TRACC
Transport Accessibility at Regional/Local Scale and Patterns in Europe

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TRACC Scientific Report

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This report presents the final results of an Applied Research Project conducted within the framework of the ESPON 2013 Programme, partly financed by the European Regional Development Fund.

The partnership behind the ESPON Programme consists of the EU Commission and the Member States of the EU27, plus Iceland, Liechtenstein, Norway and Switzerland. Each partner is represented in the ESPON Monitoring Committee.

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Table of contents

Introduction

The ESPON project TRACC (**TR**ansport **ACC**essibility at regional/local scale and patterns in Europe) aimed at taking up and updating the results of previous studies on accessibility at the European scale, to extend the range of accessibility indicators by further indicators responding to new policy questions, to extend the spatial resolution of accessibility indicators and to explore the likely impacts of policies at the European and national scale to improve global, European and regional accessibility in the light of new challenges, such as globalisation, energy scarcity and climate change.

The Transnational Project Group (TPG) for the ESPON project TRACC consisted of the following seven Project Partners:

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This report is part of the TRACC Final Report. The TRACC Final Report is composed of four volumes.

- Volume 1 contains the Executive Summary and a short version of the Final Report
- Volume 2 contains the TRACC Scientific Report, i.e. a comprehensive overview on state of the art, methodology and concept, and in particular results on the global, Europe-wide and regional accessibility analyses and subsequent conclusions of the TRACC project.
- Volume 3 contains the TRACC Regional Case Study Book. Here, each of the seven case studies conducted within the project is reported in full length.
- Volume 4 contains the TRACC Accessibility Indicator Factsheets, i.e. detailed descriptions of all accessibility indicators used in the project.

This report is the TRACC Scientific Report. It contains a review of the main literature on global, European and regional accessibility studies. Based on the previous elements, the TRACC set of accessibility indicators and impact indicators is presented for analysing global, European and regional accessibility. Selected results of the accessibility analysis at the different spatial levels are presented and discussed. This includes at the regional level also a summary of the case studies conducted. Here, regional accessibility pattern were analysed with a strictly harmonised methodology across Europe.

1 Objectives

Accessibility is the main 'product' of a transport system. It determines the locational advantage of an area (i.e. in ESPON a region, a city or a corridor) relative to all areas (including itself). Indicators of accessibility measure the benefits households and firms in an area enjoy from the existence and use of the transport infrastructure relevant for their area.

The important role of transport infrastructure (i.e. networks and transport services) for spatial development in its most simplified form implies that areas with better access to the locations of input materials and markets will, *ceteris paribus*, be more productive, more competitive and hence more successful than more remote and isolated areas.

However, the impact of transport infrastructure on spatial development has been difficult to verify empirically. There seems to be a clear positive correlation between transport infrastructure endowment or the location in interregional networks and the *levels* of economic indicators such as GDP per capita. However, in most countries this correlation may merely reflect historical agglomeration processes rather than causal relationships effective today.

Attempts to explain *changes* in economic indicators, i.e. economic growth and decline, by transport investment have been much less successful.

The reason for this failure may be that in countries with an already highly developed transport infrastructure further transport network improvements bring only marginal benefits. A different situation can be observed in some regions of the new EU member states where the lack of modern infrastructure (motorways, high-speed trains) is still a major barrier to economic development and where the rapid increase of freight flows by road on the main transport corridors between western and eastern Europe was not followed by new road, rail or multimodal transport investment.

While there is uncertainty about the magnitude of the impact of transport infrastructure on spatial development, there is even less agreement on its direction. It is debated whether transport infrastructure improvements contribute to spatial polarisation or decentralisation. From a theoretical point of view, both effects can occur. A new motorway or high-speed rail connection between a peripheral and a central region makes it easier for producers in the peripheral region to market their products in the large cities, however, it may also expose the region to the competition of more advanced products from the centre and so endanger formerly secure regional monopolies.

These developments have to be seen in the light of changes in the field of transport and communications which will fundamentally change the way transport infrastructure influences spatial development. Several trends combine to reinforce the tendency to diminish the importance of transport infrastructure for regional development:

- An increased proportion of international freight comprises high-value goods for which transport cost is much less than for low-value bulk products. For modern industries the *quality* of transport services has replaced transport *cost* as the most important factor.
- Transport infrastructure improvements which reduce the variability of travel times, increase travel speeds or allow flexibility in scheduling are becoming more important for improving the competitiveness of service and manufacturing industries and are therefore valued more highly in locational decisions than changes resulting only in cost reductions.
- Telecommunications have reduced the need for some freight transports and person trips but they also increase the demand for transport by their ability to create new markets.
- With the shift from heavy-industry manufacturing to high-tech industries and services other less tangible location factors have come to the fore and have at least partly displaced traditional ones. These new location factors include factors related to leisure, culture, image and environ-

ment, i.e. quality of life, and factors related to access to information and specialised high-level services and the institutional and political environment.

On the other hand, there are also tendencies that increase the importance of transport infrastructure:

- The introduction of totally new, superior levels of transport such as the high-speed rail system create new locational advantages, but also disadvantages for regions not served by the new networks.
- Another factor adding to the importance of transport is the general increase in the volume of goods movements (due to changes in logistics such as just-in-time delivery) and travel (due to growing affluence and leisure time).
- In the future rising energy prices and the need to reduce greenhouse gas emission of transport may increase the importance of transport cost for regional development.

Both above tendencies are being accelerated by the increasing integration of national economies within the European Union and by the continuing globalisation of the world economy.

Key policy questions

In this situation the TRACC project has addressed the following key policy question from a European point of view:

- What are the differences between accessibility at three different levels (global, European and regional) considering the four modes road, rail, water and air?
- What is the link between accessibility at the different levels and for different modes of European regions and their economic development? How has this link changed over time? Does the strength of this link differ across the EU?
- What could be the territorial impact of rising energy prices on the future developments of road, rail, water and air transport?
- What could be the impact of various transport scenarios on climate change, access patterns and economic development?

In addition the project has looked into the regional dimension of accessibility often neglected in previous studies of accessibility:

- How does accessibility/connectivity look like at the regional level? For example, how many jobs/people can be reached in 45 minutes travel time (by road or by train), how many city centres can be reached by flying out in the morning and returning in the evening?
- In which type of regions is the level of European accessibility very different from their regional accessibility?

From a research point of view, the following key research questions have been addressed:

- What is the accessibility of European regions for travel by different modes (road, rail, air) at the European level?
- What is the accessibility of European regions for air travel at the global level?
- What is the potential of intermodal travel, in particular the combination of high-speed rail and air?
- What would be the impacts of different policies to make rail more competitive on the modal share of travel and travel accessibility?

- What would be the impacts of different policies to make rail and water more competitive on the modal share of freight transport and freight accessibility?
- What are the most favoured urban centres and most disadvantaged regions with respect to travel accessibility (island, mountain areas)?

Project objectives

From these key policy and research questions the main objectives of the project have been derived:

- to take up and update the results of existing studies on accessibility at the European scale using most recent available network and socio-economic data,
- to extend the range of accessibility indicators by further indicators responding to new policy questions and further developing the quality and validity of the existing indicators,
- to extend the spatial resolution of accessibility indicators by calculating, besides European accessibility, also global and regional accessibility,
- to explore the likely impacts of available policies at the European and national scale to improve global, European and regional accessibility in the light of new challenges, such as globalisation, energy scarcity and climate change.

Geographical coverage of all analyses is according to the project specification NUTS-3 or equivalent regions in all countries participating in the ESPON 2013 Programme plus ideally the EU candidate countries Croatia, FYR Macedonia and Turkey and the other countries of the Western Balkans Bosnia and Herzegovina, Serbia, Montenegro, Albania and Kosovo under UN Security Council Resolution 1244.

When calculating accessibility indicators transport connections to destinations outside the study area have been usually included. When calculating European accessibility, also links to destinations in neighbouring countries, such as Belarus, Moldova, Russia and Ukraine, have been considered, and when calculating global accessibility, links to destinations in all world regions.

2 Political context

The European transport system serves key roles in the transportation of people and goods in a local, regional, national, European and international context. At the same time, it is essential to Europe's prosperity and closely linked to economic growth and quality of life. The grand challenge for transport is to make growth and sustainability compatible, by decoupling environmental impacts from economic growth, while assuring the competitiveness and innovative character of the European transport industry. Economic crisis, increasing scarcity of non-renewable energy sources, aging, migration and internal mobility, urbanisation, and globalisation of the economy are among the other challenges to be faced by Transport policy.

The Common Transport Policy

The Common Transport Policy (CTP) is an essential component of the EU policy since the Maastricht Treaty of 1992, when the concept of Trans-European transport Networks (TEN) was introduced for the first time, with a special emphasis on interconnection and interoperability of the diverse national networks. The main policy instruments of the CTP are the White Paper on Transport and the TEN-T programme. The TEN-T programme is intended to increase the co-ordination in the planning of infrastructure projects by the member states. Progress in the TEN-T implementation has been relatively slow due to the scale, complexity and cost of the proposed projects in the past. A new proposal of TEN-T guidelines was presented in October 2011 and agreed upon in December 2013, intended to focus the efforts of the program on key network elements of European relevance. The White Paper on Transport is the document of strategic reflection providing the conceptual framework for the CTP, having had substantial influence on EU, national and regional policies since 1992 (e.g. liberalisation of transport markets and modal change from road to rail). The 2009 EC Communication on the Future of Transport triggered the debate for the 2011 White Book revision, proposing that focus should now turn on improving efficiency of the transport system through co-modality, technology development, and prioritise infrastructure investment on links with highest returns. The new transport White Paper was presented in late March 2011.

According to the 2011 Transport White Paper, one of the major challenges in the field of transport is to break the system's dependence on oil without sacrificing its efficiency and compromising mobility, in line with the flagship initiative "Resource efficient Europe" set up in the EU2020 Strategy and the new Energy Efficiency Plan 2011. Curbing mobility is not an option. The EU and Governments need to provide clarity on the future policy frameworks (relying to the greatest extent possible on market based mechanisms) for manufacturers and industry so that they are able to plan investments.

The concept of co-modality introduced by the White Paper back in 2006 implies that greater numbers of travellers are carried jointly to their destination by the most efficient (combination of) modes. Individual transport is preferably used for the final miles of the journey and performed with clean vehicles. In the intermediate distances, new technologies are less mature and modal choices are fewer than in the city. However, this is where EU action can have the most immediate impact. Better modal choices will result from greater integration of the modal networks: airports, ports, railway, metro and bus stations, should increasingly be linked and transformed into multimodal connection platforms for passengers.

The EU-wide multi-modal TEN-T 'core network' defined by the TEN-T guidelines of December 2013 should be fully functional by 2030. The core network must ensure efficient multi-modal links between the EU capitals and other main cities, ports, airports and key land border crossing, as well as other main economic centres. It should focus on the completion of missing links – mainly cross-border sections and bottlenecks/bypasses – on the upgrading of existing infrastructure. Better rail/airport connections must be devised for long distance travel. By 2030, the length of the existing high-speed rail network should be tripled, and a dense railway network in all Member

States should be maintained. By 2050, a European high-speed rail network should be completed. By 2050 the majority of medium-distance passenger transport should go by rail, and by 2050, all core network airports should become connected to the rail network, preferably high-speed. The quality, accessibility and reliability of transport services is to be increasingly important, requiring attractive frequencies, comfort, easy access, reliability of services, and inter-modal integration.

The cost of EU infrastructure development to match the demand for transport has been estimated € 1.5 trillion for 2010-2030. The completion of the TEN-T network requires about € 550 billion until 2020 out of which some € 215 billion can be referred to the removal of the main bottlenecks. This does not include investment in vehicles as well as guidance and information systems.

Other key elements in relation to passenger transport are according to the transport White Paper improved energy efficiency performance of vehicles across all modes and more efficient use of transport and infrastructure through improved traffic management and information systems. The gradual phasing out of 'conventionally-fuelled' vehicles is a major contribution to significant reduction of oil dependence, greenhouse gas emissions and local air and noise pollution. The use of smaller, lighter and more specialised road passenger vehicles must be encouraged. By 2030, the use of 'conventionally-fuelled' cars in urban transport should be halved, and by almost eliminated in cities by 2050. Low-carbon sustainable fuels in aviation would have to reach 40% by 2050; at the same time it should be reduced EU CO2 emissions from maritime bunker fuels by 40% (if feasible 50%). Road pricing and the removal of distortions in taxation can also assist in encouraging the use of public transport and the gradual introduction of alternative propulsion.

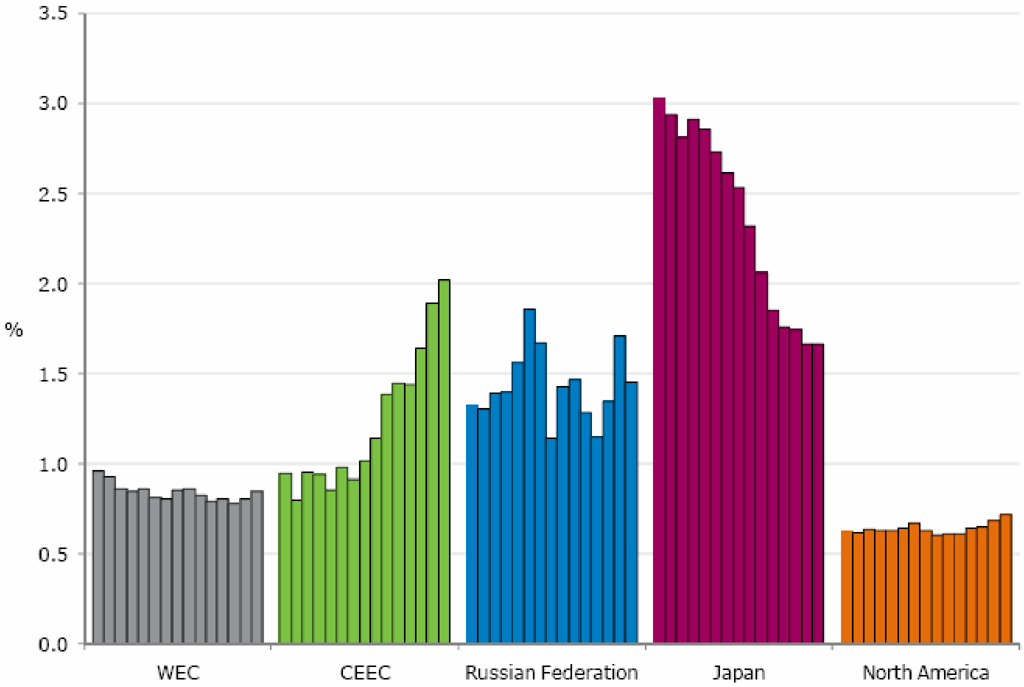
According to the CTP Evaluation report (EC 2009), substantial progress has been made in the last 20 years towards meeting the objectives of the CTP of creation of a competitive internal market for transport services by liberalising the transport market. Market opening has been very successful in the air sector and there would be signs that market opening in the rail sector is starting to bring success. In all sectors, further reforms are required in order to fully implement liberalisation. Whilst there has been progress towards the objective of introducing a system of transport infrastructure pricing and taxation which better reflects marginal costs, and most of the specific measures proposed in the 2001 White Paper have been implemented, overall progress towards meeting this objective has been limited, largely because most decisions about pricing and taxation are still taken by Member States, and in some cases face strong public opposition.

In order to ensure that the limited TEN-T funds are used most efficiently to address infrastructure bottlenecks, decision-making about the allocation of funding should tend to be, according to the same source, increasingly based on cost benefit analysis of different schemes, using consistent criteria and parameters, not favouring specific modes of transport. The different environmental and other social costs of different modes should be taken into account in this cost benefit analysis. In fact, the EC provides unified criteria for project appraisals, as embodied in the regulations of the Structural Funds, the Cohesion Fund, and Instrument for Pre-Accession Assistance, through its Cost-Benefit guidelines . However many methodological issues remain unsolved (e.g. appraisal of the so called intangible effects, both positive and negative) and even worse, the very paradigms of e.g. time savings in cost-benefit analysis are still being debated intensely.

But emphases on different type of policy aims and instruments may change over time, also in the CTP. The Commission has identified seven transport policy areas in which specific policy measures could have a key role in stimulating the expected shift of the transport system to another paradigm. These policy areas are: pricing, taxation, research and innovation, efficiency standards and flanking measures, internal market, infrastructure and transport planning. Only a long-term and overarching strategy established for all identified policy areas has a reasonable chance of achieving the EU objectives. It should combine policy initiatives targeted at enhancing the efficiency of the system through better organisation, infrastructure and pricing with those that are more focused on technology development and deployment. It should also provide a framework for action at all levels of government.

Transport investment in Europe over time and over space

The total investment in infrastructure in Europe between 1995 and 2010 has been on average between 0.9% and 1.2% of total European GDP (Figures 2.1 and 2.2). The level of investment in Western European Countries has been substantially lower than in the Eastern European countries, but overall level are well above mean values in some other regions of the World such as North America, but lower than in Japan.



Note: WECs include Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Spain, Sweden and the United Kingdom. CEECs include Albania, Croatia, Czech Republic, Estonia, FYROM, Hungary, Latvia, Lithuania, Montenegro, Poland, Romania, Serbia, Slovakia and Slovenia. North America: United States data 2003-2009 estimated. Public road investment based on Bureau of Economic Analysis data on Investment in Government Fixed Assets (highways and streets). Private road and private rail investment based on U.S. Census Bureau data on Construction Spending. Public rail investment estimated based on Bureau of Economic Analysis data on Investment in Government Fixed Assets (transportation) using fixed share for rail investment based on 2003 data. Inland waterways investment estimated based on data from U.S. Census Bureau data on Construction Spending (from 2003 level annual change). Japan: not including private investments.

Figure 2.1 Investment in inland transport infrastructure 1995-2009, as % of GDP at current prices. (OECD 2011)

About 1/3 of all invested funds in transport were merely spent on infrastructure maintenance, and only about 60% were specifically dedicated to providing new infrastructure. The funding of new infrastructure proceeded mostly from national budgets of Member States (almost 90%), and only 5% of total expenditure was assumed by European funds (Cohesion Fund and ERDF) despite the fact that 50% of total investment was devoted to new infrastructure in TEN-T networks.

The analysis per mode reveals that around 60% of total investment, i.e. the sum of all sources, has been devoted to Road mode, 20% to Rail and 10% equally split between Air and Water modes (IWW = Inland waterways, SEA = maritime) (including maintenance, see Figure 2.2). However, almost half of the investment on TEN-T was devoted over the last 10 years to rail, and around 35% to road. This was especially important in Western European countries, where the development of High Speed Rail networks required large investments (around € 20 million per kilometre of HSR, against € 5 million per kilometre for motorways, on average). In Eastern European countries, investment on roads was still dominant.

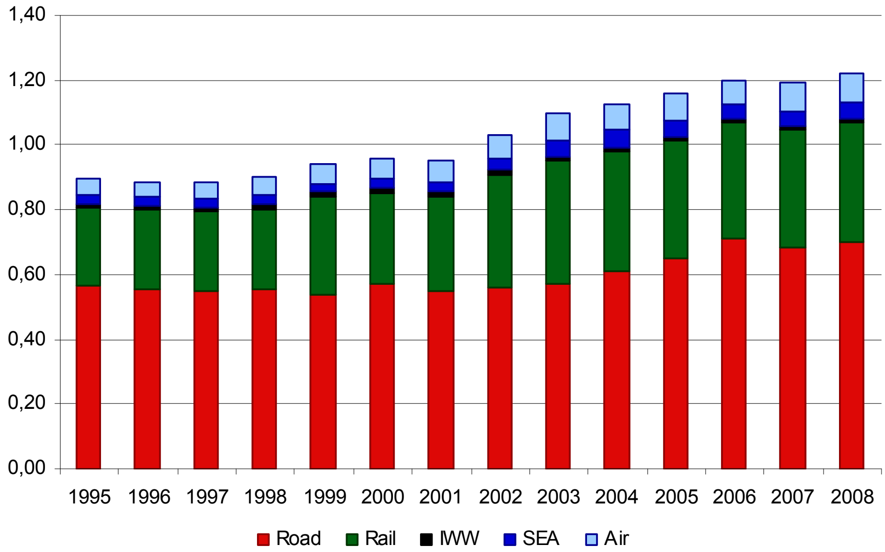


Figure 2.2. Transport infrastructure investment per mode as a share of GDP 1995-2008 (EEA 2010)

Transport and Territorial Cohesion

A central element of the Community Strategic Guidelines on Cohesion 2007-2013 (2005) is the assumption that transport infrastructure and accessibility are necessary conditions for economic growth in the Union, having a direct impact on the attractiveness of regions for businesses and people. This is supported by the Reports on economic and social cohesion (2007, 2010), which reiterate how improved accessibility tends to create new job opportunities for rural and urban areas, but warns that potentialities from improving accessibility depend on the previous competitiveness of the regions concerned, being some regions liable to lose out as they become more open to competition from elsewhere. The reports claim the importance of combining investment in transport infrastructure with support for businesses and human capital development to achieve sustainable economic and social development. The Territorial Agenda of the EU (2007) claims the need to support to the extension of the TEN-T for economic development in all regions of the EU, especially in the EU12 countries, while the Green Paper on Territorial Cohesion (2008) later puts the accent on regional and local accessibility as key elements for granting balanced access to services and European transport terminals and networks.

The two dominant themes of spatial planning in Europe, as reflected already in the Europe 2000 study programme, are the urban and regional dichotomy, and the centre and periphery dichotomy. The “integration” between urban-rural, as well as between centre-periphery has always been the European narrative to overcome territorial unbalances. The necessary links to integrated urban and rural zones were included into the wider concept of “partnership”, later on by the ESDP. On the other hand, solving “missing links” in the networks of transport and communication was an important issue in the definition of the Trans-European Transport Networks, and the creation of “integration zones”, “polycentric and cross-border development areas”, between central and more peripheral regions.

The European Spatial Development Perspective (ESDP) of 1999 (European Commission,1999) lists the trans-European transport networks as major policy field of importance for European spatial development, only second to EU economic policy, because of their effect on both the functioning of the Single Market and economic and social cohesion. In line with its spatial vision of polycentric and balanced system of metropolitan regions, city clusters and city networks, the ESDP called for improvement of the links between international/national and regional/local networks and strengthening secondary transport networks and their links with TENs, including efficient regional public transport systems, improvement of transport links of peripheral and ultra-peripheral regions, both within the EU and with their neighbouring third countries and promoting the interconnection of inter-modal junctions for freight transport, in particular on the European corridors.

Following the European Spatial Development Programme (ESDP), the Study Program on European Spatial Planning (SPESP), carried out a number of specific researches territorial structures and typologies, and the opposition between urban and rural areas. Urban-rural partnerships as defined by the ESDP required among others, a balanced settlement structure and improvement of accessibility (concerning land use and development of public transportation networks). Improved infrastructure and accessibility bring new kinds of rural-urban linkages.

The first Territorial Agenda of the European Union: Towards a More Competitive and Sustainable Europe of Diverse Regions of 2007 (European Commission, 2007) took up the vision of polycentric territorial development of the EU of the ESDP, highlighted the territorial dimension of cohesion and emphasised the importance of integrated and sustainable multi-model transport systems but failed to set priorities.

The new Territorial Agenda of the European Union 2020: Towards an Inclusive, Smart and Sustainable Europe of Diverse Regions of 2011 (European Commission, 2011d) puts spatial development into the framework of the Europe 2020 Strategy and the 5th Cohesion Report and takes up the proposals of the ESDP for inter-modal transport solutions, further development of the trans-European networks between main European centres and improvement of linkages between primary and secondary systems and accessibility of urban centres in peripheries.

The Europe 2020, the growth strategy of the EU for the coming decade, aims at five targets in the fields of employment, research and development, greenhouse gases, renewable energy, energy efficiency, education and social inclusion. European Commission, 2010). The Commission emphasises that essential elements of the transport policy are better integration of transport networks, promoting clean technologies, and upgrading infrastructure. Among the obstacles to be overcome, insufficiently interconnected networks are listed. Transport is listed among the policy tools to be applied only in very general terms as "smart transport and energy infrastructure".

A further example of the current debate on cohesion aspects is the changes in the understanding of the “urban-rural narrative” as put forward through the Spanish Presidency (2010) Its contribution highlights the need for a thorough investigation of urban-rural relationships and spatial trends in conceptualizing the new pattern of spatial relations, becoming visible through increased flows and implying analysis beyond core and periphery paradigms. New territorial paradigms emerge today thanks to ICTs and to faster and cheaper transport, increased accessibility and connectivity. These changes result on severe reductions of distance or cost to reach core areas of Europe from the peripheries (“cost of being peripheral”) and making remote places more accessible when well connected to the networks. Even when distance still matters, impacts on spatial development become today more complex, ubiquitous centres and peripheries can suddenly emerge almost anywhere, even in remote rural areas, and the challenge is to face increasing development opportunities but also to manage exposure to threats.

3 Conceptual framework

In this section first a introduction into the state of the art of calculating accessibility indicators is given showing the major dimensions of accessibility, the most frequently types of accessibility indicators and important extension of these. Based on this conceptual framework, the research concept of the project is outlined.

3.1 Accessibility dimensions

Accessibility indicators may be sensitive to the following dimensions: origins, destinations, impedance, constraints, barriers, type of transport, modes, spatial scale, equity and dynamics. These dimensions are summarised in Table 3.1.

Origins

Accessibility indicators are calculated for areas such as regions or cities. From a pure semantic point of view, an area is called accessible if it can be easily reached from other areas. However, in practice a reverse view is used: an area is called highly accessible if many attractive destinations can be reached from it in a short time. In that sense the area can be considered the origin of trips to destinations of interest. In both perspectives the notion of accessibility is closely linked to movement, and so it matters who moves. Different actors such as business travellers, tourists or commuters are attracted by different destinations and have different travel preferences and travel budgets. By the same token different firms have different views of destinations as purveyors, customers or other firms and require different transport services depending on the kind of goods they ship. Accessibility indicators therefore have to be calculated with different types of actors or transport users in mind.

Destinations

Different actors are attracted by different destinations. Business travellers find their clients most likely in city centres. Tourists are attracted by tourist attractions such as beach resorts, mountains or historical towns. Commuters are interested in job opportunities. Consumer-oriented firms want to reach their customers, whereas business-oriented firms deliver their goods and services to other firms. Accessibility indicators therefore have to be calculated with respect to different destinations such as economic activities, population or tourist attractions.

Impedance

Simple accessibility indicators consider only transport infrastructure in the area itself, expressed by measures such as total length of motorways or number of railway stations, or in the vicinity of the area, expressed by measures such as access to the nearest nodes of interregional networks like motorway exits, intercity stations, freight terminals or airports. More complex accessibility indicators distinguish between destinations in the area itself and those in other areas. The effort needed to overcome that distance is measured as spatial impedance. Spatial impedance is calculated as a function of distance or time or money or a combination of the latter two (generalised cost). There are two different approaches:

- *Euclidean distance*. If no transport network is considered, geographical or Euclidean distance between areas is taken as spatial impedance: Origins and destinations are assumed to be concentrated in nodal points in the centre of the areas called centroids, so distances between the centroids are calculated. In this case other attributes such as travel time, travel cost, capacity, congestion, convenience, reliability or safety have no meaning. The mean length of internal trips in the origin area is estimated as a function of its size.

Table 3.1. Dimensions of accessibility

Dimension	Comments
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).
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 of maximum driving hours) or by capacity constraints (road gradients or congestion).
Barriers	In addition to spatial impedance also non-spatial, e.g. political, economic, legal, cultural or linguistic barriers between areas may be considered. In addition, non-spatial linkages between areas such as complementary industrial composition may be considered.
Types of transport	Only travel or only freight transport, or both, may be considered in the analysis.
Modes	Accessibility indicators may be calculated for road, rail, inland waterways or air. Multimodal accessibility indicators combine several modal accessibility indicators. Intermodal 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 TEN projects or other transport policies, including their impacts on convergence or divergence in accessibility between areas.

- *Network impedance*. If one or more transport networks are considered, the travel time or cost along the minimum path between areas over the network(s) are taken as spatial impedance between the areas. Besides distance, link attributes such as travel time, travel cost, capacity, congestion, convenience, reliability or safety may be considered. Origins and destinations are assumed to be concentrated in the centroids, and the centroids are linked to the nearest network node by non-network access links. The mean length or travel time or cost of access links and internal trips in the origin area is estimated as a function of the size of the area as above.

If the assumption that origins and destinations of areas are concentrated in their centroids is abandoned, additional access links are estimated between the micro locations of origins and destinations in the areas and their centroids.

