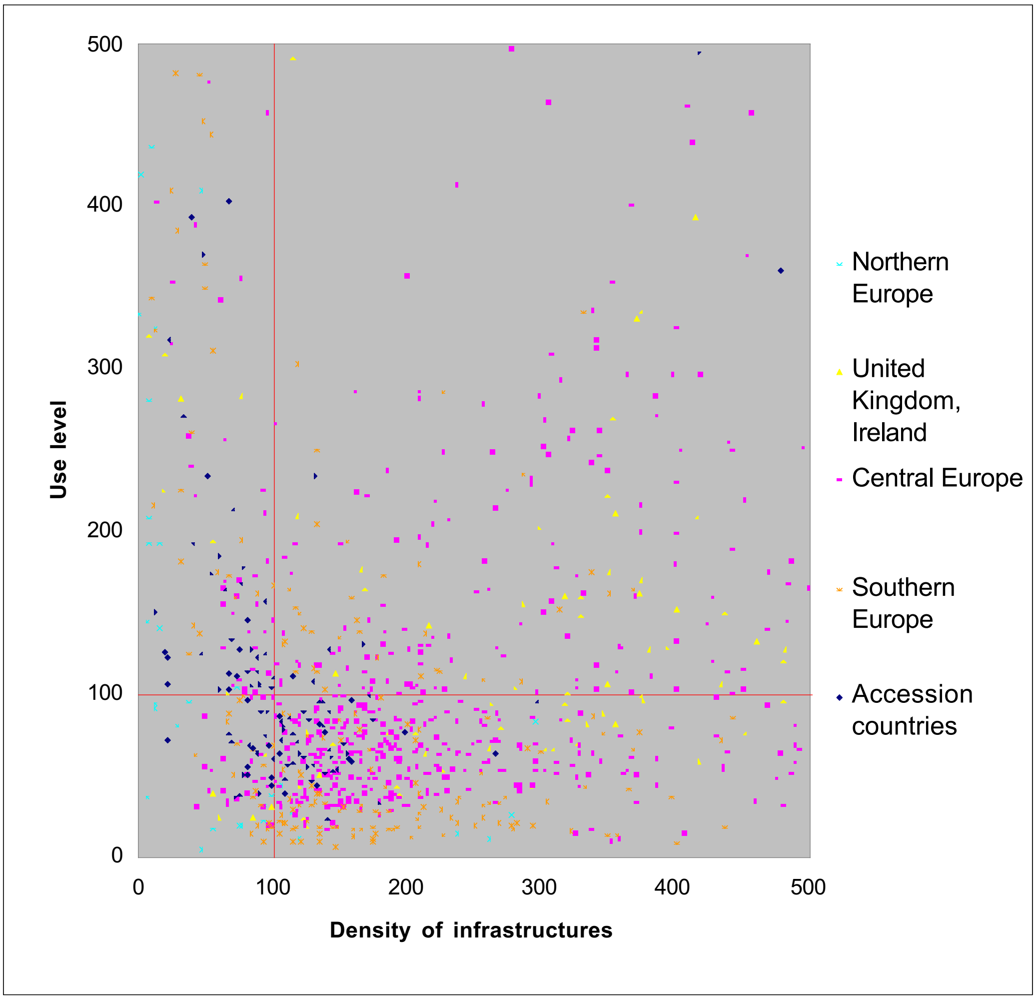

Figure 7.1.8 Diagram of use level and density of infrastructures in Nuts 3 regions. Colours refer to location in Europe

Comparing, in an aggregated analysis, the infrastructural performances of the EU15, CC10, and CC12, we can find the whole good condiction 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.

7.2 Accessibility and GDP

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.
- 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 7.2.1 by GDP per capita and multimodal (road/rail/air) accessibility. Both indicators are standardised with respect to the European average (for GDP the average of the current European Union was used). Each dot represents one region. The dots are colour-coded to indicate regions in central Europe (red), regions in the Nordic countries (orange), Mediterranean regions (blue), regions in Ireland and the UK (green) 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.

This dispersion suggests a typology of regions which is based on their position in the diagram of Figure 7.2.1. Four types of regions corresponding to the four quadrants of the diagram can be distinguished:

- *Successful regions with high accessibility*. 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.

