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

ESPON Project 1.2.1

Second interim report

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Summary

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

1.4 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.

1.5 Indicators of transport services and networks

1.5.1 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).

1.5.2 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.

1.5.3 Service provision, 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.

1.5.4 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.

1.5.5 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.

1.5.6 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.

1.5.7 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 ⊂ 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.

The software reproduces or simulates effects of the floods on the road and railway infrastructures. The software was used to model the risings of the Loire whose most notable consequences would be strong disturbances with regard to:

- the accessibility to the most important cities
- North-South traffic passing in transit through this area
- accessibility to strategic infrastructures (nuclear thermal power station, stations of purifications...) and public (hospital, schools...)

Methodology: the results of this simulation are provided in the form of a map: accessibility by the minimal ways translated into times of distance between, before and after the removal of the bridges, a map of the minimal ways before and after removal of the bridges, a zoom on the area.

For ESPON Project 121, the use of the hydraulic model will be replaced in a first evaluation by CORIN LAND COVER and the air photographs of the floods of the summer 2002. The logic of the model being the same one from these data, the level of floods could then be modified

Data requirements: the problem lays in the sufficiently precise data layout: a digital model with a decimetrical precision.

1.6: New Map Types

The creation and the improvements of the fast transport systems have for effect to modify the time-space. The question of the representation of this complex interaction is of major interest for a better understanding of the spatial effect of the transport networks.

1.6.1 Time-Space Maps

Time-space maps represent the elements of a map in a configuration based on the travel times between them. For ESPON 1.2.1, in which the effects of trans-European transport policies are to be investigated, time-space maps are of interest because they show the European continent is moving closer together. The elements of a time-space map are organised in such a way that the distances between them are not proportional to their physical distance as in topographical maps, but proportional to the travel times between them. Short travel times between two points result in their presentation close together on the map; points separated by long travel times appear distant on the map. The scale of the map is no longer in spatial but in temporal units. The change of map scale results in distortions of the map compared to physical maps if the travel speed is different in different parts of the network. If one assumes equal speed for all parts of the network, the result is the familiar physical map.

To construct a time-space map requires two sets of data, usually maintained in a geographical information system (GIS): *network data* and *map data*.

- *Network data* consist of a set of calibration nodes with their geographical coordinates and the travel times between them over the calibration network. The travel time data can be current travel times or assumed future travel times if the effect of network improvements on the time space are to be investigated.

- Map data consist of GIS data (points, lines or polygons) of other map elements besides the calibration network, such as locations of cities, coast lines or regions, i.e. all map features that are to be visible on the time-space map.

Time-space maps can be used to visualise the ‘shrinking’ of space through transport system improvements. However, they show travel time reductions only for the most accessible nodes of the networks. What they do not show, or even hide, are the much smaller travel time reductions in the areas *between* the nodes.

1.6.2 Crumpled time space maps

Time-space as it is produced by the inscription of transport networks in the territory, is strongly distorted by the high speed terrestrial networks, motorways and high speed trains. When new high speed infrastructures opens, some places are coming closer together whilst some parts of the territory –some of them located in the very neighbourhood of the high speed networks– are not touched by the accessibility improvements. The time space modified by transport networks is deformed by two distinct movements: a global contraction, and a more local distortion due to the articulation or interconnection between high speed transport and usual networks and space. If anamorphosis maps illustrates this global contraction, it sometimes fails on expressing the second distortion due to the confrontation of high speed and lower speeds.

Crumpled time-space maps aims at representing the complex movement of contraction due to the transport systems including high speed and lower speed networks irrigating space. This type of representation must be seen in complement to the anamorphosis map, each map expressing a different view on the same object.

On the time-space relief map the length of each link is proportional to the time of the journey according to the speed allowed by the transport mode, and several transport modes are represented. The speed differential between modes is represented in the third dimension. The model supporting the representation uses averaged speeds for each distinct network: high speed trains, motorways, and roads.

The fastest links takes the form of direct segments drawn in the plane of the cities, whilst slower links are drawn under the form of two segments in the third dimension, under the plane of cities. By means of a time-space scale, the distances in the network can be read.

The data necessary to produce the crumpled time space map resides in the graph representing the transport network. The length in kilometres of each arc representing a link of the network corresponds to its length in kilometres. Average speeds for each network are considered. From these data –lengths in kilometres and speeds– lengths in time-space are determined.

The given example is a crumpled time space map of Europe with 425 nodes and three transport networks, high speed trains, motorways, and roads at the year 1999. The emerging high-speed rail network is the cause of the global contraction of time space, but the gaps between sub networks are patent. If the crumpling is more pronounced in the peripheral parts of the continent, isolated cities –their deficit of accessibility is expressed by their position at the summit of a time-space peak– can also be observed in the core of Europe.

1.6.3 Raster-Based Accessibility Maps/Surfaces

To overcome this problem, Spiekermann and Wegener developed spatially disaggregate accessibility indicators using raster-based GIS techniques (Spiekermann and Wegener, 1994a). In this method a raster structure is used to represent a quasi-continuous activity surface of Europe. For that purpose the European territory is disaggregated into some 70,000 raster cells of 10 kilometres width. By making assumptions about the distribution of population and economic activity around large cities in the regions and about the mean access time form each raster cell to the nearest network node, accessibility indicators can be calculated not only for network nodes but also for each raster cell in Europe.

A raster-based visualisation of accessibility indices requires three sets of data usually maintained in a GIS: *region data*, *city data* and *network data*.

- *Region data*: a file with the boundaries of the regions of the study area and their population and economic activity (GDP),
- *City data*: a file with geographical coordinates of major cities in the study area and their population,
- *Network data*: a file with the geographical coordinates of the nodes of the network investigated and the travel times between them.

Population, economic activity and travel times may be current or may represent assumptions about future developments or scenarios.

The raster-based accessibility indicators so calculated can be visualised in raster-based accessibility maps or three-dimensional accessibility surfaces.

1.6.4 European transport corridors in relief

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.

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

As 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.

The data presented in the example come from simulation of computations minimum path through the European road network. The European corridors appears as wide and deep valleys with high mountains on each side. This relief representation can be associated to 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.

1.6.5 The Potential Road Network Map

These prospective maps are based on the hypothesis that the travel cost lows to long trend. The flows of goods grow in the European corridors. The potential maps show a first prospective of the future European space corridors based on the shorter travel time.

Method/ theoretical background This is the use of sub-matrix of minimum paths matrix or interregional exchanges matrix or all other matrix .

The aim of these maps is to show the potential or real flows by type of trips.

The idea is that the modal transfer is possible for only some types of trips because of the length of distance covered as international transit.

Our purpose is also to make specific maps of varied transits in european or country space.

In fact France is an international transit country. Consequently modal transfers flows are possible.

Methodology: one selects the paths or the flows in a interregional exchange matrix NUTS2 between the peripheral countries. Then one assigns these paths or flows to the road network. It possible to show only the corridors or the transit of goods that go through the country.

One can show with this methodology only the interregional exchanges from all regions of a country to all other countries and inversely. The two maps are complementary.

Data requirements: the necessary datas are the networks and the exchange matrix. Others elements are computed by MAP-NOD model of CESA.Currently, the datas are CESA network for this test, but for the TIR the GISCO datas and NUTS3 are used with the ESPON list of cities!

Demonstration to the ESPON space: We present here four maps of potential paths

- ❖ First example: Map of the minimum paths from French regions to the other regions
- ❖ Second example: Map of the minimum paths from peripheral countries to the others The minimum paths pass through France. This map is identical to the map of foreign lorries traffic in France (1997). This network is very simple two corridor with five junctions.This case is very favourable for modal transfer
- ❖ Third example: The differential Map between Europe 15 and Europe 27The superimposition of shortest paths numbers of EU15 on shortest paths EU 27 is more interesting than the simple differential map because it allows to see the two values and their ratio. The trend is really more East-West than North-South in Europe 27.
- ❖ The fourth example: The transit South-East between Europe. One see very distinctly the great diagonal SW-NE in Europe from Magrheb to Poland. It doubles the first and older Lisbon-Paris-Stockholm. Currently the corridor N-S is the more significant with the weighting of the paths by goods exchanges, but for how long?

1.6.6 Bipolar differential map

The aim is to show Spatial potential competition between two ports with tree diagram of minimum travel time paths. The paths tree shows clearly the corridors from Rotterdam.

Method/ theoretical background: The aim is to show the competition areas, all other things being equal, between the different ports using computing minimum travel times of trips.

Methodology: for computing the minimum paths we use the MAP-NOD model which then affects the network to NUTS2.

Data requirements: the network with the maximum speed by edge according to the countries.

Demonstration to the ESPON space: two maps are showed for example Le Havre and Rotterdam on the one hand and Genes and Marseille on the other hand. It is possible to generalize in order to figure any number of ports on the map. The advantage of Rotterdam is not really spatial but coming from the harbour and its services. Taking into account the gateways complete the network analysis.

This result is an example of Palander's theory in a real space.

1.7 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 km² (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	0,147103737	0,02580145	0,01344841	0,0134
4	AT113	AT	SUEDBURGENLAND	0,13771584	0,009209381	0	
5	AT121	AT	MOSTVIERTEL-EISENWURZEN	0,169684948	0,024635469	0,017368107	0,01736
6	AT122	AT	NIEDEROESTERREICH-SUED	0,13522044	0,023705585	0,00338057	0,0033
7	AT123	AT	SANKT POELTEN	0,179371545	0,047425203	0,012265854	0,01226
8	AT124	AT	WALDVIERTEL	0,159761863	0,002552979	0	
9	AT125	AT	WEINVIERTEL	0,160160033	0	0	
10	AT126	AT	WIENER UMLAND/NORDTEIL	0,16622014	0,013329291	0	
11	AT127	AT	WIENER UMLAND/SUEDTEIL	0,281468792	0,065231343	0,048641791	0,04864
12	AT13	AT	WIEN	0,74880241	0,182301205	0,043893976	0,04389
13	AT211	AT	KLAGENFURT-VILLACH	0,209856087	0,053842287	0,018599803	0,01859
14	AT212	AT	OBERKAERNTEN	0,112450121	0,011969734	0,005094431	0,00509
15	AT213	AT	UNTERKAERNTEN	0,126332839	0,014973325	0	
16	AT221	AT	GRAZ	0,185960912	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	Characterisation 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 First Interim Report

The comments made by the Coordination Unit to our First Interim Report 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 Second Intrerim Report.

All the comments and questions raised have been taken into account in the development of this Second 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).

5 Outlook to Third Interim Report

The outlook to the next interim report of ESPON 1.2.1 is relatively straightforward because this interim report can be seen as a working document towards it. The project work between now and the next report will focus on checking and finalising most parts of the analytical tasks of the project. The third interim report is expected to contain preliminary findings of the project on transport services and networks.

It is planned to document in the next report the following achievements:

- The indicators of transport services and networks which are partly described and demonstrated in Part II Chapter 5 of this report will be further developed. By then, for each indicator a short section will describe the rationale and theoretical background, the methodology and the data requirements. All indicators will be demonstrated for the ESPON space.
- The new map types which are partly described and demonstrated already in Part II Chapter 6 of this report will be further developed. The new map types will be described in terms of theoretical background, methodology, data requirements and will be demonstrated for the ESPON space.
- Territorial typologies will be further developed and demonstrated than it was possible in this report.
- All other chapters of this report will be updated based on new knowledge and insights and based on comments received.

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 3.1.2 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 Review of existing 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	$\begin{array}{l} 1 \text{ if } c_{ij} \leq c_{\max} \\ 0 \text{ if } c_{ij} > c_{\max} \end{array}$
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 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).

4.5 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 Indicators of transport services and networks

5.1 Transport infrastructure endowment

This section contains two groups of the most typical and used infrastructure endowment indicators based on the theoretical concepts explained in Section 4.1. It starts with density of transport infrastructure, followed by the connectivity to transport terminals.

5.1.1 Density of motorways and expressways

Rationale

Until now, in European studies accessibility indicators have been focused mostly on transport infrastructure measurements. The indicators most frequently used are "density of infrastructure" (km of motorways or motorways per surface or number of inhabitants). These indicators are able to capture the capacity of the infrastructure, 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.

These kinds of measures are the simplest and more widely used in regional economics as indicator of the stock of social capital allocated to transport. Most regional analysis based on Regional Productivity functions integrates these types of measures.

Method

The methodology to determine these indicators consist first on calculating the length of transport networks in each territorial division (NUTS2, NUTS3, etc.). A GIS tool with NIS ((Bridges/NIS) has been used to calculate this. It has been done considering the different types of links in each transport network.

Once the length of each transport network is calculated the function to determine the density is as follows:

$$D_{ij} = \left(\sum_{k} L_{kji} \right) / S_i$$

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 S_i is the area of territorial division *i*.

Data requirements

The basic data needed to calculate this type of indicators is a transport multimodal network at European level, precise enough in terms of intermodal connections and location of transport terminals, with information concerning infrastructural characteristics.

The transport network used is from ASSEMBLING multimodal graphs. 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). The transport network used contains 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 (See table 1 and 2). The rail and road network database contains information on speed and TEN and TINA programmes.

Rail Links

			Number
Links	Rail	Main Conventional	6268
		High speed	2220
		Secondary	9821
		Local rail	77
		HST connections	2
		Project	13

Table 5.1.1.1 Number of elements in rail network of ASSEMBLING graph.

Road Links

Links	Road	Motorway	8680
		Express	6514
		Main	50339
		Regional	22371
		Local	1
		Streets	11839
		Road Con Ports	875
		Connec aer	766

Table 5.1.1.2 Number of elements in road network of ASSEMBLING graph.

The regional data consists of area (in km2) of NUTS3, taken from Eurostat.

Demonstration example

The density of motorways and expressways (speed >= 85 km/h) has been calculated for all NUTS 3 regions of the ESPON space (see Figure 5.1.1). As showed in the map Nuts3 with high motorway density coincides with Nuts3 with big urban areas.

It has to be noted that the map is a draft version to be cross-validated and redesigned according to ESPON layout.

Motorways and expressways density, 2001

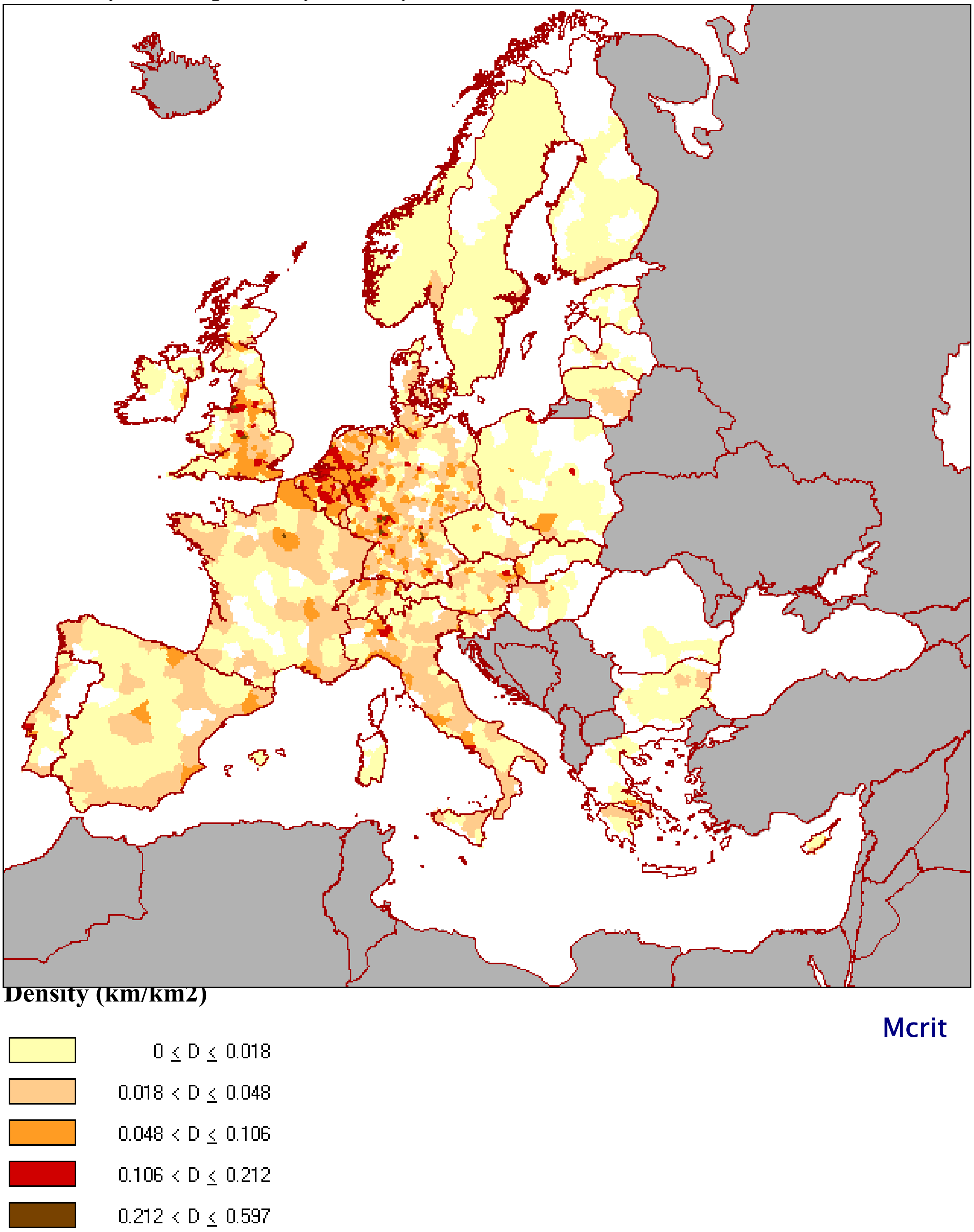


Figure 5.1.1 Motorway and expressway density, 2001

5.1.2 Density of high-speed and upgraded rail lines

Rationale

Density of high-speed and upgraded rail lines follows the same concept as motorway and expressways density, as described in the previous section.

Method

The same method as described in the previous section has been applied here, only considering high-speed and upgraded rail links in the graph.

Data requirements

The data requirements are the same to the previous requirements.

Demonstration example

The density of high-speed and upgraded rail lines in 2001 has been calculated for all NUTS 3 regions of the ESPON space (see Figure 5.1.2). Regions coloured have high-speed rail lines through it. The map represents high-speed rail density but not high-speed rail endowment (in terms of regions with high-speed rail stations).

It has to be noted that the map is a draft version to be cross-validated and redesigned according to ESPON layout.

High-speed and upgraded rail lines density, 2001

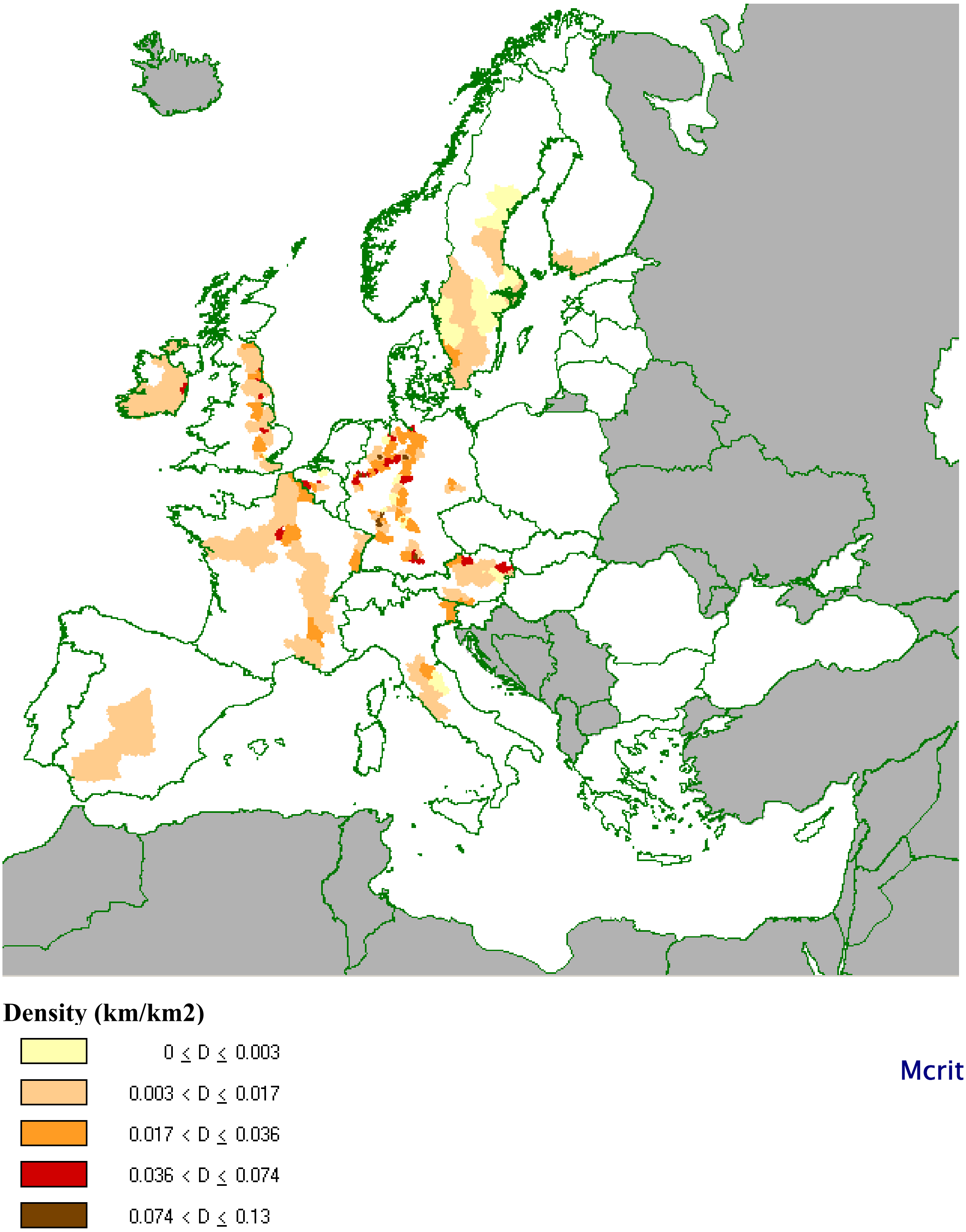


Figure 5.1.2 High-speed and upgraded rail lines density, 2001

5.2 Network morphology

The most powerful tool for network analysis is the Graph theory. This mathematic tool comprises a series of indicators used to characterize transport networks as centrality, gap, accessibility, "circuity", etc (Chapelon).

But the graph Theory treats very little the problem of representation and its characteristics. Although marked from the beginning by geographic considerations –the "bridges of Koenigsberg" problem treated by Leonard Euler– and cartographic considerations –the four colours problem– the graph theory slowly lost interest in representation focusing instead on powerful algorithms of operational research as computation of shorter paths of Dantzig, Ford, Floyd etc. and maximum flows of Ford and Fulkerson….

The problem of graph representation became recently again a field interest and research (Kaufmann 2001). Conditions of realisations of repetitive and verifiable graphs begin to be defined (Mathis 2003). 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.

5.2.1 The degree of vertices

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

If the graph is homogenous, all the vertices have the same degree and for a planar graph this number is six. The European map of Walter Christaller shows a relatively regular network with very regular faces mainly triangular and almost planar. The transport network of Christaller is a graph with triangular planar

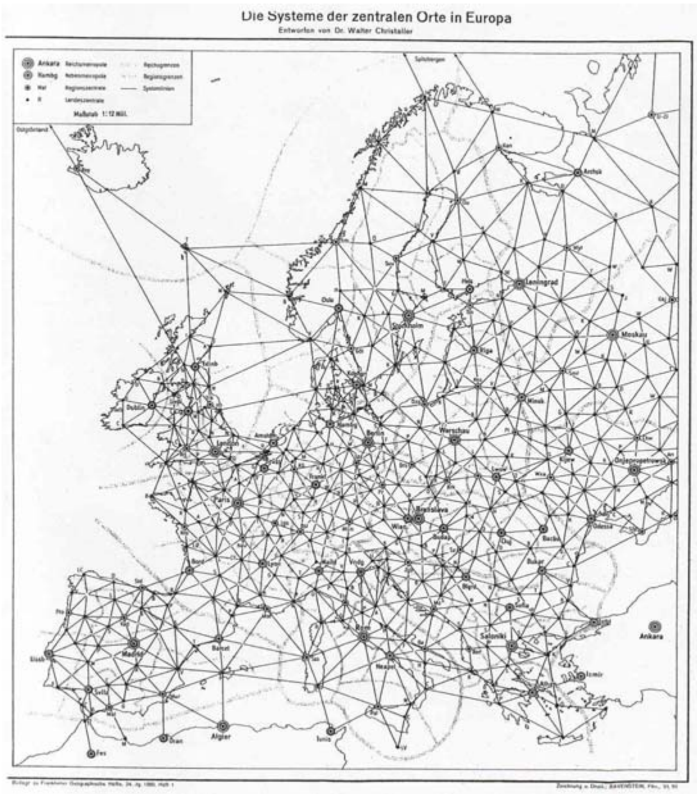


Figure 5.2.1.1: Christaller's Europe map

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

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

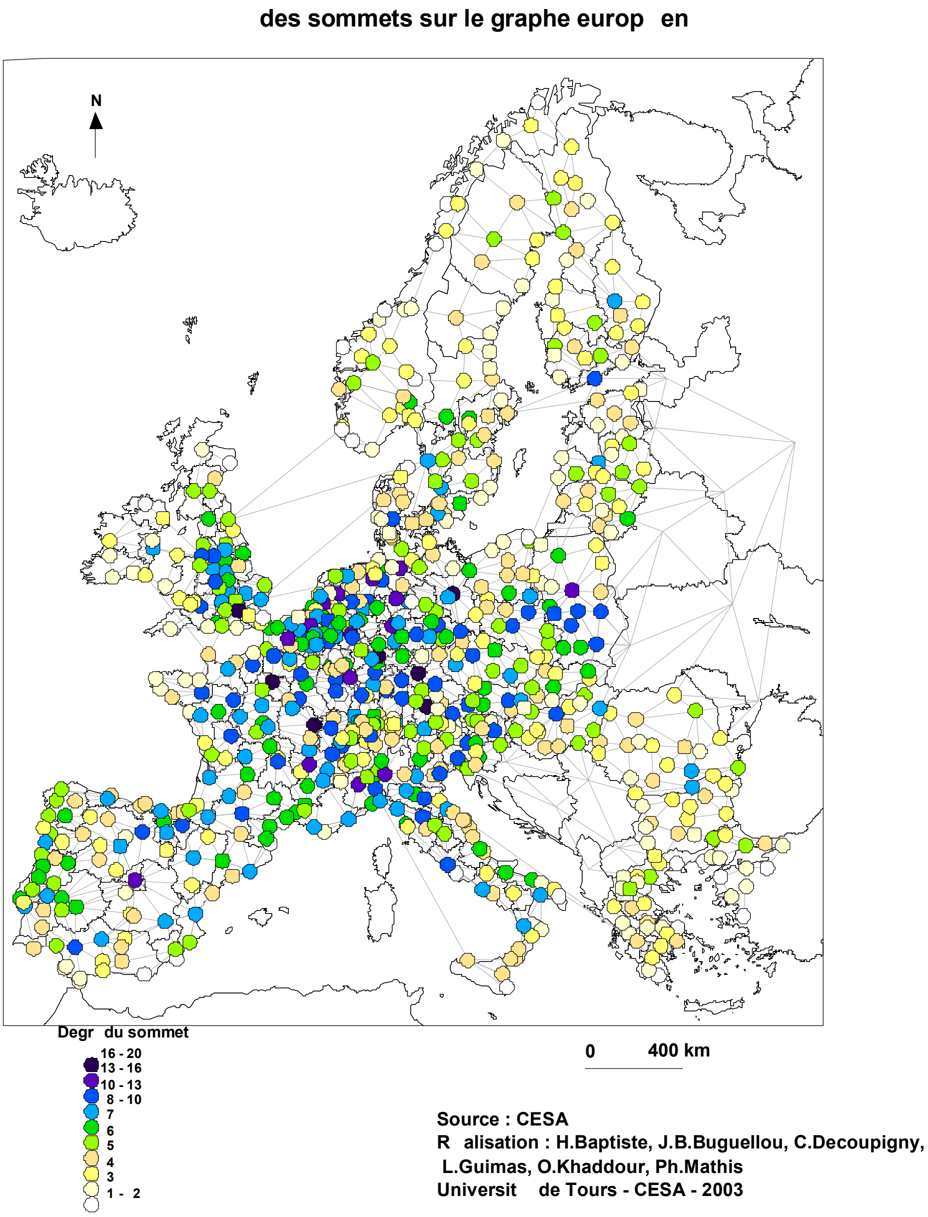


Figure 5.2.1.2: degree of vertices of the European transport network

5.2.2 The morphology of networks

Networks and cities are very bound in their development. Many studies show it (Baptiste 1999).

The « Rank Size Rule » of George Kingsley Zipf generalised by Benoit B. Mandelbrot (Mandelbrot 1977) applies also to the size of cities as Zipf quoted by Brian J.L. Berry (Berry 1964) shows it. He observes that the product of the city rank with its size (population) is constant :

$$Pr = P1/r^{**}q$$

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

André Dauphiné (Dauphiné 1995) 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. Two countries have a lower dimension: France and Netherlands whose networks have lower complexity.

The fractal analysis of cities and networks where developed by Pierre Frankhauser (Frankhauser 1994) and Cyrille Genre-Grandpierre (Genre-Grandpierre 2000).

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.

The density *"is valuable in theory only if the elements that it aims to describe are spread out homogeneously in the window of analyse that is used in the computation: this constitutes the presupposition of homogeneousness which is usual for Euclidean measures"* (Genre-Grandpierre 2000).

In others terms, each time there is hierarchical organisation and discontinuity, the density is not in theory a good indicator whilst 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 any networks there are zones of concentration and simultaneously empty spaces. The density is only in that case an approximation that hides this spatial distribution of networks

Moreover, 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.

5.2.3 The 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 relation

$$N(\varepsilon)=\varepsilon^{-Dq}$$

Give the fractal dimension Dq of square pattern which varies between 1 and 2 according to the homogeneity of the structure distribution.

A variant of this analysis is used for the segmentation and consist of computing the fractal dimension in a window and to assign this value to the centre of the window and move this window and so on. It allows to show .

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

5.2.4 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 of 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.

At each expansion, the nearest circles or squares intersect again, the aggregates forming the best served zones. The number N(ε) of necessary (?) size r = ε or a = 2ε to cover the structure, is so equal to the total surface of expanded structure divided by the surface of element: $4\varepsilon^2$ or $\pi\varepsilon^2$ if it is a square or a disc.

The relation :

$$N(\varepsilon) = cte.\ \varepsilon^{-D}$$

between the number of necessary element to cover the structure and their size is the value of Minkovsky's dimension of expansion.