Constraints

The use of the links between areas may be constrained by regulations (speed limits, access restrictions for certain vehicle types of maximum driving hours) or by capacity constraints (road gradients or congestion). It is relatively straightforward to take account of regulation constraints when calculating accessibility. Speed limits can be directly converted to link travel times. Regulations on maximum driving hours can be converted to a barrier at the link on the minimum path where the maximum driving time is exceeded. Taking account of capacity constraints when calculating accessibility is more difficult since it requires the consideration of link capacity and network flow characteristics. To restrict the use of certain links by certain vehicle types (e.g. of Swiss transalpine roads by 40-ton lorries) is only possible if different lorry types are distinguished in the accessibility model. To take account of road congestion would actually require a full-scale traffic assignment model, something rarely available when calculating accessibility. As a workaround sometimes time penalties are assigned to links passing through urbanised areas.

Barriers

In addition to spatial impedance also non-spatial, e.g. political, economic, legal, cultural or linguistic barriers between areas may be considered:

- Political barriers are, for instance, national boundaries with delays at the borders for passport control, visas, customs declarations, etc. Significant reductions of barriers between countries of the European Union have been achieved through the Schengen Protocol. However, movement of people from immigration countries across the external boundaries of the European Union has become more restricted.
- Economic barriers are customs, tariffs and other fees imposed on the exchange of goods and services between different countries. Due to the Maastricht Treaty, economic barriers between EU countries have been greatly reduced.
- Legal barriers are non-tariff restrictions imposed on movement of people and goods between countries through different standards, safety regulations, legal provisions, employment restrictions, etc.
- Cultural barriers are invisible barriers discouraging the exchange of people or goods because of different traditions, values, life styles and perceptions at two sides of a border between or within countries.
- Linguistic barriers are invisible barriers discouraging the exchange of people or goods across a border between countries or regions with different languages.

By the same token, non-spatial linkages between areas may be considered. For instance, economic exchange between regions with complementary industrial composition will be more intensive than it is to be expected from their distance and size. Barriers may also be expressed as negative linkages. For instance, exchange of people and goods between regions with the same culture and language will be more intensive than between regions that differ in this respect.

Types of transport

The majority of accessibility indicators are expressed in terms of travel. However, if origins and destinations are economic activities (firms or employment), clearly exchange of goods and services is intended. Accessibility for freight transport is explicitly addressed where freight transport is explicitly modelled. Advanced freight accessibility indicators take account of freight-specific terminals such as intermodal terminals or ports or freight-specific modes such as inland waterways. There are to date only few Europe-wide studies on freight accessibility.

Modes

Network-based accessibility indicators may be calculated for road, rail, ferry, inland waterways or air and can be unimodal, multimodal or intermodal: Unimodal accessibility indicators consider only one mode. Multimodal accessibility indicators are aggregates of two or more unimodal accessibility indicators. Intermodal accessibility indicators consider trips by more than one mode taking account of transfers between modes. Among the accessibility indicators reported in the literature, intermodal accessibility indicators are rare, except for rail and maritime freight transport where the start and end of a trip is assumed to be by road..

Spatial resolution

Origins and destinations are located in *areas* representing regions or cities. However, accessibility indicators can be calculated only for *points*, which are defined either by geographical coordinates (when calculating Euclidean distance) or as network nodes (when calculating network impedance). It is therefore not useful to classify accessibility indicators as area-oriented or nodal. All accessibility indicators are nodal, and if accessibility indicators for areas are required, some generalisation is needed.

The most common generalisation is to assume that all origin and destination activities are concentrated in nodal points in the centre of the areas called centroids. This generalisation is acceptable if the areas are small or if only the accessibility of the city centres is of interest in the study.

However, there are important issues of spatial equity concerned with the decline of accessibility with increasing distance from network nodes. If accessibility is represented as a continuous three-dimensional surface, the nodes of the (high-speed) networks are 'mountains' representing, for instance, high-speed rail stations in the city centres, whereas the areas away from the network nodes are 'valleys' representing the 'grey zones' with low accessibility between the network nodes. Accessibility indicators that are to show not only the 'mountains' but also the 'valleys' need to be more spatially disaggregate.

The most straightforward way of calculating more disaggregate accessibility indicators is to increase the number of areas. This is, however, frequently not possible because high-resolution socio-economic data are not available.

Another way to calculate spatially disaggregate accessibility indicators is to disaggregate the socio-economic data from large areas to much smaller uniform raster cells or pixels probabilistically using land cover information from geographical information systems or remote sensing images as ancillary information. By calculating accessibility indicators for each of these pixels, quasi-continuous accessibility surfaces showing not only the 'mountains' of high accessibility but also the adjacent 'valleys' of low accessibility can be created. As with larger areas, estimates of non-network travel times or cost between pixel centroids and nearest network nodes need to be made.

Equity

Issues of spatial equity arise with respect to differences in accessibility both within and between areas:

- At a regional scale, the decline in accessibility from centroids or network nodes to interstitial areas affects decisions on linkages between interregional and intraregional transport networks.
- At a European scale, spatial equity is related to the territorial cohesion objective of the European Union to reduce disparities in income between regions. To analyse territorial cohesion, accessibility indicators may be calculated for specific groups of regions or cities to identify inequalities in accessibility between rich and poor, central and peripheral, urban and rural, nodal and interstitial areas.

In addition, accessibility indicators can be used to study peripherality. The political and economic significance of peripherality issues has grown as a result of the enlargement of the European Union by the accession of the new member states in central and eastern Europe. A peripheral region is a region which is distant in terms of travel time and travel cost from opportunities, activities or assets existing in other regions – in short, a peripheral region is characterised by low accessibility. Accessibility indicators are conditioned by a number of factors. Transport networks cover the territory of the European Union unevenly and differ in relevance with respect to the requirements of individual regions, partly due to the fact that the regional division of labour and social stratification has been adapted to differences in accessibility.

This implies that accessibility indicators which may be highly relevant to core regions might be of secondary relevance for peripheral regions. This has implications for policy-making: the priorities for improving accessibility are likely to differ between peripheral and core regions. However, even if the interests of peripheral regions were given more weight in European transport policy, it is unlikely that the locational disadvantage of peripheral regions will ever be completely compensated by transport infrastructure. To analyse the difference between accessibility due to 'pure' geographical position and accessibility in transport networks, accessibility indicators based on Euclidean distance may be used as benchmarks against which improvements in network accessibility can be measured.

Dynamics

Accessibility is not static. Accessibility based on Euclidean distance changes with the distribution of socio-economic variables. Network-based accessibility changes both with socio-economic variables and with transport networks or levels of service of transport. To analyse the dynamics of accessibility, accessibility indicators can be calculated for different points in time, for instance to show changes in accessibility induced by TEN projects or other transport policies. By comparing the spatial distribution of accessibility with and without the projects or policies, it can be assessed whether the projects or policies would lead to convergence or divergence in accessibility between areas. A critical issue here is to apply meaningful measures of convergence and divergence, as commonly used cohesion indicators measure only relative and not absolute differences between distributions. However, with appropriate cohesion indicators, accessibility analysis can be used to monitor and forecast the achievement of cohesion goals of the European Union.

3.2 Generic accessibility indicators

In this section a classification of accessibility indicators is proposed that encompasses a great variety of possible indicators in three generic types.

In general terms, accessibility is a construct of two functions, one representing the activities or opportunities to be reached and one representing the effort, time, distance or cost needed to reach them:

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

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 in areas j weighted by the ease of getting from i to j. It is easily seen that this is a general form of potential, a concept dating back to Newton's Law of Gravitation. According to the Law of Gravitation, the attraction of a distant body is equal to its mass divided by its squared distance. The gravity model of regional science is somewhat more general, it states that the attraction of a distant location is proportional to its size (e.g. population) weighted by a decreasing function of its distance.

In the context of accessibility, the 'size' are the activities or opportunities in areas *j* (including area *i* itself), and the 'distance' is the spatial impedance c_{ij}. The interpretation here 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.

However, the generic equation of accessibility above is more general than the gravity model. Different types of accessibility indicators can be generated by specifying different forms of functions $g(W_j)$ and $f(c_{ij})$:

- *Travel cost*. If only destinations of a certain kind, e.g. cities beyond a certain size, are considered (the activity function is rectangular), and the impedance function is travel time or travel cost itself (i.e. the impedance function is linear), the accessibility indicator is total or average travel cost to a predefined set of destinations.
- *Cumulated opportunities*. If only destinations within a certain travel time are considered (the impedance function is rectangular), and the destinations are taken as is (the activity function is linear), the accessibility indicator measures the number of potential destinations (customers, business contacts, tourist attractions, etc.) that can be reached in a given time, e.g. a day.
- *Potential*. If the impedance function takes travel behaviour into account, i.e. the diminishing inclination to travel long distances (the impedance function is nonlinear, e.g. exponential), the accessibility indicator is a potential indicator. The activity function may take account of agglomeration effects or economies of scale (i.e. may be nonlinear, e.g. a power function).

Table 3.2 shows the most frequent specifications of $g(W_j)$ and $f(c_{ij})$ for the three types of accessibility indicator, where W_{min} and c_{max} are constants and α and β parameters:

Table 3.2. Accessibility indicators

Type of accessibility	**Activity function** $g(W_j)$	**Impedance function** $f(c_{ij})$
Travel cost Travel cost to a set of activities	$W_j \mid 1 \text{ if } W_j \geq W_{min}$ $0 \text{ if } W_j < W_{min}$	c_{ij}
Cumulated opportunities Activities in a given travel time	W_j	$1 \text{ if } c_{ij} \leq c_{max}$ $0 \text{ if } c_{ij} > c_{max}$
Potential Activities weighted by a function of travel cost	W_j^{α}	$\exp(-\beta c_{ij})$

Travel cost

This indicator is based on the assumption that not all possible destinations are relevant for the accessibility of an area but only a specified set. This set may, for instance, consist of all cities over a specified size or level of attraction W_{min}. The indicator measures the accumulated generalised travel costs to the set of destinations. In the simplest case no distinction is made between larger and smaller destinations, i.e. all destinations in the set get equal weight irrespective of their size and all other destinations are weighted zero (the activity function is rectangular). In many applications, however, destinations are weighted by size (the activity function is linear). The impedance function is always linear, i.e. does not take into account that more distant destinations are visited less frequently.

Travel cost indicators are popular because they are easy to interpret, in particular if they are expressed in familiar units such as average travel cost or travel time. Their common disadvantage is that they lack a behavioural foundation because they ignore that more distant destinations are visited less frequently and that therefore their values depend heavily on the selected set of destination, i.e. the arbitrary cut-off point of the W_j included.

Cumulated opportunities

This indicator is based on the notion of a fixed budget for travel, generally in terms of a maximum time interval in which a destination has to be reached to be of interest. The rationale of this accessibility indicator is derived from the case of a business traveller who wishes to travel to a certain city, conduct business there and return home in the evening. Maximum travel times of three to five hours one-way are used at the European scale. Because of its association with a one-day business trip this type of accessibility is often called 'daily accessibility'.

The cumulated opportunities indicator is equivalent to a potential accessibility indicator (see below) with a linear activity function and a rectangular impedance function, i.e. within the selected travel time limit destinations are weighted only by size, whereas beyond that limit no destinations are considered at all. Cumulated opportunities indicators, like the travel cost indicators above, have the advantage of being expressed in easy-to-understand terms, e.g. the number of people one can reach in a given number of hours. However, they also share their disadvantage that they heavily depend on the arbitrarily selected maximum travel time beyond which destinations are no more considered.

Potential accessibility

This indicator is based on the assumption that the attraction of a destination increases with size *and* declines with distance or travel time or cost. Therefore both size and distance of destinations are taken into account. The size of the destination is usually represented by area population or some economic indicator such as total area GDP or total area income. 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 value of the parameter β indicates that nearby destinations are given greater weight than remote ones.

Indicators of potential accessibility are superior to travel cost accessibility and cumulated opportunities in that they are founded on sound behavioural principles of stochastic utility maximisation. Their disadvantages are that they contain parameters that need to be calibrated and that their values cannot be easily interpreted in familiar units such as travel time or number of people. Therefore potential indicators are frequently expressed in percent of average accessibility of all areas or, if changes of accessibility are studied, in percent of average accessibility of all areas in the base year of the comparison.

Extensions

There is a large number of extensions of the above generic accessibility indicators. Four of them have been addressed in this project:

Multimodal accessibility

All three types of accessibility indicator can be calculated for any mode. At a European scale, accessibility indicators for road, rail and air are most frequently calculated. In most studies accessibility indicators were calculated for passenger travel only; there are to date only few studies calculating freight accessibility indicators. Differences between modes are usually expressed by using different generalised costs taking into account travel time, travel distance and convenience of travel. In addition, there may be a fixed travel cost component as well as cost components taking account of network access at either end of a trip, waiting and transfer times at stations, waiting times at borders or congestion in metropolitan areas.

Modal accessibility indicators may be presented separately in order to demonstrate differences in accessibility between modes. Or they may be integrated into one indicator expressing the combined effect of alternative modes for a location. There are essentially two ways 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 short- or medium-distance destinations, and to ignore the remaining slower modes. Another way is to calculate an aggregate accessibility measure 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 of travellers 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. This way of aggregating travel costs across modes is theoretically consistent only for potential accessibility. No consistent ways of calculating multimodal accessibility indicators for travel cost and cumulated opportunities exist.

Intermodal accessibility

A further refinement is to calculate *intermodal* accessibility. Intermodal accessibility indicators take account of trips involving two or more modes. Intermodal accessibility indicators are most relevant for logistic chains in freight traffic such as rail freight with feeder transport by lorry at either end. Intermodal accessibility indicators in passenger travel involve mode combinations such as Rail-and-Fly or car rentals at railway stations and airports. The intermodal generalised cost function consequently contains further additional components to take account of intermodal waiting and transfer times, cost and inconvenience. The calculation of intermodal accessibility indicators requires the capability of minimum path search in a multimodal network.

Regional accessibility

Intermodality is also an issue when calculating *intra-area* or regional accessibility. Most accessibility studies concentrated on the accessibility of cities, i.e. network nodes which are assumed to represent the whole metropolitan area or even a larger region. This presents two problems:

- Accessibility indicators calculated for network nodes ignore that accessibility is continuous in space. The decline of accessibility from the central node (centroid) of a region to smaller towns and less urbanised parts of the region is not considered.
- The quality of the interconnections between the high-speed interregional and the low-speed local transport networks cannot be taken into account. Yet the ease of getting from home or office to the nearest station of the high-speed rail network or the nearest airport may be more important for the accessibility of a location than the speed of the long-distance connection from there.

Global accessibility

Only a few accessibility studies have so far addressed issues of global accessibility. It has been part of the research of the project to propose and calculate meaningful accessibility indicators for global accessibility.

In addition the estimation of access times from locations within the area to the centroid as well as of travel times between locations within the area itself ('self-potential'), which greatly influence the accessibility of an area, increases in difficulty with spatial aggregation. There have been numerous proposals for approximate solutions to the problem of 'self-potential'. Most of them concentrate on the selection of an appropriate fictitious 'internal' distance or travel time estimated as a function of the radius of the area. A really satisfactory solution of the problem of calculating intra-area accessibility requires high-resolution data on the spatial distribution of activities in the region. If also the quality of the intraregional transport network and its connection with the long-distance interregional networks are to be assessed, detailed information on the intraregional road and public transport networks and the transfer possibilities at railway stations and airports are required.

3.3 Research concept

The TRACC project is based on and extends the state of the art of accessibility analysis presented in the previous sections:

- It takes up and updates the results of existing studies on accessibility at the European scale using most recent available network and socio-economic data.
- It extends the range of accessibility indicators by further indicators responding to new policy questions and further developing the quality and validity of the existing indicators.
- It extends the spatial resolution of accessibility indicators by calculating accessibility indicators for both the global and the regional scale.
- It explores the likely impacts of available policies at the European and national scale to improve global, European and regional accessibility in the light of new challenges, such as globalisation, energy scarcity and climate change.

To achieve this, the research in the project was divided into seven Tasks.

Task 1: Methodology/indicators

The objective of the first Task is to review the existing methods and indicators for different types of transport, transport modes and spatial scales, to improve the methods to measure European accessibility by calculating other indicators than potential accessibility and to extend them by calculating not only European travel accessibility as done so far in ESPON but also freight accessibility and global and regional accessibility. Based on this review, this Task is to define the methodology of the project, in particular to define a set of accessibility indicators for the ESPON Programme for all spatial levels considered, which has been implemented in the subsequent Tasks.

Task 2: Network and socio-economic data

The objective of this Task is to provide an assessment of network and socio-economic data including an assessment of data availability in the EU candidate countries and Western Balkan and to provide network and socio-economic datasets customised for all accessibility and impact modelling in the project at all scales addressed based on a comprehensive overview and assessment of available network and socio-economic databases.

Task 3: European accessibility: travel

The objective of Task 3 is to calculate a unique set of standard and new travel accessibility indicators. Those indicators are to address European as well as global accessibility for the regions of the ESPON space and the Western Balkan. Some basic accessibility travel indicators are to show the development of accessibility patterns in Europe for the last decade and for possible future situations. The accessibility patterns are to be transformed into European and global accessibility typologies. The results are to be presented in maps of the ESPON territory and the Western Balkan showing the spatial distribution of the different travel accessibility indicators by road, rail, air and combinations of these modes at the global and European level.

Task 4: European accessibility: freight transport

The objective of this Task is to calculate a set of freight accessibility indicators for European as well as global accessibility for the regions of the ESPON space and the Western Balkan. The accessibility pattern are to be transformed into European and global accessibility typologies. The results are presented in maps of the ESPON territory showing the spatial distribution of the different freight accessibility indicators computed for various modes and with reference to the different types of accessibility.

Task 5: Regional accessibility

The objective of this Task is to measure and analyse accessibility at the regional scale in Europe. This is to be done by two different approaches. On the one hand, a set of regional case studies encompassing different types of regions in Europe are to provide in-depth insight into regional accessibility indicators with as much as possible harmonised approaches across the different case studies. On the other hand, accessibility indicators are to be calculated that show accessibility to regional destinations, but are covering the whole ESPON space and the Western Balkan on a raster base. Finally, regional accessibility results and European accessibility results are to be compared to gain insight into the relationship of regional and European accessibility.

Task 6: Impacts of accessibility

The objectives of this task are to analyse the relationship between different types of accessibility and regional economic development and the environment (energy consumption and greenhouse gas emissions) and to forecast the development of accessibility and GDP per capita, employment and population and energy consumption and greenhouse gas emissions of transport subject to a set of long-term scenarios of European transport policies and assumptions about future developments in vehicle technology and alternative fuels and fuel price increases. In addition the results are to be analysed by different cohesion indicators expressing the impacts of the policies modelled on the convergence (or divergence) of accessibility and socio-economic development in the regions of the ESPON space and the Western Balkan.

Task 7: Policy implications

This Task is to summarise the findings of the project in relation to the goals of the European Union competitiveness, territorial cohesion and environmental sustainability for different types of regions and to evaluate the policy instruments available to the European Union and its member states to maintain and improve the different types of regional accessibility in order to draw as much benefit for regional development from accessibility with the smallest possible negative implications for territorial cohesion and the environment and to formulate policy conclusions which can stimulate and enlighten the ongoing political discourse on transport and accessibility policy for decision makers, experts and the wider public.

With this research concept the project started from the standard accessibility indicators developed in ESPON 1.2.1, 1.1.1, 2.1.1 and 1.1.3 and the recent Accessibility Updates and extended these to first freight accessibility and global accessibility and then to the regional/local level of intraregional accessibility in regional case studies and eventually looked at impacts of accessibility changes. By exploring several alternative ways of calculating regional/local accessibility indicators and comparing them with European accessibility indicators, the added value of more detailed accessibility indicators have been assessed.

The results of the project presented in the different volumes of the TRACC Final Report are:
- a consistent set of European network and regional socio-economic data,
- an analysis and a database of various European and global accessibility indicators at NUTS-3 level for travel and freight accessibility by different modes,
- case studies of regional accessibility in different types of regions and exploratory research on Europe-wide regional accessibility,
- evidence on the relationship between accessibility and regional development (GDP per capita, energy consumption and greenhouse gas emissions by transport),
- policy-relevant findings, policy conclusions and suggestions for further research.

4 Review of accessibility studies

This chapter contains a comprehensive review of accessibility studies done in Europe. The review was done in the first phases of the TRACC project. A focus was on studies published during the last decade. The review has been organised in three main parts which address different spatial contexts of the accessibility models, i.e. global, European and regional. In each subchapter, selected studies will be briefly presented and then systematically compared along the dimensions of accessibility and with respect to the accessibility patterns observed.

4.1 Global accessibility studies

The understanding of global accessibility studies in this report is that studies are included that analyse the accessibility of Europe and its regions to the world. This starts with short summaries of the few global accessibility studies available and compares these along the dimensions of accessibility identified in Chapter 2 and with respect to the accessibility patterns observed.

BAK Basel Economics (2004; 2005) developed a global accessibility indicator of the potential type. About 120 non-European airports were selected as destinations, and the GDP of their hinterland area constituted their attractiveness. It was stated that 99 % of the global economy outside Europe is covered. Origins were about 220 European regions of which 150 are located in the extended Alpine space. Travel times were based on intermodal trip chains from the origin regions to the airports plus the flight time to the final destination and included waiting and transfer time.

Certet (2010) computed an indicator of global accessibility for air cargo of 13 European airports. This indicator was updated on a yearly basis to monitor the performance of the airports and their relative position in competitive terms. The indicator was a sort of multicriteria index based on four main items: relevance of the destinations served by the airport, frequency of connections, quality of service and tariffs for freight forwarding.

The ESPON project "Europe in the World" (ESPON 3.4.1, 2007) did an analysis of intercontinental air connectivity of European airports. The global accessibility offered by the European airports was measured in terms of global passenger km travelled from the airport which might be considered a variant of the cumulative opportunities indicator of the three generic types. In addition, the main orientation of the individual airports was assessed by analysing the share of different world regions in the transport volume.

A somewhat different global accessibility indicator was produced by the Joint Research Centre of the European Commission (Nelson, 2008) and developed for the World Development Report 2009 (World Bank, 2009). The indicator was travel time by road or rail from subnational territorial units to the nearest of 8,500 major cities in the world. The indicator was different than the other global accessibility indicators presented before, because it calculated accessibility to regional destinations. But as this was done for the whole globe, the indicator is incorporated here as a unique example of a global accessibility indicator.

Comparison

Table 4.1 presents the global accessibility studies with respect to the dimensions of accessibility. All generic types of accessibility indicators were represented. The indicators, however, were in most cases calculated for the airport or the airport city, consequently, air transport was the only transport mode. The only exception from this are the studies by BAK Basel Economics (2004; 2005) which calculated global accessibility for a set of regions by incorporating the access time from the regions to the airports into an overall intermodal travel time. Most studies considered travel, but air freight was addressed in only one study. In the freight study, not only travel time, but also criteria such as quality of service and tariffs were included in the accessibility indicator.

Table 4.1. Dimensions of global accessibility models

Authors	Indicator type	Origins	Destinations	Impedance	Constraints	Barriers	Type of transport	Modes	Spatial scope
BAK Basel Economics (2004; 2005)	Potential	220 regions of which 150 in the extended Alpine space.	GDP represented by 120 non-European airports	Travel time	Timetable restrictions	-	Travel	Intermodal	Extended Alpine Space, Europe (partly)
ESPON 3.4.1 (2006); ESPON (2007)	Cumulative	European airports	Airports in the world	-	-	-	-	Air	ESPON space
Certet (2010)	Travel cost	13 European airports	260 airports outside Europe	Travel time, travel cost	Frequency, quality of service	-	Freight	Air	Selected airports in Europe
Nelson (2008); World Bank (2009)	Travel cost	Subnational regions	8,500 major cities world wide	Travel time	-	-	Travel	Road, rail	World

Spatial pattern

Table 4.2 gives the main results of the four global accessibility studies with respect to the accessibility patterns, spatial disparity and its changing patterns over time.

The studies looking at global accessibility by using the airports as origins and either indicators of the travel cost or cumulated opportunities type came to the result of a strong hierarchy of airport cities in Europe. The study looking at global accessibility for a set of regions by using a potential accessibility indicator stated much less disparities in Europe. This might be traced back to the fact that the different access times from the regions to the airports play a much lower role for the accessibility value, because the higher proportion of the total travel times consists of airport terminal times and the travel times of long-distance flights.

Table 4.2. Accessibility pattern stated in global accessibility studies

Authors	Destinations considered	Accessibility patterns
BAK Basel Economics (2004; 2005)	120 airports outside Europe weighted by GDP of their hinterland area	European metropolitan regions have the highest accessibility. Frankfurt, London, Paris and Amsterdam are leading with standardised index values of about 120 (Alpine regions = 100). Standardised accessibility values vary only between 69 and 124, the lowest values are found in some Alpine regions.
ESPON 3.4.1 (2007)	Airports outside Europe	The most important European gateway cities are London, Paris, Frankfurt and Amsterdam which stand also at the top of the list of world cities in terms of air connectivity. Other European cities are less important for global connectivity but play a role for connections to southern and eastern the neighbourhood of Europe.
Certet (2010)	260 airports outside Europe	Frankfurt airport has the highest intercontinental accessibility, followed by London, Amsterdam and Paris. Intercontinental accessibility of other European airports is significantly lower.
Nelson (2008); World Bank (2009)	8,500 major cities world-wide	Europe has very short travel times to the nearest cities compared with other parts of the world. Only 15 % of the population in developed countries are more than one hour away from a city, in developing countries 65 %.

Assessment

There are only a few global accessibility models available, but they are mostly concerned with the different intercontinental accessibility provided by airports, i.e. points in space, and not by the way how this translates into the global accessibility of regions. This is considered by one study only, however, its regional system is mainly confined to one European macro region. In conclusion, a systematic evaluation of the global accessibility of European regions is lacking so far.

4.2 European accessibility studies

Over the last decades a vast number of accessibility studies addressing European core-periphery issues have been published. This chapter extends earlier reviews (Rietveld and Bruinsma, 1998; Wegener et al., 2001; ESPON 1.2.1, 2005). It starts with short summaries of prominent European accessibility studies and compares these along the dimensions of accessibility identified in Chapter 3 and with respect to equity and cohesion.

There is a growing number of accessibility models addressing Europe-wide accessibility. This section briefly introduces European accessibility models developed in the last three decades and classifies them and compares the accessibility indicators they produce by applying the dimensions of accessibility presented in Chapter 2. The dimensions equity and dynamics are discussed separately. The order of the models presented is chronological.

Keeble et al. (1982, 1988) in a project for DGXVI of the European Commission analysed economic core-peripherality differences between the regions of the Community and investigated 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 were expressed as economic potential index and presented in maps as contour lines.

Törnqvist had already in the 1970s developed the notion of 'contact networks' based on the hypothesis that the number of interactions with other cities by visits such as business trips is a good indicator of the position of a city in the urban hierarchy. Based on this, Cederlund et al. (1991) and Erlandsson and Törnqvist (1993) calculated daily accessibility indicators of European cities expressed as the number of people 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 (*outbund* accessibility).

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 intermodal transport (road, rail, air) to 194 economic centres in Europe. In the same study they used also other destinations such as the nearest three agglomerations, the nearest high-speed train stop or the nearest airport. In addition, they calculated a daily accessibility indicator expressed 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 the population potential of European cities with similar results as Keeble et al. (1982; 1988) once again demonstrating the spatial correlation between economic and population centres.

Spiekermann and Wegener developed three-dimensional surfaces of daily and potential rail accessibility for Europe using raster-based GIS technology (Spiekermann and Wegener, 1994; 1996; Vickerman et al., 1999), road and air accessibility were added later (Schürmann et al., 1997; Fürst et al., 2000). The quasi-homogenous accessibility surfaces were achieved by subdividing 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. Population of raster cells was estimated by allocating the population of NUTS-3 regions to raster cells with the help of a hypothetical 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 airline travel speed of 30 km/h.

Chatelus and Ulied (1995) developed several accessibility indicators for the evaluation of trans-European networks at the level of NUTS-2 regions in the EU15 plus Norway. One of them, the FreR(M) indicator, measures the average cost to reach a market area of a certain population size by lorry. The impedance term is generalised road transport cost including cost of the driver's time, cost per kilometre and a fixed cost component. The CON(T) indicator accumulates population of NUTS-2 regions of EU15 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 competitiveness, cohesion and sustainability. The FreR(T) index is a freight accessibility indicator expressing the size of the market that can be reached in a certain travel time, e.g. the population that can be reached overnight or in 12, 36, 60 or 84 hours 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 multimodal 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 timetable travel time plus road access time and penalties for changes between road and rail (60 minutes), rail and ferry (180 minutes) and change of rail gauge between Spain and France (30 minutes).