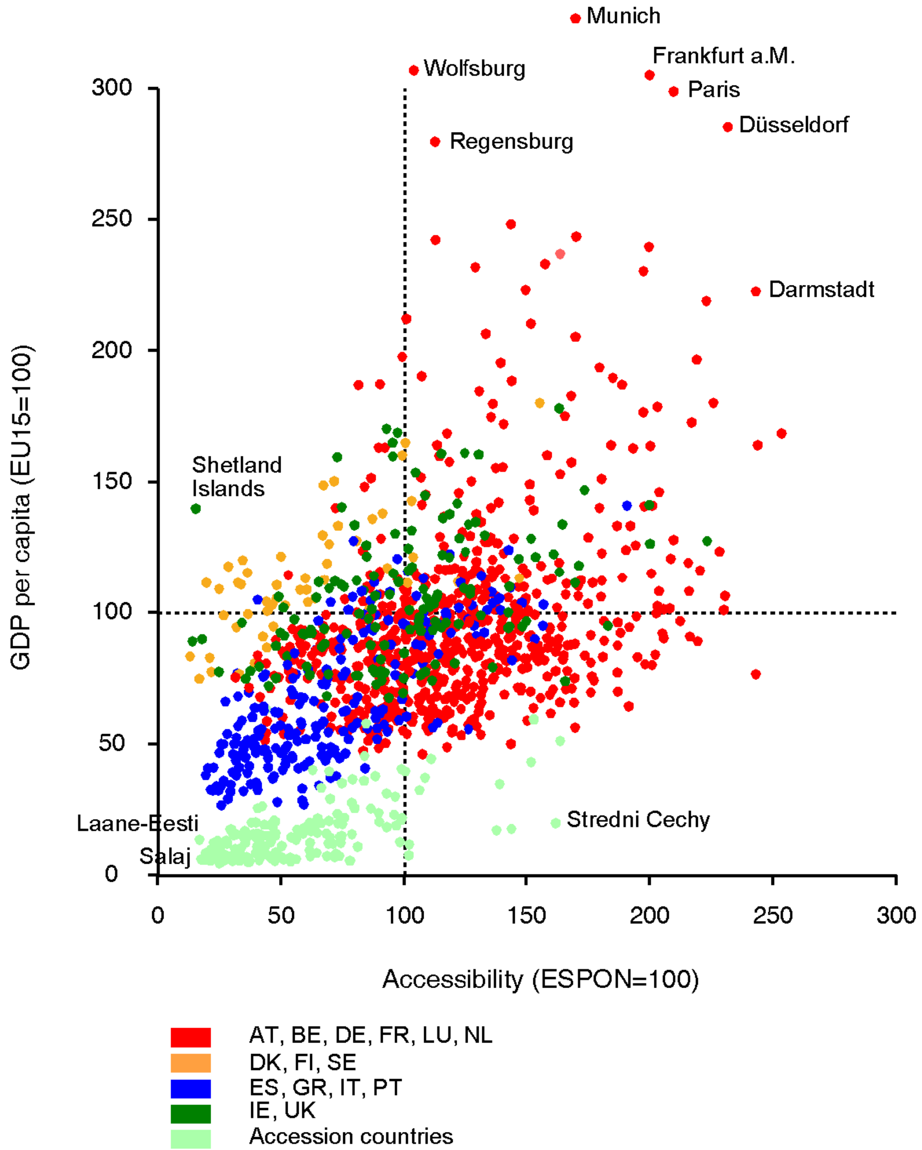

Figure 7.2.1. Accessibility and GDP per capita in NUTS-3 regions

- *Lagging 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.

Figure 7.2.2 shows the geographical location of the regions analysed in Figure 1. Now the colours indicate their position in the four quadrants of Figure 7.2.1.

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.

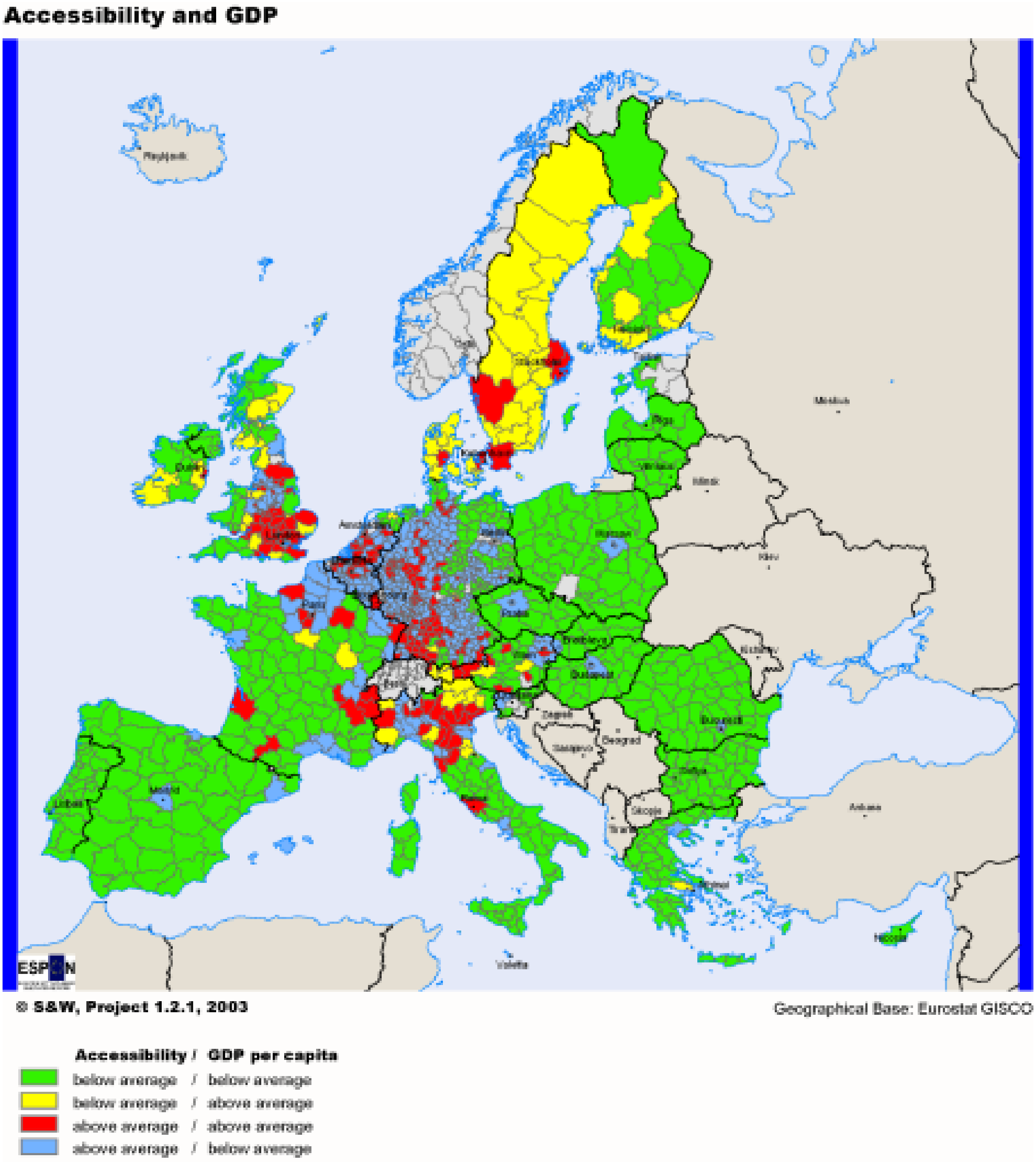

Figure .7.2.2. Accessibility and GDP per capita in NUTS-3 regions

8 Conclusions

This report is actually a intermediary and provisory report.