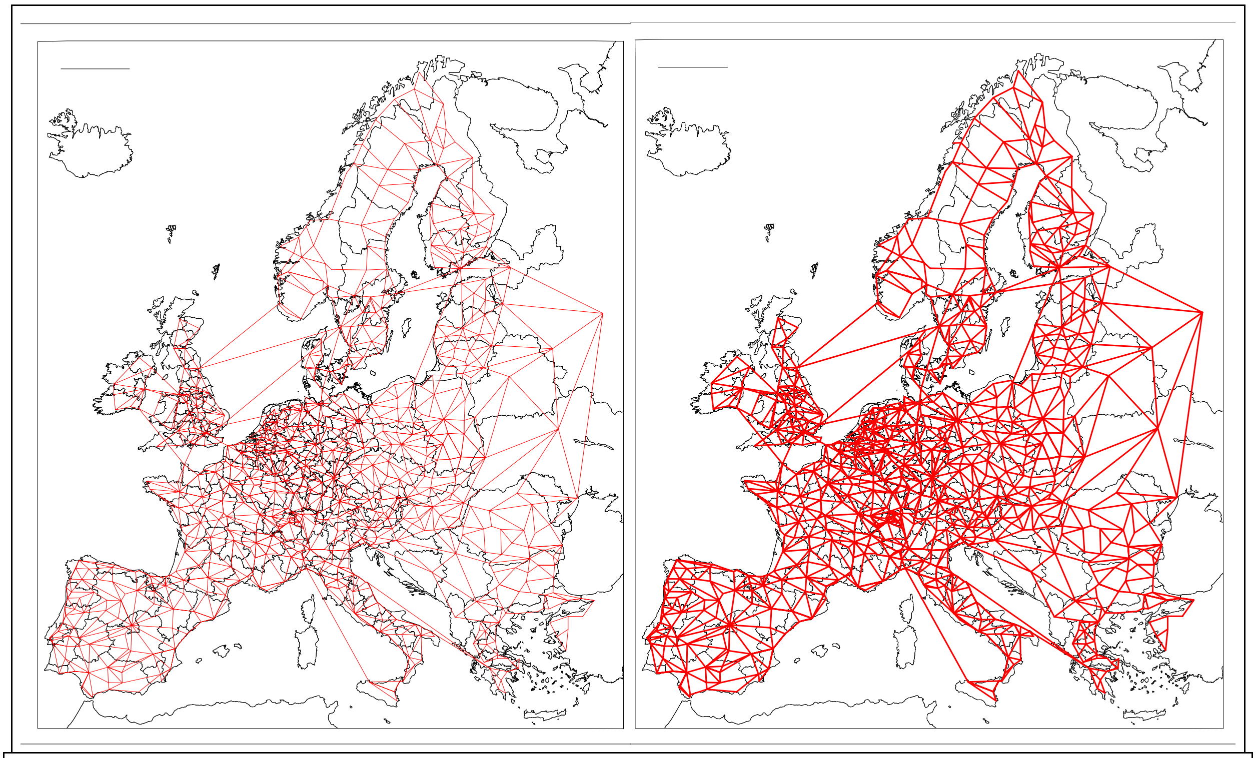
The expansion can also be interpreted as the surface to serve from a network with a continuous speed.

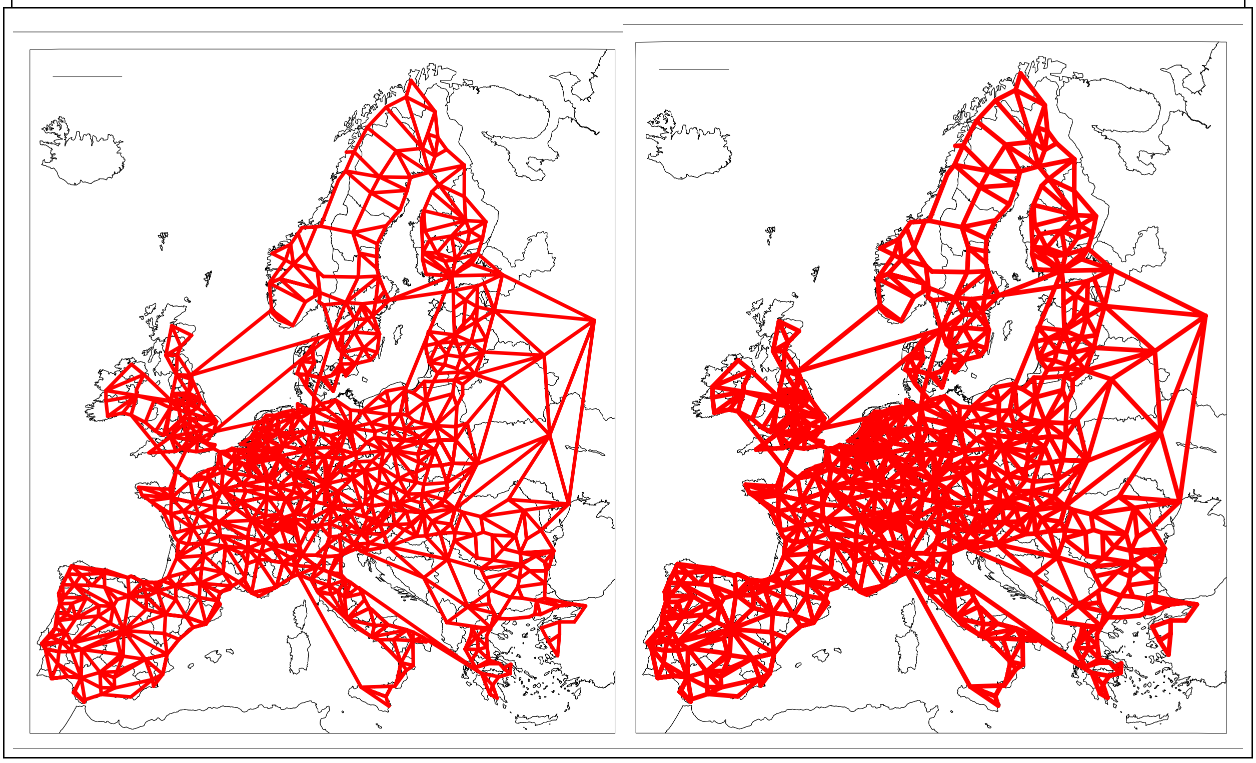
This is true for a network as national roads type but not from motorway or railway type.

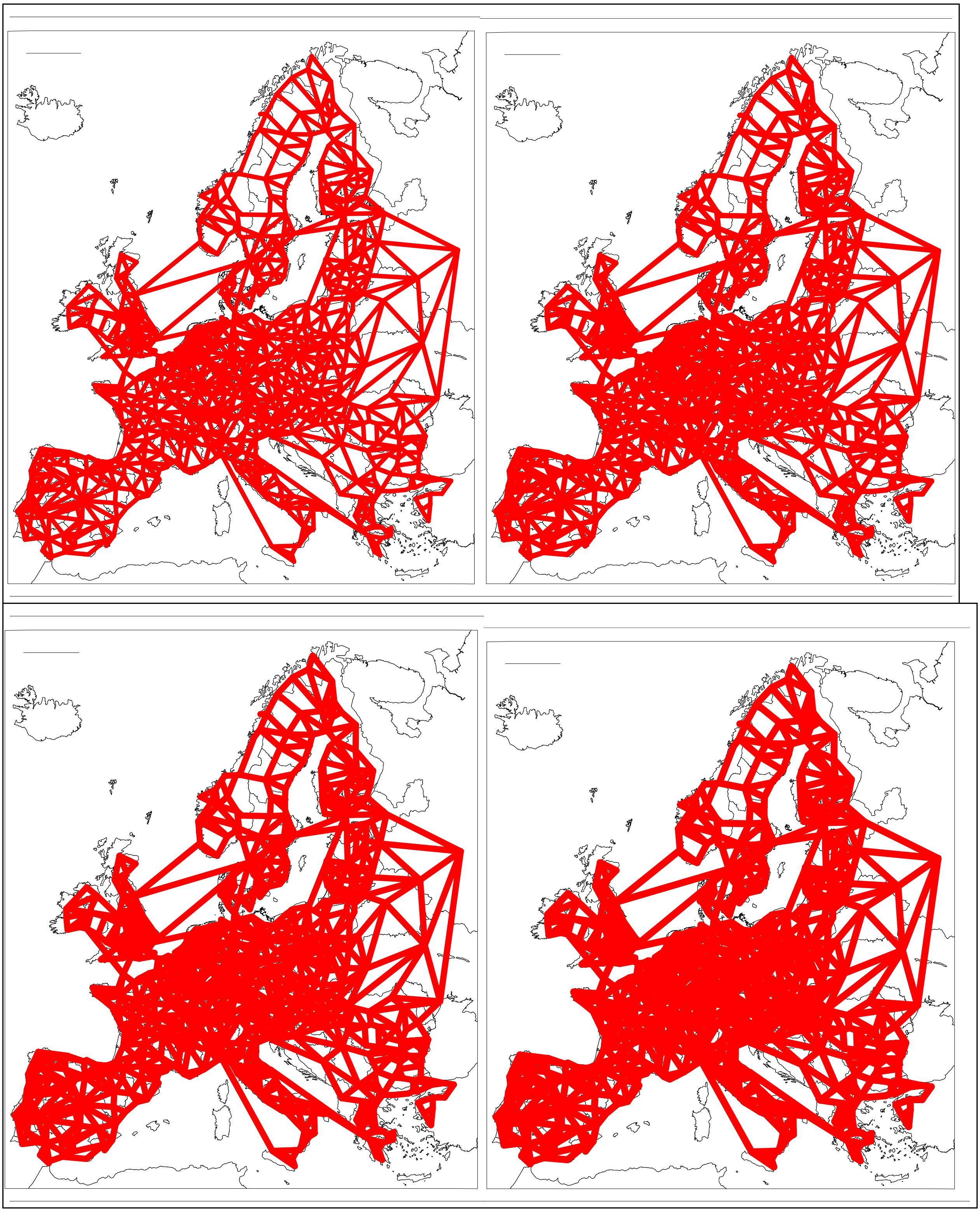
In this case it is a good indicator of servicing surfaces all things being equal otherwise.

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 on the networks: it is purely geometrical.







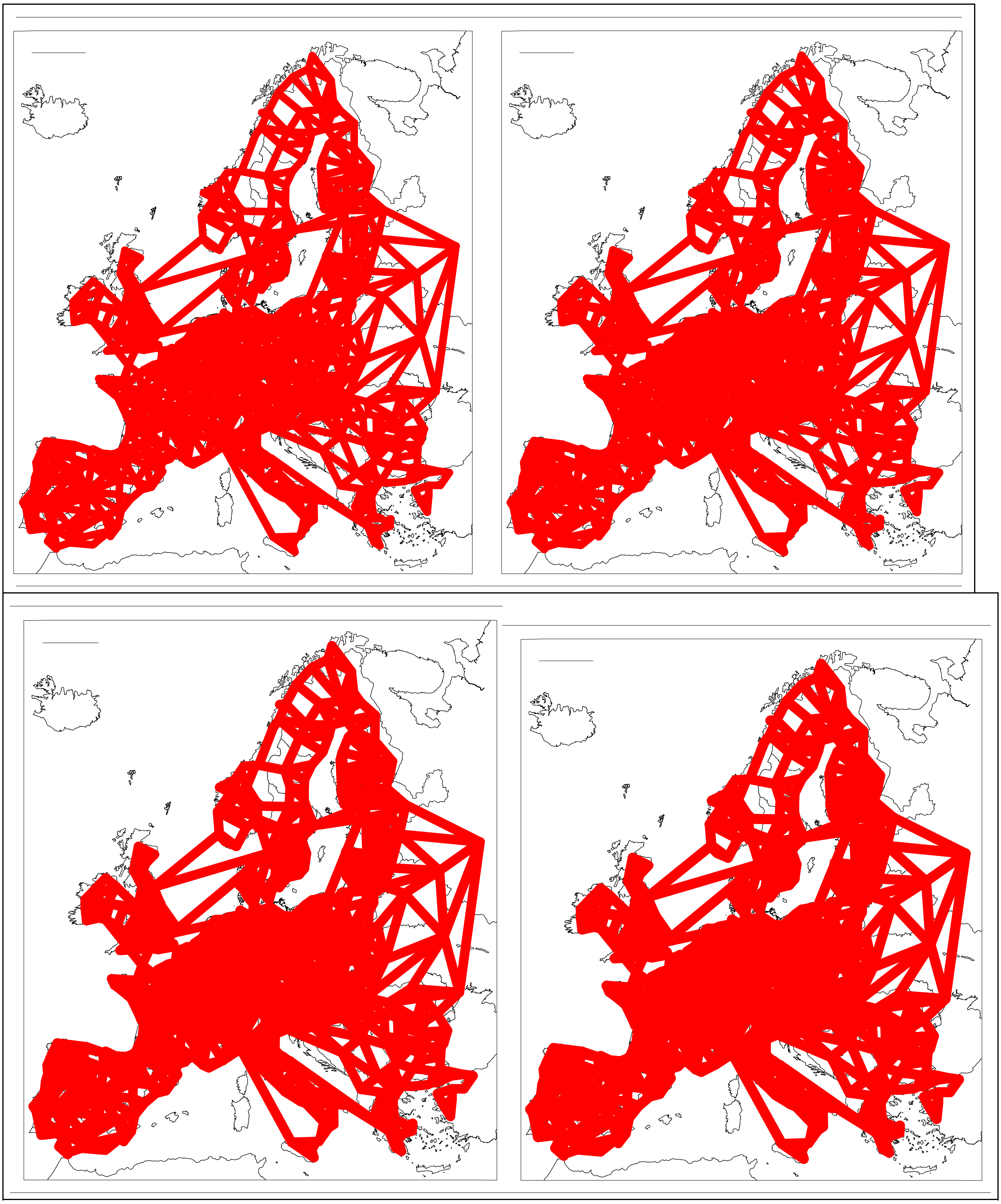


Figure 5.2.4: expansion of the European transport network

5.2.5 The « radial analysis »

The last analysis is qualified of radial 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 contained in a circle with a variable radius. For example with the graph of Von Koch the length of the fractal in a circle of radius R is four times the one that is contained in a circle of radius R/3.

The « radial analysis » is adapted to the measure of possibly decrease of the network density with the distance to 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: the xpansion is the number of cells C(l) that may be reached from a point with a maximum distance with

$de = \log C(l)/\log(l)$

de: dimension of extension if the relation is hyperbolic and so the graph log/log is linear.

It is then possible to consider, as the previously, a surface reachable from every side of a 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 (Chapelon 1998) has computed it.

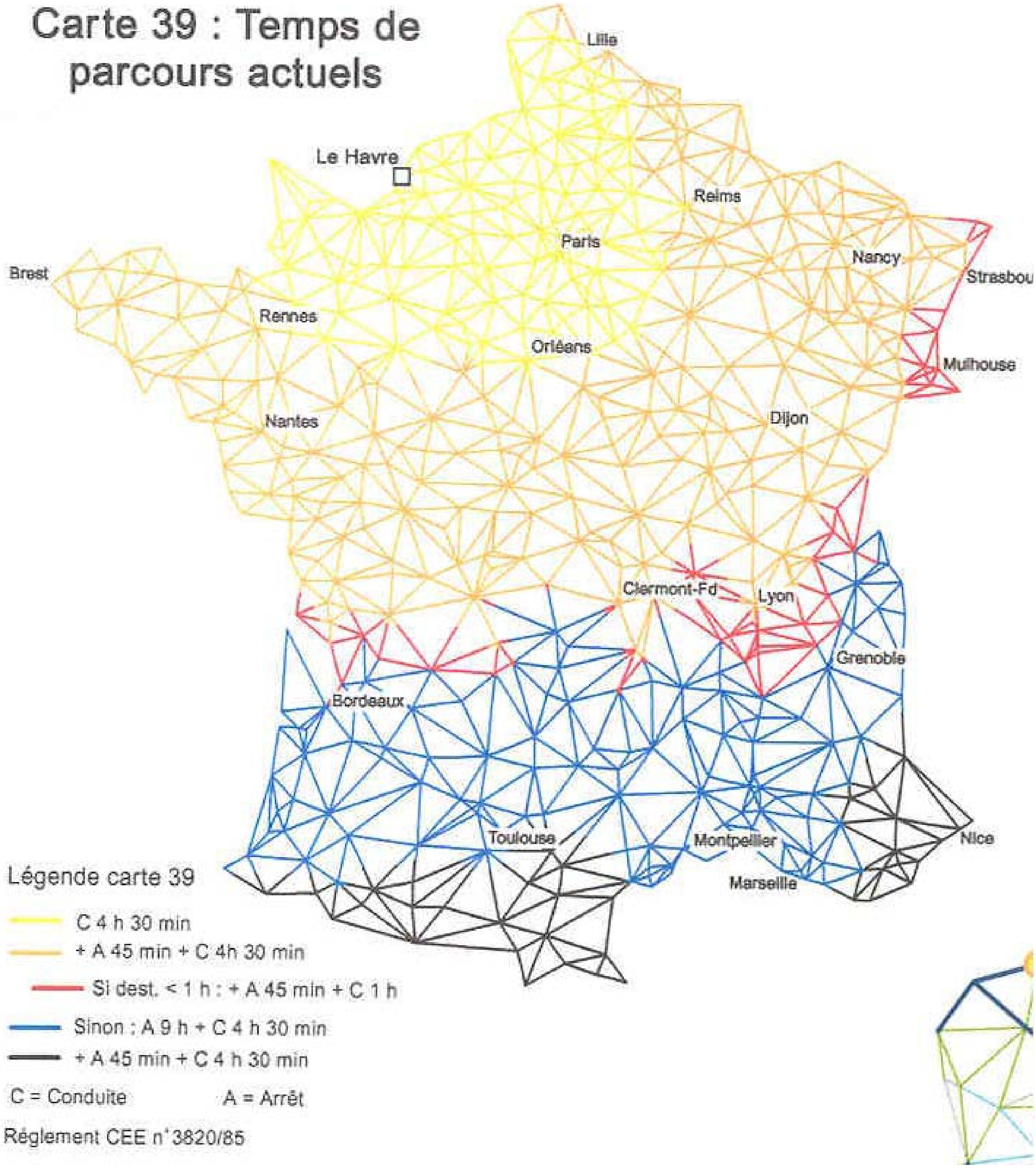


Figure 5.2.5.1: example of radial analysis from the port of Le Havre

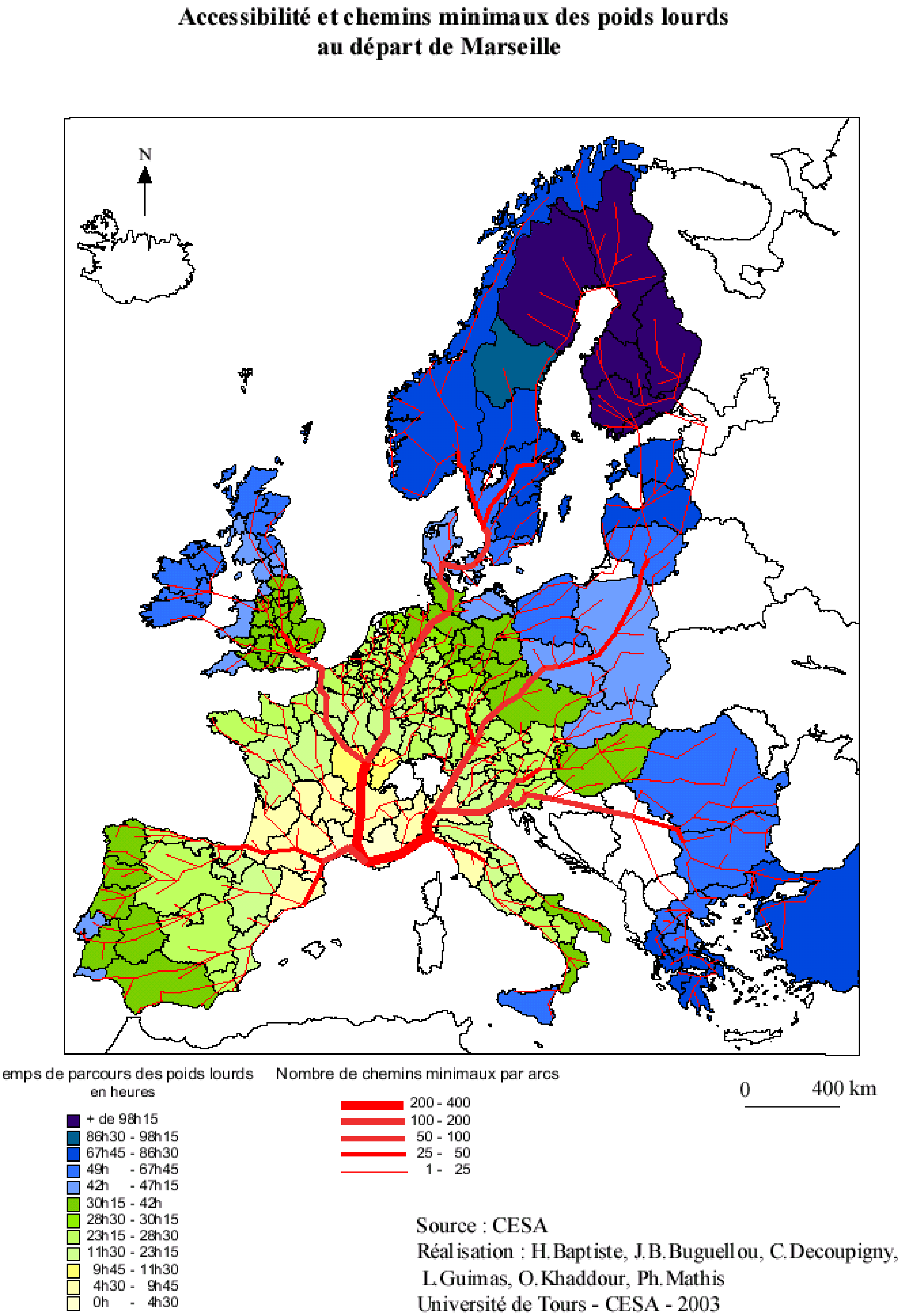


Figure 5.2.5.2: radial analysis from the port of Marseille

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

5.2.6 Summary of morphology indicators

The three indicators can be sorted in a hierarchical organization:

4. 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
5. The algorithm of expansion or Minkovsky's algorithm describes the hierarchical and discontinuous occupation of the space and the empty organization
6. 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. One concurs others indicators(M. Wegener, Cl Grasland). But the basic difference is that one do not presuppose the continuity even obtained with a mean, a density or a smoothing ("lissage") but on the contrary a discontinuity of the occupation area. That apply perfectly at the human localisation.

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 easier and localisable and so verifiable. Moreover, space will be totally covered.

5.3 Travel times and costs

5.3.1 Connectivity to transport terminals

Rationale

The indicator is focused on identifying and providing significant insights into key spatial questions. The results of the indicator highlight the spatial development implications of changes in transport endowment. It aims to produce results that are easily understandable by decision-makers without special transport and territorial knowledge. Because of the symbolic (or "iconic") approach of the indicator, that "flashes" the issues at stake, it has been called ICON (Indicator of Connectivity).
From a theoretical point of view, the indicator definition updates some of the basic hypotheses of conventional models, such as the concept of proximity. According to the present perception of transport systems, proximity is less a question of physical distance than a question of adequate connections to the main communication networks. ICON definition is based on this new notion of proximity and the process of formulating ICON has required, therefore, to explore the evolution of transport and spatial development and also present the decision-making processes in these fields.

Method

The ICON indicator 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...). 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.

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

The value of ICONi in a given place, is based on the minimum access time (tami) to reach by road, from the place, the closest transportation node of the selected network (i). To take into account that not all transportation nodes provide the same utility to the users connected to them, an additional time (twi) -that can be assimilated to a generalized waiting time- is added to the minimum access time (tami).

$$iCON_i = tam_i + tw_i + tg_i$$

If the closest transport node provides the required level of service (or utility) and connection, then ICONi=tami. (tami) -minimum time to access the closest node in the network (i)- and (taxi) -minimum time to access the closest node in the network (i) that provides the service level required (twi = 0).

(Sji) is the level of services of all nodes (j=1...N) included in the network (i).

(Soi) and (Sxi) are the minimum and maximum service levels adopted for the network (i). All nodes included in the network (i) -having service (Sji)- must verify:

$$Sx_i \geq Sj_i \geq So_i \quad j = 1...N$$

$$if \quad tam_i = tax_i \ and \ Sj_i \geq Sx_i, \quad then \quad tw_i = 0$$

$$if \quad tam_i \geq tax_i \ then$$
$$tw_i = \delta_i \ (tax_i - tam_i)$$

verifying:

$$1 \geq \delta_i \geq 0; \quad 0 \leq tw_i \leq tax_i - tam_i \ ; \quad tam_i + tw_i \leq tax_i$$

To evaluate δ , which is an aggregated measure of the utility provided for all alternative connection nodes the following expression is adopted. It can take a conventional logistic formulation in order to reduce the importance of most extreme value

$$\delta_i = \frac{1}{1 + a\, e^{-b \frac{U_i^x - U_i^T}{U_i^x - U_i^o}}}$$

where (a) and (b) are positive arbitrary parameters, and (Ux), (Uo) and (UT) are the utilities provided for all connection nodes.

Data requirements

The basic data needed to calculate this type of indicators is a transport multimodal network at European level. The transport network used is from ASSEMBLING road graph (explained in 5.1.1). with all rail stations, sea and inland ports, motorway entrances, airports 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 its service (maximum speed of the links that…) and rail stations database contains the number of trains per day. Therefore:

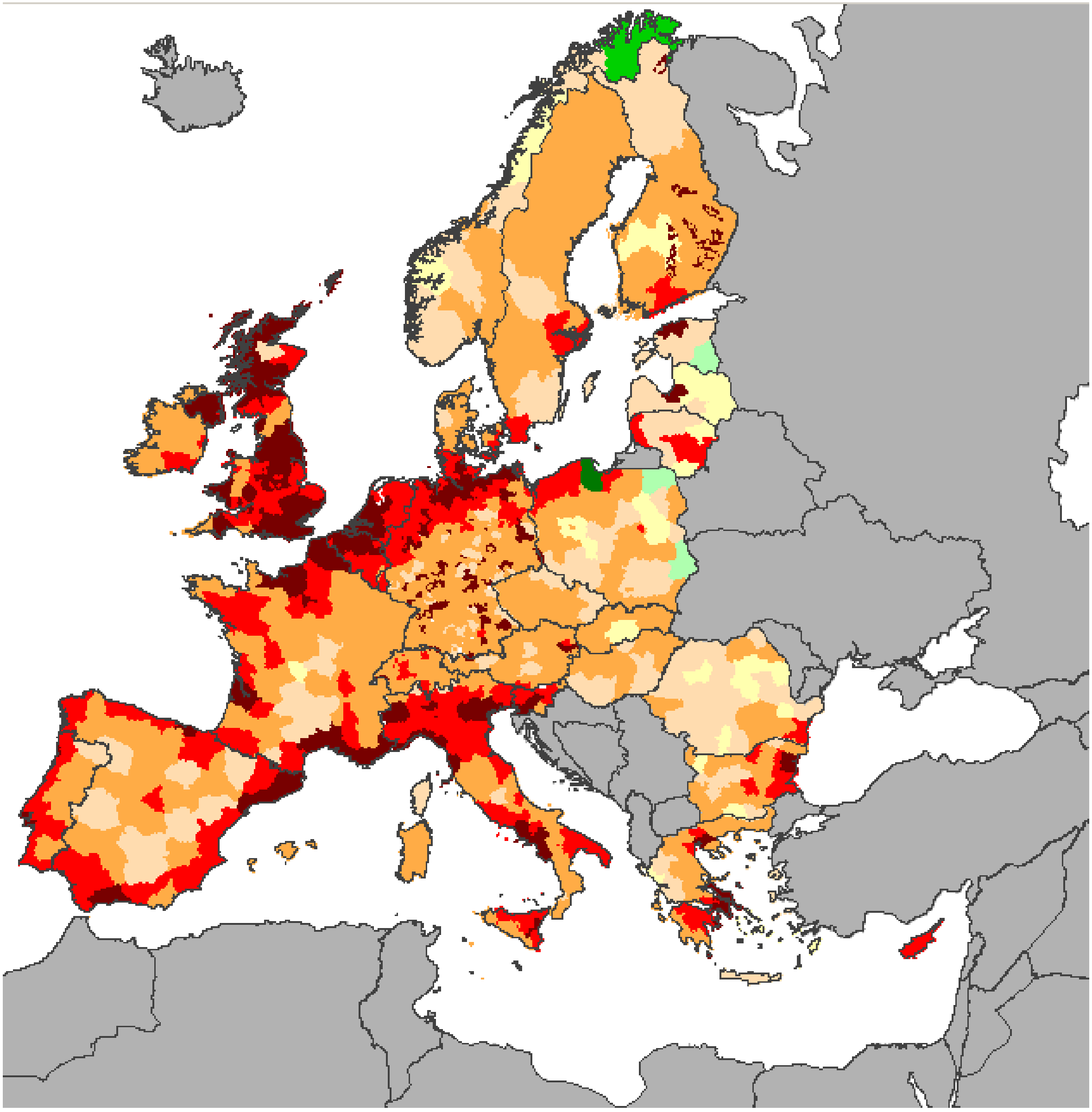
Demonstration example

The connectivity to transport terminals: has been calculated for all NUTS 3 regions of the ESPON space (see Figure 5.3.1) considering road transport network in 2001. Parameters for the calculations considered are as follows:

Transport networks	So	Sx	Pi
Road network	85 km/h	100 km/h	60
Rail network	75 trains/day	100 trains/day	10
Commercial airports	0,5 Mpass/year	15 Mpass/year	15
Commercial Seaports	0,5 Mtonnes/year	10 Mtonnes/year	15

It has to be noted that the map is a draft version to be cross-validated and redesigned according to ESPON layout.

Connectivity to transport terminals by car, 2001



Mcrit

Connectivity to transport terminals (hours)

- 0 ≤ M ≤ 0.25
- 0.25 < M ≤ 0.5
- 0.5 < M ≤ 0.75
- 0.75 < M ≤ 1
- 1 < M ≤ 1.25
- 1.25 ≤ M ≤ 1.5
- 1.5 < M ≤ 1.75
- 1.75 < M ≤ 2
- 2 < M ≤ 2.5
- 2.5 < M ≤ 1.25

Figure 5.3.1 Connectivity to transport terminals by car, 2001

5.3.2 Cost to motorway access by car

Rationale

As connectivity to transport terminals, the cost to motorway access, which is an indicator of connectivity to motorways, follows the same rationale as described in the previous section.

Method

Following the connectivity to transport terminals method, to calculate cost to motorways access 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 nodes connecting road links and its services.

Demonstration example

The cost, in hours, to motorway access has been calculated for all NUTS3 regions of the ESPON space (see Figure 5.3.2). The value represented is taxi (minimum time to access the closest node in the network (i=road network) that provides the service level required). Regions coloured in red and brown are the ones with high motorway and expressways density (see figure 5.1.1).

It has to be noted that the map is a draft version to be cross-validated and redesigned according to ESPON layout.