Copus (1997, 1999), in studies for the Highlands and Islands European Partnership Programme and for DG Regio of the European Commission 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 for the Study Programme on European Spatial Planning of DG REGIO, Wegener et al. (2001) 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 was seen as an indicator for the size of market areas for suppliers of goods and services and accessibility to GDP as an indicator of the size of market areas for suppliers of high-level business services. Accessibility was presented as percent of European average accessibility.

Schürmann and Talaat (2000) produced an index of peripherality for the Third Cohesion Report of the European Commission (2001) with a geographical information system. Potential type indicators are calculated for passenger and freight transport by road using GDP or population or labour force as destination activity. Travel times for lorries were computed separately from car travel times to take account of speed limits for lorries, delays at borders and ferry ports and statutory drivers' rest periods. The indicators were calculated for NUTS-3 regions and for equivalent regions of the candidate countries and Norway and Switzerland. The indicators were aggregated to NUTS-2, NUTS-1 and NUTS-0 regions. The peripherality index was presented in two ways: either standardised on the European average (as in Wegener et al., 2001) or to an interval between zero and one hundred (as in Copus, 1997, 1999).

In 2004 a research team led by Nordregio (2004) in a project for DG Regio analysed the socio-economic situation of mountain areas in the EU and potential accession and other countries. The study analysed different accessibility indicators, among them population potential, airline distances to national capital cities and the nearest three cities with more than 100,000 inhabitants, access to airports, universities and hospitals. Two spatial levels were used: All indicators were calculated at municipal level and then aggregated to mountain areas. First all indicators were standardised at the European average, but also at the respective national averages. Access to public facilities was initially calculated as shortest travel time by car to the nearest facility and then converted to the proportion of population at more than one hour from the nearest facility.

L'Hostis developed in ESPON 1.2.1 (2005) and ESPON FOCI (2010) a variant of the daily accessibility indicator labelled 'city network contactability'. Presented primarily in map form, the indicator expresses which other MEGAs can be accessed by an origin MEGA within a time window of 5 h until 23 h and allowing for at least 6 hours of activity at the destination.

Another study by Nordregio (Gløersen et al., 2006) analysed the accessibility of peripheral, sparsely populated regions in Finland, Norway and Sweden in the European Union. Due to their extremely peripheral location, these regions rely on transport hubs such as airports and seaports; therefore the number of destinations and the frequency of services of flight and ferry connections were analysed. In addition, access to universities and hospitals was analysed as the proportion of population living within 60 minutes from these facilities.

In a study for the Directorate-General for Internal Policies of the Union of the European Parliament (European Parliament, 2007) a 2.5x2.5 km raster system for the entire European Union plus Norway and Switzerland was used to calculate a comprehensive set of road potential accessibility indicators to population, GDP and service facilities, such as airports, high-speed train stations, universities and hospitals. The results at raster level were aggregated to the NUTS-3 and NUTS-2 level, and indicators, such as number and proportion of population within 60 minutes travel time were derived and mapped.

Spiekermann and Schürmann (2007) updated the potential accessibility indicators for road and rail introduced in ESPON 1.2.1 (2005) and used in several ESPON projects and EU documents with 2006 network data. More recently, the work was extended to air and multimodal accessibility (Spiekermann, 2009; see also ESPON, 2009). Indicators were calculated for NUTS-3 regions of the ESPON space. Particular attention was given to the question how changes over time are analysed, because different ways of presenting changes, e.g. relative change, absolute change, change of the standardised index value, give different results with respect territorial cohesion.

The number of available passenger flights within a maximum travel time by road of 90 minutes was developed for the debate on territorial cohesion (Commission of the European Communities, 2008; European Commission, 2010). This indicator of the generic type of cumulative opportunities was calculated at raster cell level and for NUTS-3 region. For each area the number of flights reachable with the maximum travel time was summed up.

Dijkstra and Poelman (2008) used a travel time indicator to measure remoteness of rural NTUS-3 regions. A rural region was considered as peripheral if more than half of its population have a travel time by car of more then 45 minutes to the nearest city with more than 50,000 inhabitants. The classification of remoteness was combined with the OECD classification of regions to overcome some of its shortcomings. The derived typology of regions, which is also part of the ESPON typology of regions, has five classes of NUTS-3 regions: urban regions, intermediate regions close to a city, intermediate, remote regions, rural regions close to a city and rural remote regions.

Hamed and Krause (2010) developed an index to measure the accessibility of transport routes by mean of a route accessibility index (TRAX: TRACECA Route Accessibility indeX). This index takes into account four basic elements: transport time, transport cost, transport reliability and cargo safety. These elements were quantified for three alternative routes linking Europe to the TRACECA countries by means of interviews with the logistics operators in the TRACECA region and in western Europe and of drivers' journals for real driven routes.

Comparison

The European accessibility models reviewed above yield a wide range of approaches with respect to various dimensions of accessibility. They differ in many respect, but there are also some commonalties (see Table 4.3):

- More than half of the models use potential type indicators, the remaining models use travel costs or cumulated opportunities indicators. A few models calculate several types of indicator.
- The origins for which accessibility indicators are calculated are usually NUTS-2 or NUTS-3 centroids, very few studies have a more detailed representation of space.

Table 4.3. Dimensions of European accessibility models

Authors	Indicator type	Origins	Destinations	Impedance	Constraints	Barriers	Type of transport	Modes	Spatial scope
Keeble et al. (1982; 1988)	Potential	NUTS-1 NUTS-2	GDP in NUTS-2 and other European NUTS-0.	Road distance	-	Sea crossings, trade barriers	Freight	Road	EU9 EU12
Cederlund et al. (1991) Erlandsson and Törnqvist (1993)	Travel time, cumulated	Cities	Cities	Travel time	-	-	Travel	Fastest mode	EU12
Lutter et al. (1993)	Travel cost, cumulated	NUTS-3	194 centres, nearest 3 agglomerations, airports etc.	Travel time	-	-	Travel	Road, rail, air, intermodal	EU12
Bruinsma and Rietveld (1993)	Potential	Cities	Cities	Travel time	-	-	Travel	Air	EU27+2
Spiekermann and Wegener (1994, 1996)	Cumulated, potential	10 km raster cells	Population in 10 km raster cells	Travel time, travel cost	-	-	Travel	Rail	EU27+2
Chatelus and Ulied (1995)	Travel cost, cumulated	NUTS-2	Population of NUTS-2	Travel cost	Statutory drivers' rest breaks	-	Travel, freight	Road Rail Air, intermodal	EU15 +2
Gutierrez and Urbano (1996)	Travel cost	4,000 nodes	94 agglomerations	Travel time	Congestion in urban areas	Change of rail gauge	Travel	Road, rail	EU12
Copus (1997, 1999)	Potential	NUTS-2 NUTS-3	Population, GDP, labour in NUTS-2/3	Travel time	Statutory drivers' rest breaks	Border delays	Travel	Road	EU15+2+12
Wegener et al., (2001)	Potential	NUTS-3	Population, GDP in 10 km raster cells	Travel time, travel cost	-	Border delays	Travel	Road, rail, air	EU15
Schürmann and Talaat (2000)	Potential	NUTS-0 - NUTS-3	Population, GDP, workforce in NUTS-3	Travel time	Statutory drivers' rest breaks	Border delays	Travel, freight	Road	EU15+12
Nordregio (2004)	Cumulated	LAU-2 of mountain areas	Municipality facilities	Travel time	-	-	Travel	Road	EU27+2+5

Table 4.3. Dimensions of European accessibility models (continued)

Authors	Indicator type	Origins	Destinations	Impedance	Constraints	Barriers	Type of transport	Modes	Spatial scope
L'Hostis in ESPON 1.2.1 (2005); ESPON FOCI (2010)	Cumulated	FUAs	FUAs	Travel time	Timetable re-strictions	-	Travel	Rail, air, inter-modal	EU27+2
Gløersen et al. (2006)	Cumulated	LAU-2	Airports, seaports, universities Hospitals	Travel time	-	-	Travel	Road Air	EU27+2
European Parliament (2007)	Potential	2.5 km raster cells NUTS-3 NUTS-2	Population, GDP airports, HSR sta-tions, universities, hospitals	Travel time	-	-	Travel	Road	EU27+2
Spiekermann and Schürmann (2007); Spiekermann (2009); ESPON 1.2.1 (2005)	Potential	NUTS-3	NUTS-3 population	Travel time	-	Border delays	Travel	Road, rail, air, multimodal	EU27+2
Dijkstra and Poelman (2008)	Travel cost	LAU-2	Cities > 50,000	Travel time	Slope	-	Travel	Road	EU27+2
Commission of the European Communities (2008); European Commission (2010).	Cumulated	Raster cells, NUTS-3	Daily flights at air-ports	Travel time	-	-	Travel	Road	EU27+2

- The destination activities are usually population or GDP for potential type accessibility indicators and a pre-defined set of agglomerations for the travel cost indicators. For daily accessibility indicators both population and public facilities, such as airports, high-speed train stations, universities or hospitals are used as destinations.
- Nearly all models use travel time as impedance term, only few models apply travel costs or a combinations of both as generalised cost.
- Only few models consider constraints on the impedance term. Models that consider freight transport use statutory drivers' rest breaks as constraints.
- Only few accessibility models consider barriers, such as waiting times at national borders. Only Keeble et al. use trade barriers, such as tolls.
- Nearly all accessibility models are based on passenger travel, only few models 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 intermodal travel times.

Equity and cohesion

Table 4.4 summarises the main results of the accessibility models with respect to spatial disparity and its changing patterns over time.

It can be seen that all European accessibility studies expose the existing core-periphery pattern of accessibility in Europe and all indicate that over time the gap in accessibility between core and peripheral regions has increased.

A distinction can be made between potential and cumulated opportunities. Whereas potential accessibility has improved in the former cohesion countries in southern Europe and increasingly also in the new member states in central and eastern Europe, cumulated opportunities, in particular where business trips are concerned, have increased mainly in central regions with good air connections.

Another important distinction can be made between whether changes in accessibility are measured in relative or in absolute terms. Whereas in relative terms (e.g. in percent) accessibility has improved more in the peripheral regions, in absolute terms accessibility in the core regions in western Europe has continued to grow more.

Assessment

An overall assessments of European accessibility models is difficult. The general tendency is that none of the models is really able to serve all purposes:

- Most models focus on person travel and ignore freight transport although freight transport might be more relevant for peripheral regions. Spiekermann and Neubauer (2002) in their review of European accessibility studies found only two out of ten studies dealing with freight accessibility. However, empirical work has shown that road accessibility by using car and trucks are highly correlated and that car accessibility can be used as a proxy for truck accessibility.
- Most models do only have an implicit relation to certain sectors of the economy, i.e. by concentrating on person travel the models are closely related to the service sector and neglect that transport has different relations with different sectors (see Vickerman, 1999).

Table 4.4. Equity and dynamic statements of European accessibility models

Authors	Spatial disparities	Changing pattern through time
Keeble et al. (1982; 1988)	Core-periphery pattern	Disparities in accessibility have increased in past periods
Cederlund et al. (1991) and Erlandsson and Törnqvist (1993)	Core-periphery pattern	Disparities in accessibility have increased in past periods
Lutter et al. (1993)	Existing, but scope depends on destination activities considered	Travel time benefits for peripheral regions, cumulated opportunities increase in central regions
Bruinsma and Rietveld (1993)	Core-periphery pattern	Increasing disparities in accessibility
Spiekermann and Wegener (1994, 1996)	Clear core-periphery pattern plus clear centre-hinterland disparities in all European countries	Increasing disparities induced by TEN
Chatelus and Ulied (1995)	Clear core-periphery pattern	Decreasing disparities
Gutierrez and Urbano (1995, 1996)	Clear core-periphery pattern	Decreasing disparities induced by TEN
Copus (1997, 1999)	Clear core-periphery pattern	Dynamics not considered
Wegener et al., (2001)	Different core-periphery patterns for different transport modes	Increasing or decreasing disparities is an outcome of the indicator
Schürmann and Talaat (2000)	Clear core-periphery pattern for road transport	Improvements mainly for EU candidate countries
Nordregio (2004)	Great disadvantage in accessibility of mountainous regions	Increasing disadvantage of mountainous regions
Gløersen et al. (2006)	Great differences in accessibility between core and periphery	Increasing peripherality of remote regions
L'Hostis in ESPON 1.2.1 (2005); ESPON FOCI (2010)	Urban connectivity differs clearly between MEGAs in Europe	n.a.
European Parliament (2007)	Great differences in accessibility between core and periphery	Increasing peripherality of remote regions
Spiekermann and Schürmann (2007), Spiekermann (2009); ESPON 1.2.1 (2005)	Great differences in accessibility between core and periphery	Cohesion improving in relative terms but declining in absolute terms
Dijkstra and Poelman (2008)	One third of rural regions are remote	n.a.
Commission of the European Communities (2008); European Commission (2010).	Access of airports differs widely	n.a.

- Following that, the reality of the business environment in peripheral rural areas is hardly represented in the European accessibility models.
- Some models, those working with travel cost indicators, support the case for public investment in infrastructure by demonstrating increased cohesion. Other models, mainly of the potential type, are much more cautious or even forecast increased regional disparities as outcome of transport infrastructure investments.

To conclude, despite the vast range of models, there is currently no model presented in the literature that would match all requirements for the different dimensions. Models that are superior in a certain dimension are behind in others. There is no model available that would be able to calculate accessibility for a spatially detailed representation of pan-Europe for person travel and freight transport for all transport modes including multi- and intermodal trips for different indicator types and destination activities and that has a database that allows assessments for different points in time, i.e. past, current and future accessibility patterns.

4.3 Regional accessibility studies

The number and diversity of accessibility studies at the regional level in Europe is much larger than those of Europe-wide studies. Consequently, only a part of these studies can be included in this review. The focus of the subsequent presentation of regional accessibility studies in Europe is on studies from the last decade. First, studies will be presented in which the study area covers more than one country, i.e. trans-national accessibility studies. The second subchapter presents studies which are either for whole countries, i.e. national accessibility studies, or are dealing with only parts of a country.

4.3.1 Trans-national accessibility studies

For several trans-national areas in Europe, accessibility studies evaluated the situation from a viewpoint that is below the Europe-wide, but above the national scale.

Nordic countries

The peripherality of Nordic regions was considered within the regions but also in the European context by Spiekermann and Aalbu (2004). On the one hand, the study assessed the disadvantages of Nordic locations in terms of real travel costs from Nordic regions to attend half-day business meetings and conferences in Brussels and in Helsinki. On the other hand, the intra-Nordic and European peripherality was assessed by multimodal potential accessibility indicators for all municipalities of the Nordic countries.

A study on northern peripheral, sparsely populated regions assessed the degree of peripherality of these regions in relation to the rest of Europe (Gløersen et al., 2006). Three extensions to the concept of accessibility were introduced: (i) The indicator of population potential within 50 km at 1x1 km raster level was used to delimitate peripheral, sparsely populated areas. (ii) A ratio of potential accessibility by air with potential accessibility by road was calculated in order to identify regions with a high dependency on air transport. (iii) Access to airports was measured based on population at 1 km raster level as the percentage of municipality population living within one hour travel time to the nearest airport.

Accessibility in peripheral Finland, Sweden and Norway was mapped as travel time zones to the nearest towns of more than 10,000 inhabitants in a study by Gløersen (2009: 46). The zone delimitations range from 45 minutes representing commuting distance to 90 minutes as an acceptable distance for access to basic services.

Baltic Sea Region

In a background study for the VASAB 2010 plus Spatial Development Action Programme, Hanell et al. (2000) calculated daily accessibility by road, rail and air for 10 km raster cells for the Baltic Sea Region for the year 1996 and a future situation with the trans-European Transport Network programme implemented. Accessibility indicators were presented in three-dimensional accessibility surfaces for the current level and for scenarios of assumed changes..

In an accessibility analysis of the Baltic Sea Region (Schürmann and Spiekermann, 2006) car, lorry and rail travel times from 2 km raster cells to the nearest rail stations, commercial airports, transport terminals and large cities were calculated. Travel times between major BSR cities by road, rail and air were used to map urban connectivity in the area. A set of multimodal potential accessibility indicators at NUTS-3 level completed the analysis. Even though the focus was on passenger travel, freight transport was tackled as well by lorry travel times to transport terminals.

Transport infrastructure, mobility and accessibility patterns were identified as main drivers of spatial development and spatial integration of the countries around the Baltic Sea (Schmitt et al., 2008; Dubois and Schürmann, 2009). Regional accessibility was analysed in a 3-step approach. First the service quality of rail, air and ferry services was assessed through the frequency of rail, air and ferry services. Second, different accessibility indicators such as population potential within 50 km radius and potential accessibility by road to GDP and to population, were generated for a system of raster cells of 2.5 x 2.5 km for the entire ESPON space. Third, travel time indicators such as lorry travel times to freight terminals, car travel times to universities and to commercial airports were generated for the same raster system illustrating regional accessibility patterns throughout Europe.

North-west Europe

Potential accessibility indicators for freight rail transport were used by Smith and Gibb (1993) to forecasts the likely impacts of the Channel Tunnel on NUTS-2 regions within seven EU member states. Rail travel times for the shortest path calculations were taken from timetables. Different scenario simulations were conducted with varying speed assumptions for the tunnel section.

Potential accessibility was used in the GEMACAII project to assess the relative position of agglomerations in north-west Europe (Spiekermann et al., 2001). Accessibility indicators were calculated at municipality level for fourteen urban regions and at NUTS-3 level for regions in-between. Population in NUTS-3 regions of Europe were used as destination activities. Transport modes considered were road, rail and air.

Central and South East Europe

The accessibility model of the BBR was used in the INTERREG IIIB CADSES project PlaNet Cense to analyse the accessibility patterns for Central and South East Europe (BBR, 2006). The potential accessibility indicator was calculated for a dense grid of reference points as origins. FUAs served as destinations. Car travel time and, if a combination of car and plane was faster, the combined travel time of the two modes were used as impedance.

The INTERREG IIIB CADSES project RePUS "*Strategy for Regional Polycentric Urban System in Central-Eastern Europe Economic Integrating Zone"* used different accessibility indicators to characterise the urban systems of Austria, the Czech Republic, Hungary, Italy, Poland, and Slovenia and to identify potentials for (cross-border) co-operations of municipalities and regions (Benini, 2007). Following the approach developed in the ESPON 1.1.1 project for the delimitation of so-called PUSH and PIA areas (Schürmann, 2004), 60-minutes car travel time isochrones from regional capitals were overlaid with municipality boundaries to delimitate service areas and population potentials within these areas. The number of overlapping service areas in each municipality was used to assess the freedom of choice for the inhabitants to travel to different regional centres to reach public and private services.

Alpine Space

BAK Basel Economics (2004) calculated potential accessibility indicators for 147 regions of the Alpine Space and its nearer surroundings. Travel times for road and public transport are based on very detailed network representations. Destinations are European NUTS-2 regions and for intercontinental accessibility also airports in other continents weighted by GDP. Results are presented in map form and in histograms showing the distribution of accessibility over aggregate classes.

Accessibility indicators were also used to contribute to a new typology of the Alpine Space in Atlas format (Tappeiner, 2008a; 2008b). Road distance and travel time by car were calculated for all municipalities of the Alps. Destinations used are the nearest motorway or major road, the nearest commercial airport, regional capitals, the nearest municipality with more than 5,000 inhabitants and the nearest hospital.

Iberian Peninsula

Figueira and Viegas (1999) measured freight accessibility of Portuguese coastal regions in the Iberian context as demographic accessibility and economic accessibility. Demographic accessibility was estimated by considering population of European regions as relevant destination activity using travel times as a threshold criterion for acceptability. Economic accessibility was based on weights summarising the complementarity of the economies of the destination regions with respect to the economy of the origin regions.

Gutiérrez Gallego et al. (2010) analysed the socioeconomic realities of border regions between Portugal and Spain with accessibility measures. The indicator used was road travel time to the nearest of the 15 main economic centres in Portugal and Spain.

Comparison

The trans-national accessibility models reviewed above yield a wide range of approaches to the various dimensions of accessibility. They differ in many respect, but there are also some commonalties (see Table 4.5):

- About half of the models use potential type indicators, the remaining models use travel costs or cumulated opportunity indicators. A few models are able to calculate more than one type of indicator.
- The origins for which accessibility indicators are calculated differ very much. The range is from NUTS-3 regions through municipalities down to a detailed representation of space in form of small raster cells.
- The destination activities are usually population for accessibility indicators of the potential type and a pre-defined set of agglomerations, cities or certain facilities, such as airports or hospitals, for the travel cost indicators. For cumulated opportunity indicators, population, cities or public facilities are used as destinations.
- Nearly all models use travel time as impedance term, only one model applies travel costs. Some models use airline or road distance.
- Only few models consider constraints on the impedance term in form of timetable restrictions for public transport.
- None of the trans-national accessibility models considers political, cultural or language barriers in the impedance term.

Table 4.5. Dimensions of trans-national accessibility models

Authors	Indicator type	Origins	Destinations	Impedance	Constraints	Barriers	Type of transport	Modes	Spatial scope
Hanell et al (2000)	Cumulated	10 km raster cells in BSR	10 km raster cells in Europe	Travel time	-	-	Travel	Road, rail, air	Baltic Sea Region
Spiekermann and Aalbu (2004)	Travel cost, potential	NUTS 3, LAU-2	Brussels, Helsinki LAU-2	Travel time, travel cost	Timetable restrictions	-	Travel	Road, rail, air, multimodal	Nordic countries
Gløersen et al. (2006).	Cumulated, potential,	NUTS 3, grid cells	NUTS 3, Airports,	Travel time, distance	-	-	Travel	Road, Airports	EU27+NO+CH SE, FI periphery
Gløersen (2009)	Travel cost	Raster cells	Cities > 10.000 inhabitants	Travel time	-	-	Travel	Road	Periphery of NO, SE, FI
Schürmann and Spiekermann (2006)	Travel cost, potential	Raster cells, NUTS-3	Rail stations, airports, transport terminals, cities	Travel time	-	-	Travel Freight	Road, rail, air	Baltic Sea Region
Schmitt et al. (2008; Dubois and Schürmann, 2009).	Travel cost, potential	2.5 x 2.5 km Raster cells	Raster cells; freight villages; higher education facilities, airports	Airline distance Travel time	-	-	Travel, Freight	Road	Baltic Sea Region, EU27
Smith and Gibb (1993)	Potential	NUTS-2	NUTS-2	Travel time	-	-	Freight	Rail	UK, IE, FR, BE, NL, LU, DE
Spiekermann et al. (2001)	Potential	LAU-2 in aggl., NUTS-3	LAU-2/NUTS-3 population	Travel time	-	-	Travel	Road, rail, air	North-west Europe
BAK Basel Economics (2004)	Potential	141 regions	NUTS-2	Travel time	Timetable restrictions	-	Travel	Road, public transport	Alpine Space extended
Tappeiner (2008a; 2008b)	Travel cost	LAU-2	Motorways/major roads, airports, regional capitals, LAU-2 > 5,000, hospitals	Road distance Travel time	-	-	Travel	Road	Alpine Space
BBR (2006)	Potential	Grid points	FUAs	Travel time	-	-	Travel	Road, intermodal	Central/South-East Europe
Benini (2007)	Travel costs	LAU-2	Regional capital cities	Travel time	-	-	Travel	Road	Central/South-East Europe
Figueira and Viegas (1999)	Cumulated	Cities	Cities	Travel time	-	-	Freight	Road	Portugal and Spain
Gutiérrez Gallego et al. (2010)	Travel cost	Raster cells	15 economic centres	Travel time	-	-	Travel	Road	Portugal and Spain

- Nearly all accessibility models are based on passenger travel, only few models 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 one model uses intermodal travel times.

Spatial pattern

Table 4.6 summarises the main results of the trans-national accessibility models with respect to the spatial pattern of accessibility observed.

Nearly all trans-national accessibility studies show large differences in accessibility for different parts of their study area. Regardless the type of indicator, spatial disparities are very much pronounced in those studies.

However, it is also stated that the question of disparities in accessibility is a question of the destinations considered. That means that some trans-national areas show large disparities if Europe-wide accessibility is considered, but are much less polarised when destinations of regional interest are considered. In addition, when evaluating the access to public facilities, such as hospitals or regional centres, some of the studies conclude that the travel times are reasonable for most of the population and better than expected.

Assessment

An overall assessments of trans-national accessibility models is difficult. The general tendency is similar to that of the European accessibility models (see Chapter 3.2): that none of the models is really able to serve all purposes.

In addition, it is difficult to compare the results of the different trans-national accessibility models in more detail. The different ways of incorporating the dimensions of accessibility in the models, in particular the different destination activities considered, the different ways the impedance terms are calculated and the very large variety of spatial detail with respect to origins, destinations and network representation, do not allow to draw more detailed conclusions concerning spatial patterns in different types of regions than those stated above.

4.3.2 National and regional accessibility studies

The national and regional accessibility studies are presented on a country by country base. However, summary tables are differentiated by the spatial coverage of the studies, i.e. whether they cover a whole country or only parts of it.

Iceland

In an accessibility study for the Greater Reykjavik area 53 sub-districts and 141 plan-districts were used as trip origins, but destinations comprised only a small number of locations of specific interest: Reykjavik city centre, the University of Iceland, the national university hospital and a large shopping mall (Bjarnason, 2005). Three variants of travel-time based accessibility indicators for cars, cycling and bus were introduced. The so-called accessibility time 50% gives the duration it takes to reach half of all working places. Second, a travel-ratio gives the ratio of travel times of bikes v. cars and buses v. cars. Finally, another set of ratios gives the quotient between the shortest distances by car, bicycles and bus to airline distance.

Table 4.6. Accessibility pattern stated in trans-national accessibility studies

Authors	**Spatial scope**	**Accessibility pattern**
Hanell et al. (2000)	Baltic Sea Region	Hugh disparities in accessibility for all modes. Highest value for German and Polish regions as well as for St. Petersburg and for cities with international airports. The largest increases are along TEN-T corridors, the largest in Germany and Poland.
Spiekermann and Aalbu (2004)	Nordic countries	Clearly above European average travel costs of Nordic regions to Brussels. High disparities in the intra-Nordic and European degrees of accessibility with extreme low values in the far north.
Gløersen et al. (2006).	Northern periphery of SE, FI	Nordic peripherality is assessed to reveal the difficulties to access goods and services produced in European core areas.
Gløersen (2009)	Northern periphery of NO, SE, FI	Population growth is observed in areas with good accessibility, i.e. within commuting distance to cities, but not beyond.
Schürmann and Spiekermann (2006)	Baltic Sea Region	Travel time to public facilities is very different in different parts. Areas of short travel time extend along the major infrastructure arteries. Areas in the northern and eastern parts of the BSR have overall weak accessibility. Denmark, Germany and the southern parts of Poland have much higher levels of potential accessibility than the remaining parts of the Baltic Sea region.
Schmitt et al. (2008), Dubois and Schürmann (2009).	Baltic Sea Region	Travel time to public facilities is very different in different parts. Areas of short travel time extend along the major infrastructure arteries. Areas in northern and eastern parts of the BSR lack many of the analysed facilities, their overall accessibility is rather weak. The spatial reference of standardising accessibility indicators, e.g. BSR v. EU, results in different assessments of central and peripheral areas.
Smith and Gibb (1993)	UK, IE, FR, BE, NL, LU, DE	The accessibility benefits of the Channel Tunnel would be restricted to the south-east of England without any further improvements in the UK rail networks.
Spiekermann et al. (2001)	North-west Europe	The 14 agglomerations considered vary considerably in terms of road, rail and air potential accessibility to European destinations. However, also within several agglomerations, there are large differences, in particular for rail and air accessibility.
BAK Basel Economics (2004)	Alpine Space extended	Regions of southern Germany have highest accessibility values, in particular for road and rail, to European destinations followed by Zürich and Milan. There are huge disparities in accessibility, Standardised index values (EU27=100) range between 18 and 140.
Tappeiner (2008a; 2008b)	Alpine Space	Due to the topography of the Alps, accessibility in terms of distance and travel time to selected destinations is spatially very fragmented with areas of long distances and travel times. But 90 % of all municipalities are located within less than 25 min. or 20 km apart from the nearest hospital.
BBR (2006)	Central and South-East Europe	From a European viewpoint the area has a clear core-periphery pattern, from a regional viewpoint, high regional accessibility spots are spread over the area without any clear core or peripheral area.
Benini (2007)	Central and South-East Europe	Depending on the urban system and the topography, accessibility to regional cities is quite different among the CADSES countries. While 60-minute isochrones for Poland, Czech Republic and Italy overlap each other to a high degree, the situation in Slovakia, Hungary and Austria is quite different with large areas suffering from a lack of access to any regional city.
Figueira and Viegas (1999)	Portugal and Spain	Peripheral regions have lower levels of accessibility, because they are farther from their potential partners. Significant gains in accessibility are obtained when the limits of acceptable travel time are slightly extended.
Gutiérrez Gallego et al. (2010	Portugal and Spain	Travel times from the Portuguese-Spanish border regions to the nearest economic centres are highest in the Iberian peninsula.