Intermediary because it shows the progresses of our work since the last report, these both documents being effectively very different in their core content and many indicators and maps.

We set out numerous methods and results.

Some of these methods are classical and established but results are actualized in terms of time as in terms of space, notably through the zoning adopted. Some other methods and results are only developed since only six month have passed since the last report and four since the last ESPON seminar in Crete.

8.1 Main findings

We have recalled the complex characteristics of the European space.

- Complex because of its geographic shape;
- Complex because of the existence of a constraining physical relief;
- Complex by its historical evolutions, by national traditions that have slowly materialised through transport networks, as for example the different level of centralisation.

The first complexity is related to geophysical consideration :

- First, a succession of peninsulas of Europe that make it nearly impossible to compare with the very continental American transportation system: thirteen countries, fifteen of which having a maritime coast (only Luxembourg and Austria does not have any maritime harbour), two are islands and six are peninsulas;
- Secondly many important relief, difficult to cross, tend to partition the Union: Alps, Pyrenees, ... ;
- Lastly, with the enlargement, the Union is going to obtain a opening onto the Black Sea and, in the East, a very important fluvial corridor with the Danube. Seven of the new members have got a sea coast.

These first elements, that may seem evident but that it is a necessary to recall, have, as it has been shown, important consequences on the evolution of the different transport mode.

First, and foremost, networks vulnerability is actually increased: crossing of the Alps, Pyrenees...

Secondly, the relations are constrained with important consequences on networks morphology. Indeed, we can distinguish two kinds of networks :

- the first is a grid network more or less hierarchical as those of Germany, Spain or Polish...
- the second one is a network dominated by two corridors that are weakly interconnected, as those of France, Italy or England...

Thirdly, history has added a level of complexity because of the different evolution in each country, notably their more or less important level of historical centralisation. England, France and Spain are territorially strongly centralised, on the contrary of Germany or Italy. But, general conclusions are possible.

Network morphology and vulnerability,

The freight transport

For the road, the driver cycle is very important in the assessment of time travel. Indeed when a truck takes a ferry or a rolling road, the driver can take a time of rest in the train or the ferry. The driver takes a rest whereas the truck continues its path. Whit this consideration, we can to compare different path (who use different mode of transport road, ferry …) for to value the best way. It is an **intermodal** approach.

The slope of road is important for the truck speed and the route choice. The average speed is very different between two links with a weak slope and a strong slope like the pollution.

For the rail network, the slope is important too. If for the road the slope increase or decrease the speed, it is different for the railway technique. The slope decreases the motor capacity and is translated by a decrease of the **number of wagon** that the train can pull and increase the cost of the fret transport. the existence of a constraining physical relief is basic.

Besides, the rail operating technique is important for the fret. Between direct train and single wagon the routing is different, and influences the cost.

The assignment of the network is a priority in term of transport. That permits to see the structure of the traffic (origin, destination, corridor…). The localization of flows on the network shows the relationship between the levels of this network (motorway, dual carriage, TGV …). For example, we can see on the map of “railway traffic” three principals corridors in Poland :

- one north/south, between Gdansk and Katowice;
- one east/west, between Szczecin and Warsawa (whit one connection with the first corridor);

- the last one between Wroclaw and Krakow (whit one connection with the first corridor).

But, when we see the assignment on the nuts region, we don't see the structure of the corridors. Besides, the network assignment permits a good comparison with the **Trans-European-Network**. This method can help us to determinate **the bottleneck or the network vulnerability**. It is a good base for an assessment the impact of different scenarios or hypothesis about the infrastructure of transport or the organisation of the logistic chain.

Transport network and passenger flows

The indicator can show all relevant aspects concerning transport networks and services spatial impact: how transport network gives economic and social value to *space*, and how transport networks channel and induce *flows*.

The first indicator (*connectivity of each place to transport*) is policy relevant in relation first to the distribution of development opportunities. It provides a refined measured in relation to traditional measures such as density of infrastructures.

The second indicator (*traffics on transport networks*) is policy relevant because it is directly linked to the actual use of infrastructure, the existence of bottlenecks and the generation of environmental impacts such as accidents or emissions.
The connectivity indicator (ICON) shows the minimum access time by road to the closest transportation nodes

The highest connectivity is in the more dense urban areas and their metropolitan regions. Coastal regions show a higher connectivity as this increases the global utility of the network Regarding connecting to the motorway network, there is a clear distinction between eastern countries and EU countries, especially those in the EU centre as nearly all country capitals in the EU are linked with a motorway network. This doesn't 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).

These measures, originally developed and applied at European level since 1989, enrich more traditional transport endowment indicators.

Traffic volume indicators capture the actual use of the transport infrastructure networks. A simplified but complete passenger's transport forecast model has been applied to obtain useful indications of trip generation, distribution, modal split and traffic assigment (this latest only for roads). *Generated trips by trip purposes (business, leisure and visits)* have been calculated

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. Km per person by car in business trips 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 centre ESPON space. Km per person by car in leisure and visits trips is characterised by eastern periphery and the rest of ESPON space. Regions in the periphery of the ESPON space drive to regions with high population and tourist attractiveness, mostly situated in the centre and south of this space. Flow assignment allow the identification of traffics on most congested road 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.