Cost to motorways access by car, 2001

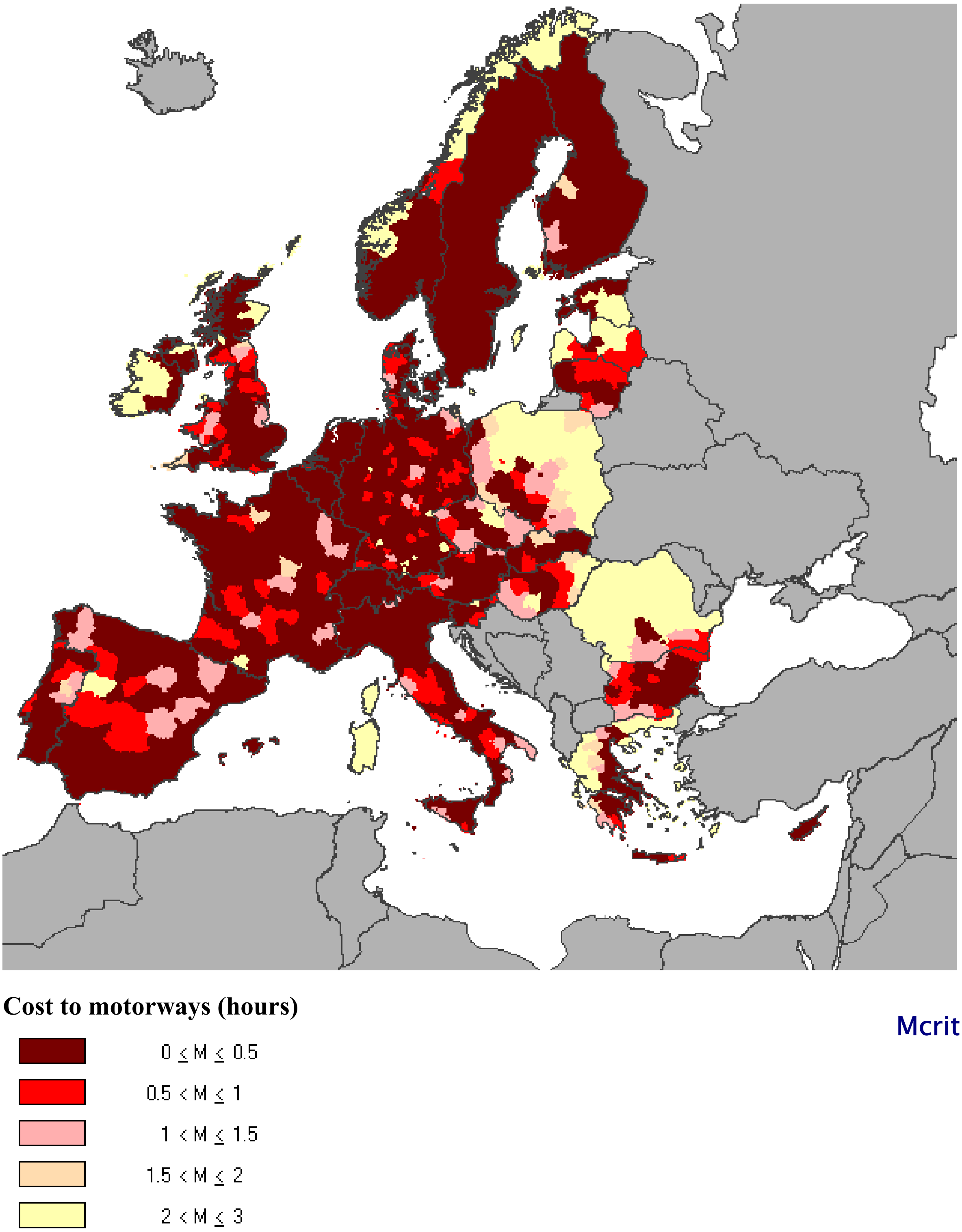


Figure 5.3.2 Cost to motorways access by car, 2001

5.3.3 Cost to high-speed railway stations by car

Rationale

As connectivity to transport terminals, the cost to high-speed rail stations, which is an indicator of connectivity to high-speed rail lines, follows the same rationale as described in the previous section.

Method

Following the connectivity to transport terminals method, to calculate cost to high-speed rail stations, the same method in the previous section has been applied here.

Data requirements

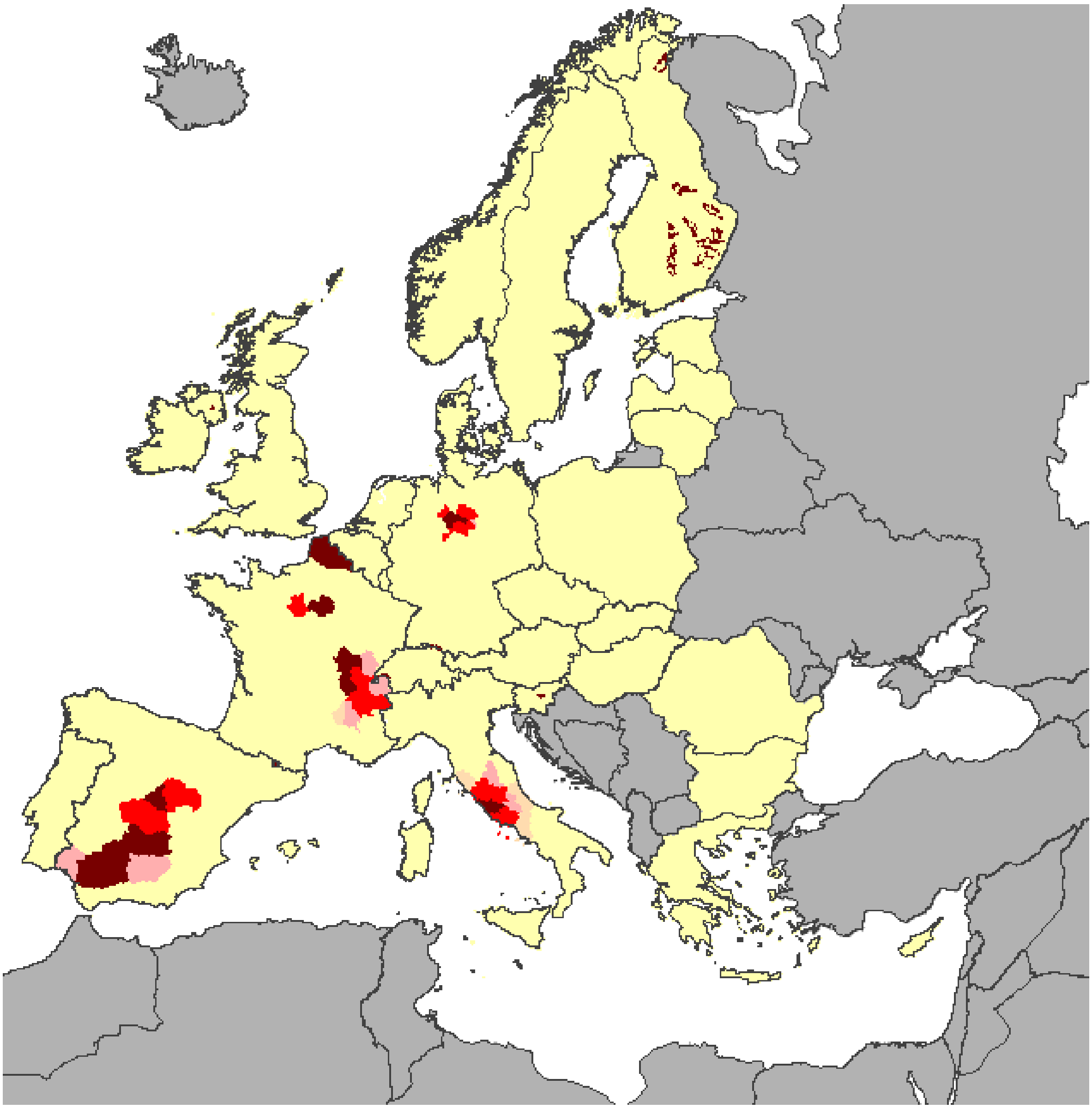
The data requirements are the same to the previous requirements, but only considering high-speed real stations and its services.

Demonstration example

The cost, in hours, to high-speed rail stations has been calculated for all NUTS3 regions of the ESPON space (see Figure 5.3.3). The value represented is taxi (minimum time to access the closest node in the network (i=high-speed rail network) that provides the service level required).

It has to be noted that the map is a draft version to be cross-validated and redesigned according to ESPON layout.

Cost to high-speed rail stations by car, 2001



Cost to high-speed rail stations (hours)

0 ≤ M ≤ 0.5
0.5 < M ≤ 1
1 < M ≤ 1.5
1.5 < M ≤ 2
2 < M ≤ 3

Mcrit

Figure 5.3.3 Cost to high-speed rail stations by car, 2001

5.3.4 Cost to commercial airports by car

Rationale

As connectivity to transport terminals, the cost to commercial airports, which is an indicator of connectivity to commercial airports, follows the same rationale as described in the previous section.

Method

Following the connectivity to transport terminals method, to calculate cost to commercial airports, 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 airports and its services.

Demonstration example

The cost, in hours, to commercial airports has been calculated for all NUTS3 regions of the ESPON space (see Figure 5.3.4). The value represented is taxi (minimum time to access the closest node in the network (i=airlines) that provides the service level required).

It has to be noted that the map is a draft version to be cross-validated and redesigned according to ESPON layout.

Cost to commercial airports by car, 2001

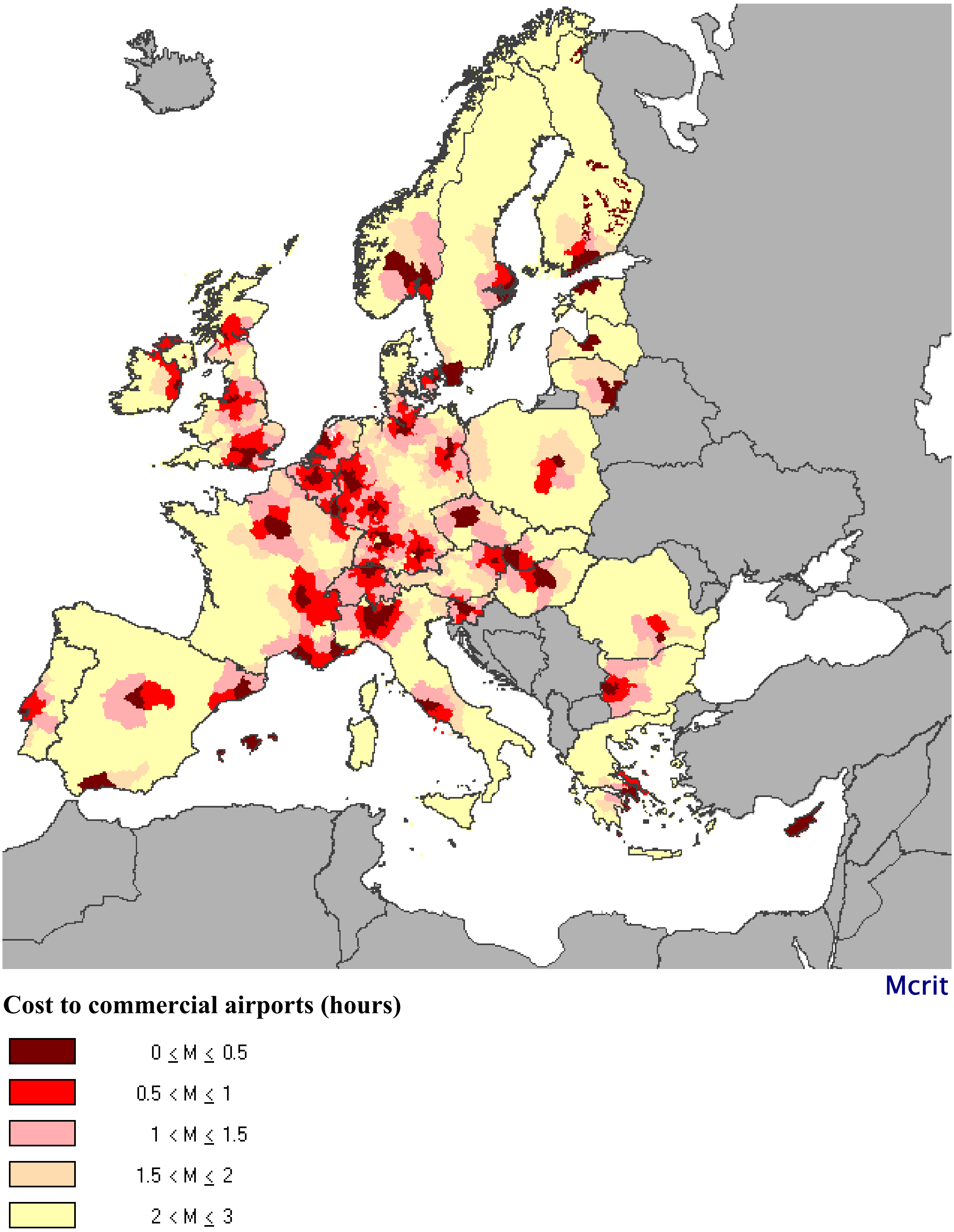


Figure 5.3.4 Cost to commercial airports by car, 2001

5.3.5 Cost to commercial seaports by car.

Rationale

As connectivity to transport terminals, the cost to commercial seaports, which is an indicator of connectivity to commercial airports, follows the same rationale as described in the previous section.

Method

Following the connectivity to transport terminals method, to calculate cost to commercial seaports, the same method in the previous section has been applied here.

Data requirements

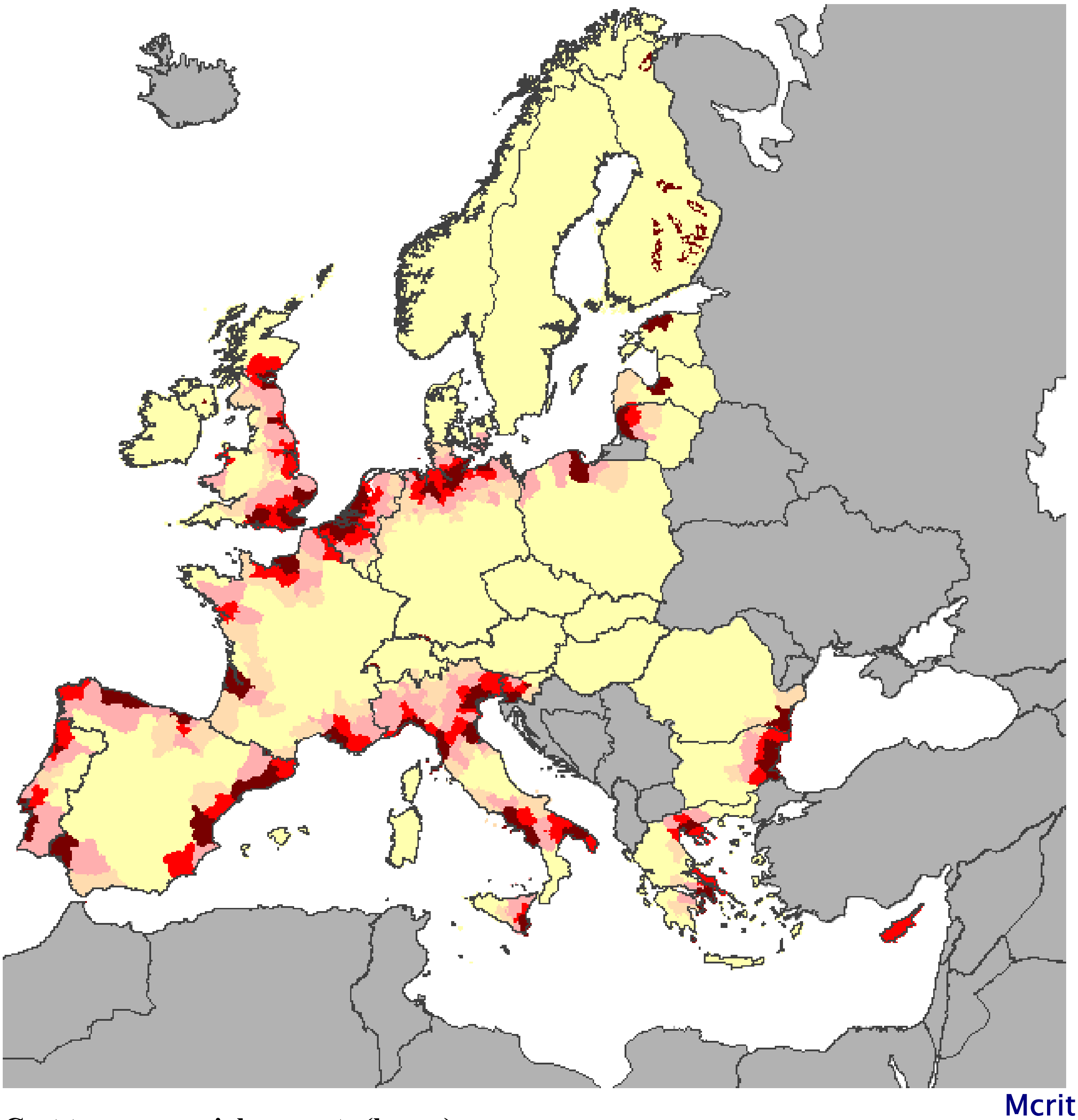
The data requirements are the same to the previous requirements, but only considering commercial seaports and its services.

Demonstration example

The cost, in hours, to commercial seaports has been calculated for all NUTS3 regions of the ESPON space (see Figure 5.3.5). The value represented is taxi (minimum time to access the closest node in the network (i=commercial sealines) that provides the service level required).

It has to be noted that the map is a draft version to be cross-validated and redesigned according to ESPON layout.

Cost to commercial seaports by car, 2001



Cost to commercial seaports (hours)

- $0 \leq M \leq 0.5$
- $0.5 < M \leq 1$
- $1 < M \leq 1.5$
- $1.5 < M \leq 2$
- $2 < M \leq 3$

Figure 5.3.5 Cost to commercial seaports by car (M=hours), 2001

5.3.6 Towards indicators of time and cost for freight transport

Transport time and costs for freight are basic indicators of European economic integration and regional accessibility.

In many former studies either time or cost, or a combination of both, a "generalised" cost or time have been used to characterise differences in accessibility or to estimate a kind of "impedance" or "resistance" function between two zones.

Today the context has become more complex and it is often not relevant any more to use a single indicator between two zones, whatever is the degree of sophistication.

Quality of service is also a factor which plays a more and more important role in the satisfaction of users, in their strategy of location for production "unit" or logistics centres which in turn influence in depth the pattern of flows in Europe: many recent studies have pointed the quality factors as well as state preference surveys (Intermodal Quality – IQ 2000, IV PCRD, MYSTIC survey IV PCRD…).

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

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

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

- ❖ For road this results in delays on certain routes although road freight transport has shown in the past a quite good aptitude to avoid peak hours in congested areas and to adapt accordingly the driving and resting hours ; but such flexibility encounters limits which become more constraining with increase of traffic.
- ❖ For rail this has led to the question of "priority for freight" because of the time lost to leave the right of the way to passenger trains and to the identification in Europe of a "priority freight" network, as recalled earlier to the policy context.

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

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

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

The freight market segments

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

For our purpose it is then necessary to take into account such structural evolution and changes in trends without introducing too much details in segmentation variables in order not to loose our main objectives of spatial development of European space ; the definition of main segments to be considered in a common platform of understanding of transport needs and trends was precisely the topic addressed in Think Up thematic network for prospective analysis of transport and the differentiation proposed here is mainly based on these results.

A first level of segmentation

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

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

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

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

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

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

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

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

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

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

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

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

The transport operating system

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

The road techniques

It is not necessary to tell much about road techniques which is considered as the most flexible mode, adapted to short distance and long distance, small shipment size and large shipment size.

However for very large shipment road meets sometimes technical problems and faces major congestion problems in the network for the years to come.

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

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

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

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

A last point to be stressed is the question of harmonisation of driving and working hours in Europe, and the question of reinforcement of regulation including speed: it is a very important point on which this project will insist on the measure of time and cost performances for road as well as for the road assignment on network and modal split.

Concerning working hours and driving hours an answer of road haulier has sometimes been the organisation of change of drivers along a given route as it is the case, in a very performing way between France and Portugal. For larger road companies this should not be forgotten and can maintain road performances with improved working conditions of drivers, remaining close to their living places. Another effect could also be the introduction of new techniques such as “rolling road” along most congested corridors: France is thinking about it for its two major corridors called the “Magistrale eco fret” in the Eastern part and the “Magistrale Atlantique” in the Western part of the country.

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

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

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.

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.

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.

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.

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.

Conclusion: next steps

1) Road time in European network in relation with driving regulation hypothesis
2) Road assignment in European network
3) Transport time/cost analysis for rail according to market segments and operating system
    - direct train
    - wagon load
    - international train.
4) Network rail assignment for
    - direct train: conventional and intermodal
    - wagon load.
5) Major trends at year 2020 and assignment on network 2020.

5.4 Accessibility and quality of services

This section contains a series of accessibility indicators based on the theoretical concepts explained in Section 4.3. It starts with potential accessibility by mode, followed by multimodal potential accessibility; finally, daily accessibility is demonstrated.

5.4.1 Potential accessibility by road

Rationale

Potential accessibility by mode has been proposed by the Working Group "Geographical Position" of the Study Programme on European Spatial Planning – SPESP as reference indicator concept (Wegener et al., 2000). Accessibility potential is one of the most common and most extensively tested accessibility indicators (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):

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

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 disaggregated 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 5.4.1). 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.

It has to be noted that the map is a draft and might change when having refined the input databases and the accessibility model.

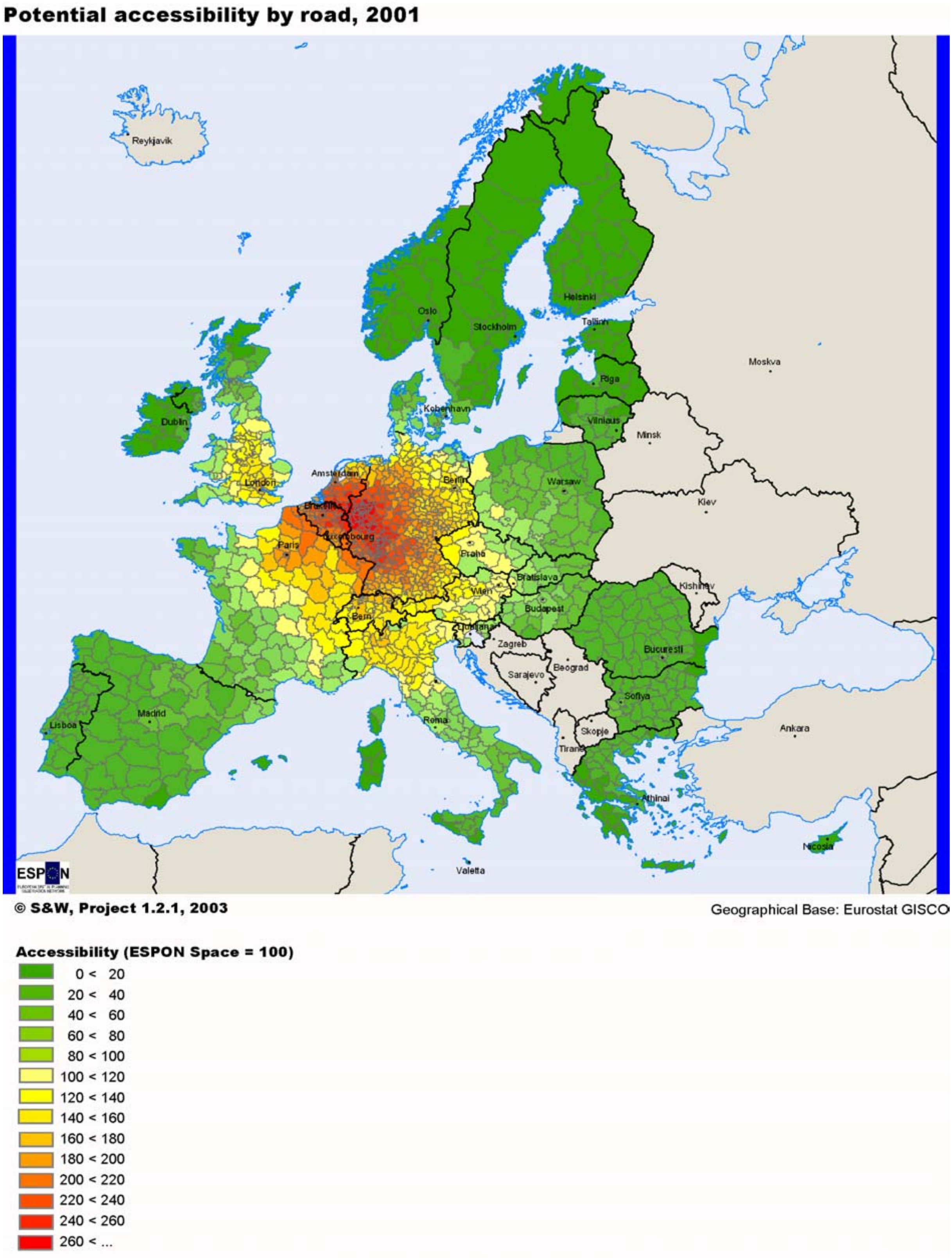


Figure 5.4.1 Potential accessibility by road, 2001.

5.4.2 Potential accessibility by rail

Rationale

As potential accessibility by rail follows the same concept as potential accessibility by road the same rationale as described in the previous sections applies here.

Method

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

Data requirements

The data requirements are similar to the previous requirements. The only change is that 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 5.4.2). 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.

It has to be noted that the map is a draft and might change when having refined the input databases and the accessibility model.

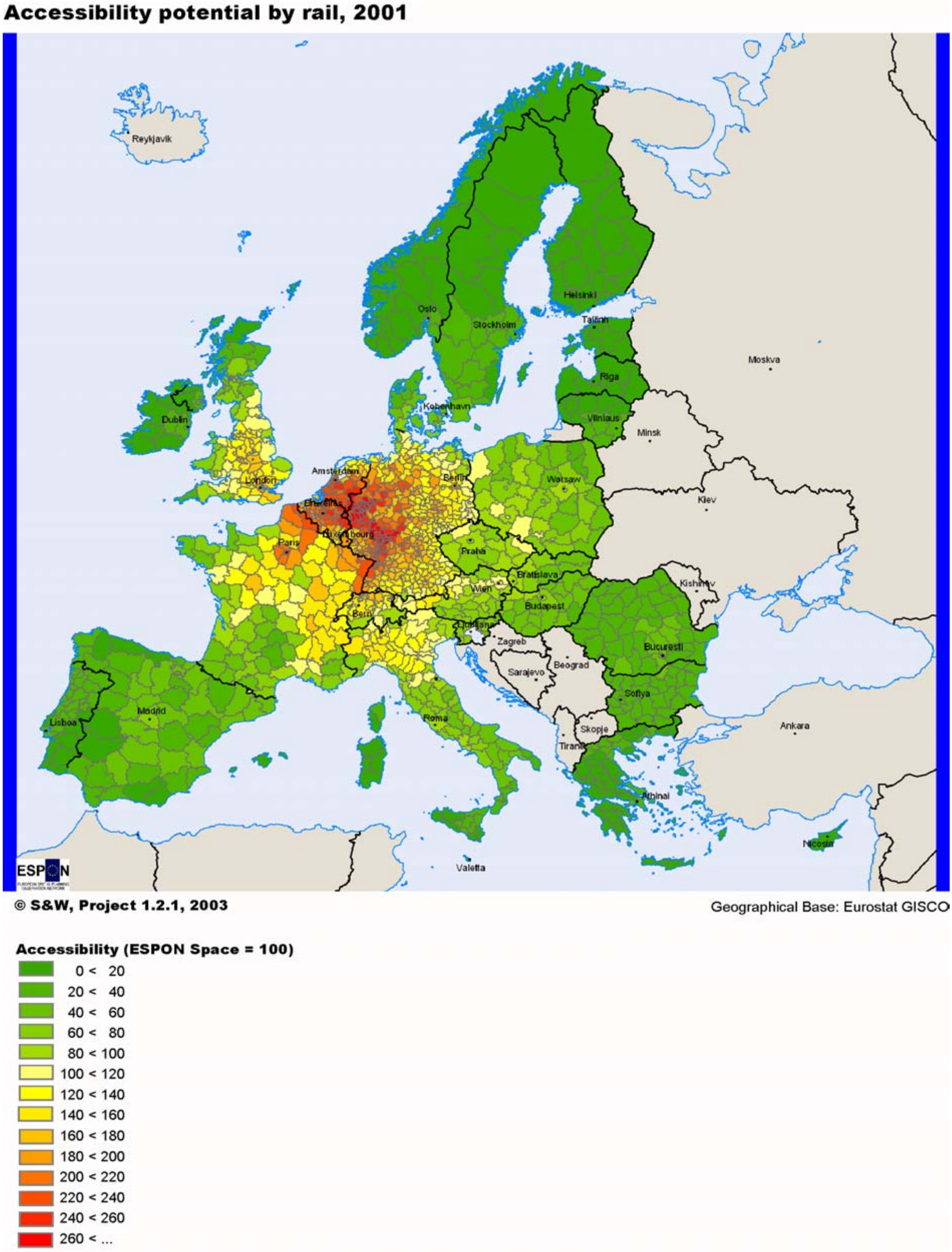


Figure 5.4.2 Potential accessibility by rail, 2001.

5.4.3 Potential accessibility by air

Rationale

As potential accessibility by air follows the same concept as potential accessibility by road and rail the same rationale as described in Section 5.4.3 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.

It has to be noted that the map is a draft and might change when having refined the input databases and the accessibility model.