Norway

Two studies related to accessibility in the Oslo region were carried out with survey-based data. Naess et al. (1995) studied the use of car and public transport and found that residents in local communities with a high population density and a short distance to downtown Oslo travel considerably shorter distances and use significantly less energy per capita than those living in more remote areas. Naess et al. (2001) considered the effect of increasing accessibility on modal choice in an empirical study about commuting patterns in two transport corridors in Oslo.

A recent study on the social and economic situation of the mountain areas in southern Norway included an accessibility analysis with population potential and access to services from a local and regional perspective (Arnesen et al., 2010). Accessibility indicators were calculated for a 1 km raster and aggregated to municipality level. A population potential within 50 km airline distance was calculated for 2000 and 2010, absolute and relative changes were mapped. Car travel times indicators to airports, railway stations, hospitals and universities.

Sweden

An early example of accessibility-related studies in Sweden applying the travel times database of the National Road Administration to compute accessibility potentials at the municipal level was carried out by Forslund and Johansson (1995). Alternative national road investment projects and programmes were evaluated by comparing project costs with benefits in terms of time savings and reduced accident rates. Three types of accessibility were analysed in association with the capacity of international ports, labour supply and population size in municipalities.

Johansson et al. (2002) investigated the relationship of municipal time distances and local and regional labor markets in a case study of southern Sweden. Accessibility was measured in terms of number of jobs, labour supply and supply of service functions. The data on time distances for accessibility potentials were obtained from the Swedish National Road Administration database.

Andersson and Ejermo (2005) applied potential accessibility indicators for explaining the competitiveness of regions and enterprises with the case of 130 Swedish corporations during 1993–1994. The number of patents was related to accessibility to internal and external knowledge sources measured as travel time-based potentials.

The Swedish National Rural Development Agency (NRDA) regularly monitors access of rural population to important public and private services, such as administration, education, health care, or airports. For this, the NRDA calculated travel time by road to the nearest airport (Dahlgren, 2005). Spatial representation of the origins is very detailed by using 250 m grid cells including information on the number of inhabitants per cell. Results were presented as isochrone maps showing which populated grid cells of Sweden have what travel time to the nearest airport.

Johansson and Karlsson (2007) analysed the intra- and inter-regional export diversity with regard to the accessibility to research and development. The focus was on spatial knowledge spillovers, external economies of scale in research and development activities and the innovative capacity of regions. Accessibility is defined as potentials by applying an origin-destination travel time matrix for road and time sensitivity parameters in local, intra-regional and inter-regional interactions.

Andersson and Karlsson (2007) analysed the role of knowledge in regional economic growth by focusing on knowledge accessibility of Swedish municipalities. Accessibility was measured as travel time-based potentials.

Finland

A pioneering Finnish accessibility study by Tykkyläinen (1981) applied three accessibility indicators: relative, mean and integral accessibility for the entire country. Calculations were done at the municipal centre level.

Meriläinen (1996) considered rural accessibility situations in Finland using the example of six villages in the commuting area of Hämeenlinna. Accessibility of villages was calculated as mean accessibility to all municipalities and as a travel time to job concentrations and municipal centres. The calculations were based on estimated average annual speeds. Alternative road improvement plans were assessed with these indicators.

Accessibility in the context of environmental efficiency was analysed by Määttä-Juntunen et al. (2010) for the Oulu region in Finland. The study focused on the possibilities of reducing transport based CO_2 emissions of trips to shopping centers. The analyses in the study was implemented at a 1 km grid cell level.

Kotavaara et al. (2010) measured Finnish potential accessibility by road and accessibility to railway stations at municipal and built-up area levels for the period 1970–2007. In the study it was found that population change was statistically related to accessibility.

Denmark

Freight accessibility in Denmark was studied by Möller and Nielsen (2007) for the case of the cost efficiency of the domestic wood chip supply chain. As transport is a major contributor to the delivered costs of wood chips, a continuous raster-based cost surface was applied for mapping the national wood chip resources in relation to selected bioenergy plants.

Baltic States

There are relatively few accessibility studies in the Baltic States. Most of the studies focused on urban public transport including relationships between accessibility and intelligent transport systems in Vilnius (Jakubauskas 2008) or between accessibility and residential land value in Riga (Pavlyuk 2008). Jakimavicius and Macerinskiene (2006) estimated potential accessibility in residential areas based on travel time from the centers of Lithuanian administrative regions.

Russia

Bougromenko (1997) analysed living standards taking into account indices like road network level and integral transportation accessibility, i.e. average travel time required to reach any point of an area from any other point. This was done for 87 regions of Russia. The accessibility by metro and bus services for elderly and disabled people in St Petersburg was analysed by Sergeyeva (1998).

Poland

Before 2000 the accessibility considerations in Poland were mainly theoretical. Emphasis was put mainly on topological issues (Domański 1979, Mackiewicz and Ratajczak 1996).

However, in the last decade there were some empirical studies concerning accessibility at the local level (Guzik and Kołoś, 2003; Taylor 2003; Niedzielski and Śleszyński, 2008, Gadziński and Beim, 2010), at the regional level (Guzik, 2003) and at the national level (Komornicki and Śleszyński, 2009; Komornicki et al., 2010). The studies differed with respect to travel purpose and destination attractiveness, e.g. access to shopping and health care facilities by rural dwellers

(Taylor, 2003), easiness to reach holiday resorts by tourists (Guzik and Kołoś, 2003), access to post-elementary educational services by pupils (Guzik, 2003), accessibility to jobs and workers (Niedzielski and Śleszyński, 2008) and accessibility to possible locations of regional airports (Komornicki and Śleszyński, 2009). At the local level Niedzielski and Śleszyński (2008) used gravity-model-based indicators differentiated by commuting mode.

At the national level potential accessibility indicators were employed by the study of Komornicki et al. (2010). Impedance was generally computed as travel time in all studies, however, Taylor (2003), Gadziński and Beim (2010) and Guzik and Kołoś (2003) used public transport timetables while Komornicki et al. (2010) adopted a speed model for road network and design speeds for railway network.

UK

The impact of the construction of the M25 London orbital motorway on economic activities for 179 zones in England, Wales and Scotland were studied by Linneker and Spence (1992) by applying a potential accessibility measure with total employment as mass variable. Travel times between all pairs of regions were calculated separately for private cars and heavy goods vehicles. A later study by Frost and Spence (1995) applied the same model in a spatially more disaggregated way to a total of 322 travel to work areas (TTWA) for the whole of Great Britain.

In the beginning of the 1990s a number of studies analysed the accessibility situation in the Highlands and Islands of Scotland (Copus, 1992; 1994). Even though potential accessibility indicators for roads were calculated, the resulting index was called 'economic potential index'. First, calculation was based on local districts; in a follow-up study, the Highlands and Islands were subdivided into 19 areas, which were adopted from the former HIDB statistical areas.

A number of accessibility studies in the UK in the late 1990s and the beginning of the 21st century were concerned with the assessment of access to rural health care centres (Martin et al., 2001 for the south west of England; Lovett et al., 2001 for East Anglia; White, 2001 for Gwynedd, Wales), in particular from the point of view of elderly people. Selected destinations in these studies included general practice surgeries and minor hospitals, and focus was given to public transport (e.g. Lovett et al., 2000), but car or walking was also assessed (Higgs and White, 2000). In most cases simple travel distance or travel time indicators were selected as the measure of accessibility, sometimes even straight line distance measures (National Assembly for Wales, 2000) were used. Alternative accessibility measures include indicators on the number of population within a certain distance to bus routes, or raster based approaches of calculating least cost paths from each resident cell to each health care facility cell. Some sophisticated approaches were also developed incorporating opening hours of the facilities, specialist clinics, or by analyzing impacts for different social groups. Kelly et al. (2001) introduced travel time indicators to health care and other public services to improve the *Standard Spending Assessment* (SSA) formula, which is the base on which funds for services are being allocated in the UK which did so far not account for the travel time or travel distance to reach such facilities from residences.

In local, urban and regional transport planning in the UK two accessibility measures have received increasing attention during the last decade (Cooper et al., 2009):

- The *Public Transport Accessibility Level* (PTAL) score measures the access to public transport networks from any point in space. The PTAL score combines walk time from home based on an agreed speed of 4.8 km/h to the public transport networks with waiting times at bus stops of 8 minutes and at rail/underground services of 12 minutes. As origins are usually represented by small-scale raster cells results are illustrated as contour maps that differentiate areas with poor access to public transport from those with good and excellent access. However, this score measures only the access to public transport, it does not take into account the speed or frequency of the services as such, the quality of the services, the ease of interchange and the destinations to reach (TfL, 2010; Nettleton et al, n.a.).

- The *Access to Opportunities and Services* (ATOS) indicator measures the access to essential services and employment by public transport and walking. Essential services include employment (defined as work places with more than 500 employees), education, health services, quality food shopping facilities and open space.

These indicators were first developed by Transport for London (TfL) and were tested with samples of local authorities in London as part of the development of Local Transport Plans. The PTAL scores were calculated based upon a grid of points at 100 m intervals (approx. 150,000 points), while ATOS was calculated based upon approx. 24,000 Census Output Areas for Greater London. In addition, a composite score was introduced that sums up all average travel times for each origin and ranks the derived overall travel time into five accessibility classes.

The UK Department for Transport (DfT) declared the PTAL and ATOS scores as core national accessibility indicators for local authorities (DfT, 2009a; 2009b). Employment, primary schools, secondary schools, colleges, general practice surgeries, hospitals and high-quality food stores were defined as important public service facilities to be included in such studies. The indicators should be calculated on the basis of road networks, public transport networks and walking and cycling networks. The analysis framework developed by the DfT assisting the local and regional authorities in accessibility analyses provided thresholds for maximum accepted travel times and distances as well as default link speeds by road class for cars, cycling and walking to be used in the models. Recommendations on calculation methods and parameters have also been developed. Emphasis was given on calculating so-called ‘catchment indicators’ defined as the absolute population and percentage of population within each travel time threshold to services, which in fact represent a further processing of the isochrones approach. The catchment indicators can also be further differentiated by relevant age groups or social groups depending on the type of destination.

The ATOS travel time approach was also used in a study calculating the Scottish public transport accessibility index as part of the *Scottish Index of Multiple Deprivation* (SIMD) (DHC, 2006). A slightly different set of destinations was chosen honouring specific Scottish conditions, i.e. covering primary and secondary schools, petrol stations, general practice surgeries, post offices and retail centres. Origins were represented again by the census output areas (COAs), but results were also aggregated to higher levels. As a specific constraint the different opening hours were taken into account when calculating public transport access.

In many rural parts of the UK and also often in small and medium-sized towns accessibility has often been discussed from the point of view of social exclusion of disadvantaged, handicapped and elderly people, and the role of public transport in alleviating these obstacles (Commission for Rural Communities, 2009). The classical travel time/isochrones approach was amended by new elements. For instance, access to certain types of specialised hospitals was not only computed by road and public transport, but in the case of the Worcestershire case study differentiations were made between times of the day (peak hours, off-peak hours) and types of public transport (conventional bus services and additional bus services through specialised operators).

Ireland

Murphy and Killen (2007) applied accessibility indicators to find the optimal location of a new pediatric hospital in Ireland. Accessibility by road and by public transport was considered as the key issue for the location decision. Travel times by car and public transport to different potential hospital locations were calculated from each municipality. Interestingly, travel time calculations were divided into peak and off-peak scenarios. The resulting isochrones were further processed to assess the percentages of total population, of children and of females aged 15-35 years located near the potential hospital sites.

Netherlands

The Netherlands were the subject of a vast number of accessibility studies addressing different topics and indicator concepts. In many studies specific attention was given to job accessibility. For example, Geurs and Ritsema van Eck (2001) used different accessibility indicators including cumulative opportunities and potential accessibility to assess the current situation and future situations due to land-use and transport changes in the country. Modes considered were road and public transport, origins working population of municipalities and destination activities jobs in municipalities.

Muhammad et al. (2008) introduced the issue of telecommuting into an accessibility model. Potential accessibility was calculated for about 1,300 transport zones of the Netherlands in which different frequencies of telecommuting per month were represented by different distance decay functions. Modes considered were road and public transport in combination with walking and cycling.

Germany

The accessibility model of the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) has developed into a comprehensive tool capable of adressing different issues at different spatial scales and resolutions with different sets of accessibility indicators (e.g. Spangenberg and Pütz, 2002; BBR, 2005; BBSR, 2011). Detailed representations of road, rail and air networks as well as different sets of destination activities allow the calculation of differently defined accessibility indicators of all generic types. However, in political documents, very often travel time to selected destinations was used. Accessibility indicators were also used to define new typologies of regions in Germany.

The accessibility of services of general interest in the state of Bavaria was the topic of a study by Schürmann and Spiekermann (2010). Services of general interest considered included those for basic needs (primary and lower secondary schools, physicians, dentists, pharmacies, banks, post and police, and those for higher needs (higher secondary schools, tax authorities, employment centres, hospitals). The accessibility of these facilities by car and by public transport for different population groups was evaluated by calculating travel times from the places of residence of the population in 100 m raster cells to the nearest facility of each type. The study was based on a full coverage of the Bavarian road network and a complete timetable for public transport.

Schürmann and Spiekermann (2011) developed applications of small-scale accessibility models for four urban agglomerations in Germany. The objective was to demonstrate the intra-regional change of the accessibility patterns over a historical period of two decades and to relate these changes to the development of land values, settlement development, population and jobs and commuting patterns. Accessibility indicators calculated were travel time to the core of the agglomeration and potential accessibility to population. The indicators were calculated for road and public transport for raster cells of 100 m size.

Switzerland

The long-term historical development of accessibility by road and public transport in Switzerland was compared with the development of the population (e.g. Fröhlich et al., 2006; Axhausen et al., 2010). Potential accessibility indicators were calculated for 150 districts for the period 1850-2000 and for the 2,900 Swiss municipalities for the period since 1950 using population as destination activity. Accessibility pattern were presented among others also in three-dimensional surfaces.

BAK Basel Economics (2007) calculated potential accessibility indicators for Swiss municipalities. Travel times for road and public transport were based on very detailed network representations. Results were presented in map form and in histograms showing the aggregate distribution of accessibility over accessibility classes. For the non-alpine northern parts of Switzerland additional indicators such as travel times by road and rail to Basel and Zürich and to the main airports as well as accessible GDP within different amounts of travel time were calculated.

Austria

In a study for the Austrian National Transport Plan, Bökemann and Kramar (1999) assessed the impacts of different transport infrastructure options on the competitive position of Austrian regions by using accessibility indicators. For all municipalities potential accessibility by road and rail were calculated. In addition to the traditional potential accessibility indicator, an alternative indicator for rail was developed. Rail stations were used as destinations. Their accessibility was measured as the number of trains serving the station each weighted by its type (intercity, regional, local etc.). Road access time to the stations weighted by a negative exponential function was used as impedance. Statistical measures such as rank-size rule and GINI coefficients with Lorenz curves were used to analyse the spatial disparities in accessibility.

The accessibility situation in Austria was assessed in a study by ÖROK (2007) by using travel time to the nearest regional and the nearest supra-regional centre as indicator. Calculation were done for a 250 m raster cell system for Austria for road and public transport. Road travel time took the traffic conditions on the network into account. Public transport travel times were based on timetables and include waiting and transfer times.

Czech Republic

The issue of changes in accessibility and its cartographic visualisation is a traditional research topic of Czech transport geographers. A map of Prague's time-based accessibility from the territory of Bohemia by rail was constructed already 1904 by Nový using an isochrone method. Blahník (2009) analysed historic-geographical accessibility of Prague by railway in 1918-2020. He reconstructed the railway network for selected years in a GIS and demonstrated the reduction of travel time from each place of the Czech Republic during the century by isochrone maps. Analogously, the historic development of accessibility of Prague by road transport in 1918-2020 was modelled. Petr (2008) modelled time accessibility maps for petrol stations generally and for each company separately. Another time accessibility example was presented for Southern Bohemia by Kraft (2008). He compared the speed of public transport connection of municipalities to the regional capital České Budějovice.

Another approach is to analyse spatial accessibility, not only time accessibility, and include differences in transport costs (Hanes, 2010). The main sources were the Czech railways timetable 2009. Several maps presenting various types of accessibility were done.

The aim of Návratil (2010) was to compare methods of accessibility analysis in Czech sociogeographic regions. The result of the analysis covered only the region itself and not the neighbouring regions. A detailed description of the functions and the approaches in the models and scripts is a core of the study.

Travel time based accessibility to regional capitals from their administrative regions was modelled by Hudeček and Marada for the Atlas of Landscape of the Czech Republic (Hrnčiarová et al. 2009). Rajman (2009) analysed the accessibility of Prague by road by using real travel times for different points in time during the day and the week. Results for the Czech territory were demonstrated for periods with very low traffic volume and for peak hours.

The social situation in transport is evident for example in the level of car ownership in rural areas (Marada and Hudecek 2006). Květoň (2006) analysed the relationship between demographic structure and accessibility using the Jesenik peripheral region as case study. Boruta and Ivan (2010) analysed also for the Jesenik region representative travel times between two municipalities, of which the fastest of all connections with arrival at 8 a.m. was used. Subsequently, through aggregation into three time intervals the municipalities were allocated to below-average, average and above-average time groups.

Slovakia

Horňák (2005) evaluated 68 regional districts of Slovakia with respect to the access to motorways. Two indicators were used: road distance to the nearest motorway exit of any motorway section longer than 20 km and road distance to the nearest motorway exit of the main arterial Slovak motorway in the western part of the country. Similarly, Michniak (2006) analysed the accessibility of municipalities to the nearest passenger railway stations.

Pšenka and Horňák (2009) analysed the accessibility of Slovak regional centres by trains and buses. Michniak (2002) evaluated the allocation of Slovak municipalities to regional centres by distance-based indicators and compared the results with the current administrative boundaries.

Hungary

Tóth (2006) calculated daily and potential accessibility by road for all Hungarian municipalities. To assess the relation between accessibility and economic development, accessibility indicators were related to income levels.

At a regional scale Györffy (2006) analysed the density and quality of the road system in northern Hungary and calculated public transport travel times from municipalities to regional centres.

Greece

Katsios et. al. (2006) developed a raster-based accessibility model for Greece by which also the transport networks were transformed into a raster representation. Travel time by road, rail, maritime shipping and air to reach all ports, airports and centres of Funcitonal Urban Areas (FUAs) were calculated. Results were presented as raster maps and as aggregate indicators for travel times.

France

The accessibility of the French urban system was the topic of several studies of the last decades. Chapelon, L'Hostis and Mathis (1994a; 1994b) studied the impact of several transport projects with accessibility analyses, among them the impact on regional accessibilities of the TGV in France and the A10 motorway from Paris to Bordeaux. Chapelon (1998; 2000; 2003) further analysed the possibilities of accessibility indicators in the late 1990s and performed evaluations of the French motorway network, of accessibility of riparian cities of the Atlantic and rail accessibility of French cities.

Cattan and Grasland (1997/1998, Grasland, 2000) analysed the inequalities in accessibility of towns by road distances compared with euclidean distances and by road, rail and multimodal travel time based indicators. Travel times between cities were transformed into average airline speeds between cities of different size. Hilal (2003) modelled the potential accessibility to jobs in the French municipalities and concluded that periurban regions had substantially lower potential accessibility to jobs than both urban or rural areas. Chapelon and Leclerc (2007) assessed accessibility by rail of French cities and analysed disparities. The study continued with analysing the rail accessibility for early 2010s and 2020 when construction plans for further high-speed rail and projects to improve the existing network will be implemented. Finally, the persistent inequalities in 2020 were highlighted and the recommendations to address them proposed. Angrand, Robin, Sarrazin and Vincent (Angrand et. al., 2007) studied indicators to measure the volume of jobs accessible from municipalities considering travel distances equal to the average distance travelled by at least 75% of the economically active persons in the urban area where they belonged, and applied these indicators 10 different cases in France.

In 2008, SÉTRA (Service d'études techniques des routes et autoroutes) published a dossier on *Territorial accessibility and services: notions and representation*, a technical paper on accessibility analysis for decision taking processes in the field of transport infrastructure including ten case studies portraying various dimensions accessibility.

The work of DRE Aquitaine (2008) on its region is an example for a regional accessibility study in France. The study focused on travel and analysed mainly in cartographic ways the regional coverage by different modes of transport, road railways and air and which zones of Aquitaine are inadequately served. For this, road travel times to motorway exits, main railway stations and airports were calculated for raster cells for today and a future situation. Raux, Mercier and Ovtracht (2007) discussed gravity accessibility measures and applied them to the agglomeration of Strasbourg to determine accessibility to jobs.

The inter- and intraregional accessibility situation of a regional capital in France was analysed in several studies taking Lille in Nord Pas de Calais as example. L'Hostis et al. (2004) used specially designed accessibility indicators of the quality of services supplied to different segments of the population. Real travel time information including transfer time were compiled for the analysis. The methodology was applied to Nord Pas de Calais and used to assess the accessibility of its regional capital, Lille. Bozzani and L'Hostis (2006) measured the accessibility benefits that accrue from the combination of high-speed rail and air transport, as opposed to the mere juxtaposition of the two fast modes. The study used real timetable data for air travel and TGV and combined the two modes to intermodal trip chains to determine the cities in Europe that are accessible from Lille during a day. The question answered was to what extent a TGV ride to CDG Airport in Paris increases the number of cities accessible.

Mathis (2003) provided a compilation of articles related to graph theory in which theoretically oriented paper presented different approaches in analysing space and networks. In this volume, Decoupigny (2003) analysed the effects of different alternatives for the impedance term to be used on route choice and resulting emissions from transport using French examples.

Spain

At the national level, the assessment of accessibility changes of the transport infrastructure investments of 5,000 km additional high-capacity roads and 6,000 km high-performance rail foreseen in the Spanish transport plan 2005-2020 got specific attention (López Suárez et al., 2006; 2008; 2009). A network efficiency indicator computed as the destination-weighted ratio of real travel time and an ideal, straight-line high-speed travel time were calculated for all municipalities to compare the different options. In addition, a destination-weighted generalised cost indicator was computed describing the average effort to go from one place to all others in Spain to consider accessibility benefits in each region due to investments undertaken in all other regions. Results were further processed in a multicriteria analysis; assessment criteria, based on the 'sustainable transport' paradigm, are structured into efficiency, cohesion and environmental criteria (López Suárez, 2007).

Ajenjo et al. (2004) and Alberich González (2004) evaluated the evolution of accessibility in Catalonia from 1985 to 2000 at municipality level and related it to changes in the demographic characteristics of these municipalities during the same period. A set of accessibility indicators was used, namely absolute travel time and distance between municipalities, a ratio of travel time or distance to ideal travel time or distance on a straight line, and access time to motorways. It was concluded that classic travel time indicators are not suitable to study accessibility as an intermediate variable of different aspects related to population in a territory with highly concentrated population in one single area such as Catalonia. Cumulated opportunity indicators considering only accessibility to places within a maximal distance range are much more suitable. It was also demonstrated that indicators incorporating ratios between actual and ideal travel time seem not to properly reflect reality as they provide highest accessibility levels to most peripheral areas.

García Palomares (2000) analysed the accessibility effects of a new orbital motorway in the metropolitan area of Madrid. Indicators used were mean travel time to employment weighted by the volume of activities reachable at destination, and accessibility potential to jobs.

Nogales Galán et al. (2002) studied accessibility in the Extremadura region by using average absolute and relative travel time indicators. A variable of wealth was incorporated in the analysis by using the level of rents available at the destination municipality as weights.

Hernández (2002) analysed the current accessibility conditions of the seven Canary Islands by means of sea transport for both passengers and vehicles. The accessibility indicator introduced to the specific geographic situation is of the cumulative opportunity type. Based on the travel time between the island capital cities by available ferry services, the time available at the destination island was measured by assuming a return trip in the evening. Using the constraints of service hours, the available time to be spent in public administration or commercial activities at the capital cities of La Gomera and Tenerifa islands was estimated.

Portugal

Figueira de Sousa, Fernandes and Galiau (2009) analysed the changes in accessibility in Portugal resulting from the large road infrastructure programme engaged since the accession of the country to the EU. They analysed travel time accessibility to major cities (Lisbon and Porto), to border points, to ports and to airports for 1985, 1988, 1992 and 2000.

Silva and Pinho (2010) analysed local accessibility conditions and the resulting potential for sustainable mobility patterns for the Greater Oporto area in northern Portugal by applying the so-called Structural Accessibility Layer (SAL) – a design support tool for integrated land use and transport policies based on a concept of structural accessibility. The accessibility indicator used is of the cumulative opportunity type. For three different modes, non-motorised transport, public transport and road, the percentage of locations of 18 different activities (e.g. employment, schools, leisure, shopping, health care) that can be reached within a mode-specific maximum time was calculated for census tracks. Evaluation of accessibility was done by classifying the results for each mode into three classes resulting in an evaluation cube with 27 sub-cubes. The geographical representations of comparative accessibility levels were found to provide a new insight in local mobility conditions and constraints for sustainability.

Viegas et al. analysed in the framework of demand studies for the a new airport in Lisbon the potential of attracting traffic of this facility using potential accessibility indicators considering the competition of already existing airports. In this analysis, three different scenarios were drawn, considering only the road network in the first one, the high-speed rail network in the second and a combined analysis in the third one. Travel time was the impedance variable.

Comparison

The national and regional accessibility models reviewed above yield a wide range of approaches with respect to various dimensions of accessibility. They differ in many respect, but there are also some commonalties (see Table 4.7 for the national and Table 4.8 for the regional accessibility models):

- Only one third of the national models and only every sixth of the regional model use potential type indicators, very few are calculating cumulative opportunities. The majority of the models use travel cost indicators mainly in the form of travel time to pre-selected destinations. A few models calculate more than one type of indicator.
- The origins for which accessibility indicators are calculated are in most accessibility models the centroids of municipalities. A few studies, mainly at the national scale, are less detailed in space. However, the main tendency of the last decade was a movement towards spatially more disaggregate accessibility models. This is done by using a raster representation of space in which the cell size ranges from a few kilometres down to 100 m only in some regional applications.
- The destination activities are much more diverse than in the European or trans-national accessibility models. The potential type models work usually with population as destination activity, however, also accessibility to jobs is the subject of several studies. Many studies, in particular those working with travel cost type indicators, use urban and regional centres, network nodes and services of general interest as destination activities.
- With a few exceptions, all models use travel time as impedance term, the remaining models work with travel distance. None of the models at these scales use travel costs.
- Some of the models consider constraints on the impedance term. This is usually done when public transport is considered and represented with real timetable based travel times..
- None of the accessibility models considers barriers.
- Nearly all accessibility models are based on passenger travel, only two models at the national scale and none at the regional scale consider freight transport.
- Many of the models consider road transport only, in particular models at the national scale. Other models have networks for rail or for all means of public transport, a few include also walking and cycling. Intermodal travel times is a rare exception of the accessibility models at these scales.

Spatial pattern

The main results of the accessibility models with respect to spatial patterns are summarised in Table 4.9 for the national accessibility models and in Table 12 for the regional accessibility models.

It can be seen that most of the national and regional accessibility studies point to the existence of large disparities of accessibility in the areas considered. This is regardless the type of indicator used. On the other hand, when evaluating the access to public facilities such as hospitals or regional centres, some of the studies conclude that the travel times are reasonable for most of the population and better than expected.