Traffic on road links for business trips has been calculated with an all-or-nothing assignment of the matrix of business trips between NUTS2, obtained with the KTEN model. The assignation is All-or-Nothing and time is the only variable is user's generalised cost function to choose the route..

The indicator of the travel times of less than one hour by air between the MEGAs expresses a factor of integration of the European territorry. The connexity of the system of relations allows the continuity of one hour realtions in the core of the continent from Rome to Edinburgh and from Bordeaux to Helsinki. Tha Baltic states are linked to the Union through relations between Tallinn, Helsinki and Stockholm.

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

The indicator of daily accessibility between 236 European cities allows to explore the qhality of the relations inside the European city network.

Firstly, the hub function of the major Europen nodes is expressed through the convergence of bilateral relations with neighbouring cities, as can be observed in London, Paris, Frankfurt, Muenchen, but also in Madrid and Rome.

Nevertheless, the high level of service in the integated Europe contrasts with the generally poor levels in the eastern and accessing countries. In these parts, the bilateral links can only be observed in intra-national relations.

Considering the European Union countries, the main crossborder gap occurs between the Iberic peninsula and the rest of the continent with with no symetric relation, confirming the result observed with the one hour relations.

The same indicator applied to the list of 62 MEGAs provided by the 111 ESPON group on polycentrism expresses mainly similar results. Firstly, the pentagon pattern 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, at the exception of Praha. The coherence of the Nordic network appears clearly with the role of gateway for Kobenhavn. In the Iberic peninsula a high level of integration is reached between Madrid and the major Spanish and Portuguese cities, but the gap with the continental Europe is still there

Nevertheless the list provided by the ESPON 111 group can be considered as not satisfying enough in terms of geographical coverage, and also if we consider a similar work done previously by the CRPM.

8.2 Policy recommendations

The first general recommendation is to reduce the level of vulnerability of each particular network, that it be the consequence of physical relief, of territories shape or population density.

The solution to increase liability is simple: increase the redundancy of each mode and the capacity of modal transfer. But its implementation is more difficult and demands, for precise and located modal recommendation, to continue and go deeper in our analysis.

It possible to propose general transitory measures.

An fundamental aspect must be underlined, it is the rarity of types of flows which permit a modal transfer, taking into account the various constraints that they undergo.

- Local movements of travellers can not use a modal transfer, with an exception concerning transfer to collective transportation mode or alternative modes that is a reality in Europe, through a tendancial or voluntary degradation of the conditions of circulation of individual vehicles.
- Local freight carriage can hardly be modified. The freight transportation between connected regions is also linked to road mode except a small part concerning remote regions located near large logistic platforms.
- Concerning inter-regional movements of travellers, we can observe an important and efficient modal transfer to high speed train. The main problem is still that territorial railway service is weak and limited to the largest agglomeration. In this domain, as it is mentioned in the White Book on Transport, the complementarily between modes must be developed.
- Concerning the long distance transportation of passengers, the most efficient mode for professional trip still is the air one, associated with high speed rail when available and completed by classical rail and road.
- On the contrary, goods in international transit can and must be the object of a modal transfer to avoid pollution problems: road transportation pollutes four more times than rail and some corridors begin to be saturated and because the railway for long distances is competitive
- For long distances, the cost per t/Km, taking into account the emission of pollution, is weaker by train; but capacities of this mode of transport have not been develop as the same rhythm as road and is at the present time insufficient.

Yet, in middle term, around fifteen years, an important modal transfer is not possible on European networks because of the lack investment for rail infrastructure in Europe of the 15 and because, in the Eastern candidate countries, road is still a synonym of freedom (as it still appears in some other European countries). And about 15 years are necessary for a railway infrastructure.

Waiting for the building of the lines dedicated to freight which must be proposed, and because of the rapid growth in the intra-community exchanges, a solution for the short term is to encourage the maritime transport.

Indeed, the infrastructures exist and could be modernize as well as the fleets, and a boat can be built faster, two years, than a railway line and, all the more, than a highway.

Moreover, the manpower in the Community is in excess (increasingly) of seamen who own the necessary maritime culture.

The modal transfer could quickly benefit from a voluntary degradation of the traffic conditions for lorries on the roads and highways (an increase of tolls, a decrease speed limit when overtaking, a reinforcement of the application of the rules of driving time...).

The modal transfer could be all the more easier that the country concerned owns a reduced set of corridor as in France, Italy, England, for which the traffic is already spatially focused, which guaranties the profitability of an infrastructural investment like dedicated railway. The Switzerland example shows that it is possible even for restricted distances.

In spite of a weak economic growth, the growth of traffic on trunk roads and especially the one of the international transit remains steady.

The striking phenomenon is the traffic with the Iberic peninsula. We can use it as a basis for traffic forecast with the PECOS whose economic development could follow a similar dynamics considering the possible relocations free from all political risks that are running in the other zones.

The relations between the Iberian Peninsula and the rest of Europe, are easily measurable in Pyrenees because there are only two important passages overall and it is a very good example of vulnerability, economic and environmental problems. Moreover this example is very important because these two corridors are the main corridors for the future of Europe with an internal or a external growth.

The best traffic indicator on trunk road links is given by the evaluation of the traffic of light vehicles essentially for both of the extreme passages of Pyrenees and in a lesser measure by Andorra.

During these last ten years, this traffic on the whole of both motorway links increased by 42 %. The traffic on the Atlantic corridor (A8-A63) increased more and in a more constant way. (18 000 light vehicles on an annual average to Hendaye D912). The monthly evolution shows that in July-August, entrances by road to Spain increased more than twofold. But this monthly average evaluation hides the peaks of saturation of the weekend.