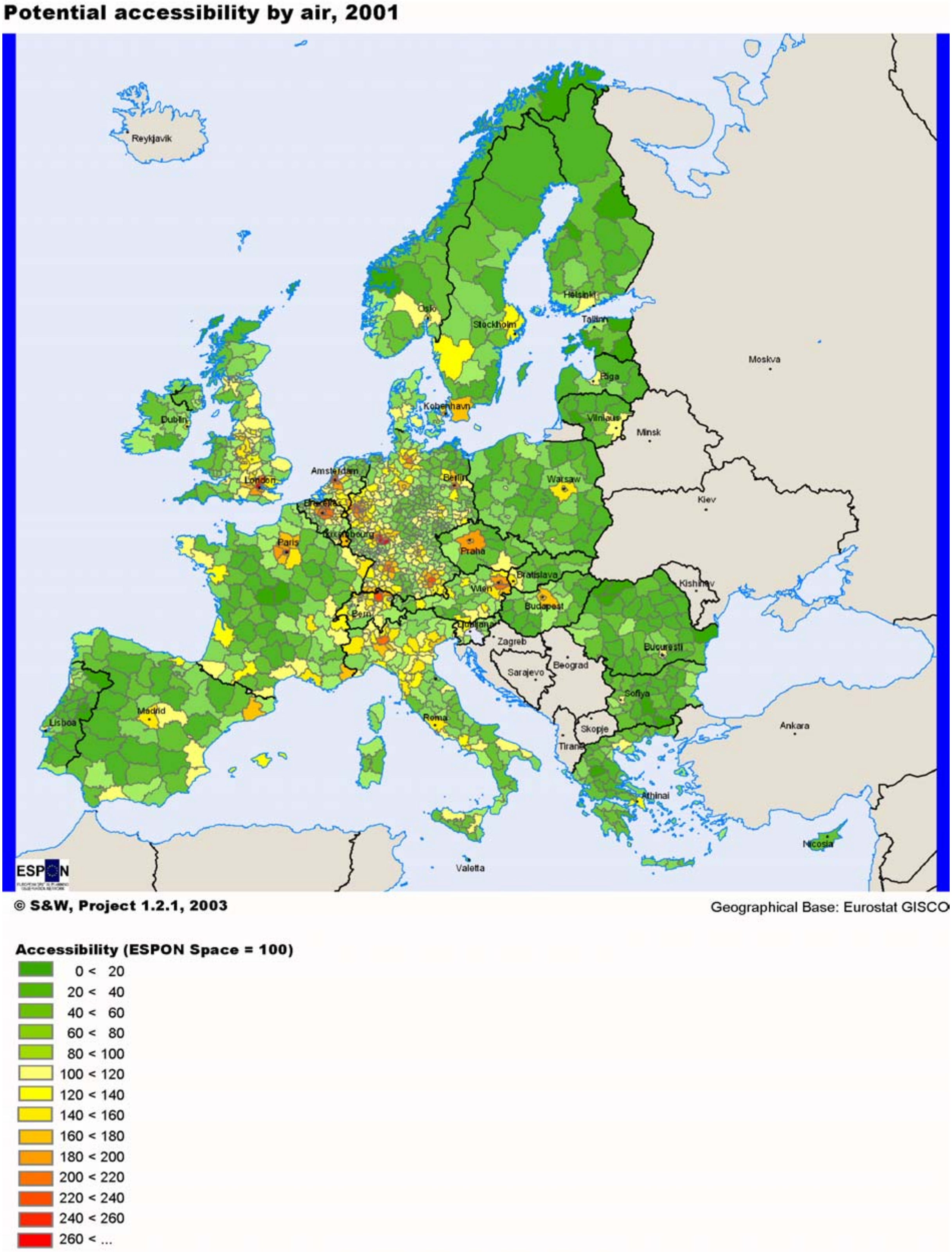


Figure 5.4.3 Potential accessibility by air, 2001.

5.4.4 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 5.4.4). 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.

It has to be noted that the map is a draft and might change when having refined the input databases and the accessibility model.

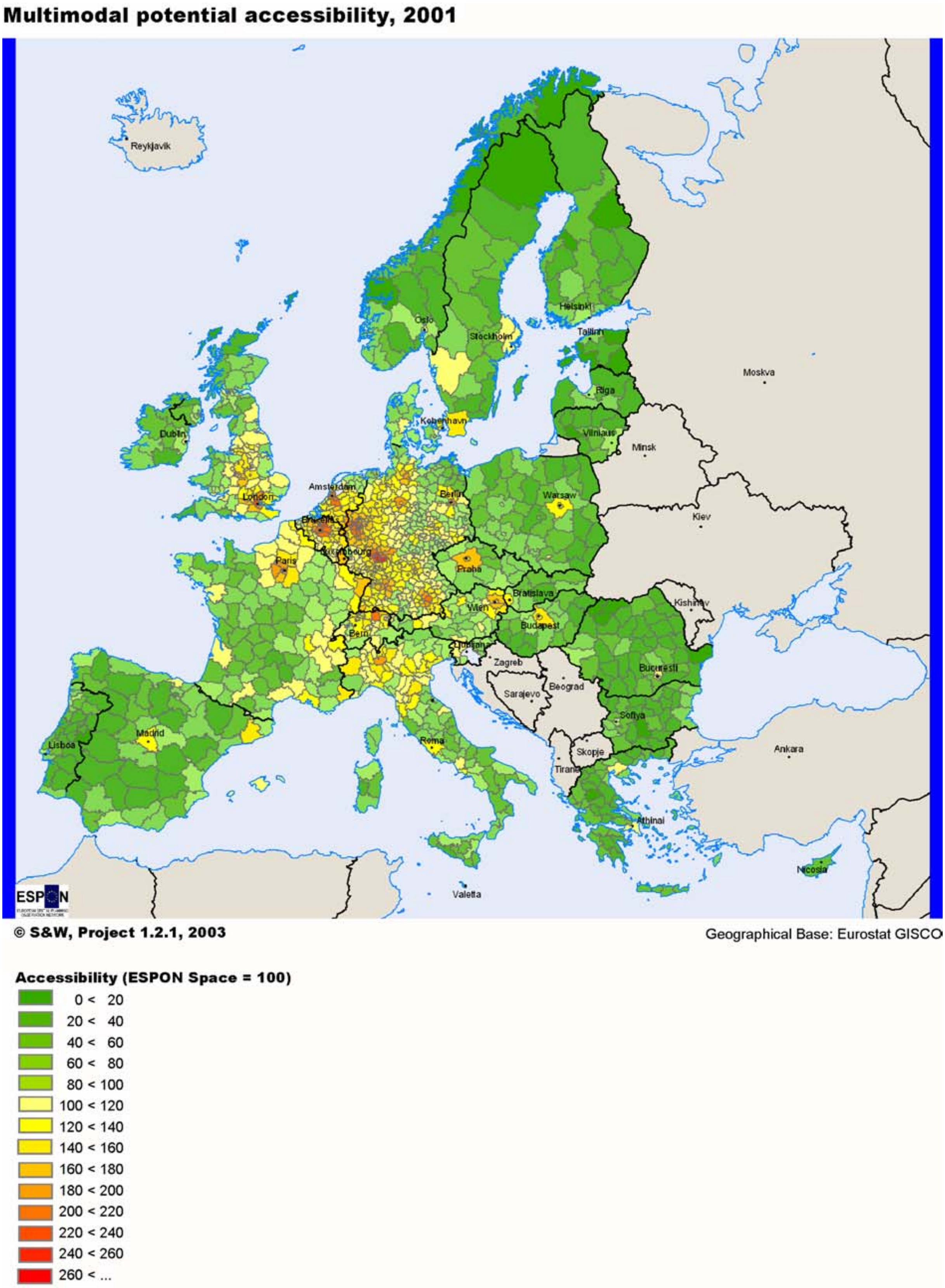


Figure 5.4.4 Multimodal potential accessibility, 2001.

5.4.5. 'City network' daily accessibility

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.

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. Typical analysis

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 is made in close relations with the work done in the ESPON theme 111 on polycentrism.

To identify the pole of the polycentrism, as an accepted ESPON list is not yet available, we have proceeded in proposing a specific list of cities. We have used a combination of criteria:

- Political functions: we have selected all the capitals of the countries of the ESPON space plus the capitals of the countries neighbouring the ESPON countries
- Weight: we have used a population level for the selection of the cities based on the GISCO data corrected according to the different methods used to quantify the populations of the settlements in the various countries.

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. Consequently we propose to evaluate the possibility of:

0 Working day commuting trips (8+1 hours available at destination)

1 Single day business trip (6 hours available at destination)

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

These 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 was 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.

Demonstration examples

From this global indicator a subset of indicators can be derived:

- map showing the possible relations inside the European city network;
- number of poles reachable from each pole;
- number of poles reachable from each NUTS zones using the combination of air an rail transport systems;
- accessibility indicators computed with and without the rail trips to identify the terrestrial network improvements to conduct to support the polycentric option.

The following map (Figure 5.4.5) is a demonstration example of the method proposed. Only air trips are considered, but in a door-to-door approach; typical business trips are illustrated with a minimum of 6 hours spent at the destination city; trips must belong to the time interval 6h to 23h. The map shows three levels of accessibility: no existing direct flight, existing direct flights but no possibility do business trips, business trips possible.

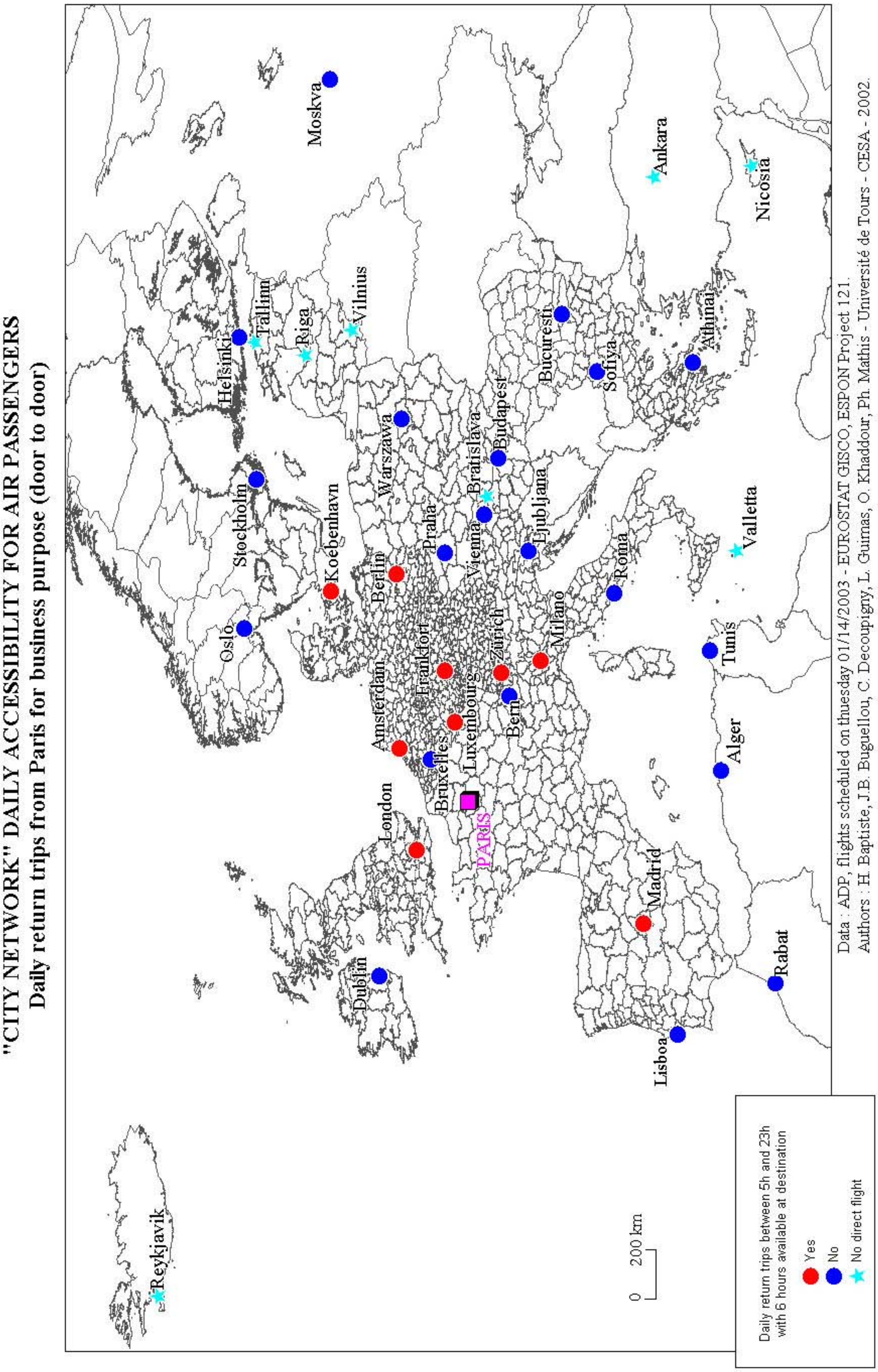


Figure 5.4.5 'City network' daily accessibility by air from Paris, 2003.

5.4.6 Daily population accessible by car

Rationale

Depending on the services provided by transport operators in a given moment, business travellers and tourists, and industries, may or not benefit from the existence of transport infrastructure. Only private transport by car or truck is independent from the services actually provided.

The indicators most frequently used are 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

To calculate accessible population by car it has been used an advanced routine programmed on C++ based on expert criteria and rules, as extension of transport-related GIS, to calculate cost matrices, with origins and destinations the main cities of each NUTS3 in the road network graph, without capacity constraints.

To determine the accessible population it is needed to add the population of all NUTS3 reacheable from a NUTS3 origin at a given time. It is considered as daily population the population accessible at 3 hours, using road network without capacity constraints.

Data requirements

The basic data needed to calculate this type of indicators is a transport multimodal network at European level, precise enough in terms of connections, with information concerning infrastructural characteristics.

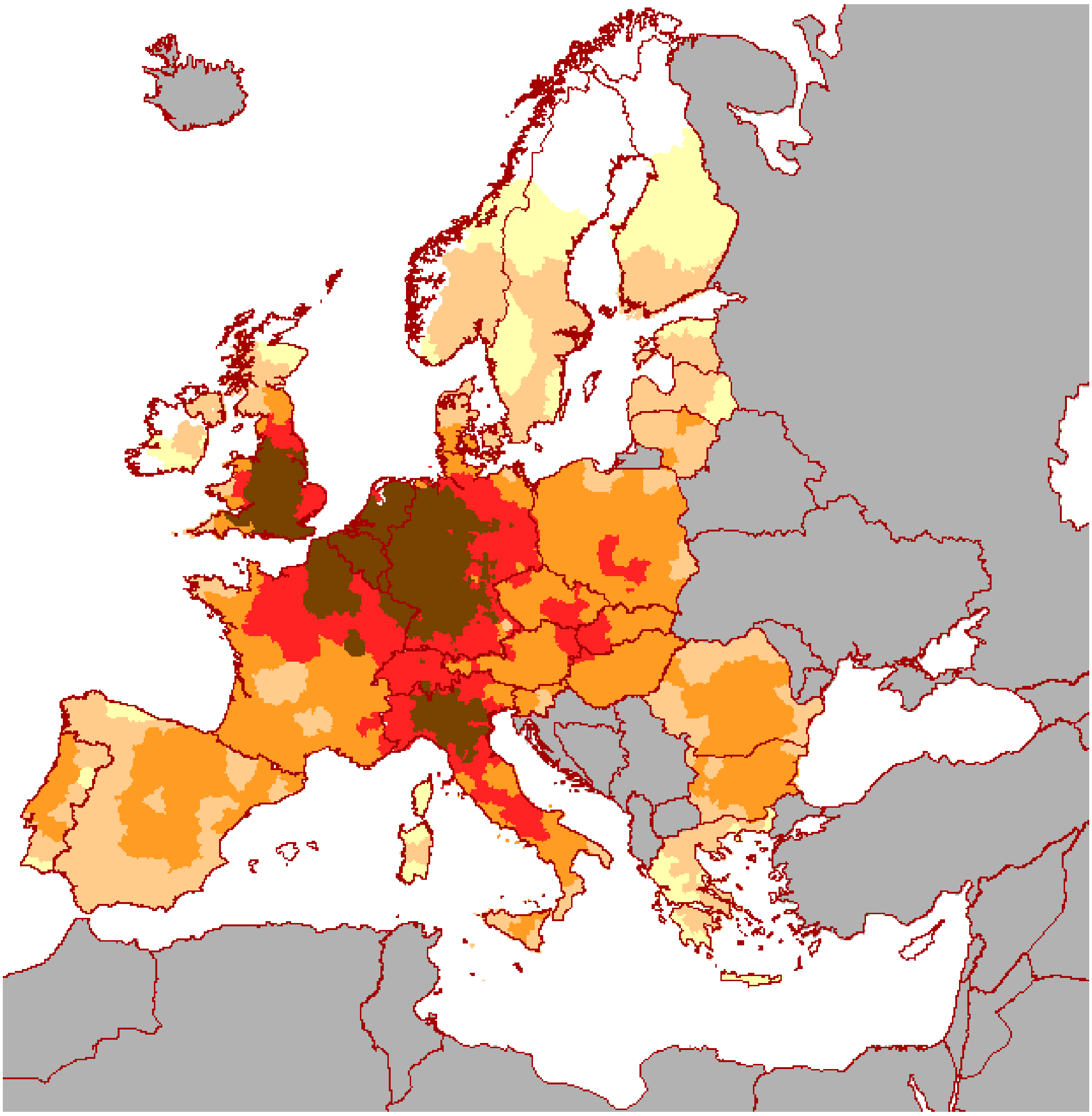
- The transport network used is from ASSEMBLING multimodal graph (see tables in 5.1), and nodes representing capitals of NUTS3.
- The regional data consists of population data to be used as destination.

Demonstration example

The daily and commuting population accessible by car from a given NUTS3 at a given time by the shortest path (time) has been calculated for all NUTS3 of the ESPON space (see Figure 5.4.6). Regions with high daily accessibility are coincide with the regions with high motorway and expressways density (see Figure 5.1.1) and high population density.

It has to be noted that the map is a draft version to be cross-validated and redesigned according to ESPON layout.

Population accessible (in 1000 inhabitants)



Daily population accessible by car, 1999

Mcrit

21 ≤ p ≤ 1000

1000 < p ≤ 5000

5000 < p ≤ 15000

15000 < p ≤ 25000

25000 < p ≤ 60418

Figure 5.4.6. Daily population accessible, 1999

5.4.7 Daily market accessible by car

Rationale

Indicator of “market area achievable at a given time or cost” follows the same concept as population accessible at a given time by road as described in the previous section.

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 regional that regional data needed consists of area to be used as destination.

Demonstration example

The daily and commuting market accessible by car has been calculated for all NUTS3 of the ESPON space (see Figure 5.4.7).

It has to be noted that the map is a draft version to be cross-validated and redesigned according to ESPON layout.

Daily market accessible by car, 2001

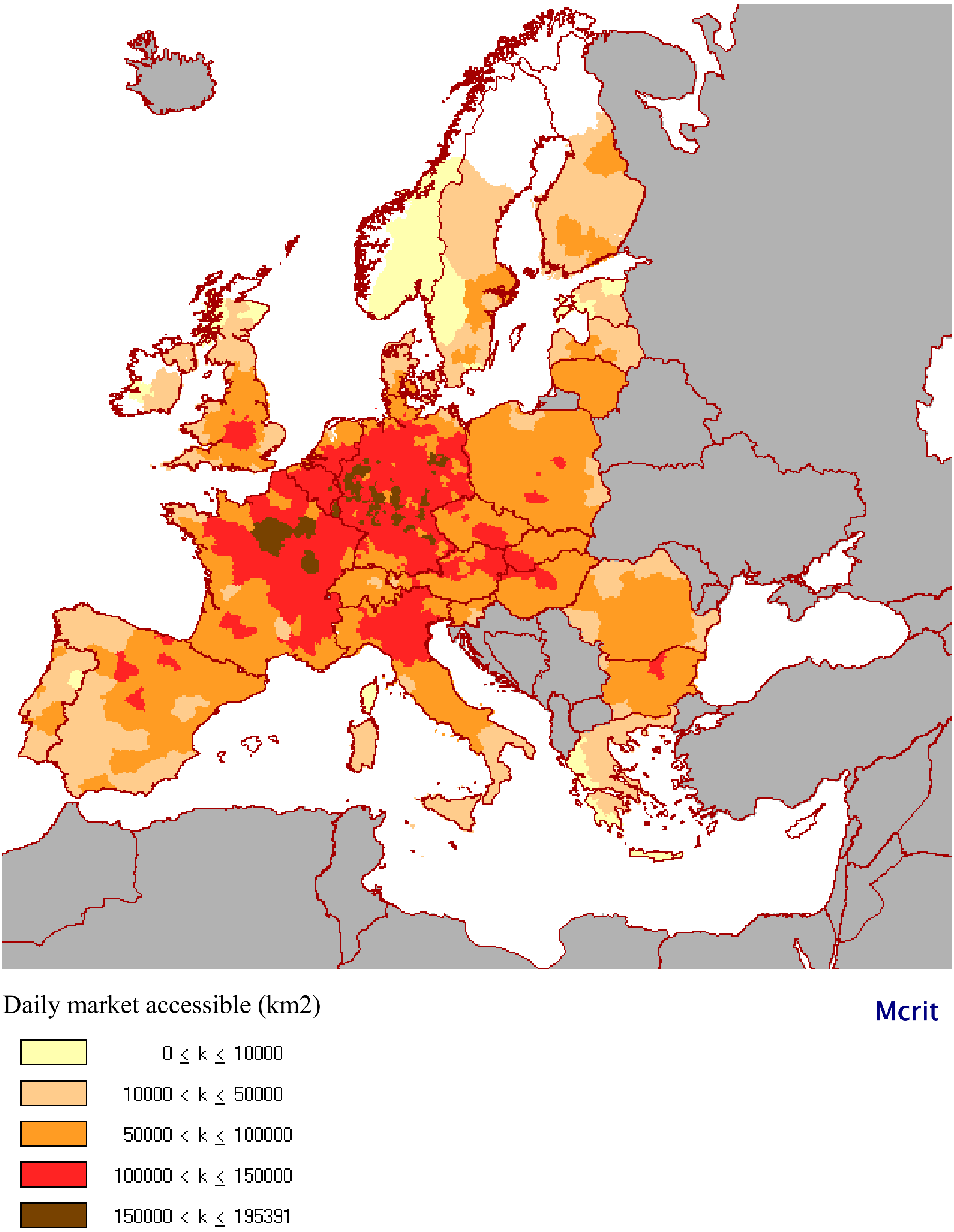


Figure 5.4.7 Daily market accessible, 2001

5.4.8 Accessibility bipolar differential map

The aim is to show Spatial potential competition between two ports with tree diagram of minimum travel time paths. The paths tree shows clearly the corridors from Rotterdam.

Method/ theoretical background:

The aim is to show the competition areas, all other things being equal, between the different ports using computing minimum travel times of trips.

Methodology :

For computing the minimum paths we use the MAP-NOD model which then affects the network to NUTS2.

Data requirements :

The network with the maximum speed by edge according to the countries.

Demonstration to the ESPON space :

Two maps are showed for example Le Havre and Rotterdam on the one hand and Genes and Marseille on the other hand. It is possible to generalize in order to figure any number of ports on the map.

The advantage of Rotterdam is not really spatial but coming from the harbour and its services.

This result is an example of Palander's theory in a real space.

Taking into account the gateways complete the network analysis.

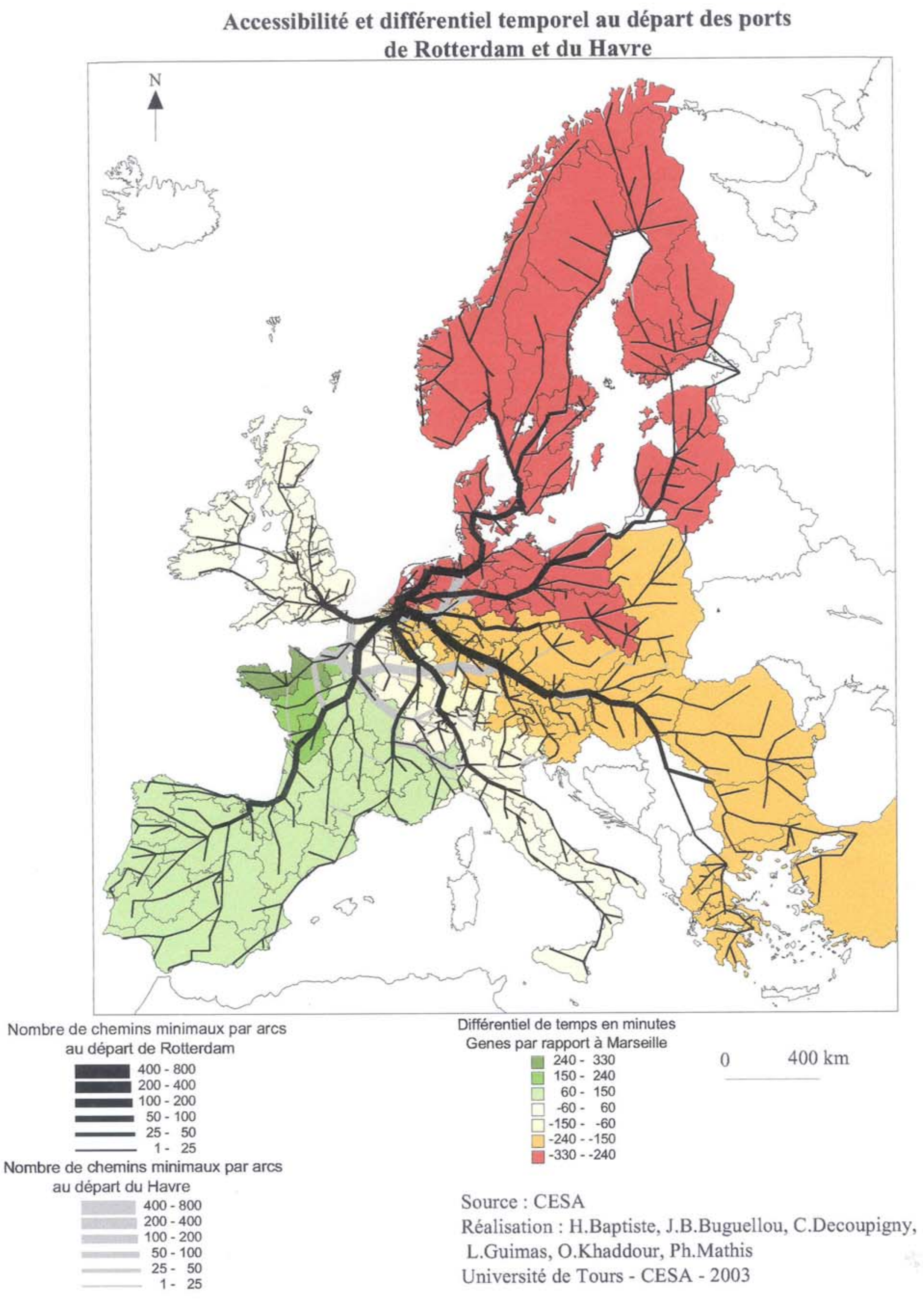


Figure 5.4.8.1 Accessibility bipolar differential map Rotterdam and Le Havre

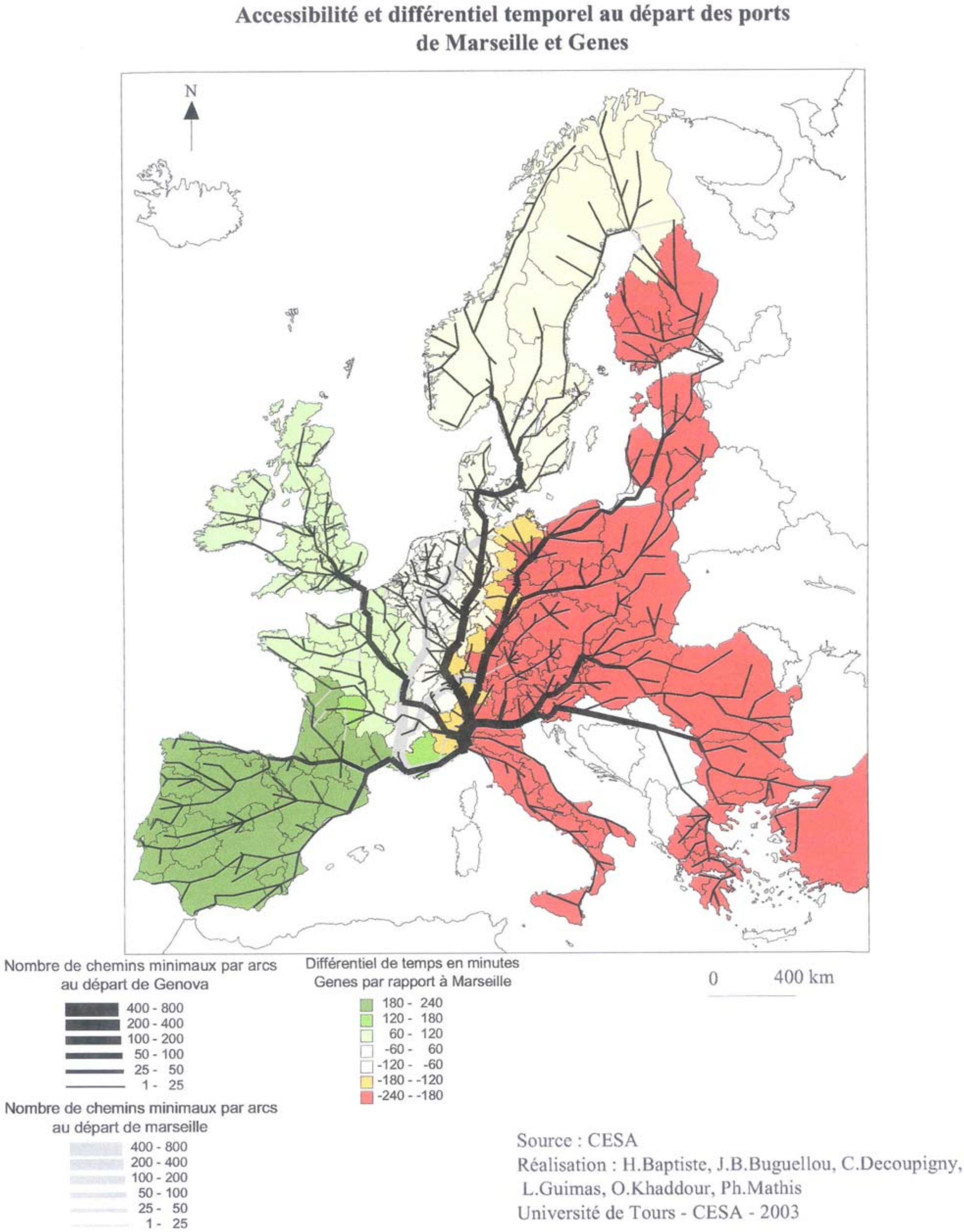


Figure 5.4.8.2 Accessibility bipolar differential map Marseille Genova

5.5 Traffic volumes and flows

Traffic volume indicators capture the actual use of the transport infrastructure networks and services and traffic flow indicators are different from traffic volume indicators as they include origin and destination, i.e. the relationship between two different points in space.

5.5.1 Transport quantities: km per person by car for business trips

Rationale

Km per person by car for business trips is a traffic quantity volume indicator of the use of road infrastructure in terms of average km per trip generated from a region and gives an idea of the destinations of these generated trips, in terms of distances.

Method

Flow matrices have been calculated with KTEN, 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 4-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.

To calculate trip generation KTEN considers zonal-based ratios (by NUTS 2 or equivalent), depending 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 Settlement (1,2,3,4,5,6) Based on Spatial Development indicators (SPESP).
- Self Containing trips: Internal trips rates
- External Trips rates

To calculate trip distribution, KTEN considers Single origin constrained. By trip purpose:

Business/Obligated

- Relationship between the country who belongs to zone (i) and the country who belongs to zone (j)
- Capitatility index (4 for Europe,2 for capital of the city and 1 for others)
- Population of zone (j)
- Gross Domestic Product of zone (j)
- Cost to travel from zone (i) to zone (j)

Vacation/Leisure

- Relationship between the country who belongs to (i) and the country who belongs to (j)
- Capitatility index (4 for Europe,2 for capital of the city and 1 for others)
- Population of zone (j)
- Tourist pressure on site of zone (j)
- Cost to travel from zone (i) to zone (j)

Modal split is combined with Assignment on a multimodal network.