Table 4.7. Dimensions of national accessibility models

Authors	Indicator type	Origins	Destinations	Impedance	Constraints	Barriers	Type of transport	Modes	Spatial scope
Dahlgren (2005)	Travel cost	250 m raster cells	Airports	Travel time	-	-	Travel	Road	Sweden
Forslund and Johansson (1995).	Potential	LAU-2	LAU-2 (worker/population), International ports	Travel time	Capacities of seaports	-	Travel, freight	Road	Sweden
Johansson et al. (2002)	Potential	LAU-2	Jobs, household and business services, labour	Travel time	-	-	Travel	Road, rail	Sweden
Andersson and Ejermo (2005)	Potential	Local labour market area	R&D resources	Travel time	-	-	Travel	Road	Sweden
Johansson and Karlsson (2007)	Potential	LAU-2	Company and university R&D	Travel time	-	-	Travel	Road	Sweden
Andersson and Karlsson (2007)	Potential	LAU-2	Business and university R&D	Travel time	-	-	Travel	Road	Sweden
Tykkyläinen (1981)	Travel cost	Municipal centres	Municipal centres	Travel distance	-	-	Travel	Road	Finland
Kotavaara et al. (2010	Travel cost, potential	LAU-2, built-up area centroids	LAU-2 centres Built-up area centroids	Travel time	-	-	Travel	Road, rail	Finland
Möller and Nielsen (2007)	Travel cost		Bioenergy plants	Travel cost	-	-	Freight	Road	Denmark
Jakimavicius and Macerinskiene (2006)	Travel cost		Regional centres	Travel time	-	-	Travel	Road	Lithuania
Bougromenko (1997)	Travel cost	87 regions	87 regions	Travel time	-	-	Travel	Road	Russia
Komornicki et al. (2010)	Potential	NUTS 4	NUTS-4 Population and 12 socio-economic variables	Travel time	-	-	Travel	Road, rail, multi-modal	Poland
Linneker and Spence (1992), Frost and Spence (1995)	Potential	179 zones 322 travel to work areas	179 zones, 322 travel to work areas	Travel time	-	-	Travel, freight	Road	Great Britain
Murphy and Killen (2007)	Travel cost	LAU-2	Potential paediatric hospital locations	Travel time	Peak hours	-	Travel	Road, public transport	Ireland

Table 4.7. Dimensions of national accessibility models (continued)

Authors	Indicator type	Origins	Destinations	Impedance	Constraints	Barriers	Type of transport	Modes	Spatial scope
Geurs and Ritsema van Eck (2001)	Cumulative Potential	LAU-2	Jobs in LAU-2	Travel time	-	-	Travel	Road, public transport	The Nether-lands
Muhammad et al. (2008)	Potential	Transport zones	Jobs in transport zones	Travel time	Telecommut-ing (reduced constraint)	-	Travel	Road, public transport	The Nether-lands
Spangenberg and Pütz (2002); BBR (2005); BBSR (2011)	Travel cost potential	Raster cells LAU-2	LAU-2, MEGAs, regional cen-tres, motorways, rail stations, airports, hospitals etc.	Travel time	-	-	Travel	Road, rail, air	Germany / Europe
Fröhlich et al. (2006); Axhausen et al. (2010)	Potential	LAU-2	LAU-2	Travel time	Slope, time-table restric-tions	-	Travel	Road, public transport	Switzerland
BAK Basel Economics (2007)	Potential	LAU-2	LAU-2	Travel time	Timetable restrictions	-	Travel	Road, public transport	Switzerland
Bökemann and Kramar (1999)	Potential	LAU-2	GDP in LAU-2 Rail stations	Travel time	-	-	Travel	Road Rail	Austria
ÖROK (2007)	Travel cost	250 m raster cells	Regional and supra-regional centres	Travel time	Congestion, timetable restrictions	-	Travel	Road, public transport	Austria
Blahník (2009)	Travel cost	Rail stations	Prague	Travel time	-	-	Travel	Rail	Czech Rep.c
Petr (2008)	Travel cost	Local district	Petrol stations	Travel time	-	-	Travel	Road	Czech Rep.
Hrnčiarová et al. (2009)	Travel cost		Regional centres	Travel time	-	-	Travel	Road	Czech Repub-lic
Rajman (2009)	Travel cost	Local dis-tricts	Prague	Travel time	Peak hours	-	Travel	Road	Czech Repub-lic
Horňák (2005)	Travel cost	68 districts	Motorway exits	Travel dis-tance	-	-	Travel	Road	Slovakia
Michniak (2006)	Travel cost	LAU-2	Railway stations	Travel dis-tance	-	-	Travel	Road	Slovakia
Pšenka and Horňák (2009)		LAU-2	Regional centres	Travel time	-	-	Travel	Public transport	Slovakia

Table 4.7. Dimensions of national accessibility models (continued)

Authors	**Indicator type**	**Origins**	**Destinations**	**Impedance**	**Constraints**	**Barriers**	**Type of transport**	**Modes**	**Spatial scope**
Michniak (2002)	Travel cost	LAU-2	Regional centres	Travel dis-tance	-	-	Travel	Road	Slovakia
Tóth (2006)	Cumulative, potential	LAU-2	LAU-2	Travel time	-	-	Travel	Road	Hungary
Katsios et. al. (2006)	Travel cost	300 m raster cells	Ports, airports, FUAs	Travel time	Topography	-	Travel	Road, rail	Greek
Cattan and Grasland (1997/1998); Grasland, 2000)	Travel cost	Municipali-ties > 20,000	Municipalities > 20,000	Travel time, travel speed	-	-	Travel	Road, rail, multi-modal	France
Halal (2003)	Potential	LAU-2	LAU-2	Travel time	-	-	Travel	Car	France
Angrand et. al. (2007)	Cumulated	LAU-2	LAU-2	Travel dis-tance	-	-	Travel	Road	France
López Suárez et al. (2006; 2008; 2009); López Suárez (2007)	Travel cost	LAU-2	LAU-2	Travel time	-	-	Travel	Road, rail	Spain
Figueira de Sousa, Fernandes and Galiau (2009)	Travel cost	LAU-2	Lisbon and Porto; border points; ports; airports	Travel time	-	-	Travel	Road	Portugal

Table 4.8. Dimensions of regional accessibility models

Authors	Indicator type	Origins	Destinations	Impedance	Constraints	Barriers	Type of transport	Modes	Spatial scope
Bjarnason (2005)	Travel cost	53/141 zones	City centre, university, national university hospital, shopping mall	Travel time	-	-	Travel	Road, public transport, cycling	Greater Reykjavik area (IS)
Naess et al. (1995, 2001)	Travel cost	Home location	Workplaces, different level centres	Travel time	-	-	Travel	Road, public transport	Oslo region (NO)
Arnesen et al. (2010)	Travel cost, potential	1 km raster cells LAU-2	Population Airports, railway stations, hospitals and universities.	Travel time	-	-	Travel	Road	Mountain areas, southern Norway (NO)
Meriläinen (1996)	Travel cost	Villages	Municipalities, job concentrations, urban centres	Travel time	-	-	Travel	Road	Hämeenlinna region (FI)
Määttä-Juntunen et al. (2010)	Travel cost	1 km raster cells	Shopping centres	Travel time	-	-	Travel	Road	Oulu region (FI)
Komornicki and Śleszyński (2009)	Travel cost		Regional airports	Travel time	Peak hours	-	Travel	Road, rail	Mazowieckie (PL)
Guzik and Kołoś (2003)	Travel cost	Regional cities	Holiday resorts	Travel time	Direct service existence	-	Travel	Public transport	Carpathian spa resorts (PL)
Taylor (2003)	Travel cost, cumulative	Villages	Shopping, health care facilities	Travel time	Time table restrictions	Opening hours	Travel	Public transport, walk	Three rural communes (PL)
Guzik (2003)	Travel cost	Cities and villages	Secondary schools	Travel time	-	-	Travel	Public transport	Małopolskie (PL)
Niedzielski and Śleszyński (2008)	Potential	Transportation zones	Jobs, workers	Travel time	-	-	Travel	Road, public transport	Warsaw (PL)
Gadziński and Beim, (2010)	Travel cost	Public transport stops	Main travellers' destinations	Travel time	-	-	Travel	Public transport	Poznań (PL)
Copus (1992; 1994)	Potential	Local districts; HIDB statistical areas	Local districts; HIDB statistical areas	Travel time	-	-	Travel	Road	Highlands and Islands of Scotland (UK)

Table 4.8. Dimensions of regional accessibility models (continued)

Authors	Indicator type	Origins	Destinations	Impedance	Constraints	Barriers	Type of transport	Modes	Spatial scope
Martin et al. (2001); Lovett et al. (2000; 2001); White (2001); Higgs and White (2000); National Assembly for Wales (2000), Kelly et al. (2001)	Travel cost	Buildings, blocks, wards	GP surgeries, (minor) hospitals, specialist clinics	Airline and travel distance, travel time	Timetable restrictions, social groups	Opening hours of services	Travel	Road, public transport, walk,	Different UK regions incl. South West of England; East Anglia
Cooper et al. (2009)	Travel cost	100 m grid Census output areas	Public transport stops Employment centres, education, health services, quality food shopping facilities and open space	Travel time	Waiting times	-	Travel	Public transport, walk, cycling	Greater London (UK)
DfT (2009a; 2009b)	Travel cost, cumulative	Census output areas	Employment, primary schools, secondary schools, colleges, general practice surgeries, hospitals and high-quality food stores	Travel time	Timetable restrictions, age and social groups	Opening hours of services	Travel	Road, public transport, walk, cycling	Local authorities (UK)
DHC (2006)	Travel cost	Census output areas	Different schools, petrol stations, general practice surgeries, post offices, retail centres.	Travel time	Timetable restrictions	Opening hours of services	Travel	Public transport	Scotland (UK)
Commission for Rural Communities (2009)	Travel cost	Census output areas	Different types of specialised hospitals	Travel time	Peak/off-peak hours	Opening hours	Travel	Road, public transport	Worcestershire (UK)
Schürmann and Spiekermann (2010)	Travel cost	100 m raster cells	Services of general interest (schools, health care facilities, pos and banks offices etc.)	Travel time	Timetable restrictions	-	Travel	Road, public transport	Bavaria (DE)
Schürmann and Spiekermann (2011)	Travel cost, potential	100 m raster cells	Agglomeration centre, population	Travel time	-	-	Travel	Road, public transport	Munich, Karlsruhe, Hannover, Hamburg regions (DE)
BAK Basel Economics (2007)	Travel cost, Cumulated, potential	LAU-2	LAU-2 (population, GDP), Basel and Zürich, airports	Travel time	Timetable restrictions	-	Travel	Road, public transport	Northern parts of Switzerland

Table 4.8. Dimensions of regional accessibility models (continued)

Authors	**Indicator type**	**Origins**	**Destinations**	**Impedance**	**Constraints**	**Barriers**	**Type of transport**	**Modes**	**Spatial scope**
Kraft (2008)	Travel cost	NUTS-3	České Budějovice (regional capital)	Travel speed	-	-	Travel	Public transport	Southern Bohemia (CZ)
Květoň (2006); Boruta and Ivan (2010)	Travel cost	LAU-2	LAU-2	Travel time	-	-	Travel	Public transport	Jeseníky region (CZ)
Györffy (2006)	Travel cost	LAU-2	Regional centres	Travel time	Interchange times	-	Travel	Public transport	Northern Hungary (HU)
EUPOLIS (2007)	Travel cost	Turin	28 European cities, 120 international airports	Travel time	-	-	Travel	Air, multimodal	Turin (IT), Europe
DRE Aquitaine (2008)	Travel cost	Raster cells	Motorway exits, main railway stations airports	Travel time	-	-	Travel	Road	Aquitaine (FR)
L'Hostis et al. (2004)	Potential	Regional cities	Lille	Travel time	Time table restrictions	-	Travel	Rail	Nord-Pas de Calais (FR)
Raux et al (2007)	Travel cost	Regional cities	Strasbourg	Travel cost	-	-	Travel	Road, rail and bus	Nord-Pas de Calais (FR)
Bozzani and L'Hostis (2006)	Cumulative	Lille	Major European cities	Travel time	Time table restrictions	-	Travel	Rail, aAir	Lille (FR)
Ajenjo et al. (2004); Alberich González (2004)	Travel cost	LAU-2	LAU-2	Travel time	-	-	Travel	Road	Catalonia (ES)
García Palomares (2000)	Travel cost, potential			Travel time	-	-	Travel	Road	Madrid region (ES)
Nogales Galán et al. (2002)	Travel cost	LAU-2	LAU-2	Travel time	-	-	Travel	Road	Extremadura (ES)
Hernández (2002)	Travel cost, cumulative	Island capitals	Island capitals	Travel time	Time table restrictions; opening hours	-	Travel	Road, fFerry	Canary Islands (ES)
Silva and Pinho (2010)	Cumulative	Census tracks	Location of 18 different activities	Travel time	-	-	Travel	Road, public transport, non-motorised	Oporto region (PT)

Table 4.9. Accessibility patterns stated in national accessibility studies

Authors	Spatial scope	Accessibility pattern
Dahlgren (2005)	Sweden	Accessibility of airports is generally good with areas of low travel time reaching far into the airport hinterland along major road arteries. However, most of these areas are uninhabited areas, so that the population potential of an airport in its service area is often low.
Forslund and Johansson (1995).	Sweden	Evaluation of national road investment projects shows how changes in accessibility properties can influence the production potential of individual regions.
Johansson et al. (2002)	Sweden	Increase of accessibility by reduced road travel time increases the spatial size of labour markets.
Andersson and Ejermo (2005)	Sweden	Accessibility to university researchers have a positive effect on performance of enterprises and regions. But intraregional accessibility to research units of other corporations or accessibility to the corporation's own research units did not have a significant effect.
Andersson and Karlsson (2007)	Sweden	Differences in growth of value added per employee across regions can be explained by intra-municipal and intra-regional knowledge accessibility, but not by inter-regional knowledge accessibility.
Tykkyläinen (1981)	Finland	Accessibility in northern Finland proved to be poor. Locations of provincial capitals were considered to be optimal.
Kotavaara et al. (2010	Finland	Strong relationship between potential accessibility by road and population change, while the role of railways proved to be rather marginal.
Möller and Nielsen (2007)	Denmark	The geographical distribution and high transportation costs of biomass fuels underpin the use of wood chips as local fuels.
Komornicki et al. (2010)	Poland	Regions in the central south of Poland (Śląskie, Małopolskie and Opolskie Voivodship) and in central Poland (Łódzkie) have the highest potential accessibility, regions in the north and west (Lubuskie, Warmińsko-Mazurskie,Pomorskie and Podlaskie) have the lowest.
Linneker and Spence (1992), Frost and Spence (1995)	Great Britain	The overall derived pattern of economic potential showed peaks in all major centres and low values in remoter rural areas of Scotland, Wales and the South-West of England.
Murphy and Killen (2007)	Ireland	Optimal location of a specialised hospital differs depending on the main objective: if the hospital is to serve the Greater Dublin area only, a city-centre location in Dublin is best; if the hospital is to serve the Irish population, a hospital location further west is preferable.
Geurs and Ritsema van Eck (2001)	The Netherlands	Accessibility to jobs by road differs by three main levels: the Randstad with highest, the area east of the Randstad with modest accessibility and peripheral areas in north-eastern, southern and southwestern parts of the country. Highest accessibility to jobs by public transport results in a much more scattered pattern in which the Randstad is less dominant and more regional centres across the country are visible as peaks.
Muhammad et al. (2008	The Netherlands	Overall pattern of job accessibility as in Geurs and Ritsema van Eck (2001). With the introduction of telecommuting a much more regionalised pattern appears with high values for job accessibility around small and medium-sized cities.
Spangenberg and Pütz (2002); BBR (2005); BBSR (2011)	Germany	There are clear spatial disparities in accessibility in Germany, e.g. accessibility to agglomeration centres or to airports is very low in border regions, but also for some regions in the centre of Germany. On the other hand, 98 % of the population can reach the nearest hospital within 20 minutes road travel time.
Fröhlich et al. (2006); Axhausen et al. (2010)	Switzerland	Road accessibility became superior to rail accessibility in the 1930s. Only in the large urban centres, accessibility by rail is better than accessibility by road. The relative advantage of the large cities decreased through population suburbanisation since the 1950s, but large cities are still dominant.

Table 4.9. Accessibility patterns stated in national accessibility studies (continued)

Authors	Spatial scope	Accessibility pattern
BAKBASEL (2007	Switzerland	Great disparities in accessibility exist between mountain regions and other regions and between larger cities and smaller municipalities. Both disparities are much more pronounced for public transport, however, which provides lower accessibility values than road.
Bökemann and Kramar (1999)	Austria	Highest accessibility is concentrated in the Vienna region and in northern and western Austria having strong economies and good links to southern Germany. Accessibility by road is higher than by rail, however, the spatial patterns of high and low accessibility are rather similar. Infrastructure investments would benefit the lagging regions, but the overall pattern cannot be reversed.
ÖROK (2007)	Austria	The accessibility to regional centres is fairly good, about 98 % of the population reach the nearest regional centre within 30 minutes by road, 95 % by public transport. Topography and related distribution of regional centres have a large impact on accessibility..
Blahník (2009)	Czech Republic	The development of accessibility by rail of Prague 1918-2020 shows high regional disparities between connected and disconnected cities.
Petr (2008)	Czech Republic	Distribution of petrol stations is relatively balanced, however. areas at national roads have advantages.
Hrnčiarová et al. (2009)	Czech Republic	The worst accessibility of regional centres can be found in so-called inner peripheries on the western, southern and eastern border of the Central-Bohemian region and at the Bohemian-Moravian border, and in some outer peripheral zones.
Rajman (2009)	Czech Republic	Prague's accessibility is changing with time of day and week and related traffic volumes. In some areas the travel time to Prague gets worse during peak hours by more than 100%.
Horňák (2005)	Slovakia	Lagging accessibility of eastern Slovakia to motorway network.
Michniak (2006)	Slovakia	About 25 percent of the Slovak population lives more 5 km away from the nearest railway station
Pšenka and Horňák (2009)	Slovakia	They conclude that the spatial division of the country in the north, serviced mostly by long-distance trains, and the south, based on better bus time accessibility has increased in between 1989 and 2009.
Michniak (2002)	Slovakia	More than 200 municipalities have a low accessibility towards their regional centre and should be allocated to other districts, or several new districts might be established.
Tóth (2006)	Hungary	Budapest and its surroundings are the centre of accessibility in Hungary. A couple of regional centres are classified as central as well. The largest number of peripherally located settlements can be found on the Hungarian Great Plain and in Southern Transdanubia. There exists a moderately strong linear relationship between accessibility of population and economic development.
Katsios et. al. (2006)	Greece	Half of the Greek territory is inadequately served by any transport infrastructure. For two third of Greek's territory the travel time to the nearest FUA is longer than 30 minutes, however, this concerns only about 20 percent of the population.
Cattan and Grasland (1997/1998); Grasland, 2000)	France	Airline speed between cities in France is a function of the distance between and the size of the cities.
Hilal (2009)	France	Accessibility to jobs appears to be substantially lower for peri-urban areas than for urban or rural areas.
López Suárez et al. (2006; 2008; 2009); López Suárez (2007)	Spain	Impacts of the Spanish transport plan PEIT appear to benefit most depressed regions in Spain. Spillover effects are important and need to be assessed for different regions in the process of the impact assessment of the national infrastructure plans. Infrastructures built in certain regions may have important impacts in neighbouring regions.

Table 4.10. Accessibility pattern stated in regional accessibility studies

Authors	**Spatial scope**	**Accessibility pattern**
Bjarnason (2005)	Greater Reykjavik area (IS)	In general, accessibility by road is much higher than by public transport: However, there are also several areas where public transport accessibility is higher, mostly these areas are in close distance to bus stops. Areas of better public transport accessibility are much more fragmented than those with high accessibility by road.
Naess et al. (1995, 2001)	Oslo region (NO)	The relative speeds of car and public transport in commuting and every day activities exert an important influence on the modal choices of the journey to work. Hence, expansion of road capacity leading to a travel time reduction cause a shift from public transport to car as well as long distances to central areas.
Arnesen et al. (2010)	Mountain areas, southern Norway (NO)	Most municipalities of mountainous Norway suffer from access to public services; only selected municipalities at the fjords or within the valleys show sufficient high access to all facilities.
Meriläinen (1996)	Hämeenlinna region (FI)	Accessibility of villages can be increased by road infrastructure, but even major improvements seem not to have significant impacts on the vitality of those villages.
Määttä-Juntunen et al. (2010)	Oulu region (FI)	A careful, accessibility based selection of the locations of shopping centers might reduce CO_2 emissions.
Komornicki and Śleszyński (2009)	Mazowieckie (PL)	Warsaw is a barrier to the accessibility of the regional airports. It will continue to play this role even after the extension of the road network.
Guzik and Kołoś (2003)	Carpathian spa resorts (PL)	The three best accessible spa resorts in the Polish Carpathian Mountains (Rabka, Ustron, Krynica) have numerous services with relatively short travel time. The non-spa resort of Zakopane is by far the most accessible town of all resorts reviewed.
Taylor (2003)	Three rural communes (PL)	The best accessibility is enjoyed by inhabitants of larger villages and medium-sized places favourably located on stage bus routes.
Niedzielski and Śleszyński (2008)	Warsaw (PL)	Residential and employment accessibility for both road and public transport exhibits a concentric though irregular pattern declining in intensity with increasing distance from Warsaw's CBD.
Gadziński and Beim, (2010)	Poznań (PL)	The isochronal analysis shows that there is a big lack of radial tram lines establishing rapid connection between Poznań districts (especially in the northern part of the city) and to new settlements and the most important destinations of the daily trips.
Guzik (2003)	Małopolskie (PL)	For 60 percent of the municipalities, travel time to the nearest secondary school before 8 am is longer than the standard of 45 min.
Copus (1992; 1994	Highlands and Islands of Scotland (UK)	Significant differences between the mainland and islands, but also a gradual decline in mainland potential with increasing distance from Central Belt and major centres.
Martin et al. (2001); Lovett et al. (2000; 2001); White (2001); Higgs and White (2000); Naude et al. (1999); National Assembly for Wales (2000), Kelly et al. (2001)	Different UK regions incl. South West of England; East Anglia	Accessibility to public service facilities is very different and depending on the mode used. Accessibility significantly varies for different social and age groups. Taking account of opening hours of the facilities results in quite different accessibility patterns, since often opening hours and time schedules of public transport as preferred mode of elderly people are not compatible.
Cooper et al. (2009)	Greater London (UK)	Local access to public transport may be extremely different depending on the home base, since every single trip from home to public transport stops may include detours and may be subject to the small-scale distribution of underground access ramps.

Table 4.10. Accessibility pattern stated in regional accessibility studies (continued)

Authors	Spatial scope	Accessibility pattern
DfT (2009a; 2009b)	Local authorities (UK)	Various local applications show that the accessibility patterns vary significantly subject to the considered destination, time of day, and the mode used. Consequently, the impact of accessibility on daily behaviour very much differs for different age or social groups.
DHC (2006)	Scotland (UK)	Accessibility patterns are subject to a variety of local conditions: (i) specific spatial configurations of different types of services, (ii) specific public transport and road infrastructure provisions, (iii) operating hours of transport as well as opening hours of facilities. Altogether the resulting accessibility patterns are different for different social and age groups, and may also differ even for neighbouring areas.
Commission for Rural Communities (2009)	Worcestershire (UK)	Accessibility for public transport is very different, with areas of high accessibility close to public transport stops, and low accessibility in areas in greater distance to the stops. Accessibility is subject to the type of public transport service and the type of destination to reach, resulting in different accessibility patterns for different age groups and trip purposes.
Schürmann and Spiekermann (2010)	Bavaria (DE)	In general, there is in Bavaria good access with reasonable travel times to basic services of general interest. However, very different access to higher level services make rural areas disadvantaged. Accessibility by public transport in rural regions is much worse than accessibility by road.
Schürmann and Spiekermann (2011)	Munich, Karlsruhe, Hannover, Hamburg regions (DE)	Suburban locations along radial corridors of newly opened motorways or railway lines have improved their accessibility within the agglomerations. The consequences were rising land values, settlement activities, population increase and extended commuting distances.
BAK Basel Economics (2007	Northern Switzerland (CH)	Accessibility of Zürich and Basel is much better than that of suburban and rural municipalities. Disparities are much higher for public transport than for road.
Kraft (2008)	Southern Bohemia (CZ)	Clear differences of regional centers according to their position in the transport system, particularly for public transport.
Květoň (2006)	Jeseníky region (CZ)	Highest rates of elderly people correlate with the worst travel time accessibility of villages.
Györffy (2006)	Northern Hungary (HU)	The main accessibility problem of rural areas is the inadequate quality and density of the road network. Public transport access to regional centres is above one hour for two thirds of the rural population, mainly because of transfer times.
EUPOLIS (2007)	Turin (IT)	The accessibility of Turin to other European cities is slightly below the average of the other cities considered, whereas its accessibility to international airports is above the average.
DRE Aquitaine (2008)	Aquitaine region (FR)	Travel times to network nodes is a function of network design.
L'Hostis et al. (2004)	Nord-Pas de Calais (FR)	The study proposes ways that the objective to reach the regional capital Lille within one hour from regional cities would become feasible which it is currently not the case.
Bozzani and L'Hostis (2006	Lille (FR)	There is a clear spatial extension of the accessibility of Lille as a result of the combination of high-speed rail and air transport.
Nogales Galán et al. (2002, 2003)	Extremadura (ES)	The road network in Extremadura follows a national logic rather than a regional one. Areas far from national axes and the border points with Portugal have the worst accessibility.
Hernández (2002)	Canary Islands (ES)	About 70 % of commercial working hours and between 80 and 90 % of public administration working time at the main islands can be utilised in a day trip travelling from the main islands, values are lower for travelling from smaller islands to the main islands.
Silva and Pinho (2010)	Oporto region (PT)	Whereas accessibility by car to activities of interest is very good, about half of the study region with 15 percent of the population has poor access by public transport.

Assessment

An overall assessment of national and regional accessibility models is difficult. The general tendency is that none of the models is really able to serve all purposes. In national and regional studies of accessibility other origins and destinations become relevant than in European studies. If a balanced polycentric urban system is a goal of national spatial planning, accessibility of cities at the second or third level of the urban systems is of interest. Accessibility on the labour market is important from both viewpoints, i.e. from the firms' and from the workers'. More and more, the provision of minimum standards of services of general interest in urban, periurban or rural areas is becoming a problem of high political importance. This makes the analysis of accessibility of public facilities such as schools, food shops, doctors and pharmacies, important.

Nearly all national and regional studies have highlighted the sometimes large differences in accessibility in their study areas. However, the review has also shown that due to the great variety of the dimensions of accessibility, more detailed statements on overall regional patterns of accessibility by type of regions cannot derived from the literature. The conclusion is to develop a systematic and consistent set of accessibility indicators at the regional scale to be applied in TRACC to elaborate an accessibility typology for different types of regions.

4.4 Accessibility impacts

Accessibility is not a goal by itself but a derived demand. Accessibility is important because it provides access to opportunities at distant locations or makes it possible to receive goods and services or visitors from distant locations. For policy making, the maximisation of accessibility is therefore an objective only as far as it helps to improve the quality of life by facilitating access to opportunities, goods and services and so participation in social and cultural life.

This section reviews the state of the art of measuring, explaining and forecasting the impacts of accessibility. It first identifies the types of impacts of interest of accessibility of political interest. It then summarises the theoretical concepts explaining the relationships between accessibility and the impacts of interest. Guided by this theoretical background it reviews available empirical evidence about these relationships and existing mathematical models to forecast them. The section closes by proposing hypotheses about the likely effects of transport policies on the most relevant accessibility impacts.

4.4.1 Types of impacts

The impacts of accessibility of political interest are scale-dependent. At the European or national level, the relevant impacts are *economic*, i.e. impacts on regional economic development and territorial cohesion. At the intraregional level, the most important impacts are *social*, i.e. effects on social inclusion or exclusion by access to services of general interest and participation in social and cultural life. *Environmental* impacts of accessibility are relevant at all levels, but they are indirect and inversely related to accessibility, as good accessibility gives rise to more movements of goods and persons over longer distances, and these movements generate negative environmental impacts, such as more energy consumption and greenhouse gas emissions.

Economic, social and environmental impacts of accessibility differ in how they are measured and forecast. Social impacts can be measured and forecast directly by appropriate accessibility indicators, such as travel time to the nearest urban centre, education facilities or health services. Economic impacts of accessibility can be measured directly, e.g. in terms of GDP per capita, but to forecast the economic impacts of accessibility requires a theory or model about the way changes in accessibility affect regional economic development. The calculation of environmental impacts of changes in accessibility requires a transport model forecasting the flows of trains, cars and lorries likely to result from transport infrastructure investments.

4.4.2 Theoretical background

According to the above classification, economic and environmental impacts of accessibility cannot be directly measured but require a theory or model of their relationship with accessibility. The theoretical concepts developed for this are discussed in this subsection.