For goods, exchanges increased by 80 % over the last ten years and the part transported by road exceeded the maritime way only in 1996. Its modal part was only 36 % ten years ago. At present road transports 55,5 % and maritime 41 %. But all the modes increased during this period: road 140 %, maritime 41 %, rail transport 32 %.

For almost the whole, these road traffics pass by highways to Irun and to Jonquera: 17000 heavy goods vehicles on average a day in 2000 and a growth of 130 % traffic in ten years i. e. 8,70 of the growth rate a year.

Considering the tonnages passing in transit through two lanes, it gives us an average load of a little more of 10t by heavy goods vehicles for 66 annual MT. This involves an important volume of regional traffic, because the average load of the heavy goods vehicles is estimated at 14t and in international at approximately 20t, now the growth rate of the international is very superior: local 3 to 5 %, interregional approximately 7 %, international 12 %. The observed rate is thus an average rate which hides a much faster growth at the international scale.

If this tendency carries on, within 10 years (2000-2010) it will represent more than 40 000 heavy goods vehicles on a daily average or 10 000 in each direction on the motorway. Considering the probably strong increase of the traffic with Maghreb, this hypothesis has nothing unrealistic.

If we consider that carrying out an infrastructure took at present 14 years, from the project to its implementation with a 8.7 % rate a year and that the figures are dated in 2000, in 2017, date of the possible opening of an infrastructure whose principle would be acted today, the heavy goods vehicles traffic would have been multiplied by more than 4 (exactly 4,1295) i. e. an increase of more than 300 % and thus 17 000 heavy goods vehicles in every direction by motorway.

The capacity by hour of a motorway is about 1800 cars on each lane which, if we consider a regular flow at 60km/h, represents 43 2000 vehicles each 24 hours. If we accept the usual (but minimal) equivalence of one lorry for two cars, the foreseeable flows at that rhythm of growth (actually realistic because of the number of lorries present in the peninsula) would imply the saturation of a lane in each direction only for lorries. Practically, this level of saturation would imply the occupation of two lanes if we consider the variations due to peak hours.

In the same time the traffic of cars is expected to grow at a rate of 3.40 % with a flow almost identical 9 000 in each direction at Hendaye. Nevertheless, these figures corresponds to an annual average hiding deep seasonal variations implying saturations. During the same period this flow will grow of 70 %. In these conditions the conflict between users is unavoidable since the building of a new lane is rendered extremely difficult because of the high level of constraints in this area of rare and expensive space. Moreover, it must be noticed that the share of the road transport is only at 55 % of the total and that this proportion is growing.

One faces immediately a physical impossibility, the existing infrastructure being not able to absorb such an augmentation. In the same time a modal report on rail is not feasible if one takes into account the available capacity and the concurrence between freight and passenger traffic, not speaking of the different rail gauge in the two countries.

The only possibility at short term, id. at less than 14 years, resides in a voluntary development of maritime freight transport through short sea shipping with regular lines for heavy weights and containers.

In this domain the infrastructures already exists and can be rapidly improved. The maritime culture also exists and the problems of fishing would make available a qualified workforce able to be redeployed.

At short term it seems to be the only viable solution for the exchanges with the Eastern countries which would not imply a deep crisis likely to lead to economic recession.

The same type of hypothesis can be applied in the context of the Eastern and accessing countries which are likely to host many industrial relocations due to a cheaper workforce well trained with a lower political risk that in the Maghreb.

To summarise:

- From now to 2017 he infrastructures will not be strongly modified, since only the projects already decided and financed will be realised
- The growth of traffic will continue even in case of low economic growth
- The present infrastructures and those to be built before 2017 will not admit the growth in traffic and the saturation is likely to be attained well before.

It will then necessary in term of transport modes to develop a short term policy (3-5 years) and a mid-term policy (12-15) based on modal transfers on positive or negative incitation concerning the international transit and a modal transfer policy with creation of a new infrastructure adapted to modern needs in terms of speed, cost and frequencies, environmentally acceptable and in line with planning orientations.

At short term, in order to satisfy the transport demand and considering the existing infrastructure unchanged, a strong modal transfer to rail being only partially possible because of the lack of capacity, it will be necessary to transfer a part of the fast growing international transit on the sea.

Indeed 20 among 27 countries have a maritime façade and three continental countries have access through inland waterways (Danube) to the sea.

The modal transfer can be effective quickly because :

- The infrastructures already exist even if they need to be improved
- Two years only are necessary to build a boat and inland waterways transfer is possible

Moreover the maritime transport is less polluting in terms of ton per kilometre.

Simultaneously it will be necessary immediately to downgrade the speed (60 km per hour as in the United States, the speed of maximum flow) in order to improve the capacity, to reduce the number of accidents and the quantity of pollutants and finally to incite the modal transfer to maritime transport. This downgrading of speed must also apply to cars.

Simultaneously, but in the middle term a modal transfer must be developed for high speed international transit. Rail is in this case the right solution because a dedicated line has a high capacity for heavy traffic and can be much faster than the road: Lille to Hendaye direct relation in ten hours, almost the same time as a night spent by a lorry driver, corresponding to a technological improvement of the same type than the high speed rail for passengers.

The international transit traffic at long distance only can be subject to a really efficient modal transfer in terms of time and cost.

This rail solution corresponds to the spatial structure of the existing networks: simple corridors with few entry points as in France, United Kingdom, Italy, Sweden and Finland. If Spain becomes a transit country between Europe and Marocco, its situation will become closer to the corridors spaces. France, as the other unavoidable areas for some origin-destinations, is a transit country for which a modal transfer is highly necessary to relieve the pressure on the regions crossed by the flows.