To determine the number km per person per mode by purpose of trips generated in each NUTS2, first the matrices per mode and purposes are calculated with KTEN model. The distances in km between nodes in the respective networks are calculated with a GIS with NIS (Bridges/NIS) applications.

$$K_{ijk} = \left(\sum_{n} L_{ijn} * N_{ijkn} \right) / \sum_{n} N_{ijkn}$$

Where K_{ijk} are the km per person per mode *j* by purpose *k* in NUTS3 *i*, L_{ijn} is the cost (in km) from $NUTS2_i$ to $NUTS2_n$ using the mode *j*, and N_{ijkn} is the number of trips generated from $NUTS2_i$ to $NUTS2_n$ using the mode *j* by purpose *k*.

Demonstration example

The number of km per person per road by obligated (business) trips has been calculated for all NUTS2 of the ESPON space (see Figure 5.5.1). Peripheric regions drive to regions with higher population and GDP, which are situated mostly in center ESPON space.
It has to be noted that the map is a draft version to be cross-validated and redesigned according to ESPON layout.

Km per person by car in business trips, 2001

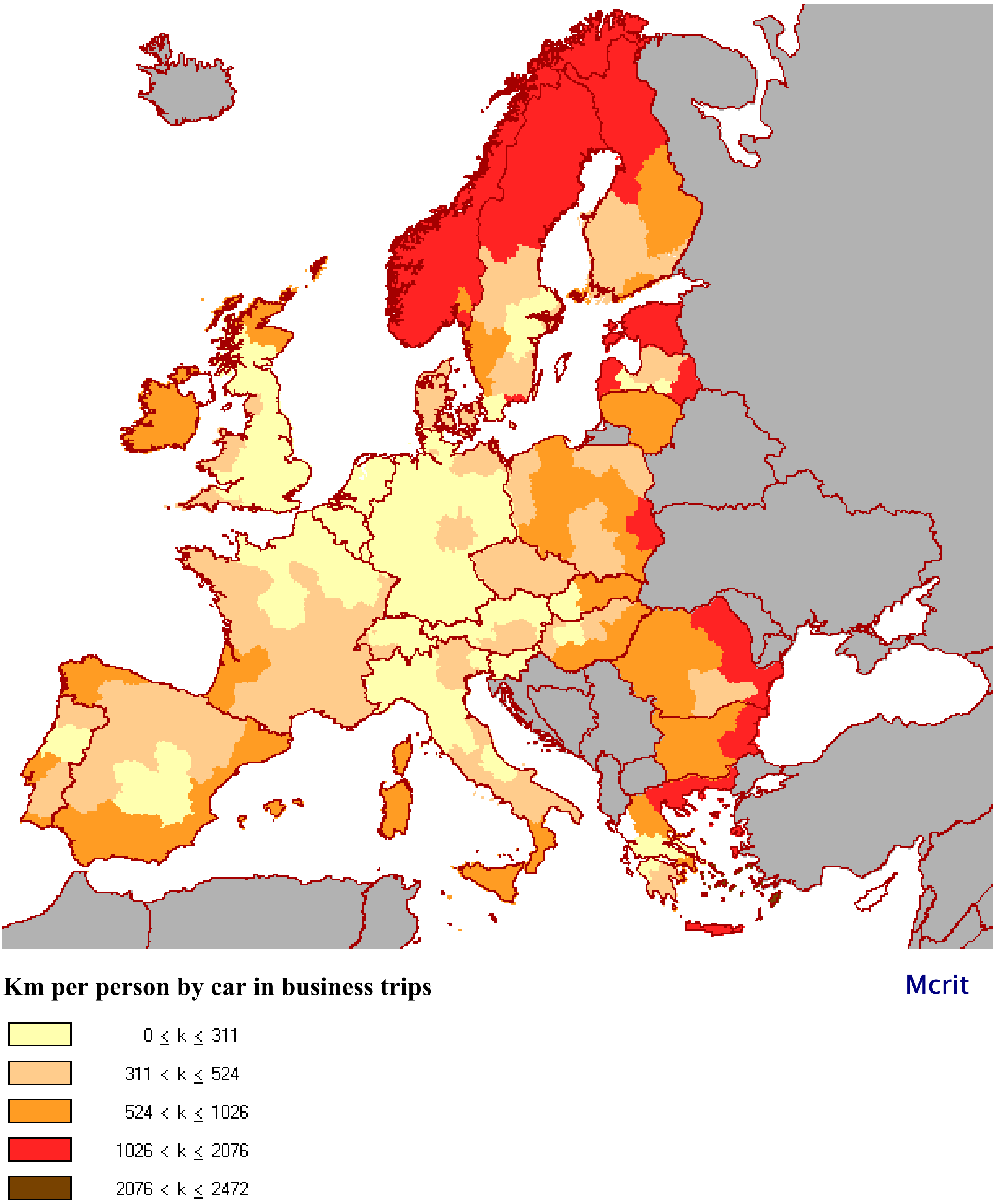


Figure 5.5.1. Km per person by car in business trips, 2001

5.5.2 Transport quantities: km per person by car in leisure trips

Rationale

As km per person by car for leisure trips follows the same concept as km per person by car for business trips the same rationale as described in the previous section applies here.

Method

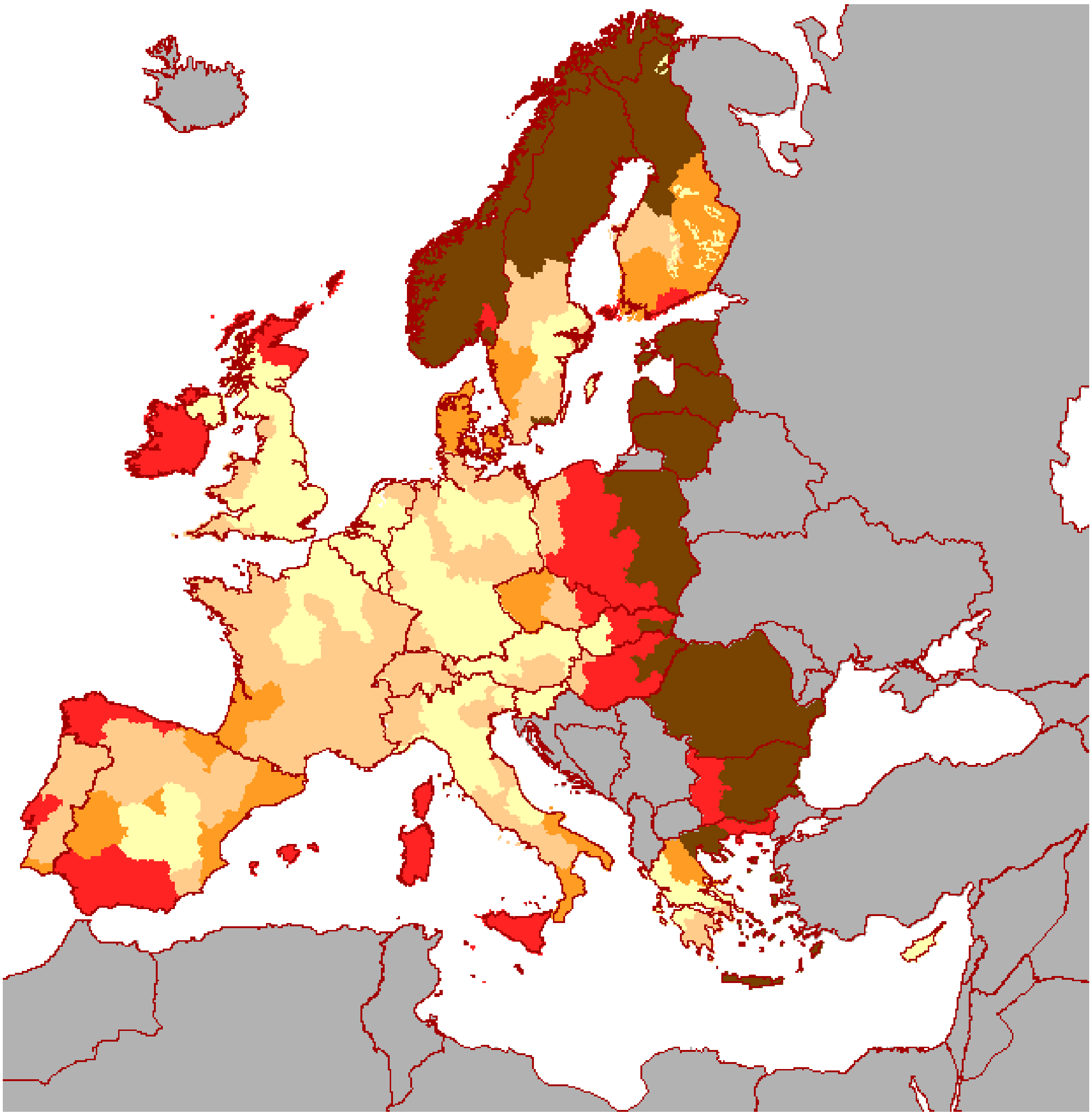
The same method as described in the previous section has been applied here.

Demonstration example

The number of km per person per road by leisure (vacational) trips has been calculated for all NUTS2 of the ESPON space (see Figure 5.5.2). Regions coloured in red and brown are the ones corresponding to the periphery of the ESPON space and the regions that drive shorter distances in this kind of trips are the ones more populated and with a high touristic attraction.

It has to be noted that the map is a draft version to be cross-validated and redesigned according to ESPON layout.

Km per person per road by leisure trips, 2001



Km per person by car in leisure trips

- 0 ≤ k ≤ 300
- 300 < k ≤ 450
- 450 < k ≤ 550
- 550 < k ≤ 1000
- 1000 < k ≤ 2387

Mcrit

Figure 5.5.2 Km per person by car in leisure trips, 2001

5.5.3 The Potential Flows Road Network Map

These prospective maps are based on the hypothesis that the travel cost lowers in the long term. The flows of goods grows in the European corridors. The potential maps show a first prospective of the future European space corridors based on the shorter travel times.

Method/ theoretical background

The method of these maps dates from the SPESP works. It is based on the use of sub-matrix of minimum paths matrix or interregional exchanges matrix or all other matrix .

The aim of these maps is to show the potential or real flows by type of trips. The idea is that the modal transfer is possible for only some types of trips because of the length of distance covered as international transit.

Our purpose is also to make specific maps of varied transits in European or country space. In fact France is an international transit country. People can not get away from Spain or go to Spain without crossing France. Consequently modal transfers flows are possible.

Methodology

We have two possibilities: either the potential corridors maps are figured with the number of minimum paths networks between different areas or the maps show the goods transit paths.

The methodology is easy. One selects the paths or the flows in a interregional exchange matrix NUTS2. Then one assigns these paths or flows to the road network. It possible to show only the corridors or the transit of goods that go through the country.

One can show with this methodology only the interregional exchanges from all regions of a country to all other countries and inversely. The two maps are complementary.

Data requirements

The necessary data are the networks and the exchange matrix. Other elements are computed by MAP-NOD model of CESA.

Currently, the data are CESA network for this test, but for the TIR the GISCO data and NUTS3 are used with the ESPON list of cities.

Demonstration to the ESPON space:

We present here four maps of potential paths:

- ❖ The minimum paths from French regions to the other regions with the number of paths by edge.
- ❖ The transit minimum paths by edge in the central countries.
- ❖ The effect of the passage of the Europe 15 to 25 +2 , with a superimposition of number paths of two solutions.
- ❖ The minimum paths between the peripheral zones of Maghreb and Eastern Europe.

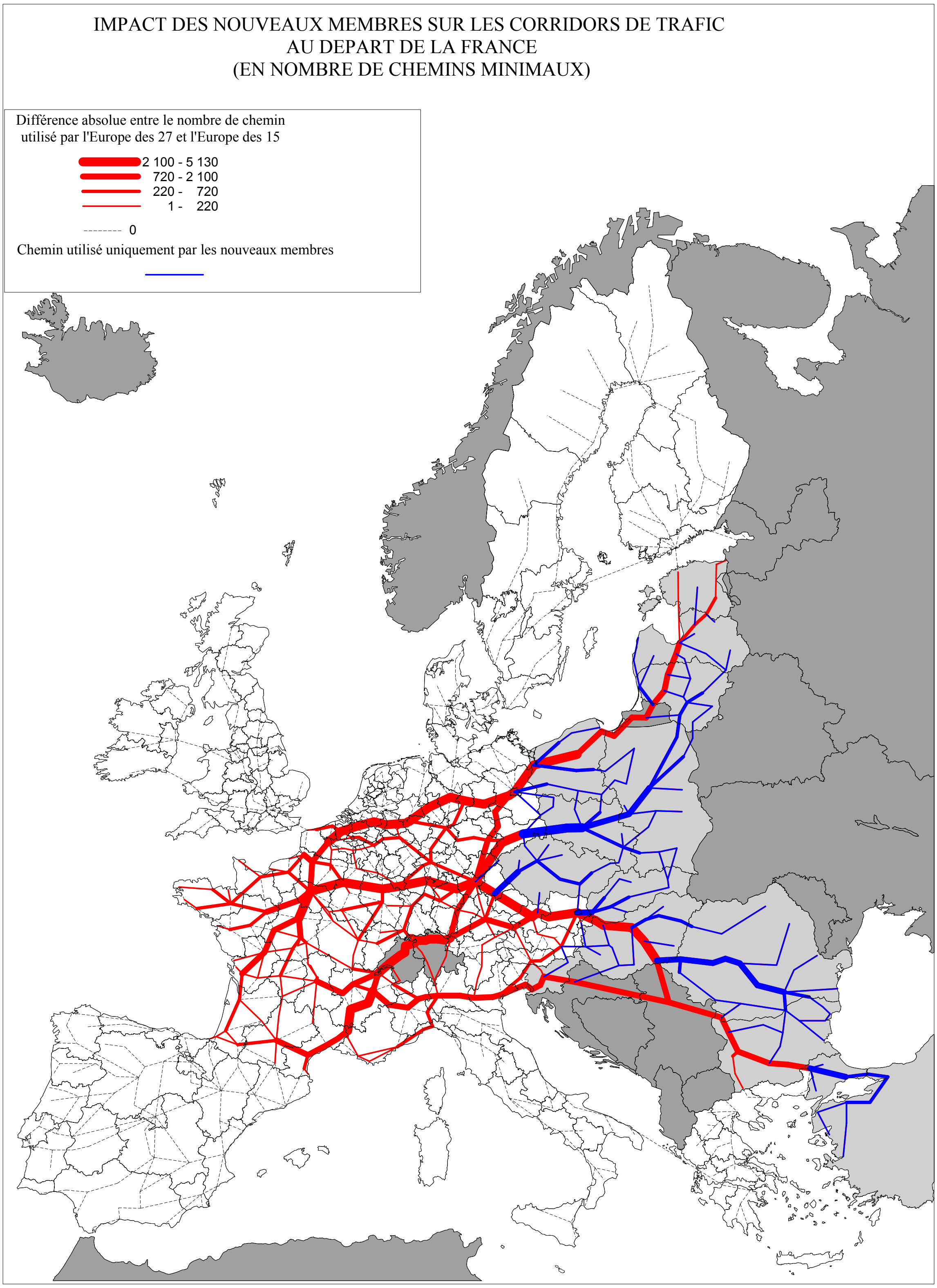


Figure 5.5.3.1Minimum paths from French regions to the other regions

This map shows the number of minimum paths by edge between the French region NUTS2 and the PECOS NUTS2. Naturally the paths are East-West unlike actual European corridors.

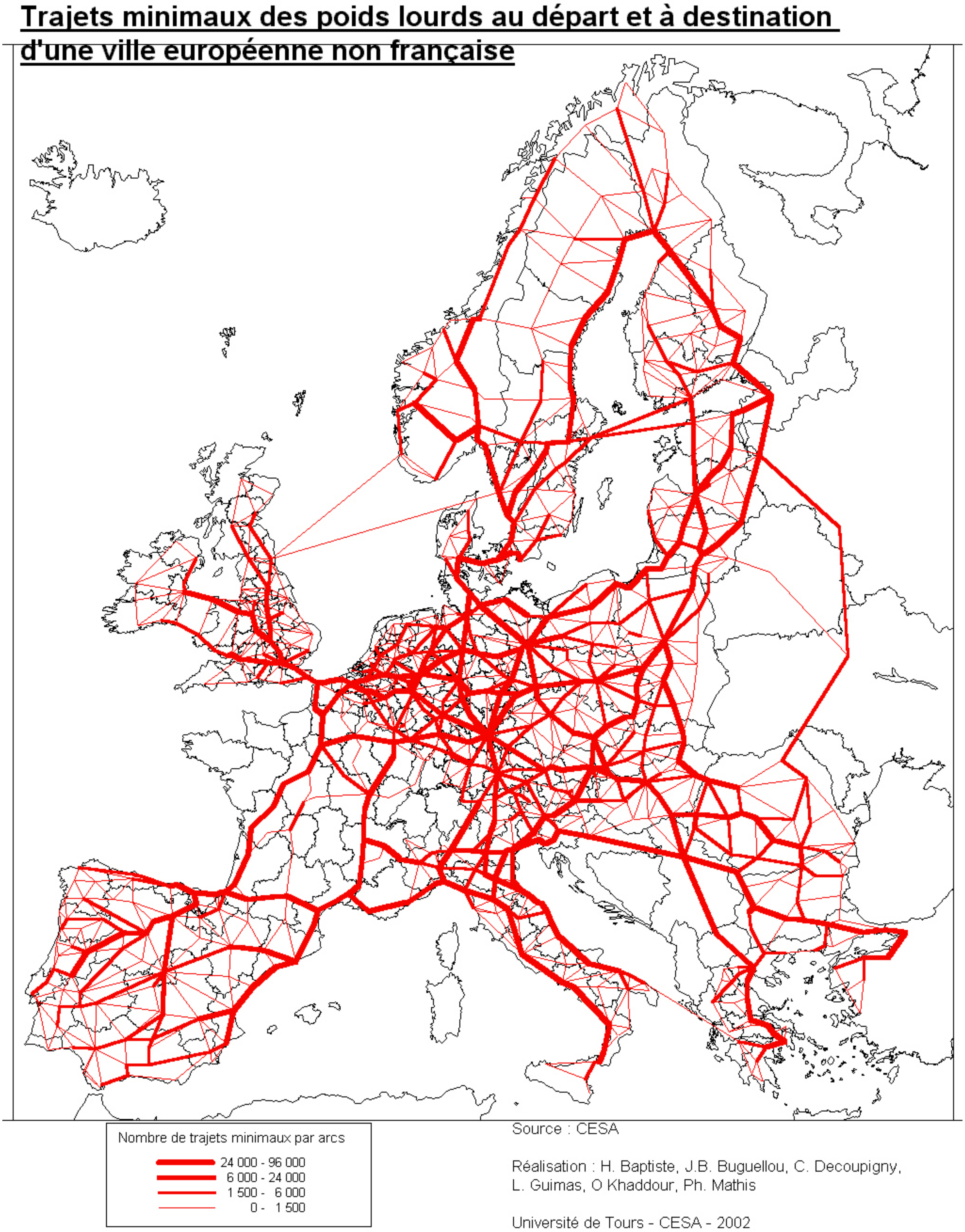


Figure 5.5.3.2 Potential flows from peripheral countries to the others

The minimum paths pass through France. This map is identical to the map of foreign lorries traffic in France (1997). This network is very simple two corridor with five junctions.

This case is very favourable for modal transfer.

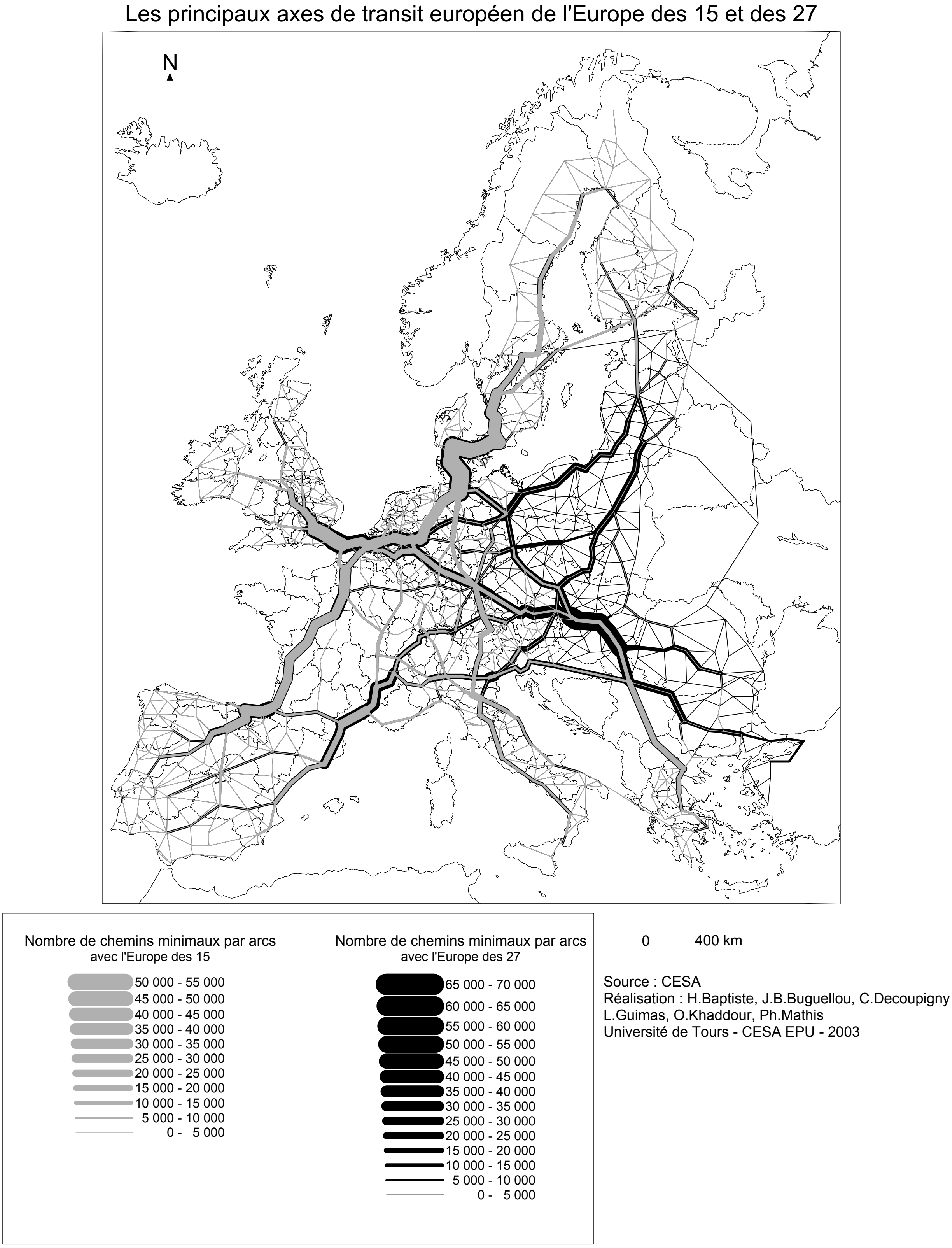


Figure 5.5.3.3 Differential map of potential flows between Europe 15 and Europe 27

The superimposition of shortest paths numbers of EU15 on shortest paths EU 27 is more interesting than the simple differential map because it allows to see the two values and their ratio. The trend is really more East-West than North-South in Europe 27.

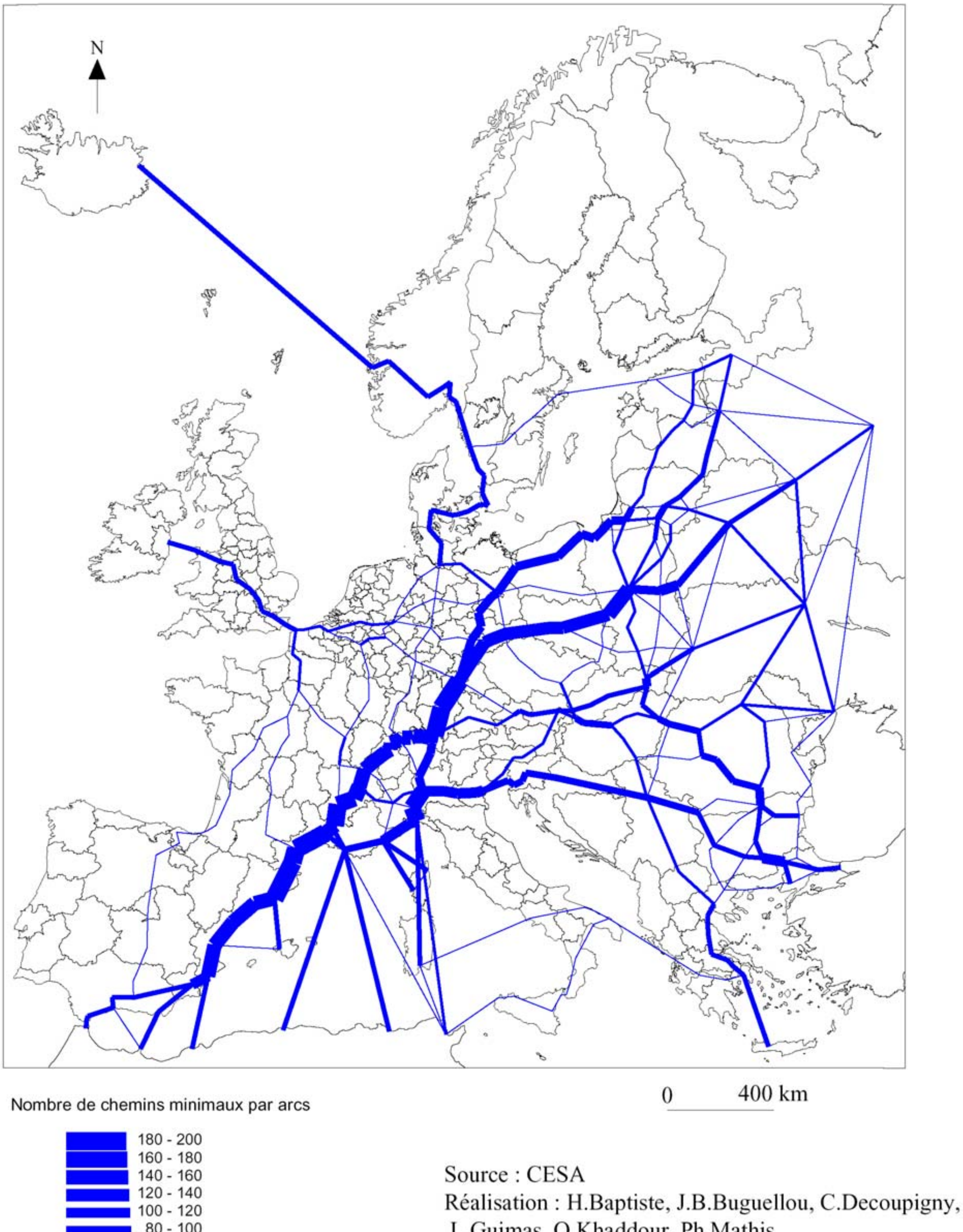


Figure 5.5.3.4 South-East transit across Europe

One see very distinctly the great diagonal SW-NE in Europe from Magrheb to Poland. It doubles the first and older Lisbon-Paris-Stokholm.

Currently the corridor N-S is the more significant with the weighting of the paths by goods exchanges, but for how long?

5.5.4 Freight transport

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 UIC network and O/D data estimated by NESTEAR.

Demonstration example

In the first point of this second interim document the influence of transport operating system on transport costs and time, and consequently on accessibility has been stressed, showing that operations constraints and performances do introduce more spatial differentiations.

This introduction of operating system will also affect the choice of route and the assignment on network.

Finally on the same route or O/D relative performance of a mode might also change according to the type of the day or the segment of market: for example speed of trains varies according to the type of train and vessel and performances between two ports will depend whether it is bulk product or RoRo service.