Economic impacts

The important role of transport infrastructure and quality of service for regional economic development is one of the fundamental principles of spatial economics. In its most simplified form it implies that regions with better access to the locations of input materials and markets will, ceteris paribus, be more productive, more competitive and hence more successful than more remote and isolated regions.

There exists a broad spectrum of theoretical approaches to explain the impacts of transport infrastructure investments on regional socio-economic development. Originating from different scientific disciplines and intellectual traditions, these approaches presently coexist, even though they are partially in contradiction.

Historically, theories about the spatial economy start with von Thünen's (1826) isolated state in which economic location is a function of market access. Marshall (1890) added synergies between complementary industries as a location factor, Weber (1909) access to suppliers and labour. Christaller's (1933) central place theory introduced economies of scale to explain the multi-level polycentric system of cities as a function of service areas of different size, and Lösch (1940) did the same for centres of production as a function of market areas. At the height of neoclassical theory, Ohlin (1933) proposed that under conditions of perfect competition and factor mobility and constant returns to scale interregional flows of capital, labour and trade will lead to equal prices of production factors and goods in all regions. The opposite position was taken by Perroux (1955) and Myrdal (1957) who proposed that because there *are* barriers to mobility and economies of scale, the presence of advanced industries will, in a process of "cumulative circular causation", lead to spatial polarisation between prospering and lagging regions.

A synthesis between the two opposing views was offered by the new economic geography (Krugman, 1991; Krugman and Venables, 1995; Fujita et al., 1999). The new economic geography explains regional economic development as the result of the interplay between agglomeration forces (economies of scale) and spatial interaction costs as illustrated by the vertical and horizontal dimensions of the diagram in Figure 4.1. The theory suggests that the prevailing historical trend of increasing economies of scale and decreasing transport costs has led from isolated dispersed settlements to an ever more polarised spatial structure with a small number of dominant agglomerations (the white arrows in the diagram). If a more balanced polycentric spatial structure is a political objective, either the trend towards increasing economies of scale or the trend towards ever lower transport costs needs to be stopped or even reversed (the solid arrows in the diagram). One important conclusion of this is that not only vertical linkages are important but also horizontal linkages between cities with complementary economic specialisation. The new economic geography has also overcome unrealistic assumptions of neoclassical theory, such as the assumption of perfect competition, by adopting the concept of imperfect (monopolistic) competition.

Other contributions to the theory of regional economic development include institutional economics, which address the importance of property rights and transactions (Coase, 1960; Williamson, 1966), evolutionary economics linked to theories of synergy, self-organisation and complexity in the spirit of Forrester (1968), and more recently theories about the role of global cities (Sassen, 1991), spatial clusters of complementary industries (Porter, 1990) and the growing importance of information technologies (Castells, 1989) and creative industries (Florida, 2004). However, only few of these newer theoretical approaches have been used for applied quantitative models of regional economic development to date.

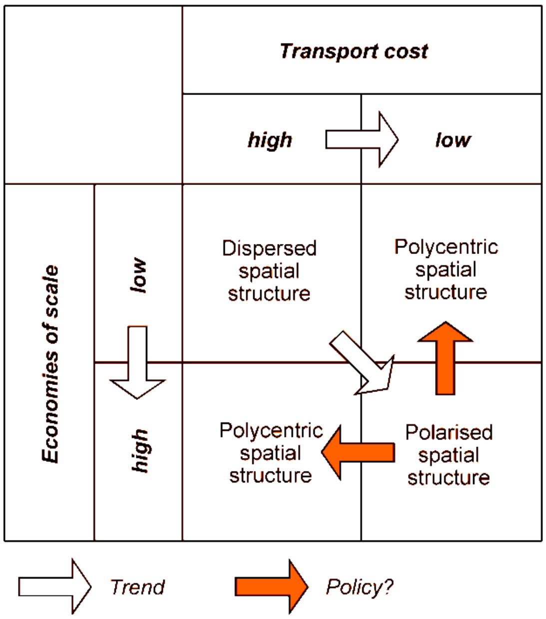


Figure 4.1. Economies of scale and transport cost

Another set of theories addresses not the location of economic activity (the demand side of regional labour markets) but interregional migration (the supply side of regional labour markets). Following migration theory (Ravenstein, 1985; Zipf, 1949), migration flows between regions are primarily job-oriented, i.e. people move from regions with high unemployment and low wages to regions with many job opportunities and higher wages. However, international migration of labour is inhibited educational, language and cultural barriers and, legal immigration constraints, as the history of labour migration in the EU since the two recent EU enlargements has demonstrated.

Environmental impacts

Environmental impacts of accessibility are indirect as they result from the flows of goods, services and persons occurring on the transport networks. The pattern of movements reflects the response of firms and households to network travel time and travel costs, i.e. is a function of the same variables used to calculate accessibility indicators.

There exists a broad range of testable theories about human travel behaviour. The most straightforward one is the model of rational behaviour under uncertainty underlying travel demand or goods transport models: Firms and households choose that combination of transport mode and transport route which minimises their travel time and/or transport cost to reach a destination (in the case of travellers) or to obtain goods from an origin (in the case of firms). Following this model, changes in transport supply, i.e. travel time and travel cost, result in shifts in the choice of origin, destination, mode and route. If transport becomes faster and less expensive, people will make more and longer trips and firms will order goods from more distant locations. If transport becomes slower and more expensive, people will make less and shorter trips and firms prefer regional products from suppliers nearby. These response mechanisms are largely responsible for the vast expansion of spatial mobility and the resulting spatial dispersal of human activities during the last century.

Things are getting more complex if also the feedback between network use and network capacity leading to congestion on the most heavily used network links is taken into account. Another complication arises if origins and destinations, e.g. firms and households, are not taken as fixed but are themselves influenced by changes in accessibility as discussed in the previous subsection.

It follows that it is not possible to calculate the environmental impacts of accessibility directly. Instead it is necessary to apply a travel and goods transport model to generate the flows of people and goods on the transport networks that are used to calculate the accessibility indicators subject to the distribution of origins and destinations at the time of analysis or forecast. To take account of feedbacks between transport and location, the transport model needs to be linked to the model of firm relocations and migrations discussed above.

If the flows of people and goods on the networks by mode resulting from a change in accessibility are made, the environmental impacts of these flows in terms of energy consumption and greenhouse gas emissions can be calculated subject to assumptions about fleet composition and fuel efficiency of vehicle types.

It is important to note that it cannot be assumed that any improvement of accessibility will also result in a corresponding improvement of sustainability. It is simple to see that a major motorway extension will attract more lorries and cars and generate more energy consumption and greenhouse gas emission. Things are getting more difficult with a major rail investment. On first sight the new line will attract more travellers and goods and so reduce vehicle-km, energy consumption and greenhouse gas emission on roads. However, if fewer lorries and cars are on the road, congestion and hence travel times will go down. This will make road transport again attractive with the effect that more and longer road trips are made. The net effect for energy consumption and greenhouse gas emissions is hard to predict; it may well be that a well-intended policy to improve sustainability is detrimental for the environment.

4.4.3 Empirical evidence

Despite the highly developed theoretical background of the likely economic and environmental impacts of transport infrastructure investments, the empirical evidence in this field is rudimentary and in many respects ambiguous.

Economic impacts

While there is broad agreement that more accessible regions are more competitive and economically successful, the empirical relationship between transport and economic development is more complex (Vickerman et al., 1999). There are successful regions in the European core confirming the theoretical expectation that location matters. However, there are also centrally located regions suffering from industrial decline and high unemployment. On the other side of the spectrum the poorest regions, as theory would predict, are at the periphery, but there are also prosperous peripheral regions, such as the Nordic countries. To make things even more difficult, some of the economically fastest growing regions are among the most peripheral ones, such as some regions in the new EU member states in Eastern Europe (see Figure 4.2).

So it is not surprising that it has been difficult to empirically verify the impact of transport infrastructure on regional development (Vickerman, 1994). There is a clear positive correlation between transport infrastructure endowment or the location in interregional networks and the levels of economic indicators such as GDP per capita (e.g. Biehl, 1986; 1991; Keeble et al., 1982; 1988). However, this correlation may merely reflect historical agglomeration processes rather than causal relationships still effective today (cf. Bröcker and Peschel, 1988). Attempts to explain changes in economic indicators, i.e. economic growth and decline, by transport investment have been much less successful. The reason for this failure may be that in countries with an already highly developed transport infrastructure further transport network improvements bring only marginal benefits (Bröcker et al., 2004). The conclusion is that transport improvements have strong impacts on regional development only where they result in removing a bottleneck (Blum, 1982; Biehl, 1986; 1991).

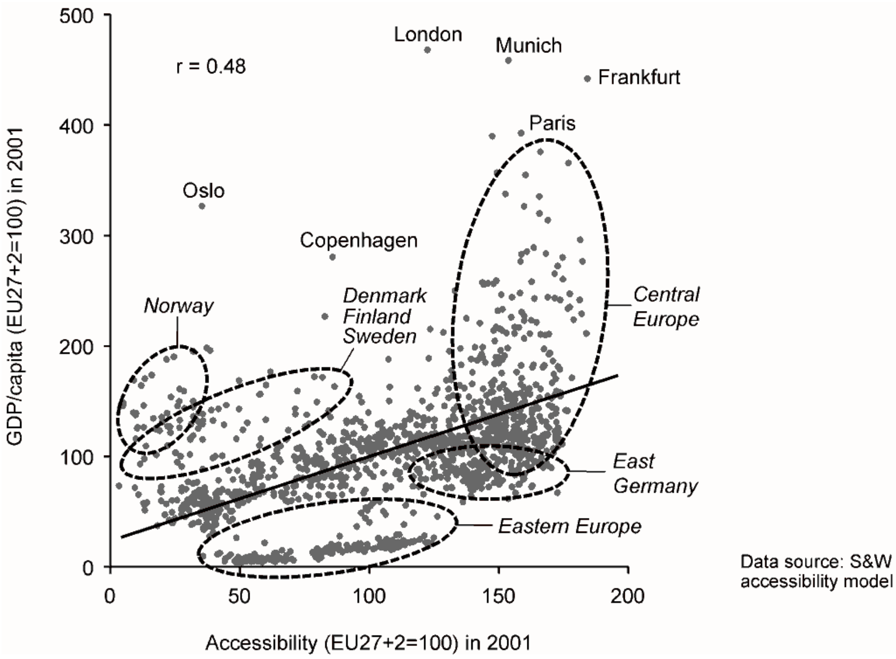


Figure 4.2. Accessibility and GDP per capita of NUTS-3 regions

There is even disagreement on the direction of the impact and thus whether transport infrastructure contributes to regional polarisation or decentralisation (Vickerman, 1994). Some analysts argue that regional development policies based on the creation of infrastructure have not succeeded in reducing regional disparities, whereas others point out that it has yet to be ascertained that the reduction of barriers between regions has disadvantaged peripheral regions (Bröcker and Peschel, 1988). From a theoretical point of view, both effects can occur. A new motorway or high-speed rail connection between a peripheral and a central region makes it easier for producers in the peripheral region to market their products in the large cities, but may also expose the region to the competition of more advanced products from the centre and so endanger formerly secure regional monopolies (Vickerman et al., 1999; Quinet and Vickerman, 2004).

Figure 4.3 visualises this dilemma for a peripheral region (A) and two central regions (B and C): Peripheral region A is disadvantaged by its location and by its poor transport connections to the central regions B and C. An improvement of the transport link between A and B enables Region A to market its products in B and C, but also opens it up to the products of B and C. In the real world, however, primarily the transport connections between the central regions are improved.

Environmental impacts

The empirical situation in the field of travel and goods transport is more clear-cut but there remain ambiguities, too. There are detailed records of the evolution of transport networks and level of service on these networks in EU countries and regions. There is, too, a huge amount of data on transport activities in terms of tonnes-km by category of goods, vehicle-km by vehicle type as well as on energy consumption of transport and greenhouse gas emissions of transport. However, these data are in general collected separately and are not brought together in a policy-relevant way at a policy-relevant spatial scale below the national level.

This makes it difficult to assess the environmental impacts of transport infrastructure investments from empirical evidence. Instead the preferred method in practice is to apply a combined travel demand and goods transport model and to calculate the energy consumption and greenhouse gas emissions generated by it.

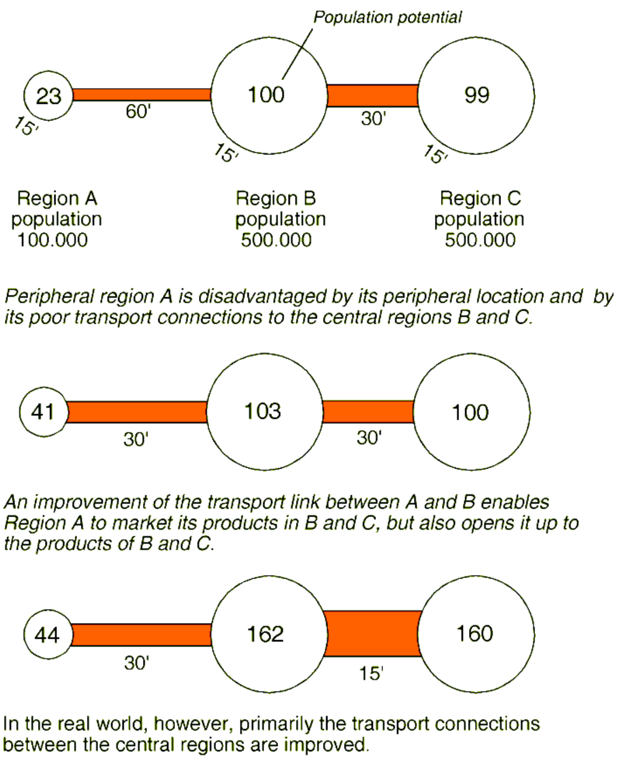


Figure 4.3. Who gains: core or periphery?

4.4.4 Regional economic models

There are three types of regional economic development models: regional production function models, multiregional input-output models and spatial computable general equilibrium models. The principles of these three types of models are summarised and the most important operational models of regional economic development applied in Europe are briefly presented here.

Regional production function models

Production functi*on* approaches model economic activity in a region as a function of production factors. The classical production factors are capital, labour and land. In modern production function approaches, among other location factors, infrastructure is added as a public input used by firms within the region (Aschauer, 1989; 1993; Jochimsen, 1966; Buhr, 1975). The assumption behind the expanded production function is that regions with higher levels of infrastructure provision will have higher output levels, and that in regions with cheap and abundant transport infrastructure more transport-intensive goods will be produced. The main problem of regional production functions is that their econometric estimation tends to confound rather than clarify the complex causal relationships and substitution effects between production factors. This holds equally for production function approaches including measures of regional transport infrastructure endowment. In addition the latter suffer from the fact that they disregard the network quality of transport infrastructure, i.e. value a kilometre of motorway or railway the same everywhere, irrespective of where they lead to.

More recent production function approaches attempt to respond to the latter criticism by replacing the simple infrastructure endowment indicators in the regional production function by more complex accessibility indicators. Accessibility indicators in most cases are some form of population or economic potential based on the assumption that regions with better access to markets have a higher probability of being economically successful. Pioneering examples of empirical potential studies for Europe are Keeble et al. (1982; 1988). Today approaches relying only on accessibility or potential measures have been replaced by hybrid approaches where accessibility is but one of several explanatory factors of regional economic growth, including soft location factors. Also the accessibility indicators used have become much more diversified by type, industry and mode (see Schürmann et al., 1997). The SASI, ASTRA and MASST models are models of this type incorporating accessibility among other explanatory variables.

- SASI. The SASI model developed at the Vienna University of Technology and the University of Dortmund is a recursive simulation model of socio-economic development of regions in Europe (Wegener and Bökemann, 1998; Wegener, 2008). Subject to exogenous assumptions about the economic and demographic development of the European Union as a whole, the model predicts the impacts of transport infrastructure investments and transport system improvements, in particular of the trans-European transport networks. It differs from other regional economic models by modelling not only production (the demand side of regional labour markets) but also population and migration (the supply side of regional labour markets). The sectoral production functions of SASI include production factors (some of them delayed) representing regional capital, labour market potential, economic structure, sector-specific accessibility indicators and soft location factors, such as research and development and quality of life. The SASI model has been applied in several EU projects, such as IASON, ESPON 1.1.3 and 2.1.1 and AlpenCorS and STEPs and projects for national and regional authorities.
- ASTRA. The ASTRA model developed at the University of Karlsruhe is a recursive-dynamic model of the system-dynamics type designed to assess the likely impacts of transport policies on the regional economy and environment (Schade, 2005). Its macroeconomic submodel determines regional supply and demand and inter-industry linkages using national input-output tables. Regional supply is forecast by a Cobb-Douglas production function calculating potential output as a function of production factors labour supply, capital stock, natural resources and technical progress in the form of total factor productivity depending on sectoral investment, freight transport time savings and labour productivity. The ASTRA model also contains submodels of passenger travel and freight transport, the size and composition of the vehicle fleet and environmental impacts of transport, such as emissions, noise, accidents and congestion. ASTRA works at the European level and provides results at country level. It has been applied in several EU projects, such as STEPs and iTREN-2030. National versions of the model have been realised and applied for Germany and Italy at a more detailed geographical level. The Italian version of the model is based on a different macroeconomic submodel where production factors (capital and labour) are complementary rather than substitutable.
- MASST. The MASST (MAcroeconomic Sectoral, Social, Territorial) model was developed at the Politecnico di Milano to assess long-term scenarios of spatial development in Europe in the ESPON programme (ESPON 3.2, 2006, Vol. 4, 11–53; Cappello, 2007; Capello et al., 2008). MASST models national and regional GDP growth, population and migration based on alternative assumptions about macroeconomic tendencies and policy assumptions, such as interest, savings, exchange and inflation rates, public expenditures, geographical reorientation, foreign direct investment, trends in public debts, energy prices, migration policies as well as new institutional arrangements, such as further integration of the European Union and European policies, such as structural and agricultural funds and transport infrastructure priorities. Accessibility of a region is calculated as its economic potential, i.e. as the sum of the difference between the per-capita income of all other regions and that of the region divided by their distance to it.

Multiregional input-output models

Multiregional input-output models represent interregional and inter-industry linkages using the Leontief (1966) multiregional input-output framework. These models estimate inter-industry and interregional trade flows as a function of technical inter-industry input-output coefficients and transport costs (Echenique, 2004). Final demand in each region is exogenous, regional supply, however, is elastic, so that the models can be used to forecast regional economic development in response to changes in transport costs. If transport costs rise, industries and households tend to order more products from suppliers in near-by regions so that the exports of these regions grow and those of far-away regions decline. Examples of operational multiregional input-output models are MEPLAN, TRANUS and DELTA.

- MEPLAN. The MEPLAN model was developed by Marcial Echenique at the University of Cambridge (Echenique et al., 1969; 1990). It models regional economic development and transport flows based on national input-output tables expanded by households of different types as consumers of goods and services and producers of labour. Interregional trade flows, i.e. regional imports and exports, are predicted as a function of regional supply and demand by commodity type and production prices plus transport costs. The trade flows are converted to freight flows and passenger trips and assigned to a multimodal transport network. The flows in the network generate congestion which affects transport costs. The revised transport costs are fed back to the economic model until equilibrium is achieved. The model is made quasi-dynamic by computing an equilibrium for a series of time steps. The MEPLAN model has been applied to many regions, countries and Europe as a whole, e.g. in the Channel Tunnel study to assess the likely economic impacts of the fixed link between the European continent and the United Kingdom (Rohr and Williams, 1994).
- TRANUS. The TRANUS model developed by Tomás de la Barra et al. at Modelistica in Venezuela is based on a random utility derivation of the spatial input-output model (de la Barra, 1979, 1989). Like MEPLAN the model simulates the location of production and consumption at the level of regions as a function of production prices and transport costs thus generating flows of commodities and services which are then converted to freight and passenger trips. TRANUS interacts with its own transport model based on a multimodal logit assignment procedure particularly suited for multimodal transport networks with multiple choices and low levels of congestion. Log-sum transport disutilities are fed back to the spatial input-output model and influence the flows of commodities and services there. The TRANUS model was applied to the State of Oregon, to Spain, to Venezuela and several other Latin American regions, and more recently to a highly detailed model of Chile.
- DELTA. The land-use/economic modelling package developed by David Simmonds and colleagues (Simmonds, 1999; Simmonds and Skinner, 2003) works at two spatial levels, though not in all applications. The higher spatial level incorporates a spatial input-output model in which trade flows are influenced by transport costs linked with a model of investment and a migration model. The higher-level version has been applied to Scotland and several areas in England and to the whole of Great Britain.

Spatial computable general equilibrium models

Following the ideas of the new economic geography, more recent input-output based models of trade flows include economies of scale and imperfect (monopolistic) competition. Such multiregional input-output models are today called spatial computable general equilibrium (SCGE) models, although the term CGE originally had a broader meaning (Bröcker, 2004). The distinction between SCGE models and multiregional input-output models is becoming more and more blurred as also the latter determine a general equilibrium between transport and location. Examples of SCGE models are CGEurope, RAEM and recent versions of the REMI model.

- CGEurope. The CGEurope model developed at the University of Kiel is a multiregional spatial computable general equilibrium model in which transport costs are expenditures of firms for transport and business travel (Bröcker, 1998; Bröcker et al., 2004; 2010). It assumes imperfect (monopolistic) competition of the Dixit-Stiglitz (1977) type in each region for the markets of tradable goods and perfect competition for local goods and factor markets. Prices and quantities respond to changes in transport times and transport costs resulting in changes in income and welfare in each region. The CGEurope model predicts the spatial distribution of production factors in a target year in a comparative static equilibrium analysis, i.e. by comparing cases with and without implementation of the policies leaving everything else unchanged. The main output of the model is the so-called Hick's measure of variation, i.e. the monetary equivalent of the change of welfare of households. CGEurope has been applied in several EU projects, such as IASON, ESPON 2.1.1 and TEN-CONNECT.
- RAEM. The RAEM model developed at the University of Groningen and TNO Delft is an SCGE model of regional capital investment and stock and flow relationships of households and firms (Oosterhaven et al., 1998; Ivanova, 2007). Households maximise their utility of consumption of goods and services under budget constraints, and industries minimise their costs of labour, capital and inputs under technology constraints. Each sector consists of identical firms each producing a unique specification of a particular commodity, which gives them monopolistic power over their consumers. Households and domestic sectors consume transport services in their consumption and production activities. The latest version RAEM 3.0 includes international trade and interregional migration. The model determines equilibrium of supply and demand and interregional trade flows in each time period. RAEM was developed for the Netherlands and has been applied in a simplified version (RAEM-Light) in Hungary, Japan and South Korea.
- REMI PI+. The REMI model developed at the University of Massachusetts (Treyz, 1980; Treyz et al., 1992) originally was a multi-regional input-output model with endogenous final demand. Its latest version, PI+ (Policy Insight), is a new economic geography extension of the original REMI framework with endogenous real estate prices, labour mobility and inter-industry purchases (Fan et al., 2000). It relaxes some of the restrictive assumptions of new economic geography in that workers are mobile between sectors and regions, real estate prices are explicit in consumption and production, and differentiated inputs are used in production. Agglomeration forces in the model are consumers' and producers' prices and wages, the centrifugal force in the model is the limited supply of land. Evolutionary equilibrium is determined taking account of different speeds of adjustment of different subsystems over time. Previous generations of the REMI model have been applied for policy analyses in over a hundred regional and state agencies in North America and Europe.

Comparison

The three types of model, regional production function models, multiregional input-output models and spatial computable general equilibrium models, have much in common with respect to underlying theory (see Table 4.11). All three are aggregate models at the meso scale of regions. All consider transport a production factor of great importance for regional economic development. There are no neoclassical models assuming perfect factor mobility in the set of models discussed here, as all of them model spatial impedance in the form of transport costs and other forms of barriers, though with different detail. Markets with imperfect competition, increasing returns to scale and bounded rationality under uncertainty by economic agents are addressed in models of all three groups, either by the nonlinear specification of production factors in the extended production functions or by logit type utility functions in the multiregional input-output models or by the Dixit-Stiglitz model of monopolistic competition in the SCGE models.

Table 4.11. Comparison of multiregional economic models

Model type	Model	Trade flows	Imperfect competi-tion	Networks	Demo-graphy	Migration	Dynamics
Regional production function	SASI	no	implicit	yes	yes	yes	yes
	ASTRA	output	implicit	no	yes	yes	yes
	MASST	no	implicit	no	yes	yes	yes
Multiregional input-output	MEPLAN	yes	no	yes	no	no	no
	TRANUS	yes	no	yes	no	no	no
	DELTA	yes	implicit	external	no	yes	yes
Spatial computable general equilibrium	CGEurope	yes	yes	external	no	no	no
	RAEM	yes	yes	external	no	yes	no
	REMI PI+	yes	yes	no	yes	yes	yes

However, there are also major differences. Multiregional input-output models and SCGE models explicitly model trade flows between regions based on product prices and transport costs and determine regional growth of industrial sectors from these flows. Production function models aggregate trade and travel flows into one complex variable, accessibility. Needless to say that the explicit modelling of purchases of firms from other regions based on comparison of product price, diversity and transport cost is superior to the econometric estimation of the aggregate impact of accessibility on regional economic development, in particular if not only trade volumes but also prices are endogenous as in SCGE and some multiregional input-output models.

More problematic are obvious omissions in some of the models. If in the ASTRA model accessibility is expressed only as freight transport time for distance bands or in the MASST model only by interregional distance or km of roads in a region, these models are likely to underestimate the impact of network improvements, in particular of rail investments. The CGEurope model assumes that regional labour is constant and immobile and so fails to take account of the impacts of demographic change and interregional migration on regional labour markets. The SASI model presently treats regional sector productivity as exogenous instead of modelling improvement in productivity through better accessibility. However, all these deficiencies can be easily overcome by relatively minor model modifications.

Another relevant difference between the models is their treatment of dynamics. Multiregional input-output models and SCGE models assume that markets are in equilibrium, at the start and target year (CGEurope), at the end of each period (MEPLAN, TRANUS, DELTA, RAEM) or after a number of periods (REMI PI+). The production function models, however, are all recursively dynamic with different types of adjustment delays.

In particular the latter difference, between equilibrium and dynamics, seems to affect the sensitivity of the models to transport cost changes. This is suggested by a comparison of the results of the CGEurope and SASI models. In the EU projects IASON (Bröcker et al., 2004) and ESPON 2.1.1 (Bröcker et al., 2005) the two models were applied to the same study area, the same regional and network data and the same policy scenarios. It turned out that the two models agreed with respect to the direction and spatial distribution of the effects of the policies and whether the policies contribute to greater cohesion or polarisation between the regions in Europe, but differed with respect to the magnitude of the responses by a factor of up to ten, with the SASI model showing the stronger responses. Possible reasons for this divergence included differences in the specification of transport costs, in particular with respect to border impediments, the neglect of mobile capital in SASI and the neglect of mobile labour in CGEurope. Another hypothesis was that CGEurope as an equilibrium model primarily predicts short-term responses, whereas the quasi-dynamic SASI model shows self-reinforcing cumulative effects over time (Bröcker et al., 2004, 168-175). Further research is necessary to test the two hypotheses.

4.4.5 Hypotheses

The combined results of empirical and modelling studies suggest that the present European transport policy may widen rather than narrow differences in accessibility between central and peripheral regions. Although the biggest absolute changes in accessibility are gained in some peripheral regions which start with very poor levels of provision, the relative gap between the best and the worst of the main centres increases.

This does not imply that the relative gains in accessibility of peripheral regions may not be beneficial to their economic development, however it must be pointed out that these gains will always be overshadowed by the much larger gains in accessibility of the regions in the European core. It is therefore not possible to refer to transport network improvements unambiguously as instruments to promote the cohesion between the regions in Europe and the reduction of interregional economic and social disparities. A European transport policy truly committed to that goal would have to shift significantly the focus of the trans-European networks investment programme to transport links within and between the peripheral regions, not in addition to, but at the expense of, transport investment in the European core.

Similarly, the results of the empirical and modelling studies suggest that transport policies that aim at improving accessibility do not automatically also improve sustainability. Even transport policies explicitly aimed at shifting transport to environmentally more sustainable models are not certain to achieve that goal due to the inherent nonlinear dynamics of transport and location.

5 TRACC accessibility and impact indicators

Based on the review of accessibility and impact indicators in the previous chapter, this chapter presents the TRACC set of accessibility and impact indicators implemented in the project.