The goods dedicated lines must:

- Avoid the urbanised zones where the land is expensive and the pollution already important
- Be connected to the existing network while remaining dedicated to high speed freight transport avoiding slower trains that would diminish drastically the capacity
- Be the expression of a voluntarist strategy and not a simple matter of transport business. In the case of France this dedicated line should be built the most in the West as possible doubling the motorway of the estuaries, to release the pressure of transit flows on the Parisian region and to connect the ports of Le Havre and Nantes. This new line could also contribute to the development of the peripheral Atlantic regions.

A policy of freight transport infrastructure must then be multimodal (rail, road maritime), territorial (strategic planning, economic development, environment, vulnerability of the axes) and temporal (taking into account the short and medium terms).

Table of figures

Table 2.1 Example for Data set NUTS level 3 18
Table 2.2 Example of Meta data set and documentation 18
Table 2.3 Example of data set NUTS level 3 20
Table 2.4 Example of Meta data set and documentation 20
Table 3.1.1 European transport policy goals, aims and actions....30
Table 3.1.2 Policy aims....31
Table 3.1.3 Environmental policy aims....32
Table 3.1.4 TEN policy aims....32
Table 3.1.5 Strategic Policy Goals 33
Table 4.1 Existing indicators of transport infrastructure supply....48
Table 4.2 Existing indicators of transport infrastructure capacity....49
Table 4.3 Existing indicators of transport services 49
Table 4.4 Existing indicators of transport vulnerabilities....49
Table 4.5 Existing traffic volume indicators....50
Table 4.6 Existing traffic flow indicators 50
Table 4.7 Generic accessibility indicators.....52
Table 4.8 Dimensions of European accessibility indicators....59
Figure 5.1.1 Density of expressways by population....71
Figure 5.1.2 Density of rail lines by population....73
Figure 5.1.3. Commercial seaports infrastructure 75
Figure 5.1.4. Commercial aiports infrastructure....77
Figure 5.2.3.1. Evolution of the motorway network....86
Figure 5.2.3.2. Main railway network....88
Figure 5.2.3.3 Inland waterway network 90
Figure 5.2.6.5 Cartogram of population in Europe 27 with main transport corridors....94
Figure 5.2.6.6 Cartogram of GDP in europe 27 with main transport corridors....95
Figure 5.2.6.7 Cartogram of density of motorway by surfaces of NUTS 2 in Europe....96
Figure 5.2.6.8 Cartogram of density of road by population of NUTS 2 in Europe (km/inhabitants) 97
Figure 5.2.7 Fractal dimension of European countries....100
Figure 5.2.8.1 European road network with a square grid of 2.5 Km 103
Figure 5.2.8.2 European road network with a square grid of 5 Km 104
Figure 5.2.8.3 European road network with a square grid of 7.5 Km 105
Figure 5.2.8.4 European road network with a square grid of 10 Km 106
Figure 5.2.8.5 European road network with a square grid of 15 Km 107
Figure 5.2.8.6 European road network with a square grid of 20 Km 108
Figure 5.2.8.7 Surface served by a road in Europe with a square grid of 2.5 Km 109
Figure 5.2.8.8 Surface served by a road in Europe with a square grid of 5 Km 110
Figure 5.2.8.9 Surface served by a road in Europe with a square grid of 7.5 Km 111
Figure 5.2.8.10 Surface served by a road in Europe with a square grid of 10 Km 112
Figure 5.2.8.11 Surface served by a road in Europe with a square grid of 15 Km 114
Figure 5.2.8.12 Surface served by a road in Europe with a square grid of 20 Km 116

Figure 5.2.9.1. Example of radial analysis on main European cities(circle of 25 Km of radius) 118
Figure 5.2.9.2. Example of radial analysis on main European cities(circle of 50 Km of radius) 119
Figure 5.2.9.3. Number of cities accessible from each city in less than 30 minutes....120
Figure 5.2.9.4. Number of cities accessible from each city in less than 60 minutes....121
Figure 5.2.9.5. Number of cities accessible from each city in less than 180 minutes....122
Figure 5.2.9.6. Number of cities accessible from each city in less than 360 minutes....123
Figure 5.2.11 Relief map of the main european transport corridors 126
Table no. 5.3.1: Services and weights....128
Figure 5.3.1. Connectivity to transport terminals....129
Figure 5.3.2. Cost to motorway entrances 131
Figure 5.3.3. Connectivity to rail stations....133
Figure 5.3.4. Connectivity to commercial seaports....135
Figure 5.3.5. Cost to commercial airports by truck 138
Figure 5.3.6. Connectivity to commercial airports....140
Figure 5.3.7 Travel times for trucks 143
Figure 5.3.8 Exploitation cost of a road operator from Valencia....145
Figure 5.4.1. Daily population accessible, 1999 150
Figure 5.4.2 Daily market accessible by car, 2001 152
Figure 5.4.3 Travel times of one hour or less by air between MEGAs 2003 154
Figure 5.4.4 Travel times of one hour or less by air between MEGAs 2003 157
Figure 5.4.5 Travel times of one hour or less by air between MEGAs 2003 159
Figure 5.4.6 Travel times of one hour or less by air between MEGAs 2003 162
Figure 5.5.1 Potential accessibility by road, 2001. 166
Figure 5.5.2 Potential accessibility by rail, 2001. 168
Figure 5.5.3 Potential accessibility by air, 2001. 171
Figure 5.5.4 Multimodal potential accessibility, 2001....173
Figure 5.6.1.1: KTEN: Main interface of the Trip generation module....174
Figure 5.6.1.2: KTEN: Trip rates interface of the Trip generation module 175
Figure 5.6.1.3. Trips generated for business purpose. 176
Figure 5.6.2.1: KTEN: Leisure and Personal trips by GDP of the Trip generation module...177
Figure. 5.6.2.2: KTEN: Relation between Leisure and Personal trips of the Trip generation module....177
Figure. 5.6.2.3: Trips generated for Leisure purpose 179
Figure. 5.6.3: Trips generated for visit purpose....181
Figure 5.6.4.1: KTEN: Interface of the Trip distribution module....183
Figure. 5.6.4.2: Trips generated for business purpose 184
Figure. 5.6.5: Trips attracted for leisure purpose 187
Figure. 5.6.6: Trips attracted for visit purpose....189
Figure 5.6.7.1 : modal split for interregional trips....190
Figure. 5.6.7.2: km per person in trips generated by car for leisure purpose 192
Figure. 5.6.8: km per person in trips generated by car for leisure and visit purpose....194
Figure. 5.6.9: traffic on roads for business purpose....196
Figure. 5.6.10: volumes of exportations....200
Figure. 5.6.11: road traffic link and minimal path between the 27 (country by country).......203