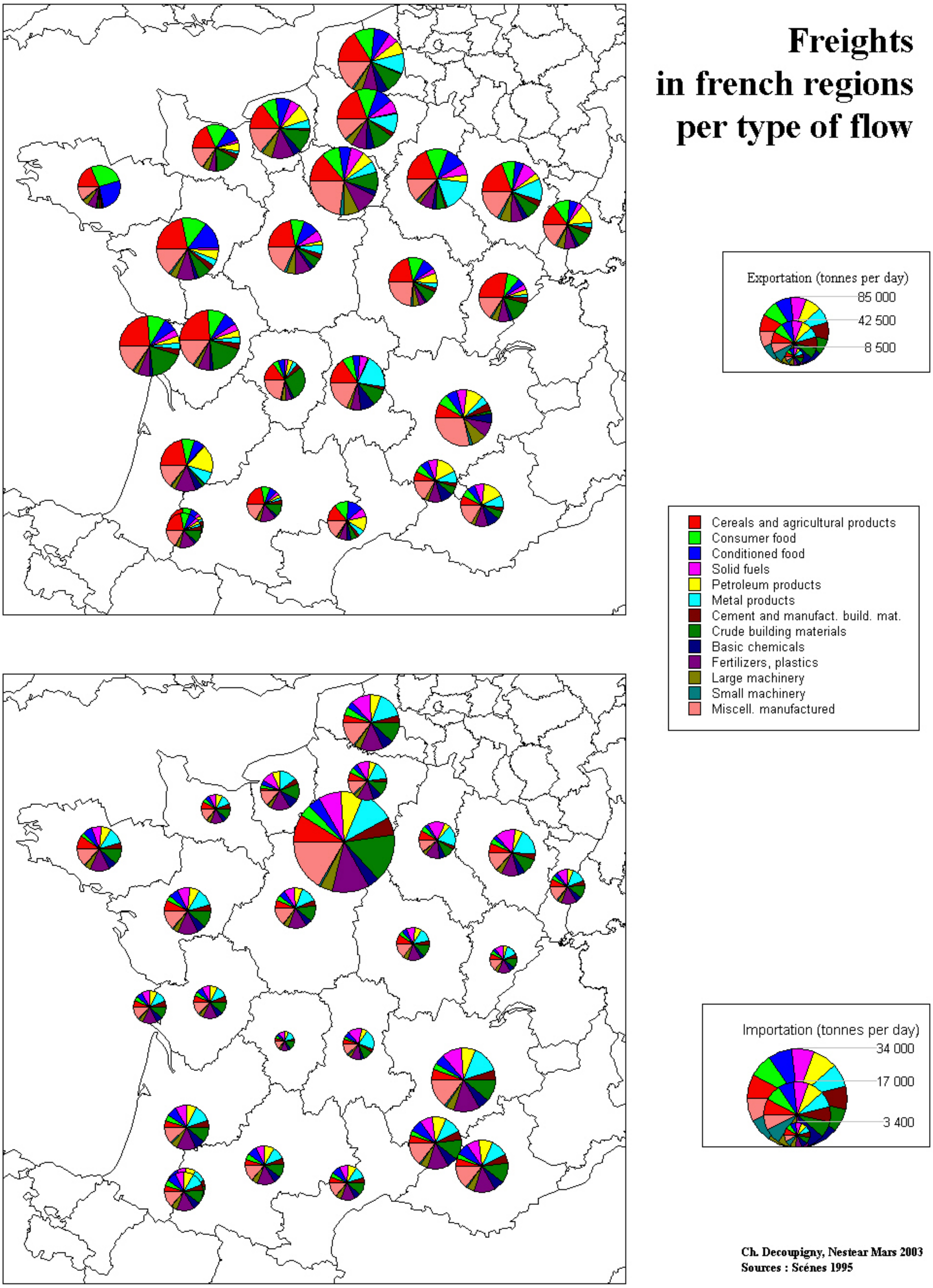


Figure 5.5.4.1 Sample freight in NUTS 2 regions per type of flow

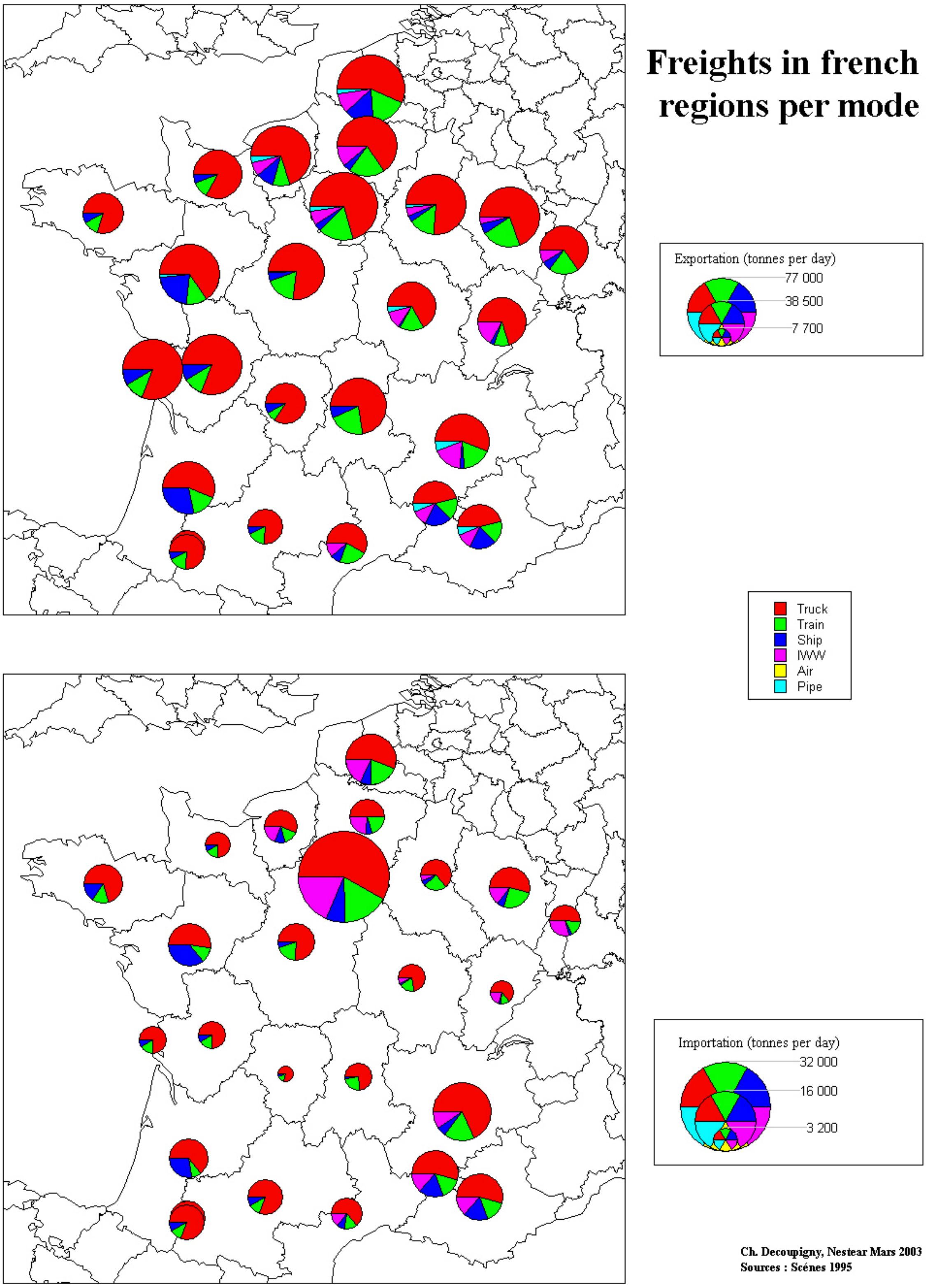


Figure5.5.4.2 Sample freight in NUTS 2 regions per mode

5.5.5 Freight road assignment maps

Road assignment maps have been focusing on the crossing of Pyrenees which are the corridor where a very high road increase of freight traffic has been observed: a doubling between 93 and 99 of truck traffic according to the CAFT survey, which means a route, two times higher than transalpine traffic.

These maps show clearly what are the possible alternative routes for road taking into account the resting time constraints of drivers.

However when company with observed traffic assignment some links with higher gradient (slopes) such as in Massif Central in France must be corrected so that it will more clearly appear that, at the present time, trucks still use a longer road in Rhone Valley with lower gradient. Problems of this type also exists in Southern Spain and will be corrected. The flows taken as reference are international traffic flows of long distance which characterised the foreign trade market of Spain: network is GISCO network and traffic flows come from SCENES project which has been a reference project for DG TREN traffic analysis.

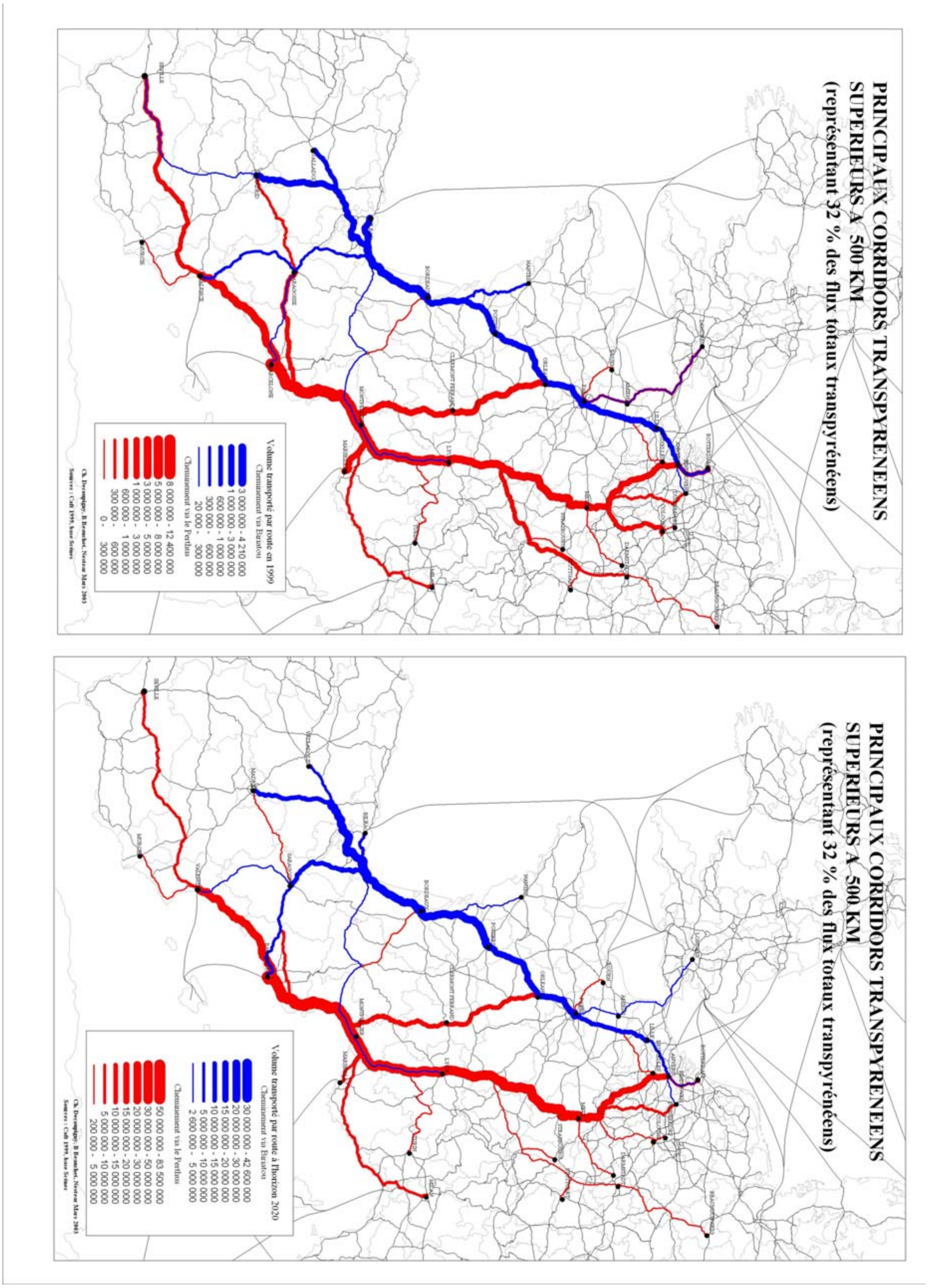


Figure 5.5.5 Sample freight road assignment map

5.5.6 Freight rail assignment maps

For rail assignment differentiation is made between direct trains and single wagon trains which go through marshalling yards.

The assignment differentiation is made between direct trains and single wagon trains which go through marshalling yards.

The assignment shown concern the direct trains in European networks: the network used is UIC network made compatible with GISCO network and information in traffic flows were obtained from EUFRANET project.

The "dedicated freight network" proposed by EUFRANET is also given as illustration, because on such a network with Europe there could be substantial reduction of time and cost of rail transport because of potential concentration of flows on such network, and possibilities on such lines to give more priority for freight.

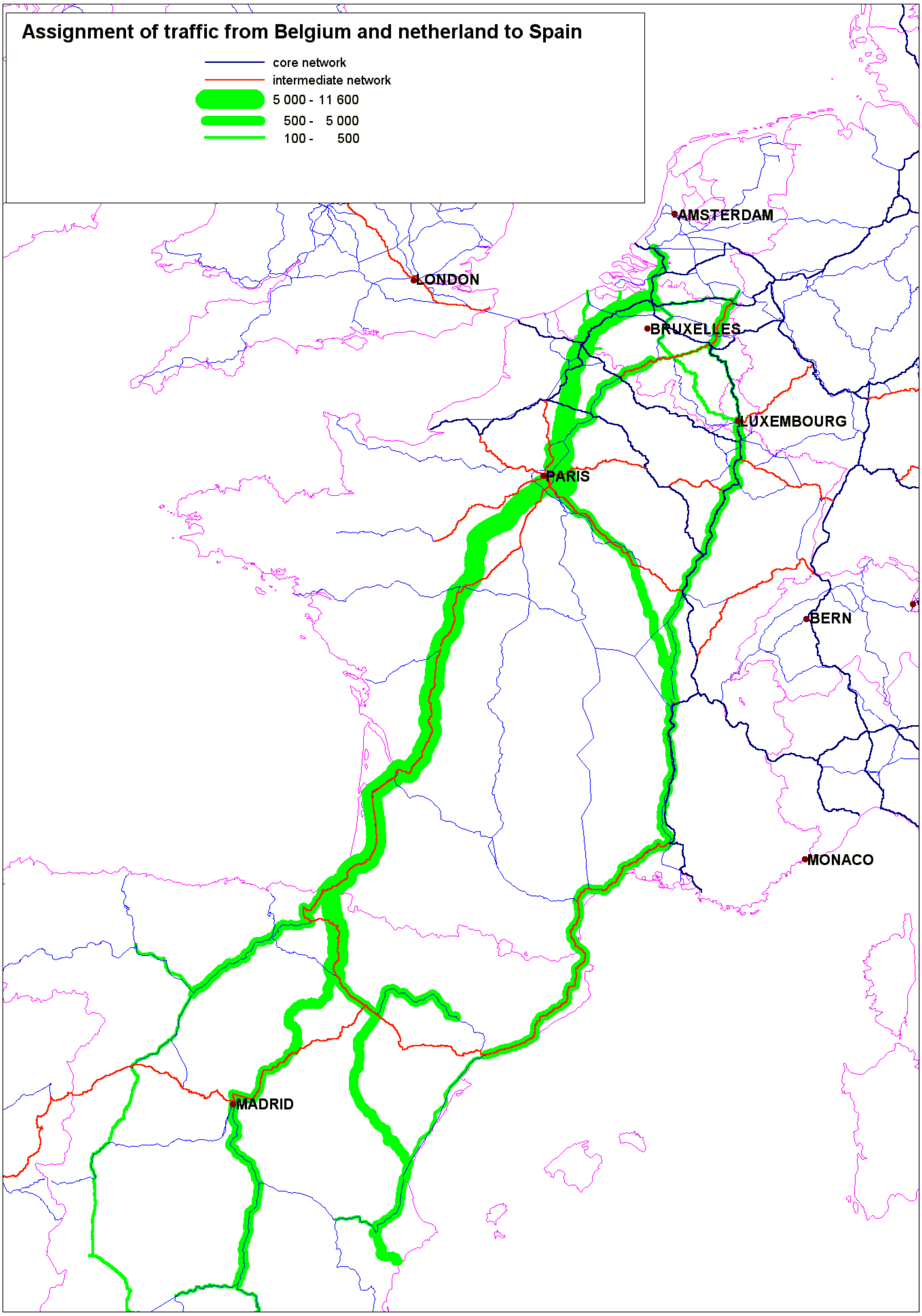


Figure 5.5.6.1 Sample freight rail assignment map

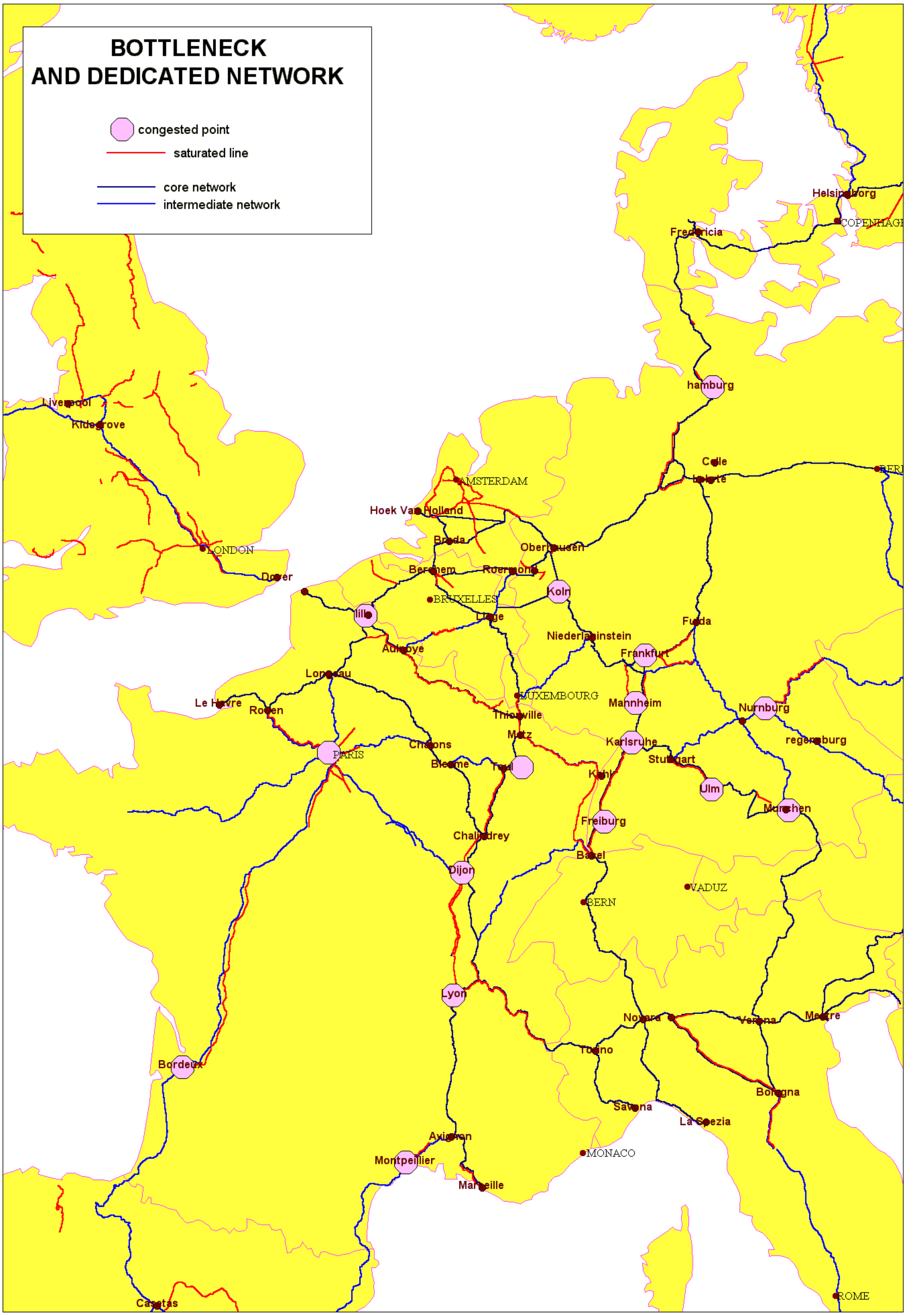


Figure 5.5.6.2 Bottlenecks and dedicated network

5.5.7 Differentiation of rail speed

Rail speed and time is often a debate ; when trains are running the speed is not so low as average speed between the origin and destination let it suppose.

5.6 Transport externalities

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

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

5.6.1 Road traffic deaths

Rationale

Deaths and injuries in road accidents are one of the most direct negative impacts of the transport system on human beings. Road traffic deaths have been selected here as transport externality indicator.

Method

The method applied here is data collection from harmonised sources and standardisation of data by relating traffic deaths to regional population to make the data comparable across regions.

Data requirements

The REGIO database of Eurostat contains data on deaths and injuries in road accidents at NUTS-2 level in a time series going back to 1988 (European Commission, 2002). Harmonised data on NUTS-3 level are not available

Demonstration example

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.

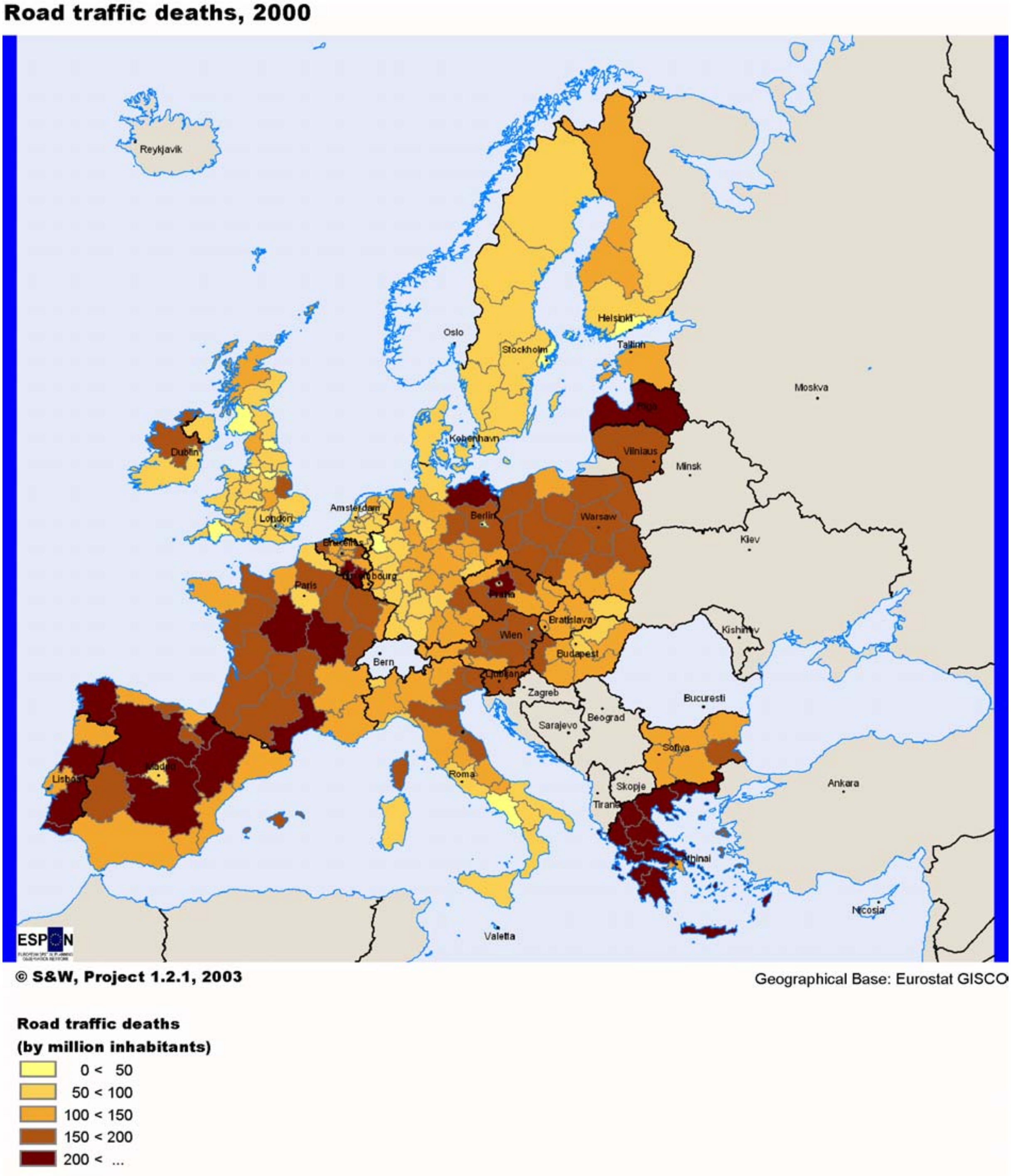


Figure 5.6.1 Road traffic deaths, 2000.

5.6.2 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 5.5. 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 later phases of the project.

5.6.3 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 later phases of the project.

5.6.4 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 km² and is still 175 km² 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 km² in Belgium to about 600 km² 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 later phases of the project.

5.7 Network vulnerability

Analysis of the climatic vulnerability: flooding example

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.

The software reproduces or simulates effects of the floods on the road and railway infrastructures. The software was used to model the risings of the Loire whose most notable consequences would be strong disturbances with regard to:

- the accessibility to the most important cities
- North-South traffic passing in transit through this area
- accessibility to strategic infrastructures (nuclear thermal power station, stations of purifications...) and public (hospital, schools...)

The aim of these works is double :

- To develop an evaluation modelled with the consequences of centennial or multicentennial risings on transport networks.
- To check the accessibility of large strategic and public equipment.

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 from flooding, snow, ice, storm…
- The geological risk: landslide…
- The anthropic causes: from the technical, technological or human error to the will to temporarily or definitively stop this functionality, whatever the reason or the means are.

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 points, 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. For example, England is not related to the continent by the road and the connectivity of Scandinavia and Finland is due to the bridge of OSLOW and the passage through St Petersbourg, there is no territorial continuity.

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.

One will distinguish for the vertex one point of articulation or pivot and its extension to the set of articulation, and for the arcs, the isthmus or the whole of isthmus:

A point of articulation or pivot

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

Isthmus

An 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 connectivity 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 connectivity 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.

Methodology

The example of the middle Loire valley.

We retained as an example the catastrophe scenario of an extreme rising such as the whole bridges of the middle Loire would be inaccessible. The results of this simulation are provided in the form of a map: accessibility by the minimal ways translated into times of distance between, before and after the removal of the bridges, a map of the minimal ways before and after removal of the bridges, a zoom on the area of Blois-Tours and on the one of Amboise.

These maps show a relative regionalization of the effects, the decrease of the relative difference being clear from the banks of the Loire. If this difference in absolute value is constant, it naturally decreases in relative value progressively with the increase of the covered distance. The increase of the time distance is important for all the destinations and considering the importance of the traffic, the cost will be considerable.

Data requirements

But the problem lays in the sufficiently precise data layout: a digital model with a decimetrical precision.

For ESPON Project 121, the use of the hydraulic model will be replaced in a first evaluation by CORIN LAND COVER and the air photographs of the floods of the summer 2002. The logic of the model being the same one from these data, the level of floods could then be modified

The result on the ESPON Space should be available for August 2003.

The next maps are a example on the Loire Valley at three scales.