5.1 Accessibility indicators

The review of accessibility studies ranging from a few studies addressing global accessibility down to a vast number of studies dealing with regional accessibility has shown the variety of indicators and approaches. Most frequently used are accessibility indicators of the basic type travel cost, particularly in studies at the regional or national scale. However, also the two other generic types of accessibility indicators, cumulated opportunities and potential accessibility, are used in several studies, the latter in particular in studies at the European scale and only rarely at the regional scale. The activities of interest at the destination are very often population, but also GDP, jobs, labour force, cities of different functions, different public and private services or institutions or freight terminals are used. The spatial resolution differs much. Whereas some European studies consider only a few points in space or are working at the NUTS-2 level, many studies work at the NUTS-3 level or are even based on a raster representation of Europe. Most studies at the regional scale work at the LAU-2 level, however, with the availability of high-resolution grid data, there is a tendency towards calculating accessibility at the regional scale for small raster cells. The level of network detail differs accordingly. Whereas a few studies use no network at all but airline distances, the other end of the spectrum is marked by studies working with full road networks and public transport timetables including real transfer times. Most accessibility studies deal with passenger travel, only very few are concerned with freight transport.

The review has shown that there is no single standard accessibility indicator serving all purposes. The conclusion for TRACC has been therefore to develop a systematic and consistent set of accessibility indicators which is derived from the conceptual framework as laid down in Chapter 3 and which matches the following requirements:

- As different types of accessibility indicators provide answers to different questions, the three generic types of accessibility indicators, i.e. travel cost, cumulated opportunities (daily accessibility) and potential accessibility should be used at all levels considered.
- The TRACC project is expected to analyse accessibility at very different spatial levels ranging from the global through the European to the regional level.
- The spatial coverage should be at least the ESPON space. Candidate countries and other countries of the Western Balkan should be included if possible. Regional case studies should cover different types of the regional typologies developed by ESPON.
- The spatial resolution should be appropriate. This is NUTS-3 for the Europe-wide indicators and LAU-2 for the regional case studies. In addition, raster representations of space should be explored to analyse to what extent a finer spatial resolution influences results.
- All relevant transport modes should be addressed, i.e. road, rail and public transport, air and water as well as combinations of modes in form of multimodal aggregation and intermodal trip chains.
- Traditional accessibility indicators should be amended by newer forms of accessibility. The traditional indicators should guarantee continuity with previous ESPON studies; in particular the potential accessibility indicator should be updated to a recent year.
- There should be accessibility indicators dealing with passenger travel and indicators dealing with freight transport.

Table 5.1 presents the resulting TRACC set of accessibility indicators. The indicator set is differentiated by the three main spatial contexts to be taken into account (global, European, regional), and at each level further differentiated by travel and freight. For the European level, accessibility indicators for travel are further divided into traditional and newer ones. For the regional level, the indicators are differentiated into those regional indicators for both travel and freight that can be calculated for the whole of Europe and those that can be calculated in the regional case studies only. For the latter, a distinction is made between traditional indicators and indicators looking at the accessibility to selected services of general interest to reflect current policy debates on the subject of services of general interest. For all levels, each generic indicator type is represented by one indicator.

Global accessibility

The task of the global accessibility indicators is to describe the linkages of the regions to the world. As demonstrated in Chapter 3.1, previous analyses of global accessibility were in most cases restricted to travel time indicators for selected points in Europe, usually airports. The TRACC set of global accessibility indicators provides progress in three directions: (i) Besides travel also freight accessibility is included. (ii) Not only travel cost indicators are included but also accessibility indicators of the types cumulated opportunity and potential: (iii) The indicators are not restricted to preselected rare points in Europe, but are calculated for all NUTS-3 regions of the ESPON space.

There are three global accessibility indicators defined for travel, i.e. each generic type of accessibility indicators is represented:

- *Access to global cities*. What are the travel times from the European regions to selected global cities? New York serves as example for a non-European global city. For each NUTS-3 region the shortest total travel time is calculated including intermodal trips by road, rail and/or air to airports with intercontinental flights plus the flight time to this city.
- *Global travel connectivity*. How many intercontinental flights can be reached from the European regions within a maximum travel time of three hours? For each NUTS-3 region the shortest total intermodal travel times by road, rail and/or air to airports with intercontinental flight services is calculated. If an airport is within the maximum travel time, the intercontinental destinations served from that airport is added to the regional global connectivity value.
- *Global potential accessibility travel.* What is the relative position of the European regions towards global destinations? For each NUTS-3 region the shortest total intermodal travel times by road, rail and/or air to airports with intercontinental flight services is calculated. The intercontinental flights weighted by seat capacity are used as attraction, i.e. the mass term in the calculation of the potential accessibility.

Accordingly, there are three global accessibility indicators for freight transport following a similar approach as the indicators for travel:

- *Access to global freight hubs*. What are generalised travel costs for specific commodity groups from the European regions to selected global freight hubs? New York and Shanghai serve as examples for non-European global freight hubs. For each NUTS-3 region the lowest total generalised costs is calculated including intermodal trips by road, rail, water and/or air to seaports and airports with intercontinental services plus the generalised costs from there to the two freight hubs.

Table 5.1. TRACC set of accessibility indicators

Spatial context	*Basic characteristics*	*Generic type of accessibility indicator*		
		Travel cost	***Cumulated opportunities***	***Potential***
Global	***Travel***	***Access to global cities*** Travel time (intermodal) to global city (New York)	***Global travel connectivity*** Number of flights from European airports to intercontinental destinations reachable within three hours	***Global potential accessibility travel*** Intermodal accessibility to intercontinental flights of European airports weighted by seat capacity as mass
	Freight	***Access to global freight hubs*** Travel time/cost (intermodal) to major intercontinental terminals (New York, Shanghai)	***Global freight connectivity*** Intercontinental container throughput of European sea ports reachable within maximum travel time	***Global potential accessibility freight*** By road and rail to container throughput of European sea ports
Europe	***Travel (traditional)***	***Access to top ten MEGAs*** Average fastest travel time to top group of MEGAs	***European daily accessibility travel*** Daily accessibility to population by road, rail, fastest mode	***European potential accessibility travel*** To population by road, rail, air, multimodal
	Travel (new)	***Travel speed*** Average travel speed by road and rail	***Urban connectivity*** Urban connectivity by road, rail, air, intermodal	***European potential acc. intermodal travel*** To population intermodal
	Freight	***Access to nearest maritime ports*** Generalised cost to nearest maritime port	***European daily accessibility freight*** GDP accessible within allowed lorry driving time	***European potential accessibility freight*** Accessibility potential to GDP by different modes
Regional	***Travel (Europe-wide)***	***Access to high-level transport infrastructure*** Weighted access time to motorway exits, rail stations, airports	***Availability of urban functions*** Cities > 50.000 within 60 minutes by road and rail	***National potential accessibility travel*** To national population by road and rail
	Freight (Europe-wide)	***Access to freight terminals*** Weighted access time to freight terminals	***Availability of freight terminals*** Freight terminals within 2 h by lorry	***National potential accessibility freight*** To national GDP by lorry
	Travel (case studies, traditional)	***Access to regional centres*** Travel time to nearest regional centre by road and public transport/rail	***Daily accessibility of jobs*** Jobs accessible within 60 minutes by road and public transport/rail	***Regional potential accessibility*** To population by road and public transport/rail
	Travel (case studies, to services of general interest)	***Access to health care facilities*** Travel time to nearest hospital	***Availability of higher secondary schools*** Number of higher secondary schools within 30 minutes travel time	***Potential accessibility to basic health care*** Potential accessibility to general practice surgeries

- *Global freight connectivity*. What amount of intercontinental container throughput of ports can be reached from the European regions within a mode-specific maximum freight transport time? For each NUTS-3 region the shortest total travel times by road, rail, water and/or air to seaports with intercontinental container services are calculated. If a seaport is within the maximum travel time, the intercontinental container throughput of that port is added to the regional global connectivity value for freight.
- *Global potential accessibility freight.* What is the relative position of the European regions towards global destinations with respect to freight transport? For each NUTS-3 region the shortest total travel cost by road, rail, water and/or air to ports with intercontinental container services are calculated. The intercontinental container throughput of the ports is used as attraction, i.e. the mass term in the calculation of the global freight potential accessibility.

European accessibility

The task of the European accessibility indicators is to provide assessments of the attractivity and competitiveness of European regions in the European context based on their location and their integration in the transport networks. As shown in Chapter 3.2, there is already a wide collection of previous studies including ESPON work on European accessibility available. The TRACC set of European accessibility brings value-added in three directions: (i) Traditional accessibility indicators such as the accessibility potential are updated to a current point in time thus allowing an up-to-date assessment and also the analysis of trends over time. (ii) The additional inclusion of new types of accessibility indicators and in particular of indicators addressing freight transport enables new insights into European accessibility conditions. (iii) The explorative analysis of raster-based indicators enables methodological conclusions on the appropriate spatial resolutions of accessibility indicators.

For each of the three generic types of accessibility indicators, first a traditional indicator for accessibility travel is defined:

- *Access to top group of MEGAs*. What is the average travel time from the regions to the upper level subset of the European MEGAs? For each NUTS-3 region the fastest travel time of road, rail and air transport to reach the top group of MEGAs is calculated, and an average value is determined.
- *European daily accessibility travel*. How many people can I reach within a day's round trip? How many people can visit my region within a day's round trip? For each NUTS-3 region the number of persons that can be reached within a one way travel time of five hours by road, rail and fastest mode is summed up. Five hours per way is used to allow for at least five hours of activities at the destination.
- *European potential accessibility travel.* What is the relative competitive position of European regions towards European destinations? For each NUTS-3 region the population in destination regions is weighted by the travel time to go there. The weighted population is summed up to give the value of the accessibility potential for the origin region. The potential accessibility indicator is calculated for road, rail, air and as an multimodal aggregate. The indicator is calculated with the same specification and network detail for the year 2011 as the potential accessibility indicators of ESPON 2006 and the Accessibility Updates. That means that the development of potential accessibility by road, rail, air and multimodal is also analysed over a time period of ten years in total.

There is a second set of European accessibility travel indicators that goes somewhat beyond the traditional indicators described before. These indicators include relatively new aspects and are more complex in terms of data requirements and calculation methods:

- *Travel speed*. What is the average travel speed to serve regional transport demand? The rationale of this indicator is based on the assumption that transport policy cannot provide the same degree of accessibility everywhere in Europe, but might provide the same quality of the infrastructure by delivering comparable speeds to the regional transport demand. First, regional transport demand is calculated by a negative exponential model in which the number of trips from the region to all other regions is estimated. Then, the travel time to the destination regions is converted to airline speeds. Finally, the average travel speed of a region is calculated as the trip-weighted average speed to all other regions.
- *Urban connectivity*. What opportunities or restrictions for urban connectivity does transport infrastructure provide? For each city of more than 50,000 inhabitants the travel time to other cities of that minimum size is calculated for road, rail, air and intermodal travel. Urban connectivity is there if two cities are less than three or alternatively five hours of centre-to-centre travel time apart from each other. The indicator is mainly presented in map form, but could also be numerically defined by using concepts of graph theory.
- *European potential accessibility intermodal travel.* What is the relative competitive position of European regions towards European destinations by using the best combination of all transport modes in intermodal trip chains? For each NUTS-3 region the population in destination regions is weighted by the intermodal travel time to go there. The weighted population is summed up to give the value of the accessibility potential for the origin region. The potential accessibility indicator is calculated by using shortest intermodal travel times between regions.

A third group of European accessibility indicators is concerned with freight transport. The indicators developed follow the logic of the more traditional accessibility indicators for travel:

- *Access to nearest maritime ports*. What are the costs to reach the nearest maritime ports? For each NUTS-3 region the average generalised travel cost for different commodities to reach the nearest three maritime ports are estimated. Modes considered are road, road and rail and road and inland waterway.
- *European daily accessibility freight*. What market area can be served by lorries from a region? For each NUTS-3 region the amount of GDP that can be reached within the maximum allowed driving time of a lorry driver is calculated.
- *European potential accessibility freight.* What is the relative competitive position of European regions towards European destinations with respect to freight transport? For each NUTS-3 region the GDP in destination regions is weighted by the generalised travel time to go there. The weighted GDP is summed up to give the value of the potential accessibility freight for the origin region. Freight handling categories considered are unitised goods and non-unitised goods (bulk and general cargo) thus reflecting different conditions with respect to impedance, e.g. different times and costs for loading and unloading. Modes included are road, rail, inland waterways, short sea shipping and air. For those modes that are generally used in combination with other modes, e.g. short-sea shipping needs feeder service by an inland mode to connect non-coastal regions, travel times and costs are calculated based on intermodal trip chains.

Regional accessibility

The task of the regional accessibility indicators is to provide the base for an analysis of the restrictions and opportunities for daily life provided by the transport infrastructure in the regions to the population and economic actors. The review of regional accessibility studies provided in

Chapter 3.3 has shown that there is a huge variety of approaches at this scale. In most of them travel cost type indicators in the form of travel time to a few selected destinations and the trend towards high spatial resolution dominate. The TRACC set of regional accessibility indicators provides progress in three directions: (i) A Europe-wide modelling of accessibility to regional destinations allows a comparison of regional accessibility for all NUTS-3 regions. (ii) The systematic integration of freight accessibility provides insights in the local restrictions and opportunities for economic actors. (iii) A harmonised set of accessibility indicators implemented in different regional case studies allows a unique Europe-wide comparison of local and regional conditions of daily life in very different types of European regions.

There are two basic groups of regional accessibility indicators. In the first group accessibility for travel and freight to destinations of regional importance are calculated for the whole ESPON space and the Western Balkan. The indicators of the second group have been calculated in the seven TRACC case studies only.

The regional accessibility travel indicators calculated for the whole of Europe cover again all three generic types of accessibility indicators:

- *Access to high-level transport infrastructure*. What is the access time to reach the nearest entrance nodes of higher-level transport infrastructure? Access time to the nearest transport nodes (motorway exits, main rail stations and airport) is calculated for raster cells for road and rail. Access times are aggregated by including the relative importance and utility of the different networks for the regional population (so called ICON approach, see Vol. 4, Chapter 4.1). Aggregation from raster cells to NUTS-3 allows comparison with other accessibility indicators.
- *Availability of urban functions*. What amount of urban functions can be reached in reasonable travel time? By looking at road and rail transport, it is assessed which cities with more than 50,000 inhabitants can be reached within a travel time of 60 minutes maximum. Calculation are for raster cells and are aggregated to NUTS-3 regions.
- *National potential accessibility travel.* What is the relative competitive position of regions towards national destinations? This indicator is similar to the potential accessibility at the European level. For each NUTS-3 region the population in destination regions are weighted by the travel time to go there. and the weighted population is summed up to give the value of the accessibility potential for the origin region. However, the destinations are restricted to regions in the same country as the origin region. That means that in practice national accessibility calculations is done separately for each country of the ESPON space and the Western Balkan. The potential accessibility indicator is calculated for road and rail.

The regional accessibility indicators for freight transport calculated Europe-wide follow a similar logic as those for travel:

- *Access to freight terminals*. What is the access time to reach the nearest freight terminals? Access time to nearest transport nodes (cargo transport centres, seaports, inland ports, airports with cargo handling) is calculated for raster cells for road and rail. Access times are aggregated by including the relative importance and utility of the different networks for the regional economic actors (so called ICON approach, see Vol. 4, Chapter 4.4). Aggregation from raster cells to NUTS-3 allows comparison with other accessibility indicators.
- *Availability of freight terminals*. What amount of options do regions have with respect to freight logistic centres? By looking at road transport, it is assessed which number of freight terminals can be reached within a lorry travel time of two hours maximum. The indicators are for raster cells and then aggregated to NUTS-3 regions.
- *National potential accessibility freight.* What is the relative competitive position of regions towards national destinations with respect to freight transport? This indicator is similar to the potential accessibility for freight at the European level. For each NUTS-3 region the GDP in desti-

nation regions is weighted by the generalised travel time to go there and the weighted GDP is summed up to give the value of the accessibility potential for the origin region. However, the destinations are restricted to regions in the same country as the origin region. That means that in practice national accessibility calculations for freight is done separately for each country of the ESPON space and the Western Balkan. The potential accessibility indicator is calculated for road and rail.

In the regional case studies, the first set of indicators follows the traditional set of accessibility indicators calculated at the European level. All indicators have been calculated for municipalities, i.e. at the LAU-2 level. However, in same case studies the calculation has been done first for smaller raster cells and has then been aggregated to LAU-2:

- *Access to regional centres*. How distant or how far is the nearest regional centre? Proximity to an urban centre has often been used as a proxy for accessibility to jobs and different services such as higher education, health care, commerce etc. For each municipality or raster cell of the case study region, the minimum travel times by road and public transport to the nearest urban centre are calculated.
- *Daily accessibility of jobs*. How many jobs can I reach from my place of residence? This indicator approaches the opportunities of the regional labour market from the point of view of the population. For each municipality or raster cell the amount of jobs reachable within a maximum commuting distance of 60 minutes by car and by public transport is estimated.
- *Regional potential accessibility.* What is the regional population potential of a municipality? In order to evaluate the different locations within a region from the viewpoint of economic actors, e.g. firms assessing the regional labour market, or retail industries assessing the market area, the population potential of each municipality or raster cell within the case study region is calculated. As for the other spatial levels the population potential is calculated as the sum of people in destination areas weighted by the travel times to go there. Modes considered are road and public transport.

The second set of indicators of the regional case studies is also for travel and considers destinations of specific relevance for daily life, i.e. services of general interest:

- *Access to health care facilities*. What is my travel time to go to the nearest hospital? Travel times for each municipality or raster cells by road and by public transport show the spatial diversity in access to important health care facilities.
- *Availability of higher secondary schools*. Do I have access to higher secondary schools in reasonable travel time and do I have a freedom of choice to select between different options? For each municipality or raster cells travel time contours of 30 minutes travel time by road and by public transport are calculated, and it is checked how many higher secondary schools are reachable within this travel time.
- *Potential accessibility to basic health care.* What is my locational quality with respect to basic health care? Using general practice surgeries as destination activity in a potential accessibility indicator allows to assess the relative distribution of health care provision of different areas within the case study region. For each municipality or raster cell, the potential value is calculated as sum of general practice surgeries located in the case study region weighted by travel times by road and public transport.

In Table 5.2 a synopsis of the TRACC set of accessibility indicators is given with respect to the main dimensions of accessibility (see Table 3.1). The accessibility indicators are classified according to the origins, the destinations, the type of impedance and the form of the impedance function and the transport modes.

Table 5.2. Main dimensions of TRACC set of accessibility indicators

Spatial context	***Basic characteristics***	***Generic type of accessibility indicator***		
		Travel cost IF linear	***Cumulated opportunities*** IF rectangular	***Potential*** IF non-linear
Global	***Travel***	***Access to global cities*** O NUTS-3 regions D New York I Travel time M Intermodal	***Global travel connectivity*** O NUTS-3 regions D Flights from European airports to intercontinental destinations I Travel time within 3 hours M Intermodal	***Global potential accessibility travel*** O NUTS-3 regions D Flights from European airports to intercontinental destinations (weighted by seat capacity) I Travel time M Intermodal
	Freight	***Access to global freight hubs*** O NUTS-3 regions D New York, Shanghai I Travel time/cost M Several modes	***Global freight connectivity*** O NUTS-3 regions D Intercontinental container throughput of European seaports I Travel time M Several modes	***Global potential accessibility freight*** O NUTS-3 regions D Container throughput of European seaports I Generalised time M Several modes
Europe	***Travel (traditional)***	***Access to top ten MEGAs*** O NUTS-3 regions D Top ten MEGAs I Travel time (average) M Fastest of road, rail, air	***European daily accessibility travel*** O NUTS-3 regions D Population of NUTS-3 regions I Travel time within 5 h M Road, rail, fastest	***European potential accessibility travel*** O NUTS-3 regions D Population of NUTS-3 regions I Travel time M Several modes
	Travel (new)	***Travel speed*** O NUTS-3 regions D NUTS-3 regions weighted by transport demand of origins I Travel time M Road, rail	***Urban connectivity*** O Cities > 50.000 D Cities > 50.000 I Travel time within 3 or 5 h M Several modes	***European potential acc. intermodal travel*** O NUTS-3 regions D Population of NUTS_3 regions I Travel time M Intermodal
	Freight	***Access to nearest maritime ports*** O NUTS-3 regions D Nearest three maritime ports I Generalised cost M Several modes	***European daily accessibility freight*** O NUTS-3 regions D GDP of NUTS-3 regions I Travel time (maximum allowed for lorry drivers) M Road	***European potential accessibility freight*** O NUTS-3 regions D GDP of NUTS-3 regions I Generalised time M Several modes

O Origins D Destinations I Impedance IF Impedance function M Modes

Table 5.2. Main dimensions of TRACC set of accessibility indicators (continued)

Spatial context	Basic characteristics	Generic type of accessibility indicator		
		Travel cost IF linear	***Cumulated opportunities*** IF rectangular	***Potential*** IF non-linear
Regional	***Travel (Europe-wide)***	***Access to high-level transport infrastructure*** O NUTS-3 regions / raster cells D Motorway exits, rail stations, airports I Weighted travel time M Road, rail	***Availability of urban functions*** O NUTS-3 regions / raster cells D Cities > 50.000 I Travel time within 60 minutes M Road, rail	***National potential accessibility travel*** O NUTS-3 regions D Population of NUTS-3 regions of origin country I Travel time M Road, rail
	Freight (Europe-wide)	***Access to freight terminals*** O NUTS-3 regions / raster cells D Freight terminals I Weighted travel time M Road, rail	***Availability of freight terminals*** O NUTS-3 regions / raster cells D Freight terminals I Travel time within 2 h M Road	***National potential accessibility freight*** O NUTS-3 regions D GDP of NUTS-3 regions of origin country I Generalised costs M Road
	Travel (case studies, traditional)	***Access to regional centres*** O LAU-2 regions / raster cells D Regional centre (next) I Travel time M Road, public transport	***Daily accessibility of jobs*** O LAU-2 regions / raster cells D Jobs of LAU-2 I Travel time within 60 minutes M Road, public transport	***Regional potential accessibility*** O LAU-2 regions / raster cells D Population of LAU-2 I Travel time M Road, public transport
	Travel (case studies, to services of general interest)	***Access to health care facilities*** O LAU-2 regions / raster cells D Hospital (nearest) at LAU-2 or exact location I Travel time M Road, public transport	***Availability of higher secondary schools*** O LAU-2 regions / raster cells D Higher secondary schools at LAU-2 or exact location I Travel time within 30 minutes M Road, public transport	***Potential accessibility to basic health care*** O LAU-2 regions / raster cells D General practice surgeries at LAU-2 or exact location I Travel time M Road, public transport

O Origins D Destinations I Impedance IF Impedance function M Modes

There are two different spatial reference systems for which accessibility indicators is calculated. All global and all European accessibility indicators as well as Europe-wide regional travel and freight indicators are calculated for NUTS-3 regions or partly for raster cells of the ESPON space and the Western Balkan. Turkey is not included as internal zone in the accessibility models nor in the SASI model because this would raise some fundamental methodological and data issues.: If Turkey would be an internal zone, countries in the Caucasus, countries in the Arab world (Near East and Middle East), and also Russian regions in central Asia would have to become 'external zones', as they have direct boundaries with Turkey or because important transport routes are directly linked to Turkey. In consequence, this would require to include these countries as external zones into the models, and to collect all required network and socio-economic data for them as well. As this is not feasible in the TRACC framework the Turkish regions are included as external zones only with higher spatial detail than done so far.

It has to be noted that the destinations in the accessibility models are not confined to the ESPON space and the Western Balkan. In particular for the indicators of the type cumulated opportunities and potential it is important to include destinations in Eastern Europe and North Africa to avoid edge effects. The second spatial reference system is that of the case study region for which the last two groups of accessibility indicators are calculated.

The results of the different accessibility indicators are presented in map form and analysed with respect to their spatial pattern. In addition, a post-processing of the indicators is done to compare different accessibility indicators with each other. This includes a comparative analysis of European and regional accessibility. In addition, the aggregation of indicators to relate it to the ESPON regional typologies, and the provision of indices for territorial cohesion with respect to accessibility has been done

The TRACC set of accessibility indicators yields a major innovation compared to other accessibility studies, because it addresses different aspects of accessibility of municipalities and regions in Europe in a systematic way, something that has not been done by any previous accessibility study. Each place in Europe can be classified according to different accessibility aspects ranging from its relative location in the global competition or within Europe down to the daily accessibility requirements of the local population.

5.2 Accessibility impact indicators

As indicated in Section 4.4, the relevant impacts of accessibility at the European or national level are *economic* and *environmental* impacts. At the intraregional level, the most important impacts are *social* impacts.

The indicators of *economic* impacts of accessibility have been produced by the SASI model: impacts on regional economic development expressed as gross domestic product (GDP) per capita and impacts on territorial cohesion expressed by several cohesion indicators. Cohesion indicators are either relative or absolute. Relative cohesion indicators measure relative convergence or divergence in terms of percent of GDP per capita. Absolute cohesion indicators measure absolute convergence or divergence in terms of GDP per capita in Euro. The difference between relative and absolute cohesion is important because relative convergence can be associated with absolute divergence. For instance, regions in the new EU member states may benefit from a certain transport infrastructure investment more than regions in the old member states in relative terms (in percent), but in absolute terms (in Euro) the regions in the old member states may benefit more. Relative cohesion indicators are the Gini coefficient, the coefficient of variation and the correlation between GDP per capita and the relative change in GDP per capita. Absolute cohesion indicators are the correlation between GDP per capita and the absolute change in GDP per capita.

Social impacts of accessibility, i.e. effects on social inclusion or exclusion by differences in access to services of general interest, are measured by a number of accessibility indicators, such as travel time to the nearest urban centre, travel time to education facilities and travel time to health services.

Environmental impacts of accessibility are measured as energy consumption and greenhouse gas emissions by transport calculated with a travel and goods transport model attached to the SASI model.

6 Accessibility to global destinations

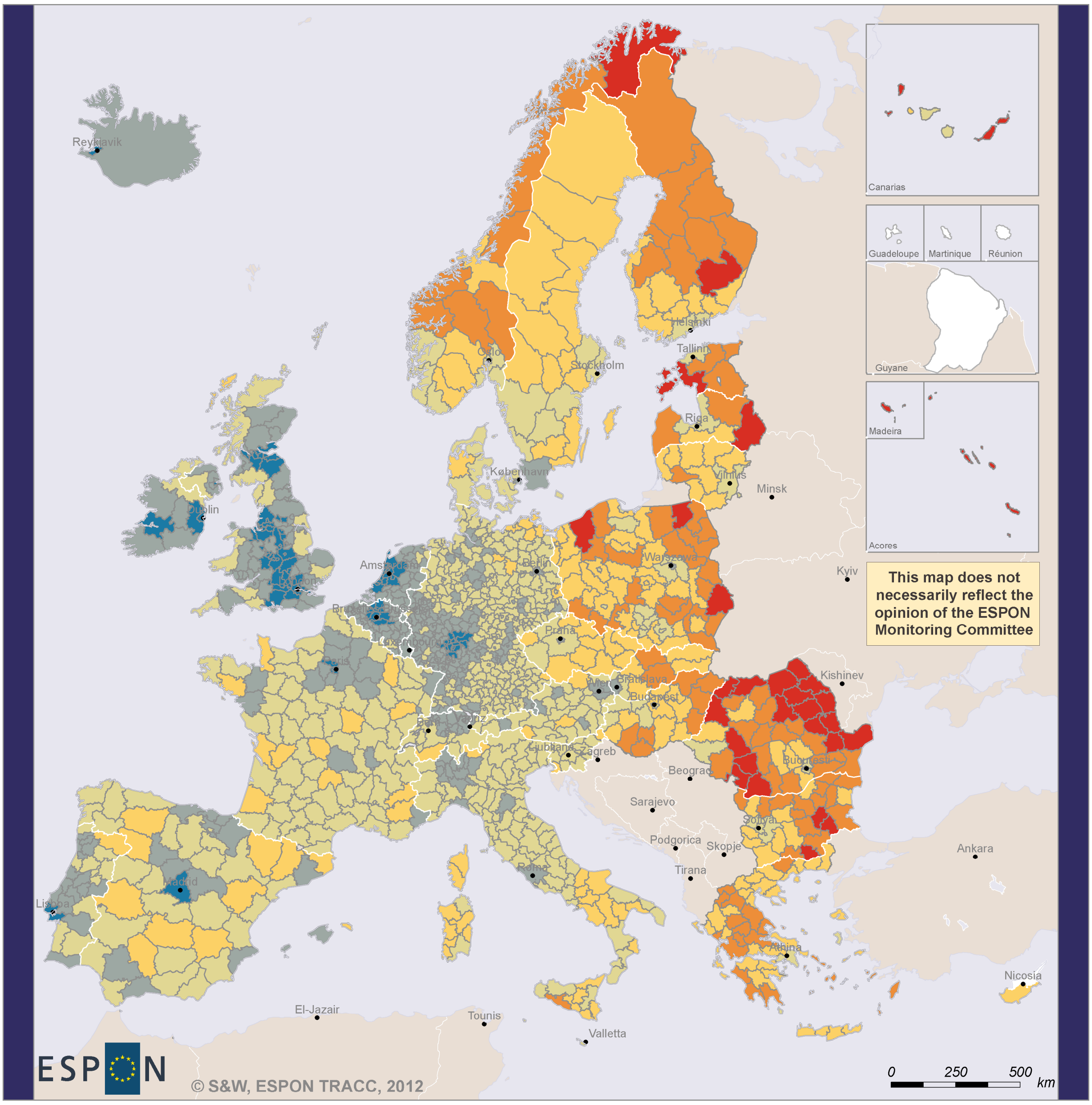
What are the linkages of European regions to the world? How are the regions embedded in the global economy seen from an accessibility point of view? What are their linkages to global hotspots outside Europe or to European gateways to the world, what is their necessary transport efforts to such destinations? To address such questions, TRACC has developed a set of global accessibility indicators that go beyond the few examples in the literature that usually provide restricted travel time indicators from airports only. The TRACC set of global accessibility indicators provides progress as it includes also freight accessibility, indicators of the types cumulated opportunity and potential and as the indicators are not restricted to preselected rare points in Europe, but are calculated for all NUTS-3 regions of the ESPON space.