Figure. 5.6.12.1: road traffic link and minimal path between the 27 (country by country)....205
Figure. 5.6.12.2:GISCO road traffic....206
Figure. 5.6.13.1: rail freight flows in the CEE....208
Figure. 5.6.13.2: railway traffic in Europe....209
Figure. 5.6.13.3: railway traffic in Europe per NUTS zone....210
Figure. 5.6.14.1: railway traffic number of trains....212
Figure. 5.6.14.2: railway line capacity....213
Figure. 5.6.14.3: saturation of rail network....214
Figure 5.7.1 Road traffic deaths, 2000....216
Figure 5.8.1.1 Transfer of flows in freight transportation and additional time after the suppression of the "Tunnel de Frejus"....222
Figure 5.8.1.2 Transfer of flows in freight transportation and additional time after the suppression of the link Bolzano-Innsbruck....223
Figure 5.8.1.3 Transfer of flows in freight transportation and additional time after the suppression of the link Irun-Hendaye....224
Figure 5.8.1.4 Transfer of flows in freight transportation and additional time after the suppression of the link Narbonne-Perpignan....225
Figure 5.8.2 Superposition of main transport corridors for the transit through France in Europe 15 and Europe 27....227
Figure 5.8.3 Main transport corridors for transit through Europe 27....229
Figure 7.1.1 Diagram of the comparative study on infrastructures endowment....231
Figure 7.1.2 Diagram of use level and density of infrastructures in Nuts 3 regions. Colours refer to urban-rural profile....232
Figure 7.1.3 Diagram of use level and density of road and motorway network in Nuts 3 regions....233
Figure 7.1.4 Diagram of use level and density of motorway and high speed network in Nuts 3 regions....233
Figure 7.1.5 Diagram of use level and density of high speed trains, upgraded and main lines network in Nuts 3 regions....234
Figure 7.1.6 Map of use level and density of infrastructures in Nuts 3 regions....235
Figure 7.1.7 Maps of use level and density of road, main roads and high speed trains in Nuts 3 regions....238
Figure 7.1.8 Diagram of use level and density of infrastructures in Nuts 3 regions. Colours refer to location in Europe....240
Figure 7.2.1. Accessibility and GDP per capita in NUTS-3 regions....242
Figure .7.2.2. Accessibility and GDP per capita in NUTS-3 regions....244

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Annex: Data request to Eurostat and/or other data providers

Currently, basic data (transport networks, administrative boundaries, population and GDP, basic traffics in main terminals) are already available and, based on it, strategic indicators can be calculated and mapped.

In order to advance and improve the quality of the analysis, a number of new data collections are being made in ESPON 1.2.1 (e.g travel schedules from Internet inteligent searching processes).

The following information, in hands of EUROSTAT or other institutions (to be explored), will complement ongoing works of ESPON 1.2.1 in data assembling:

1. CDRom on Transport Statistics from EUROSTAT
    - Everything on transport statistics
    - Transport by Air: National and international intra- and extra EU Data 1993-2000
    - Transport by Sea: National and international intra- and extra EU Data 1997-2000
2. Traffics between airports from IATA
3. Traffics in ports by categories from ESPON and/or other organisations
4. Traffic in roads from United Nations survey
5. Traffic and rail characteristics from UCI
6. Logistic terminals: localization and traffics
7. Origin-Destination trip matrices by purpose between NUTS2 or NUTS3, freight and passengers
8. Population trends in Europe

   Already delivered:

    - Active population 1995-2001 NUTS2 and NUTS3
    - Average population 1999 by sex NUTS3
    - Population 2000 by sex and age groups NUTS2

9. Evolutions of basic socioeconomic data at NUTS3

   Already delivered:

   - GDP 1995-2000 NUTS2 and NUTS3
   - Persons employed by Sectors and Sex 1995 2000 NUTS2
   - Unemployment by Sex and Age NUTS2 and NUTS3

10. National investments on the trans-European Networks
11. Environmental basic statistics
12. High-resolution DTM of EUROSTAT for vulnerability analysis
13. CORINE land cover for Europe
14. Air photos for recent flooding in Europe

Table of contents

Summary 2

PART ONE 4

Introduction 4

1 Summary of main findings 5
- 1.1 Review of existing indicators 5
- 1.2 Indicators of transport services and networks 8
  - 1.2.1 Transport endowment indicators 8
  - 1.2.2 Network morphology 8
  - 1.2.3 Travel times and costs 11
  - 1.2.4 Daily and potential accessibility 12
  - 1.2.5 Traffic volumes and flows 14
  - 1.2.6 Transport externalities 14
  - 1.2.7 Network vulnerability 15
- 1.3 Typologies 16