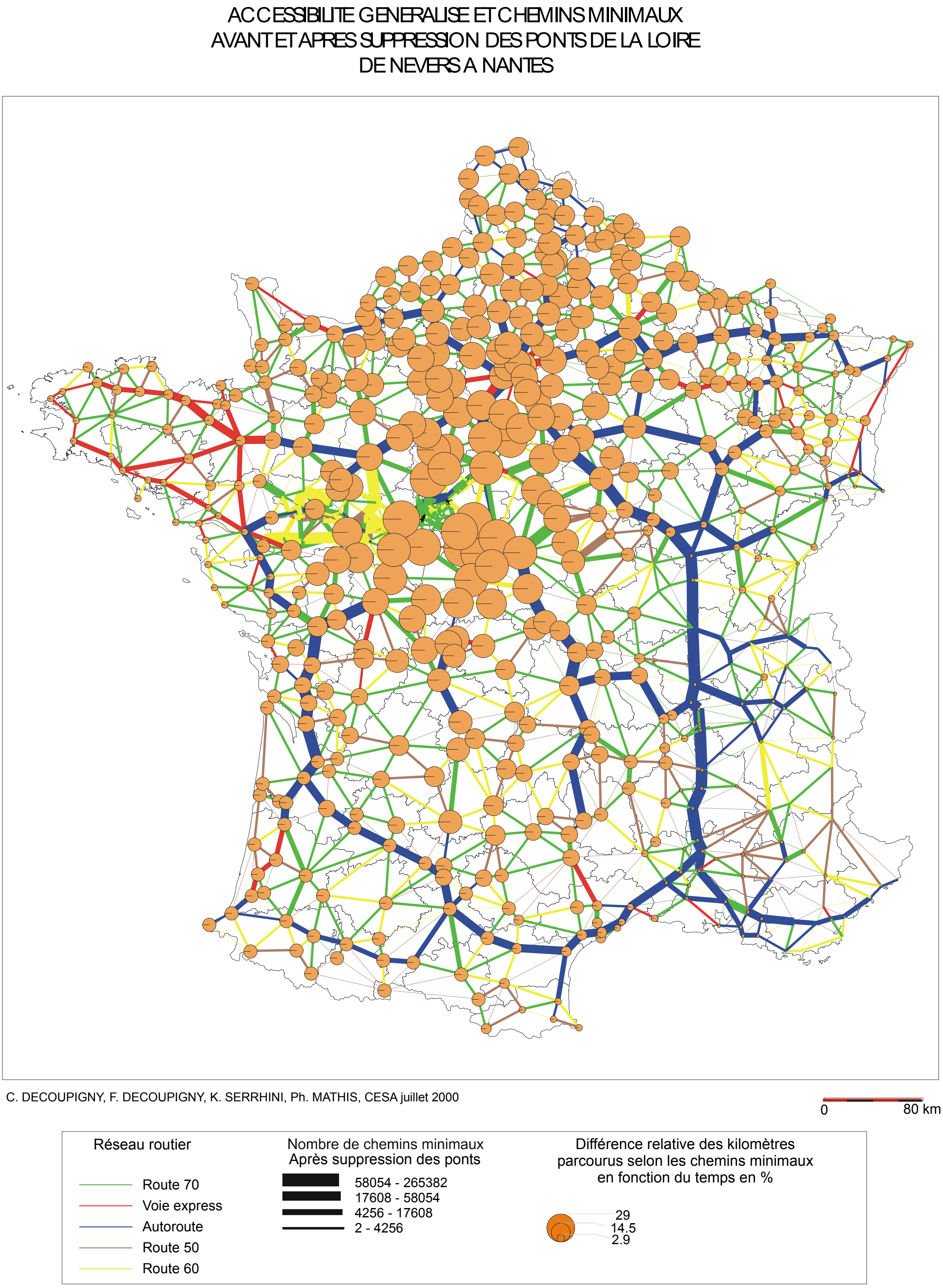


Figure 5.7.1 Sample network vulnerability for France

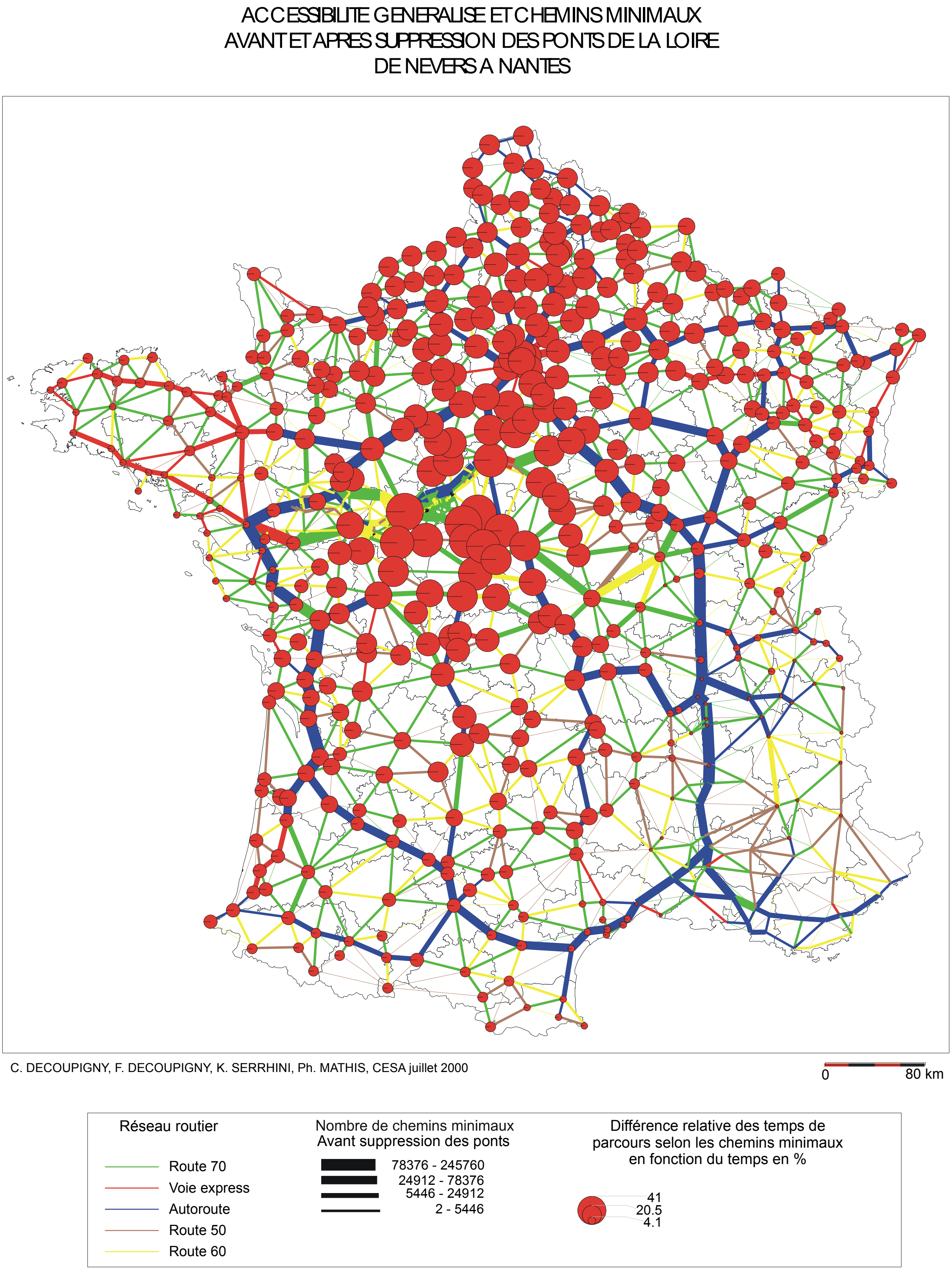


Figure 5.7.2 Sample network vulnerability for France

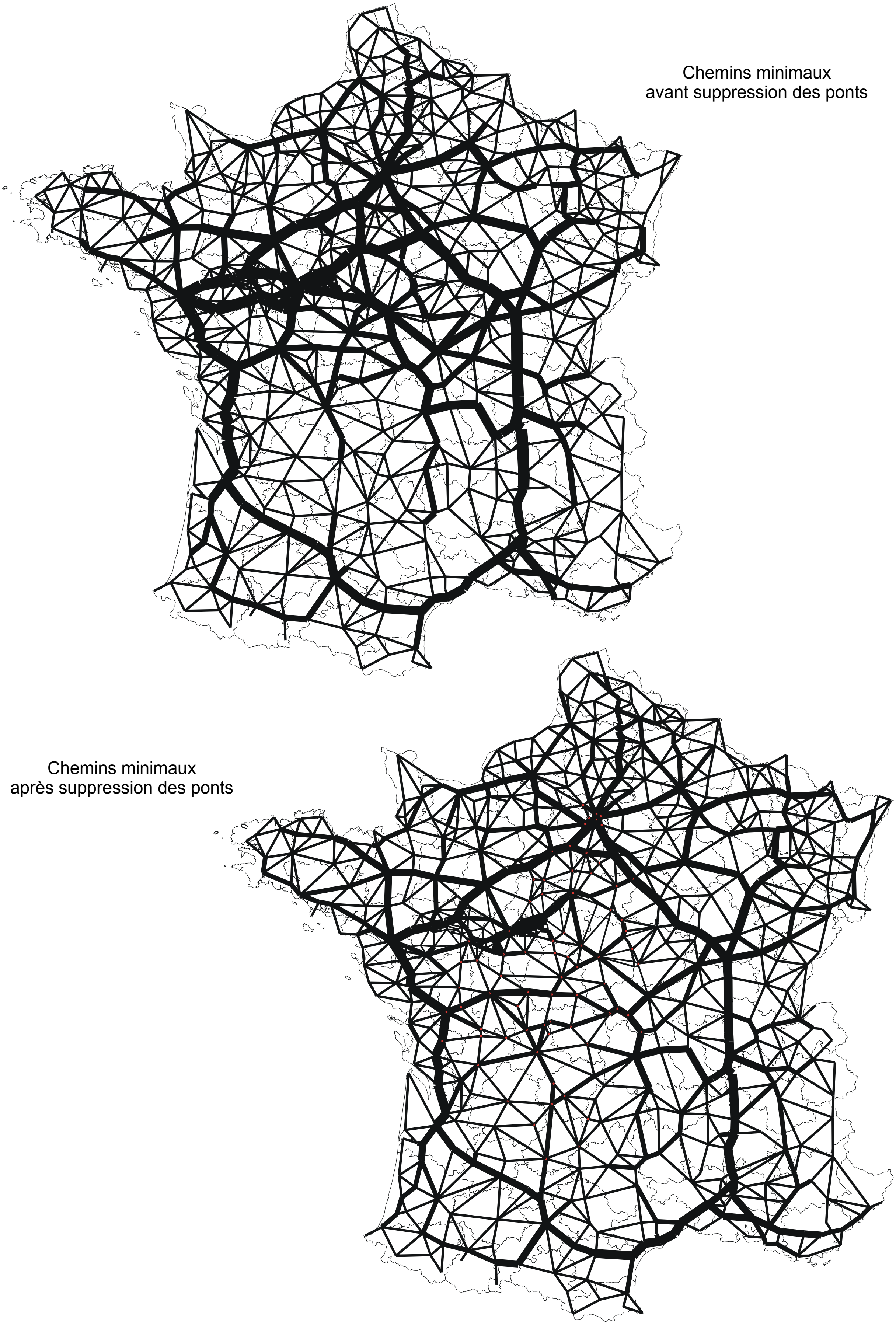


Figure 5.7.3 Sample network vulnerability for France minimum path

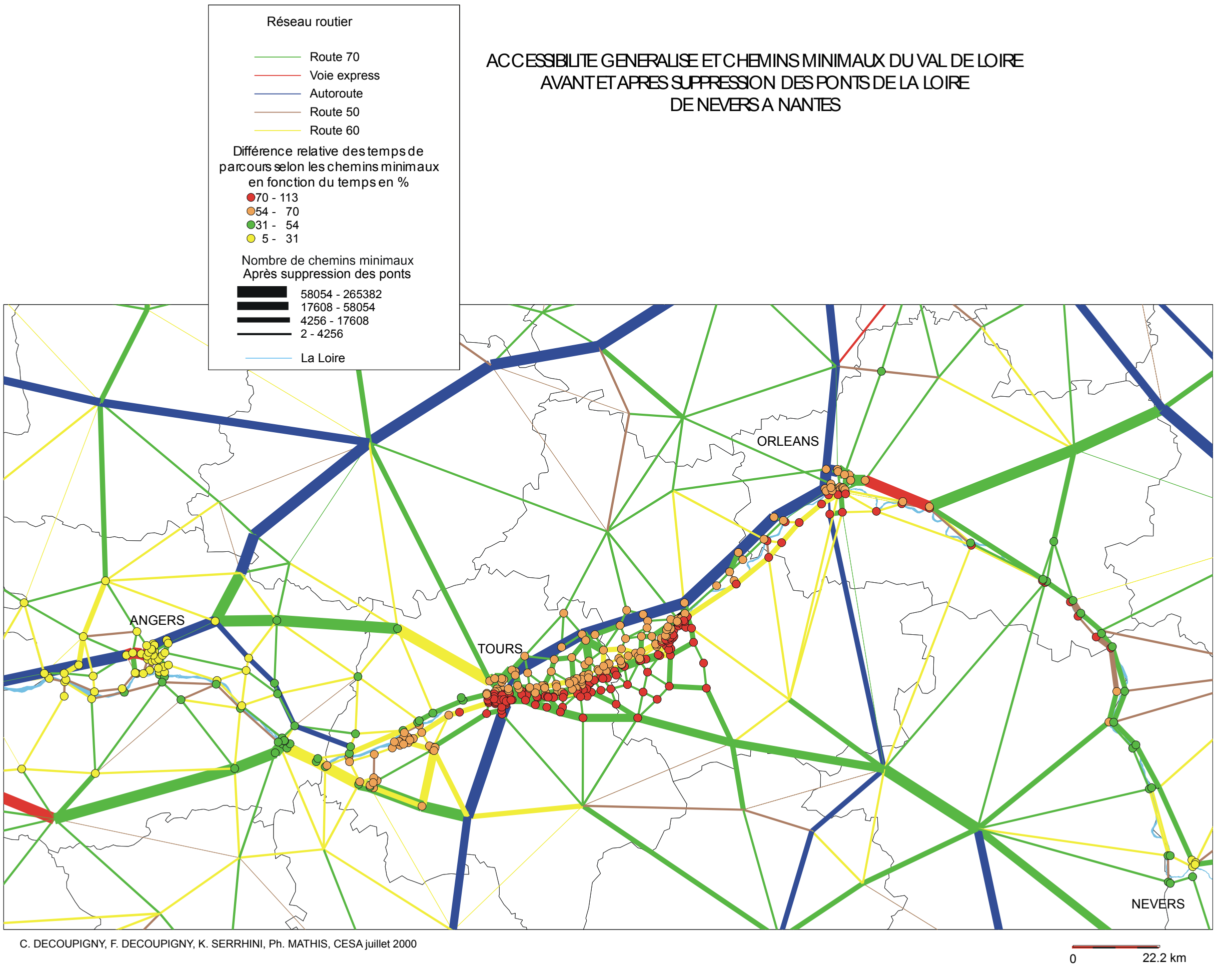


Figure 5.7.4 Sample network vulnerability for regional space

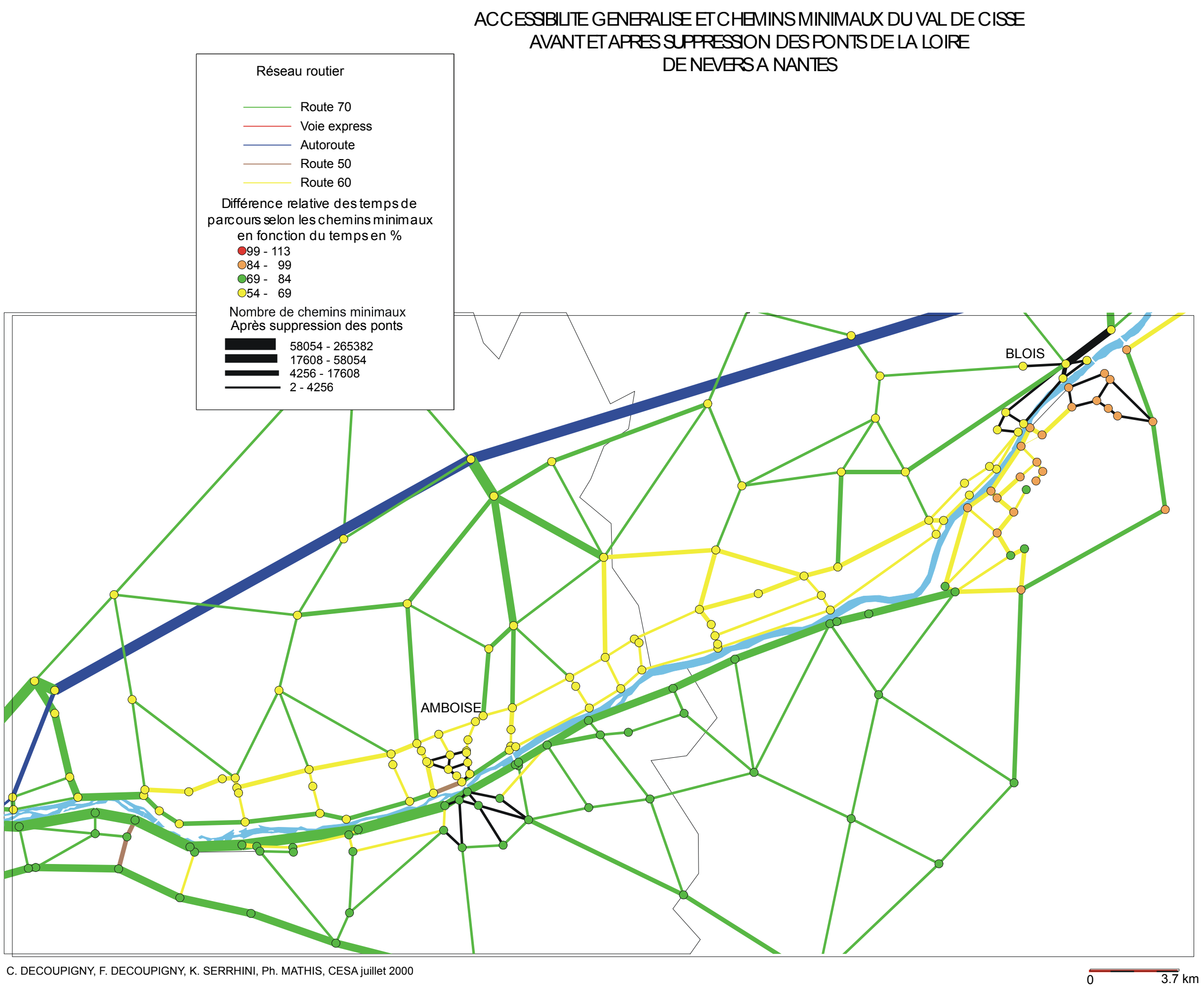


Figure 5.7.5 Sample network vulnerability for local space

6 New map types

The ESPON programme is organised around thematic teams that share concepts, data and indicators. To facilitate the exchanges inside the ESPON a common platform including a common cartographical design based on regional choropleth maps is being built, under which all the results are supposed to be expressed. Nevertheless, concerning transport issues, the developments of cartography –understood as the field of geographical visualisation– proposes different types of representations that can be of great interest for the understanding of spatial dynamics. Based on previous developments of project partners a range of innovative mapping methodologies is developed in order to gain new insight in territorial aspects of transport infrastructure and services.

Time-space cartography is a domain in which innovation in map design has been very dynamic in recent years. Configurations that moves the locations of places and crumpled time-space that uses the third dimension to draw the networks are presented here. A third way of mapping time-space is then presented in three dimensions and using thematic mapping techniques.

Thematic three dimensional mapping techniques can also be used to represent flow data, as can be seen on a map that shows the European corridors.

6.1 Time-Space Maps

There are different methods to display the interrelation of space and time on a map. Three types of maps can be distinguished: isochrones maps show temporal relations in space by preserving the spatial distances between map elements. Cognitive maps visualise the temporal efforts of travel by associative illustrations that are not exact in cartographic terms. Time-space maps represent the elements of a map in a configuration based on the travel times between them. For ESPON 1.2.1, in which the effects of trans-European transport policies are to be investigated, time-space maps are of interest because they show the European continent is moving closer together.

Rationale

Time-space maps represent the time space. The elements of a time-space map are organised in such a way that the distances between them are not proportional to their physical distance as in topographical maps, but proportional to the travel times between them. Short travel times between two points result in their presentation close together on the map; points separated by long travel times appear distant on the map. The scale of the map is no longer in spatial but in temporal units. The change of map scale results in distortions of the map compared to physical maps if the travel speed is different in different parts of the network.

If one assumes equal speed for all parts of the network, the result is the familiar physical map. Time-space maps with equal speeds can be used as reference for the interpretation of other time-space maps.

Time-space maps may include all elements of normal maps such as coast lines or borders, transport networks or single buildings. In practice only elements relevant for understanding the map are displayed. The emphasis is on the distortions of time-space maps compared with physical maps or with other time-space maps.

Method

Time-space maps are created by transforming physical coordinates of a physical map into time-space coordinates. The transformation is calibrated in a manner that the distance between two points on the time-space map is in as close agreement as possible with the time distance between them. Because there are different speeds in the network, it is not possible to exactly reproduce the time distances of a time-space map in two dimensions. This would require a coordinate space with more dimensions. Time-space maps therefore can only be approximate.

Usually the technique of multidimensional scaling (MDS) is used for generating time-space maps. If the differences between a set of phenomena in one dimension (in metric or non-metric units) are known, the MDS technique generates a spatial configuration in multidimensional coordinate space of additional attributes of the phenomena such that the distances between the items are as close as possible to the known distances. The MDS approach was developed in psychometrics in order to analyse, for instance, similar or different reactions of persons on multiple stimuli through visualisation in multidimensional space. Time-space mapping is an example of applying metrical MDS.

The calibration points may represent cities or other places, but they do not represent a complete map. Other map elements such as coast lines or borders have to be added. The time-space coordinates of the additional elements are not generated by MDS but by interpolation. The transformation of physical into time-space coordinates can be represented by displacement vectors or offsets in X- and Y-direction. These vectors indicate for each calibration node the transformation from physical to time-space coordinates. Offsets of additional map elements can be calculated by interpolation between the offsets of adjacent calibration nodes. This is normally done by calculating the mean of the offsets of the closest calibration nodes weighed by their distance.

There are several problems associated with time-space maps. Technical problems include the possibility that the topology of the map is destroyed. For instance, if from a certain origin node a more distant node can be reached faster than a node closer by, the map will be 'warped'. Several modifications of the original method have been proposed to overcome that difficulty (Spiekermann and Wegener, 1994b). Conceptual problems are related to the fact that time-space maps show travel time reductions only for the most accessible nodes of the networks. What they do not show, or even hide, are the much smaller travel time reductions in the areas *between* the nodes. In some cases travel times there may even increase, for instance when with the introduction of high-speed rail intermediate stops of former express trains are only served by local trains. This, however, is not revealed by time-space maps.

Data Requirements

To construct a time-space map requires two sets of data, usually maintained in a geographical information system (GIS): network data and map data.

- *Network data* consist of a set of calibration nodes with their geographical coordinates and the travel times between them over the calibration network. The travel time data can be current travel times or assumed future travel times if the effect of network improvements on the time space are to be investigated.
- *Map data* consist of GIS data (points, lines or polygons) of other map elements besides the calibration network, such as locations of cities, coast lines or regions, i.e. all map features that are to be visible on the time-space map.

Demonstration Examples

Figure 1 (top) shows time-space maps of the rail network in Europe in 1993. It can be seen that countries in which already high-speed rail systems were in operation, are contracted compared to their familiar shape, whereas countries in eastern Europe appear larger than usual because their rail systems were still underdeveloped. Figure 1 (bottom) shows how the same map will look in 2020 if the present TEN-T outline plan will be implemented. The full 'space-eating' effect of high-speed rail becomes visible with the implementation of the trans-European rail network. In 2020 the continent will have dramatically shrunk in time space, yet its shape will have become more similar to the familiar physical map.

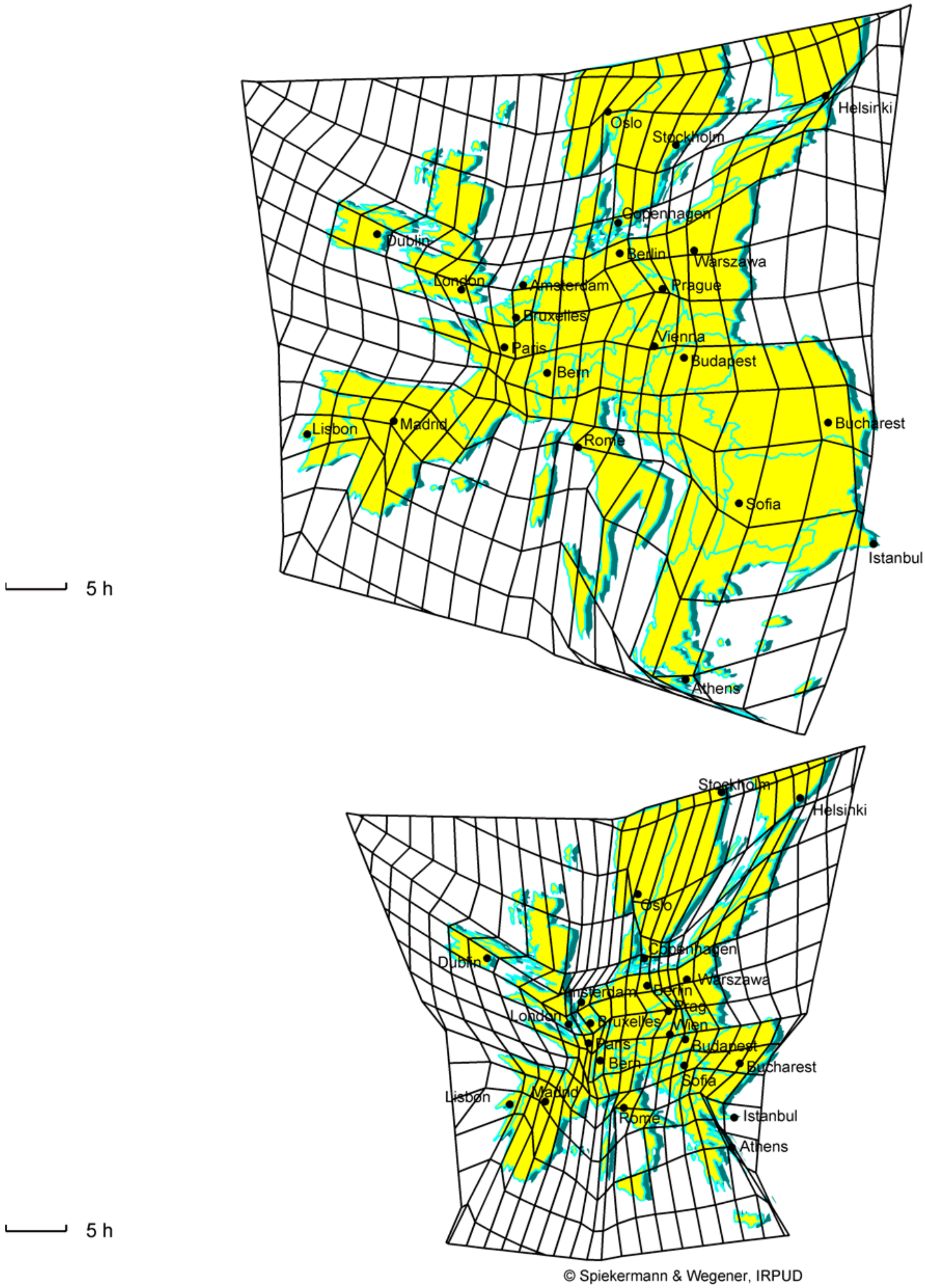


Figure 6.1 Time-space maps of rail travel times 1993 (top) and 2020 (bottom)

6.2 Crumpled time-space maps

The creation and the improvements of the fast transport systems have for effect to modify the time-space. The question of the representation of this complex interaction is of major interest for a better understanding of the spatial effect of the transport networks.

Rationale

Time-space as it is produced by the inscription of transport networks in the territory, is strongly distorted by the high speed terrestrial networks, motorways and high speed trains. When new high speed infrastructures opens, some places are coming closer together whilst some parts of the territory –some of them located in the very neighbourhood of the high speed networks– are not touched by the accessibility improvements. The time space modified by transport networks is deformed by two distinct movements: a global contraction, and a more local distortion due to the articulation or interconnection between high speed transport and usual networks and space. If anamorphosis maps illustrates this global contraction, it sometimes fails on expressing the second distortion due to the confrontation of high speed and lower speeds.

Crumpled time-space maps aims at representing the complex movement of contraction due to the transport systems including high speed and lower speed networks irrigating space. This type of representation must be seen in complement to the anamorphosis map, each map expressing a different view on the same object.

Method

On the time-space relief map the length of each link is proportional to the time of the journey according to the speed allowed by the transport mode, and several transport modes are represented. The speed differential between modes is represented in the third dimension. The model supporting the representation uses averaged speeds for each distinct network: high speed trains, motorways, and roads.

The principle of construction of the crumpled time-space maps can be expressed in the form of three constraints :

- the location of the vertices of the graph (nodes) corresponds to their usual geographic position.
- the length of the edges of the graph is proportional to their effective length (it can be kilometres, hours, a cost, or a combination of the three) ;
- to make the proportionality of the length possible, the edges are drawn in the third dimension.

The fastest links takes the form of direct segments drawn in the plane of the cities, whilst slower links are drawn under the form of two segments in the third dimension, under the plane of cities. By means of a time-space scale, the distances in the network can be read.

Transport data requirements

The data necessary to produce the crumpled time space map resides in the graph representing the transport network. The length in kilometres of each arc representing a link of the network corresponds to its length in kilometres. Average speeds for each network are considered:

- High speed trains: 220 kilometres per hour
- Motorways: 110 kilometres per hour
- Usual roads: 90 kilometres per hour

From these data –lengths in kilometres and speeds– lengths in time-space are determined.

Demonstration example

The given example is a crumpled time space map of Europe with 425 nodes and three transport networks, high speed trains, motorways, and roads at the year 1999. The emerging high-speed rail network is the cause of the global contraction of time space, but the gaps between sub networks are patent. If the crumpling is more pronounced in the peripheral parts of the continent, isolated cities –their deficit of accessibility is expressed by their position at the summit of a time-space peak– can also be observed in the core of Europe.

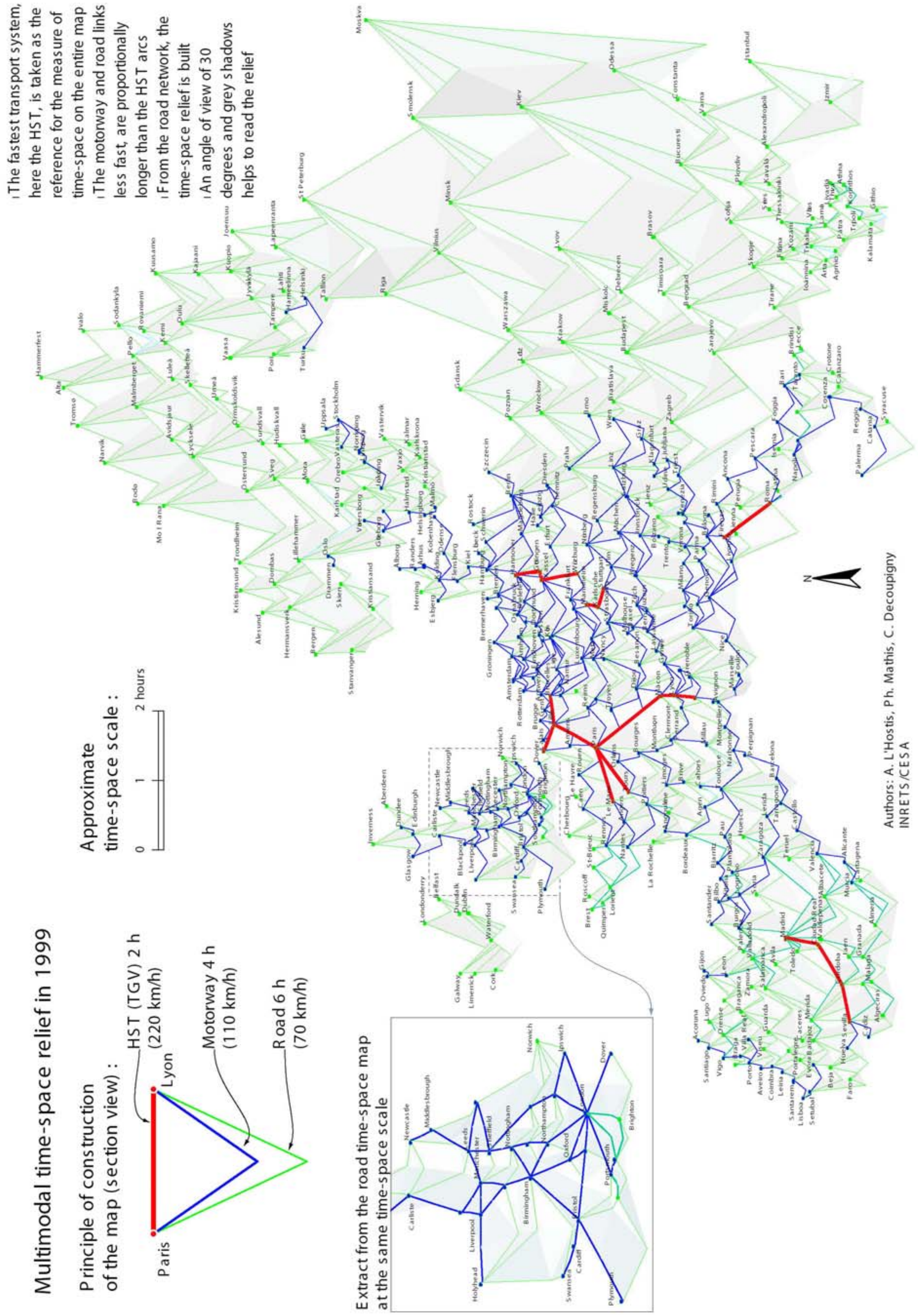


Figure 6.2 Multimodal crumpled time-space map

6.3 Raster-Based Accessibility Maps/Surfaces

It was noted in the section on time-space maps that time-space maps only show the accessibility of nodes of the networks analysed. What they do not show are the 'grey zones' of lower accessibility between the nodes. Time-space maps therefore tend to highlight the positive effects of high-speed network improvements on the nodal centres which are already highly accessible and hide the possibly negative effects on the areas in between.

Rationale

To overcome this problem, Spiekermann and Wegener developed spatially disaggregate accessibility indicators using raster-based GIS techniques (Spiekermann and Wegener, 1994a; 1996, Vickerman et al., 1997). In this method a raster structure is used to represent a quasi-continuous activity surface of Europe.

For that purpose the European territory is disaggregated into some 70,000 raster cells of 10 kilometres width. By making assumptions about the distribution of population and economic activity around large cities in the regions and about the mean access time form each raster cell to the nearest network node, accessibility indicators can be calculated not only for network nodes but also for each raster cell in Europe.

Method

As no raster data for Europe are available, synthetic raster data are generated by allocating the population of each region to the raster cells belonging to it. For each region first the population of large cities is allocated to raster cells at and close to their geographical location. The number of cells for each city and the population allocated to each raster cell is determined as a function of total population of the city using the model of urban density gradients by Clark (1951). After the distribution of the population of large cities, the remaining population of each region is evenly distributed across the rest of the region, i.e. a homogenous density of the population living in smaller settlements is assumed. The method leads to a plausible intraregional distribution of population taking account of population centres and meeting the constraint that the sum of the population of all raster cells is equal to the regional population total. In the same way, also a raster distribution of economic activity (GDP) can be generated.

Accessibility indicators are calculated by using each raster cell both as origin and destination, i.e. by generating a 70,000 by 70,000 origin-destination travel time matrix. The access time from each raster cell to the nearest node of the network is calculated by assuming an air-line travel speed of 30 km/h. The total travel time between two cells therefore consists of three parts: the access time from the origin cell to the nearest network node, the travel time on the network, and the terminal time to the destination cell from the node nearest to it. If the direct air-line travel time between two cells is shorter than travel over the network, the shorter direct travel time is used.

With this travel time matrix, all accessibility indicators discussed in Section 4.3 can be calculated. The result are accessibility indicators for each raster cell.

Data Requirements

A raster-based visualisation of accessibility indices requires three sets of data usually maintained in a GIS: *region data*, *city data* and *network data*.

- *Region data*: a file with the boundaries of the regions of the study area and their population and economic activity (GDP),
- *City data*: a file with geographical coordinates of major cities in the study area and their population,
- *Network data*: a file with the geographical coordinates of the nodes of the network investigated and the travel times between them.

Population, economic activity and travel times may be current or may represent assumptions about future developments or scenarios.

Demonstration Examples

The raster-based accessibility indicators so calculated can be visualised in raster-based accessibility maps or three-dimensional accessibility surfaces. Examples of raster-based accessibility maps are contained in Schürmann et al. (1997). Two examples of raster-based three-dimensional accessibility surfaces are presented in Figure 2.

Figure 2 (top) shows the surface of potential accessibility to population (population potential) by rail in 1993. Potential accessibility was calculated on the basis of 70,000 raster cells of 10 x 10 km width. The intraregional distribution of population and the access times from the raster cells to the nearest network nodes were estimated as described above. The elevation of the accessibility surfaces is proportional to its population potential The accessibility surface shows the large differences in accessibility between the major cities which are network nodes and the spaces in between. Although peripheral agglomerations such as Moscow, St. Petersburg or Istanbul are poorly connected to the network, they have high accessibility values because of their large population.