2 Application of the ESPON Common Platform 18

3 Integration of comments to Second Interim Report 21
- 3.1 Co-operation with other ESPON projects 21
- 3.2 Indicators and data 21
- 3.3 Typologies of regions 22
- 3.4 Policy recommendations 22

4 Networking with other TPG 23
- 4.1 ESPON Project 1.1.1 The Role, Specific Situation and Potentials of Urban Areas as Nodes in a Polycentric Development 23
- 4.2 ESPON project 2.1.1 Territorial Impact of EU Transport and TEN Policies 24
- 4.3 ESPON project 3.1 Integrated Tools for European Spatial Development 24

PART TWO 25

1 Introduction 25

2 The concept of ESPON 121 25

3 Policy scope: key Issues 27
- 3.1 The general policy context 27
- 3.2 Major transport policy objectives 34
  - 3.2.1 Liberalisation and harmonisation: the market regulation 35
  - 3.2.2 To shift the balance between modes 36

3.2.3 The implementation of TEN network 39
3.3 The spatial approach of transport 41
3.3.1 European spatial development perspectives and the polycentric development 41
3.3.2 Structural funds policies 42
3.3.3 The accessibility concept in spatial development 43
3.4 To bridge transport and spatial policies 44
3.4.1 Opportunities of transport policies 45
3.4.2 A new role of regions and local institutions in transport organisation 45
3.4.3. A multilevel governance 46

4 State of the art on transport indicators 48
4.1 Supply of transport infrastructure and services 48
4.1.1 Indicators of transport infrastructure supply 48
4.1.2 Indicators of transport infrastructure capacity 48
4.1.3 Indicators of transport services 49
4.1.4 Indicators of network vulnerability 49
4.2 Use of transport networks and services 50
4.2.1 Traffic volume indicators 50
4.2.2 Traffic flow indicators 50
4.3 Accessibility indicators 50
4.3.1 Accessibility concepts 51
4.3.2 New regional accessibility models 53
4.3.3 Accessibility models for Europe 55
4.4 Travel times and costs 59
4.4.1 ICON: Connectivity to transport terminals 59
4.5 Map-based indicators 67
4.6 Conclusions on existing indicators 67

5 Implemented indicators and maps 69
5.1 Transport infrastructure endowment 69
5.1.1 Density of motorways and expressways by population 69
5.1.2 Density of rail lines by population 71
5.1.2 Density of rail lines by population 72
5.1.3 Commercial seaports infrastructure 74
5.1.4 Commercial airports infrastructure 76
5.2 Network morphology 78
5.2.1 The degree of vertices 79
5.2.2 The morphology of networks 82
5.2.3 Evolution of the motorway network 85
5.2.4 Railway network 87
5.2.5 Inland waterways 89
5.2.6 Cartograms and network morphology 91
5.2.7 The algorithm of square pattern 99
5.2.8 The algorithm of expansion or Minkovsky's algorithm 101
5.2.9 The « radial analysis » 117
5.2.10 Summary of morphology indicators 124
5.2.11 European transport corridors in relief 125

5.3 Travel times and costs 127
5.3.1 Connectivity to transport terminals 127
5.3.2 Cost to motorway entrances 130
5.3.3 Connectivity to rail stations 132
5.3.4 Connectivity to commercial seaports 134
5.3.5 Cost to commercial seaports by truck 136
5.3.6 Connectivity to commercial airports 139
5.3.7 Time for freight road transport 141
5.3.8 Cost for freight road transport 144
5.3.9 The rail operating techniques 146
5.3.10 Short sea shipping operations 148
5.4 Daily accessibility 149
5.4.1 Daily population accessible by car 149
5.4.2 Daily market accessible by car 151
5.4.3 'City network' air relations for MEGAs 153
5.4.4 'City network' daily accessibility 155
5.4.5 'City network' daily accessibility for MEGAs 158
5.4.6 'City network' daily accessibility for modified MEGAs list 160
5.5 Potential accessibility 163
5.5.1 Potential accessibility by road 163
5.5.2 Potential accessibility by rail 167
5.5.3 Potential accessibility by air 169
5.5.4 Multimodal potential accessibility 171
5.6 Traffic volumes and flows 174
5.6.1 Trips generated / Purpose: business 174
5.6.2 Trips generated / Purpose: leisure 177
5.6.3 Trips generated / Purpose: visits 180
5.6.4 Trips attracted / Purpose: business 182
5.6.5 Trips attracted / Purpose: leisure 185
5.6.6 Trips attracted / Purpose: visits 188
5.6.7 km per person in trips generated by car / Purpose: business 190
5.6.8 km per person in generated by car / Purpose: leisure and visits 193
5.6.9 Traffic on road links / Purpose: business 195
5.6.10 Freight transport quantities 197
5.6.11 Freight road assignment : volumes 201
5.6.12 Freight road assignment : Number of lorries 204
5.6.13 Freight rail assignment : volumes 207
5.6.14 Freight rail assignment : Number of freight trains 211
5.7 Transport externalities 215
5.7.1 Road traffic deaths 215
5.7.2 Emission of greenhouse gases 217
5.7.3 Emission of air pollutants 218
5.7.4 Fragmentation 219
5.8 Network vulnerability 220
5.8.1 Analysis of the vulnerability : 220
5.8.2 The new corridors of enlargement 226

5.8.3 The new corridors between Maghreb and Eastern countries 228

7 Typologies **230**

7.1 Typology based on endowment 230

7.2 Accessibility and GDP 240

8 Conclusions **245**

8.1 Main findings 245

8.2 Policy recommendations 249

Table of figures **254**

References **257**

References **257**

Annex: Data request to Eurostat and/or other data providers **263**

Table of contents **265**