Figure 2 (bottom) shows daily accessibility to population by rail in 1993. Daily accessibility indicators were calculated as the total number of population of all destination cells that can be reached from the origin cell within a certain number of hours weighted equally regardless of travel time; for all other raster cells the weight is zero. Five hours is assumed to be the maximum one-way door-to-door travel time for a one-day return trip. The elevation of the accessibility surfaces is proportional to the population that can be reached within five hours. Even larger differences in accessibility than in the previous accessibility surface become visible. Urban regions have the highest and rural areas the lowest accessibility. Accessibility decreases from the city centres to the rural areas. Moreover, the areas in central Europe, both urban and rural, have a higher accessibility than regions at the European periphery. With a little imagination the 'Blue Banana', the European megalopolis stretching from London along the Rhine corridor to northern Italy, can be recognised. Although peripheral agglomerations such as Moscow, St. Petersburg or Istanbul are poorly connected to the network, they have high accessibility values because of their large population.

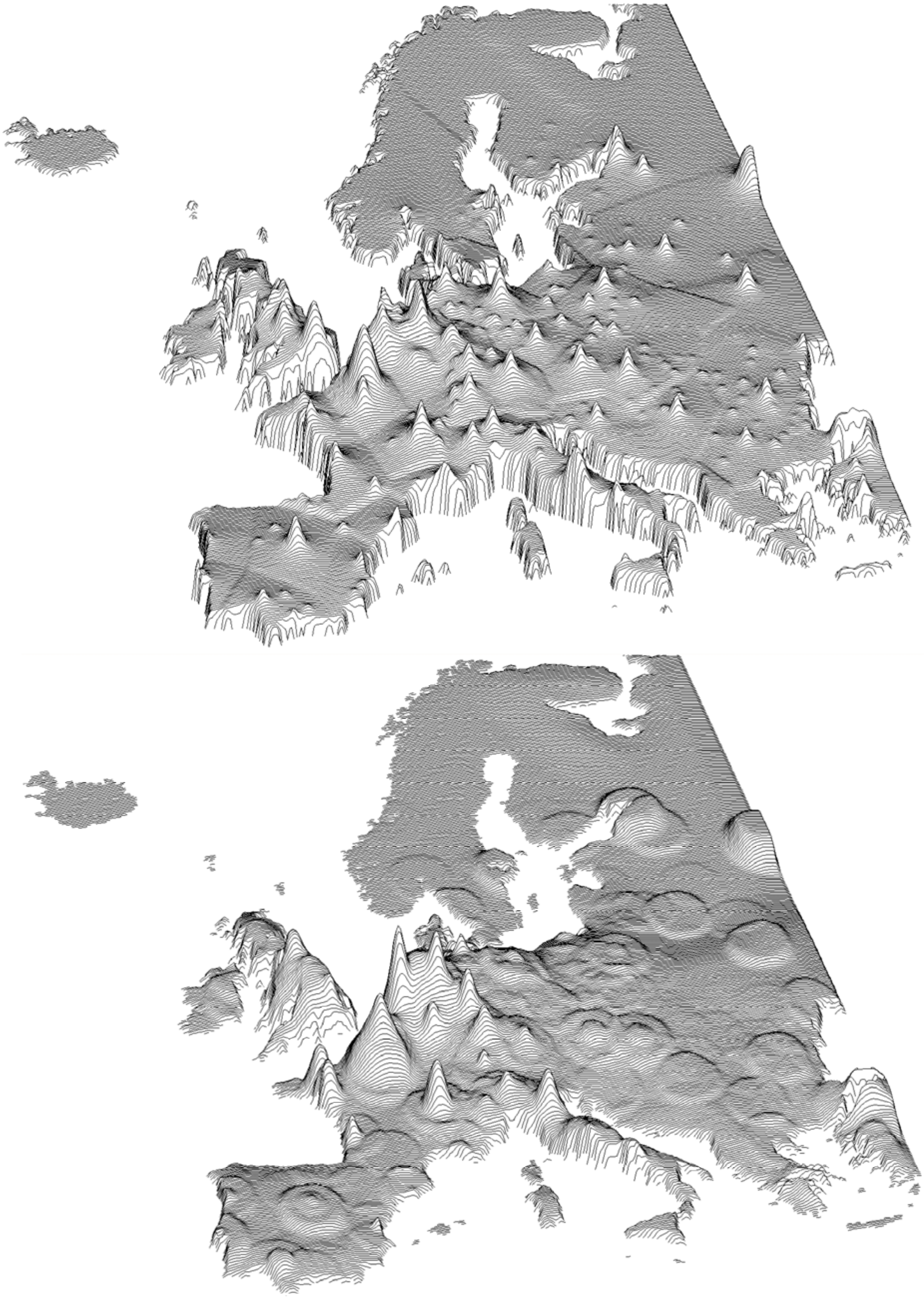


Figure 6.3 Accessibility surfaces: Potential accessibility (top) and daily accessibility (bottom)

6.4 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

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

Demonstration example

The data presented in the example come from 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.

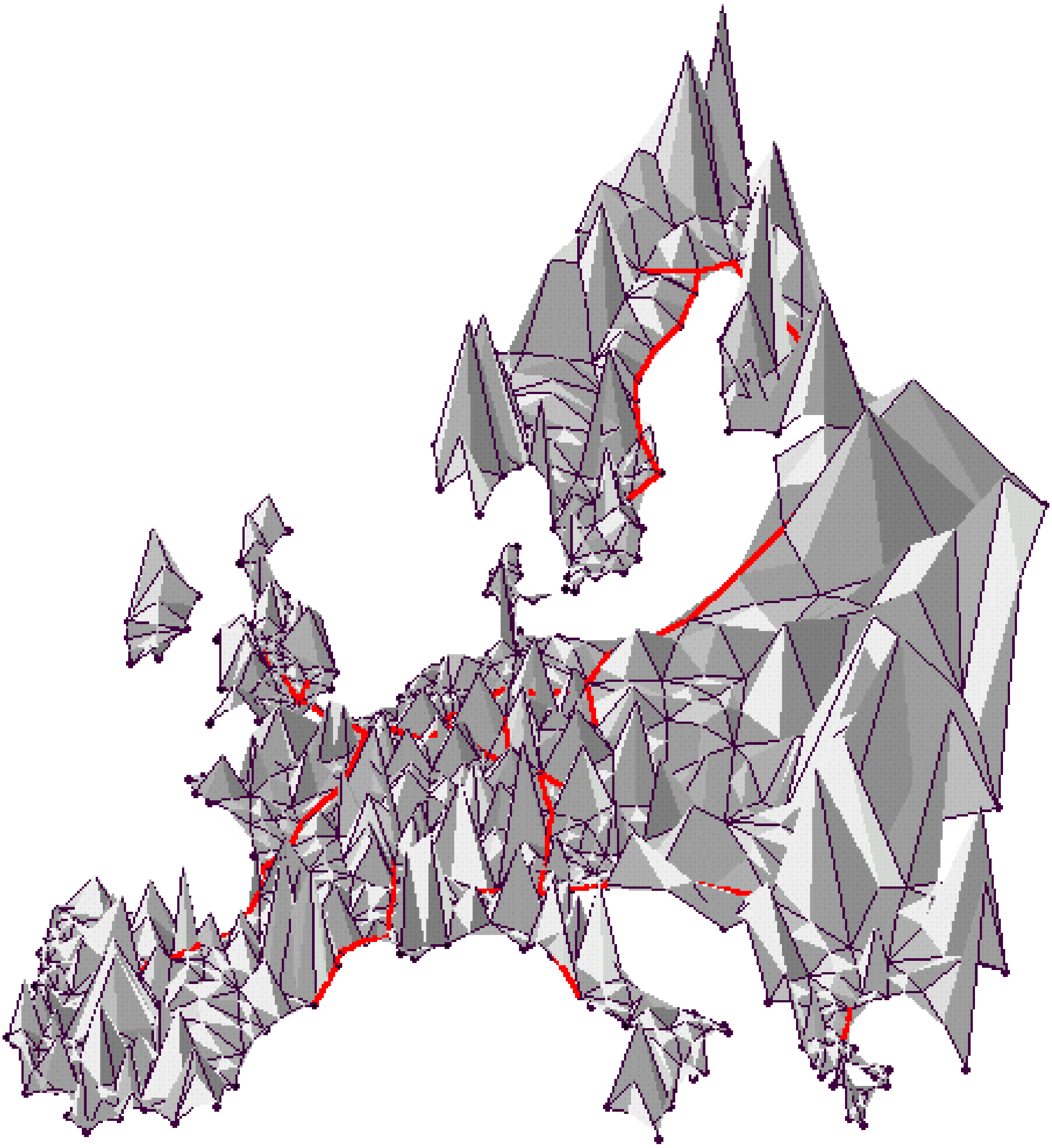


Figure 6.4 European transport corridors in relief based on minimum path

7 Typologies

7.1 Accessibility and GDP

There are essentially two ways to classify regions by their location in Europe, i.e. by their accessibility:

1. 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.
2. 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 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 1. Four types of regions corresponding to the four quadrants of the diagram can be distinguished:

1. *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.
2. *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.

3. *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.

4. *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.

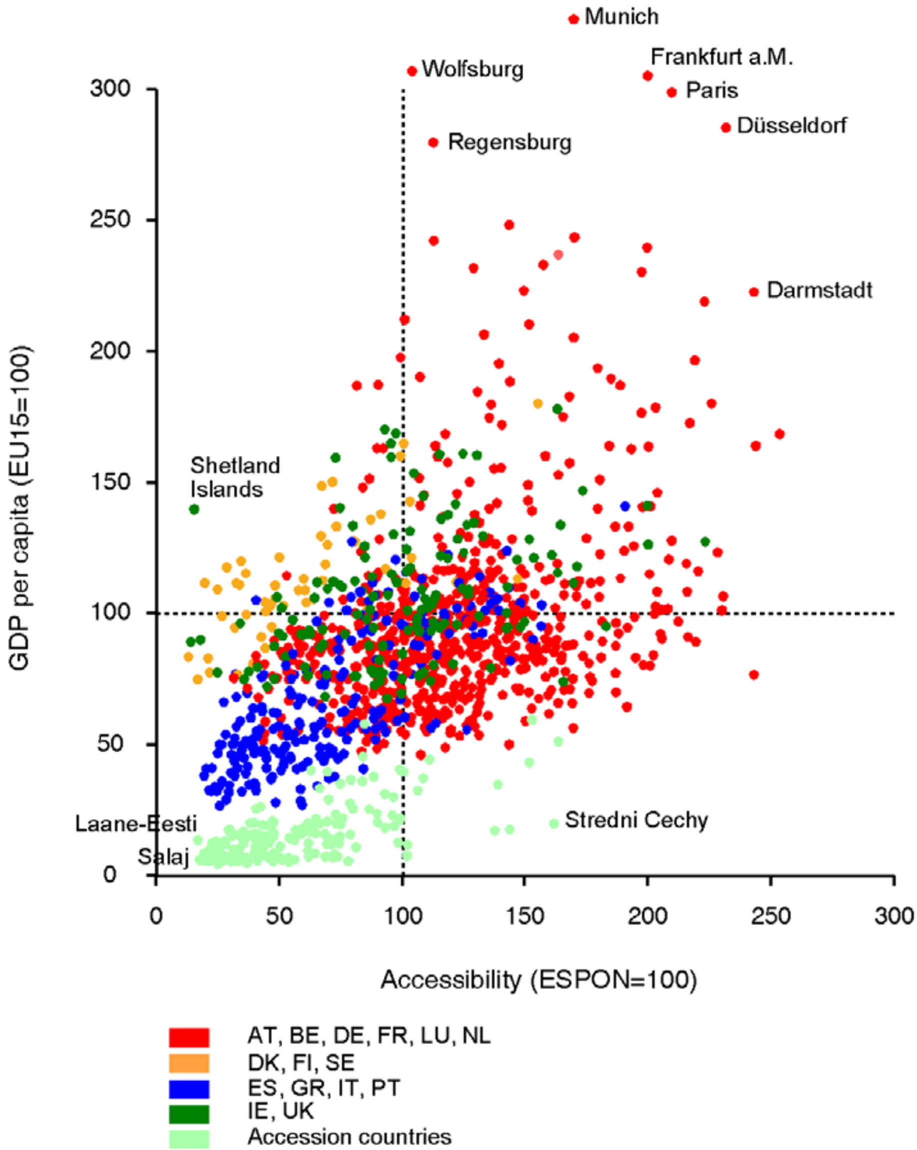


Figure 7.1 Diagram of accessibility and GDP per capita in NUTS-3 regions

Figure 2 shows the geographical location of the regions analysed in Figure 1. Now the colours indicate their position in the four quadrants of Figure 1.

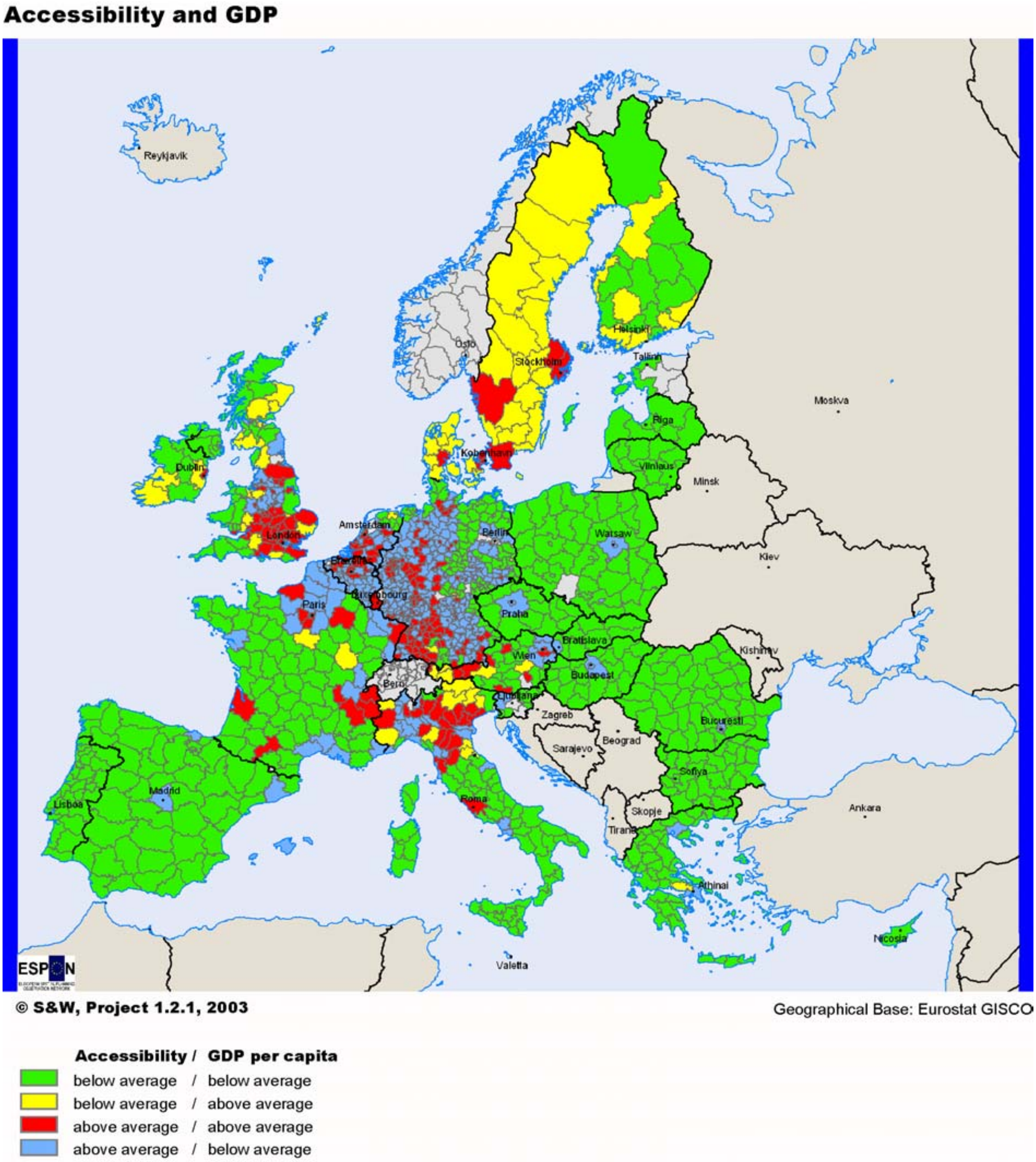


Figure 7.2 Map of accessibility and GDP per capita in NUTS-3 regions

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.

7.2 Transport networks and polycentrism

The results of the diagram classifying regions by Accessibility and GPD per capita at the Nuts3 level (see 7.1) suggest to study the relationships between the territorial settlements typologies and networks morphologies.

In the preliminary results of the diagram crossing accessibility/GDP per capita the distinction between rural and urban regions offers a synthetic but simplified image related to the settlements conditions of the territories in which the settlements typologies and the transport networks play an important role to specify the transport demands and infrastructural policies.

The indicators considered give an aggregate image in which stand out the territorial corridors and some regions with a strong potential that break the consolidated outline plans and they came the new main areas for cohesion planning policies[1].

The main aim is to analyse, in an integrated way, the infrastructure endowments and the territorial morphologies in some case studies selected in order to individuate planning programs purposed to improve territorial cohesion, and to facilitate, where it is possible, the polycentric relationships[2].

The hypothesis is that crossing the morphology of the networks with the morphology of the territorial settlement has an important role in modifying the results on the accessibility levels of the European Nuts3.

The idea is to analyse how different morphologies in the territorial and urban settlements have a different relationship with the infrastructure endowment, and how they put in action different transport demands.

A preliminary working hypothesis selects some cases-study as significant and interesting about the relationships between accessibility levels and networks morphology in reference to the territorial settlement and, in a following step, widens the study in EU-27 Nuts3 regions.

The selection criterion

The selection criterion of the cases study derives from the results of the diagram classifying regions by Accessibility and GPD per capita at the Nuts3 level (see figure 7.1).

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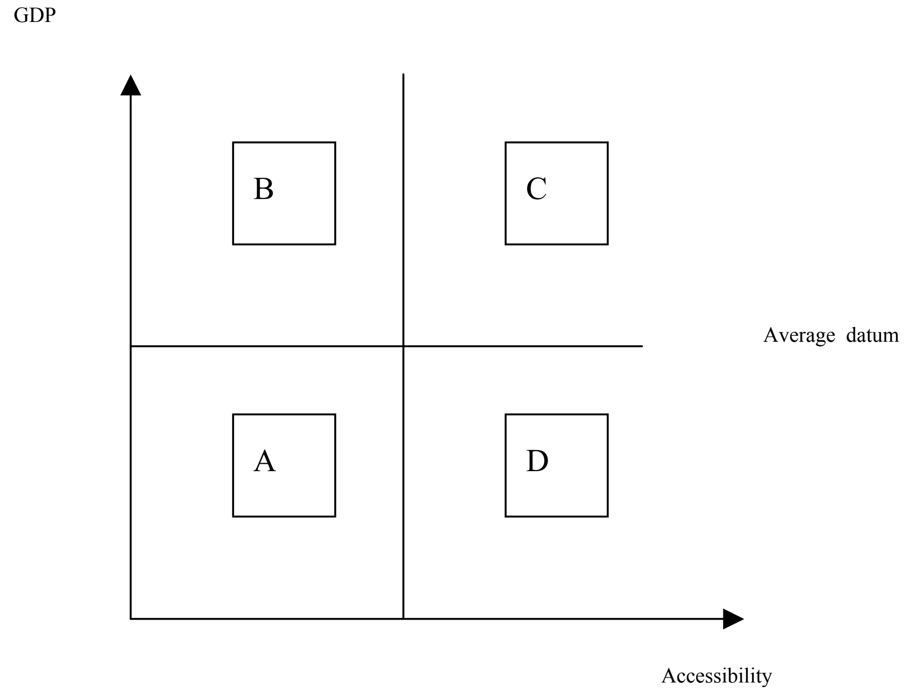
[1] p.e. in the north west of Italy the "metropolitan area" as a monocentric and polarised area dominated by hierarchical relationships erases the presence of the important and dynamic towns that offer an articulated range of services and opportunities becoming increasingly autonomous from the ones of central city itself, and they are characterized by a growing interactions, by a weaker and less cohesive socio-economic system, by a new urban situation, that have important consequences also on the infrastructure demand.

[2] The suggestions are that it is needful to assume the urban and regional polycentric idea in reference not only to the relationships of the complementarity and cooperation between towns, urban areas, but also in reference to the relationships of dominance and dependence, because the important existing territorial corridors in UE in which winds the urban settlement of the Europe, influence the nature of the relationships between the different areas.



Four types of regions corresponding to the four quadrants of the diagram can be distinguished:

A. *Lagging peripheral regions*: regions with below-average accessibility and below-average GDP per capita. In this condition (structural deficit) it is necessary to promote an important, strategic and structural program in the economic, in the transport fields to guarantee a territorial, economical cohesion with the other European regions;

B. *Successful peripheral regions*: regions with an economically successful even if the infrastructure endowments are below-average for which it's interesting to understand if it's necessary to improve the transport networks in order to guarantee a competitive development or if their territorial organization can be supported by the existing transport networks, even if below-average datum;

C. *Successful regions with high potentialities*: regions with above-average accessibility and above-average GDP per capita where it is necessary to govern the development processes and the transformations of the territories in order to avoid future deficit in the transport endowments, particularly by taking steps on the distribution of activities and functions on the territory;

D. *Lagging regions*: regions in which the above-average accessibility levels doesn't correspond to a high level of the GDP per capita; the weakness of the economical structures requires structural policies locally declined.

From this statement, the B and the C situations are the most interesting cases-study for our working hypothesis because in both situations the territorial cohesion can be assured by an appropriate **infrastructure policy**:

- searching to reduce the infrastructural gaps in the regions characterized by a differential of the accessibility and of the infrastructure endowments;
- evaluating, for the regions with a good level of accessibility and infrastructure endowments how the territorial typologies and the type of the settlement (sprawl, or compact cities, or polycentric region) can influence the infrastructure demands.

The working hypothesis

The working hypothesis about the selected cases study, is articulated in 3 levels:

1. a comparative study about infrastructures, linking the potential use of infrastructures (road and rail km/inhabitants) to the network endowment (multicriteria analysis on the road km/ area km^2, rail km/area km^2, number of stations/area....) in the Nuts 3 chosen as case study;
2. a morphological approach to study and to interpret the relationships between urban settlements and infrastructure networks;
3. an observation of infrastructural and territorial policies undertaken in the case study area.

These levels are useful to understand the different forms which assumes the "territorial cohesion" in the UE policies:

- *social-economical integration*[3] that recognizes the reduction of the social-economical gaps between European regions as one of the most important goals to achieve for the promotion of cooperation and coordination in the territorial policies;
- *cohesion as an integration/cooperation between stakeholders*[4], in urban and territorial policies, in reference to the public/private partnerships, in the policy making and in the policy design;
- *territorial integration*[5], that considers an integration inside and between different European territories, for which it is necessary to differentiate the territorial policies in which exogenous (general) determinations, and endogenous (local) determinations come into action. The territorial cohesion concerns not only areas with socio-economical differences or infrastructure networks gaps, but also areas in which it is strategic to increase and to promote new relationships.

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[3] The aim of the socio-economical cohesion is to assure an improvement in the physical and social infrastructure endowments in backward regions; to assure an integration between different social textures, aging on the job market, on the productive organization and on the service organization.

[4] The measures alleged, are Urban exchange initiatives to promote partnerships in the planning policies at the regional level, without the new institutional governments, but with a cooperative action of the local governance to build identities of the collective stakeholders; European action programs, conceived to promote transboundary cooperation.

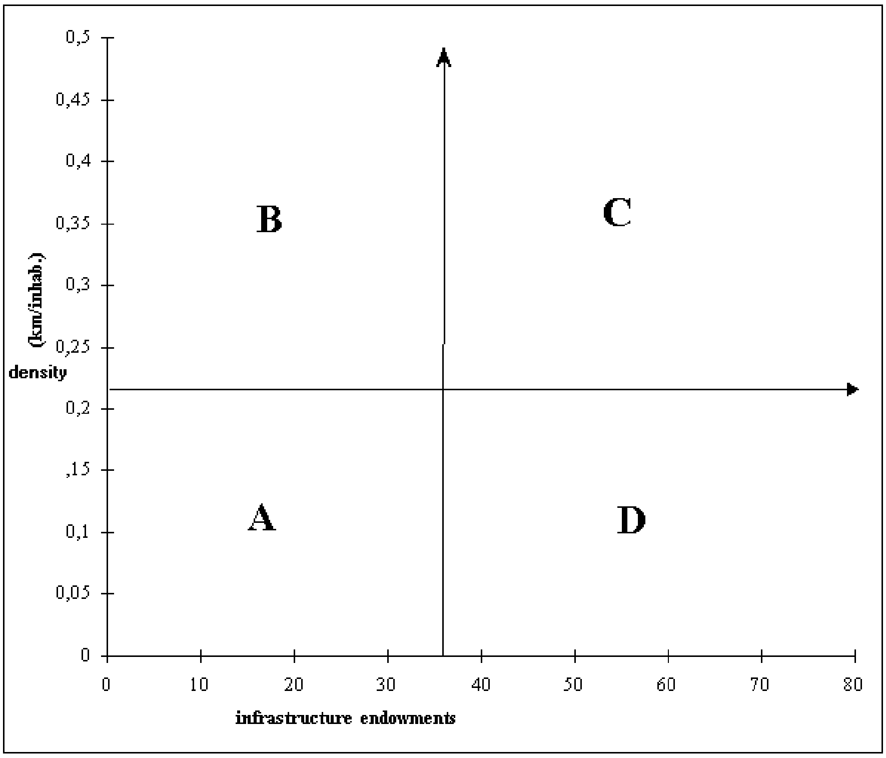
[5] The *"territorial cohesion"* in the transport issues, in the Amsterdam treaty, "supposes the creation of new relations between networks and between territories, and beyond the administrative boundaries constraints (NUTS 2, NUTS 3, etc), the creation of relations between spaces" (Interim Report).

A comparative study on the infrastructures densities

The method consists in the comparison between the infrastructural equipment of the Nuts 3 and the capacity of the infrastructural network to meet the needs of the potential demand, expressed as number of inhabitants. It's possible to calculate, at the Nuts 3 level, the density of infrastructures dividing the total length of roads or rails with the Nuts 3 surface.

The potential demand of infrastructures is analysed by calculating the total length of infrastructure / Nuts 3 inhabitants.

The aim is to identify different types of regions based on their position in the following diagram that classifies the regions crossing the infrastructure endowments and the infrastructure density.



Four types of regions corresponding to the fours quadrants of the diagram can be distinguished:

- in the **"A"** square there are *congested regions*, presenting a deficit both in density levels and in the infrastructures equipment, with a high settlement density, the result of long-term economic growth development. In this condition (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 **"B"** square (infrastructures under average datum, but with a good services level), there can be found the *peripheral regions*, characterized by a low population density, rural villages and by a sprawl settlement. 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 "**C**" box (high level of infrastructures and good density levels) it's necessary to govern the growth processes and the transformations of the territory that are, here, strongly dependent upon vehicular mobility.
- in the **"D"** box fall situations of congestion because a good infrastructure system is matched – on the contrary – by a high congestion 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.

The different urban settlements are investigated as a condition interfering with the infrastructure demands in the point 2.

A morphological approach

The morphological approach studies the relationships between urban settlements and infrastructure networks.

Using the Corine Land Cover database will be analysed the different urban settlements forms, in reference to the distance between the buildings.

In a preliminary hypothesis, three types of the territorial typologies can be distinguished:

1. urban sprawl: if the distance between buildings in the Corine Land Cover maps are > 100 mt
2. low building density or reticulated area if the distance between buildings is 50< x< 100 mt
3. compact city if the distance between buildings is < 50 mt

These territorial typologies will be related to the network morphology assumed as a result of the CESA analysis (chapter 5.7).

The hypothesis is that the infrastructure demand changes in reference to the urban settlements: the differences in infrastructure morphologies can take a different meaning and can direct planning policies in a different way.

The identification of settlements pattern is an important tool in order to understand the territorial problems of the European space. The presence of urban linear structures or of reticulated areas, or of continuing urban settlements, in reference to the existing infrastructural network underlines the need of specific policies and programs. The integration of settlements morphology and infrastructures network can help the definition and the identification of priority of actions in the field of planning and infrastructural policies.

For instance in the metropolitan area of Milan (north west of Italy), which is characterized by high level of accessibility, coexist radial networks morphologies (radial ring-roads) and important and dynamic towns (networks cities) characterized by a growing interactions not only with Milan centre. New infrastructural East-West connections are needed for guaranteeing and increasing these relationships, as highlighted by a deep reading of settlements morphologies.

A model of the possible integration between morphologies and networks will be prepared in order to recognize typical situations in which could fall the case study regions.

Cohesion as integration/ cooperation between policies and stakeholders

In reference to the case study, will be studied the goals of the local transport planning policies, and the contents of the infrastructure projects as a **local reply** (endogenous) to the transport demands, but also as local policies that interfere with the European transport projects.

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 nature and core content.

We propose 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 provisional since only four month have passed since the last report and three since the last ESPON seminar in Mondorf.

8.1 Main findings

The main results have been exposed in the first part, in the summary of main findings; the reader may refer to this part of the report for further details.

We have limited ourselves in this conclusion to recall 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. It is obvious that recommendations will differ depending on of each case.

8.2 Outlook to further work

It is unusual to have to provide almost definitive results halfway through the period of the research. There is here a risk that we will do our best to avoid. The period between August 2003 and August 2004 will be necessary to systematically and theoretically validate the indicators developed and presented collectively in this second interim report.

The indicators presented in this second interim report do not appear at the same level of development. Some of them are already giving elements of analyse whilst others still need to be developed, that it be concerning the data collection, the method of processing, or the cartographical output. All this work will be done before the release of the next interim report. Once a set of indicators stabilised and completed a deeper analysis will be conducted in order to formulate policy recommendations.

8.3 Towards 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.

The application of these kind of recommendation can not be immediate and require often very long delay, sometimes nearly a decade; moreover, during this period, the problems and their perception may increase in proportions that rise the question of the initial choice.

It is why immediate transitory measures must be proposed.

An other aspect must be underlined, it is the comparative rarity of modes of transport 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.

Interregional freight transportation is also linked to road mode except a small part concerning remote regions located near large logistic platforms.

On the contrary, 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 complementarity between modes must be developped.

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.

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.

Yet, an important modal transfer is not possible immediately 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).

Waiting for the building of the lines dedicated to freight which could be proposed, and because of the rapid growth in the intra-community exchanges, a solution could be 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 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.

More globally, the diverse kinds of analysis lead with the available indicators converged towards similar and complementary statements.

The first is the difference observed in Europe between peripheral and central countries. On the one hand, there is partially the classical statement of the economic dichotomy Periphery/Centre; on the other hand, this is coupled with the higher volumes and the larger growth coefficient of transport in the core of the continent than elsewhere. Even if this duality is going to be limited with the development of relations with others countries, corridors will not diffuse at the same level in every regions. Problems of traffic will be different, that is explaining their complexity.

The second statement is that areas are unequally spread out and endowed in infrastructure. The different kind of analysis converge on the same idea and this problem of a spatially unbalanced territory will be developed in the next interim report with refined tools and new approaches.

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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

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