6.1 Global travel accessibility

A first approach to consider the global integration of European regions is to analyse the total travel effort people have to take into account when travelling to global destinations. As an illustrative example for that TRACC has calculated travel times from the European regions to selected global cities. Figure 6.1 presents the travel time from Europe to New York which serves as one proxy for such global hotspots. For each NUTS-3 region the shortest total travel time to New York City (Downtown Manhattan) was calculated. The travel time reflects intermodal trips from the centres of the regions. It is based on road, rail and/or air travel times to airports in Europe with intercontinental flights plus the flight time from there to New York, plus the travel time from one of the city's airports to Manhattan and includes necessary terminal times as well.

The travel times to New York differ very much across European regions (Figure 6.1). There are regions in Europe from which the total travel time is clearly below 15 hours. Not surprisingly, these regions are located in western parts of Europe with close access to airports with intercontinental flights. Countries in which most of the regions belong to this favourable group are the UK, Ireland, Iceland, Portugal and the Benelux. In addition, there are larger areas around Paris, Frankfurt, Madrid; Milano and Zürich and some smaller areas in Spain or France benefitting from relatively low travel times which can also be experienced when travelling from Copenhagen, Vienna or Rome. However, travel times clearly increase up to 18 hours in other regions of western Europe that have a longer access to intercontinental flight services; similar travel times have to be expected when travelling from capital city regions in eastern or northern Europe. Longest travel times exist from non-metropolitan regions in northern and eastern Europe; for few regions it might take almost a full day to travel to New York.

This very unbalanced pattern of global accessibility is also reflected in the two other types of indicators. Figure 6.2 represents a different notion of global accessibility. The interest here is not related to a single destination such as New York, but to all global destinations. Being of the accessibility indicator type of cumulative opportunities, the indicator sums up the number of global destinations to which a departure flight can be reached within a maximum travel time of five hours. So, if departure flights from an airport are within the maximum travel time, the intercontinental destinations served from that airport will be added to the regional global connectivity value. Figure 6.2 shows a very strict differentiation of European regions with areas of high global connectivity in the UK, the Benelux, parts of Germany, France and Northern Italy. However, highest global connectivity can be found in south-western Europe, namely in Barcelona, Madrid and Lisbon. Those regions benefit on the one hand from serving several global destinations on their own and from having good access times to other European intercontinental hubs. In northern and eastern Europe only the capital regions have higher global connectivity all other regions are clearly much behind. Figure 6.3 which represents a potential type indicator using the annual seat capacity of intercontinental flights of airports as proxy for the opportunities provided by global destinations shows similar disparities of the global integration of European regions.



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Regional level: NUTS-3
Source: RRG GIS Database
S&W Flight Network
Origin of data: S&W Accessibility model, 2012
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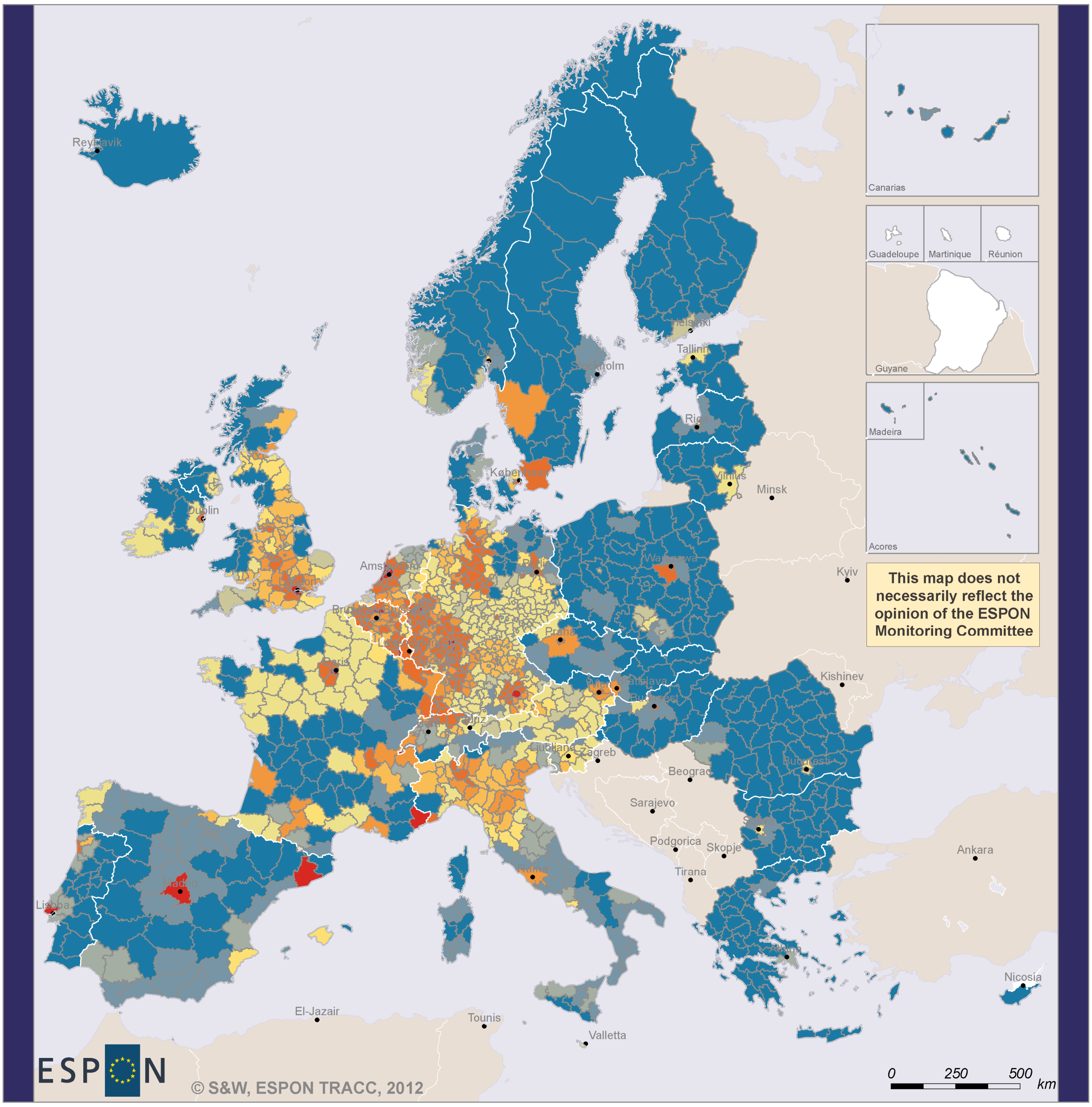
Travel Time to New York, intermodal (minutes)

- 702 - 800
- 801 - 900
- 901 - 1000
- 1001 - 1100
- 1101 - 1200
- 1201 - 3256
- no data

Figure 6.1: Accessibility to global hubs: travel time to New York City



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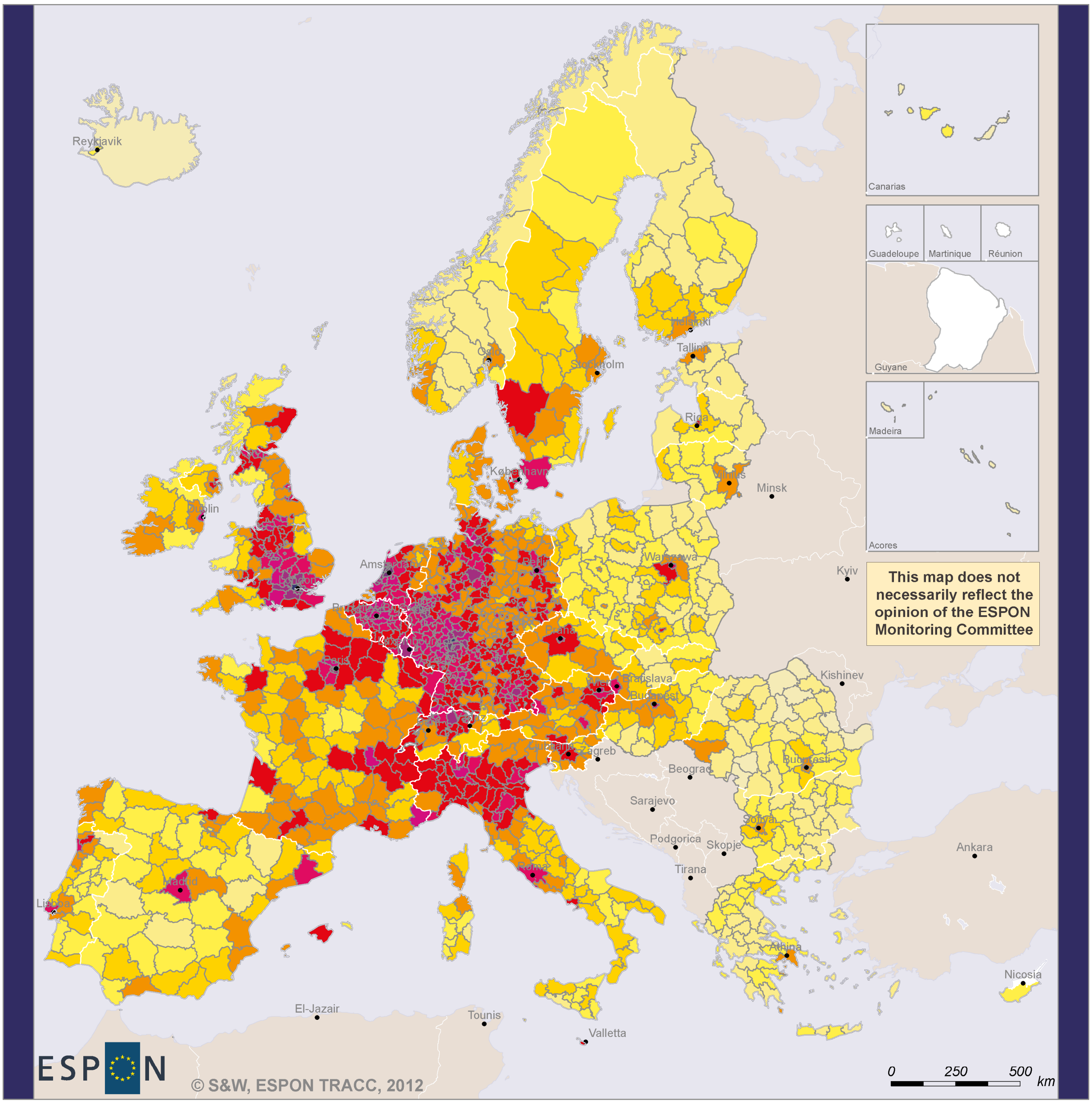
Number of intercontinental destinations to which flight departures are reachable within 5 hours travel time.

- 0 - 20
- 21 - 40
- 41 - 60
- 61 - 80
- 81 - 100
- 101 - 120
- 121 - 140
- 141 - 160
- 161 - 180
- 181 - 200
- no data

Figure 6.2: Number of intercontinental destinations to which flight departures are reachable within 5 hours travel time



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Regional level: NUTS-3
Source: RRG GIS Database
S&W Flight Network
Origin of data: S&W Accessibility model, 2012
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Global potential accessiblity (ESPON=100)

0 - 20	121 - 140
21 - 40	141 - 160
41 - 60	161 - 180
61 - 80	181 - 200
81 - 100	201 - 220
101 - 120	no data

Figure 6.3. Global potential accessibility

6.2 Global freight accessibility

Global freight accessibility is described by three different indicators making reference to different dimensions. It is considered how far representative intercontinental global hubs are (travel cost type accessibility) as well as how much intercontinental traffic can be reached in a relatively short time (cumulated opportunities type accessibility) and, finally, the potential accessibility to intercontinental traffic. In order to get a comprehensive picture of the level of global accessibility of European regions the contribution of all three indicators should be taken into account.

The accessibility to intercontinental global hubs is significantly affected by the geographical position of regions. In general, western European zones are more accessible to the New York hub, while the South-eastern European zones are more accessible to the Shanghai hub (compare Figures 6.5 and 6.6 below). However, in most of the cases, for an European forwarder, the accessibility to European intercontinental ports is more critical than the connection from the European port to the overseas port. In other words, the navigation time for deep sea shipping is usually far less important than the time and cost of the European leg of the shipment. For instance, despite reaching Shanghai is faster from Genoa than from Le Havre, for the Paris region the latter is a much more convenient port than the former.

That's why it is important to consider the accessibility to European intercontinental ports, described by the other two indicators. The picture these two indicators provide is somewhat difference as the relevance of the geographical position changes and the role of infrastructures rises, with particular reference to rail and water accessibility (Figures 6.7 and 6.8). As far as rail (and road) is concerned, a clear separation is visible between central western Europe and peripheral Europe in terms of global freight connectivity: peripheral regions are connected to a much lower amount of intercontinental container throughput. The geographical position matters as the most important intercontinental ports are in the North Sea, but also to the poorer inland infrastructures in some regions (e.g. the Balkan area or the extreme north of Norway) or the distribution of rail intermodal centres has an effect. Infrastructures – i.e. ports and inland waterways – are of course of particular relevance for water accessibility. From this point of view it should be considered that the picture of accessibility shown in the maps can change if some ports are subject of large improvements which attract new traffic (as the case of Gdansk, for instance, where the opening of direct services with China has increased the port throughput at the extent that is might become one of the major intercontinental hub ports in Europe). Another significant change might occur if future melting of North Pole ice because of global warming makes the Northern Sea route an available alternative towards East.

Figure 6.4 shows how the different countries perform in terms of global accessibility. For each indicator, the height of the bar is proportional to the share of NUTS-3 zones in the country with a value above the European average. Looking at this overall picture a clear indication is that the central western European area – Benelux, Germany, France and UK – has a level of global accessibility much larger than the average. This is explained most of all by maritime-related accessibility (the role of air is minor in freight trade and actually most of the indicators concerns accessibility to or from ports). North Sea ports are the most attractive destinations and are generally quite conveniently accessible given their central position (of course that the biggest ports are also central is probably not a mere combination). The pattern is particularly clear for road accessibility as road infrastructures are more evenly distributed than terminals, intermodal centres, ports, etc. Rail accessibility shows some discontinuity because of the location of intermodal centres while water accessibility is conditioned by availability of ports and inland waterways. In any case the advantage of the central-European area is anyway clear. Northern Europe is instead clearly disadvantaged whereas Southern Europe is in an intermediate position.

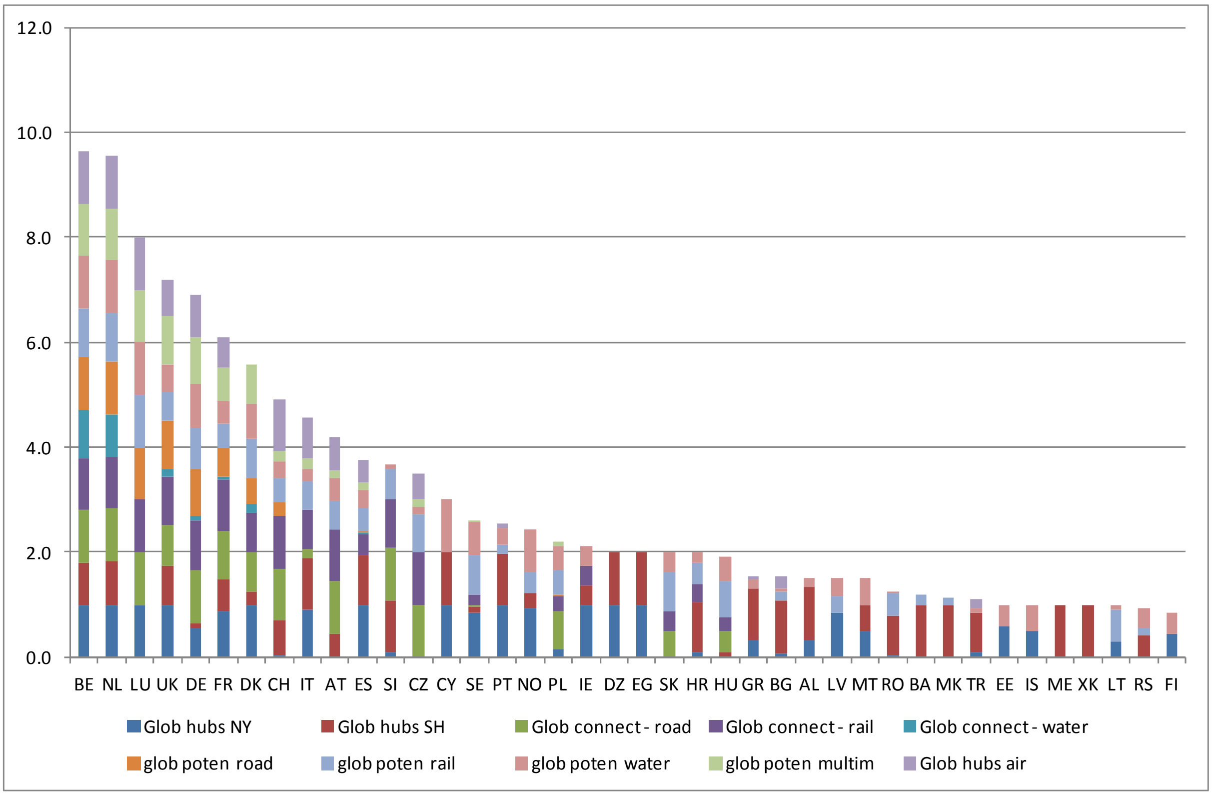
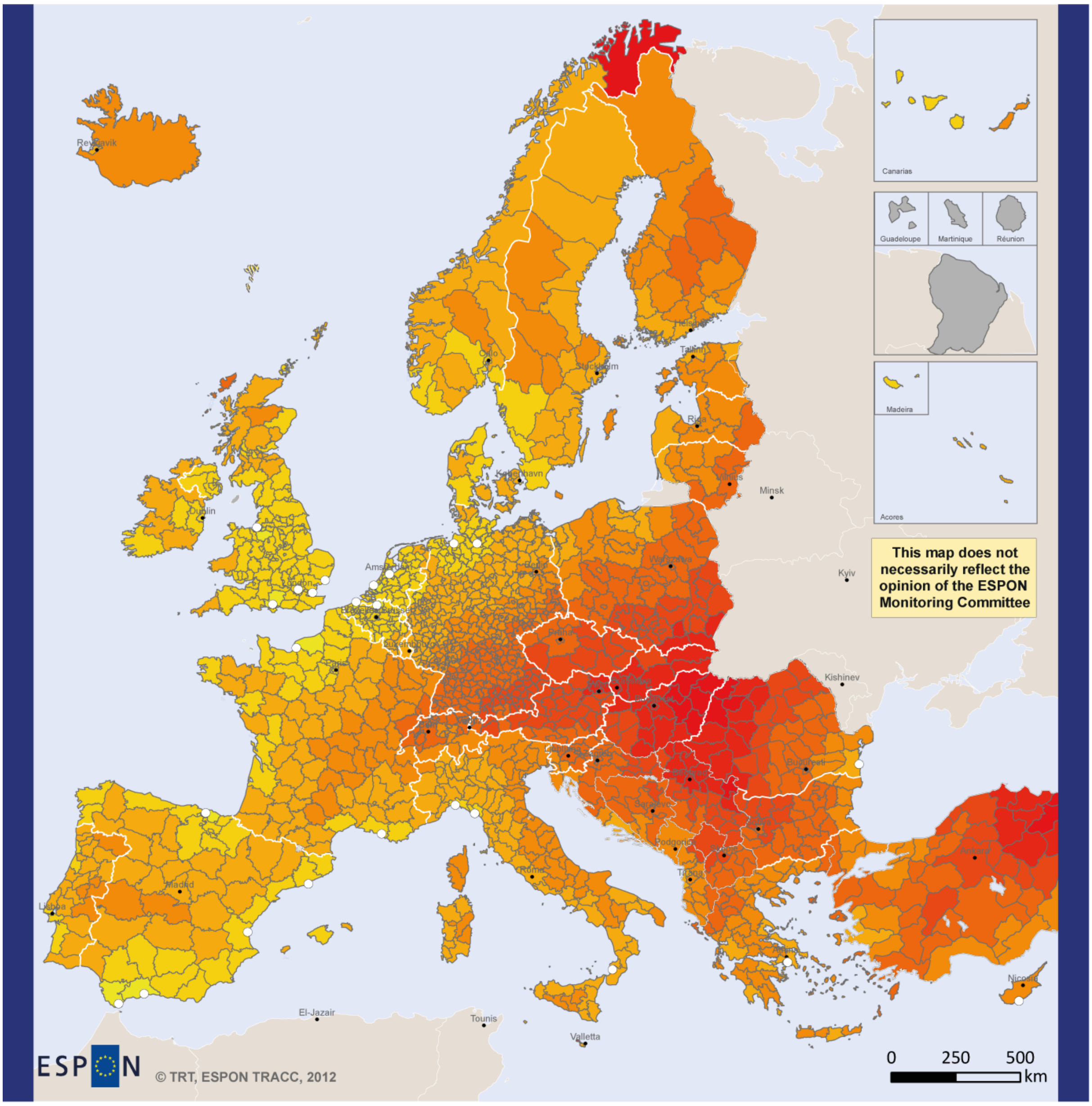


Figure 6.4. Performance of countries on global accessibility

The analysis of global accessibility of different parts of Europe crosses with the considerations on global accessibility by different transport modes. Modes should not be considered as pure competitors. In some terms they are at least partially complementary. Water (especially maritime) is a convenient transport alternative especially for larger volumes of freight on longer distances. Its role in the logistic chain is closer to the production than to the consumption end. Conversely, road transport is more efficient for small or even individual shipment and to reach the final distribution. Rail is in an intermediate position. Therefore different levels of accessibility depending on the transport mode considered can also suggest that different functions can be located in one region. For instance, southern Europe, which is better ranked in terms of global accessibility by water, performs better as European transhipment platform to handle large volumes to and from overseas. At the same time, despite maritime transport is dominant for the freight transport between Europe and Asia, land routes (mainly by rail but also by truck) exist and might develop in the future (ECMT, 2006). Considering inland connections, the global accessibility of eastern European regions would be higher.

In summary, there are differences in terms of global freight accessibility between European regions which partly depend on their geographical position and part on availability of infrastructures. However these two aspects are not independent. While it is difficult to conceive that Scandinavian countries or Finland can fully remove the gap of accessibility due to their position, the advantage of the North sea area is the result of the location of European major ports which however are not there only by chance but also because they can benefit of the geographical centrality. Nevertheless, the progressive rise of Far East as trade partner opens to Mediterranean regions the perspective of exploiting a position advantage. In this respect, efficient multimodal infrastructures (ports, transhipment facilities, intermodal centres, roads, railways) might increase the global accessibility of Southern Europe regions thus reducing the current differences with respect to the North Sea area.



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Source: TRUST Accessibility Model (TRT 2012), Maritime Network: TRUST Model, Road/Rail Network: TransTools (2005), IWW network: RRG GIS Database, Intercontinental container throughput of ports (Eurostat data 2007-2009) © EuroGeographics Association for administrative boundaries

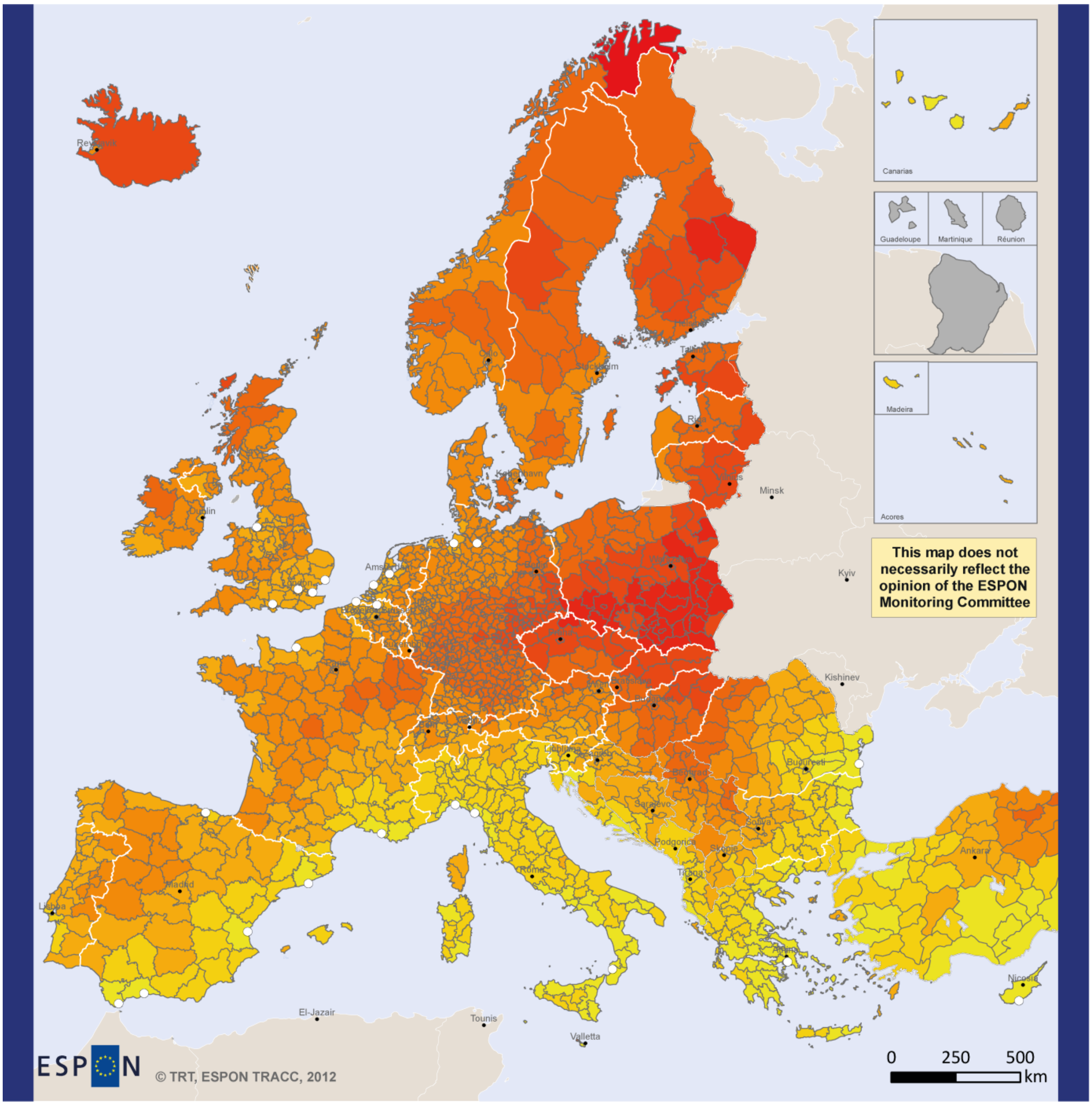
Access to global freight hubs (2011):
Sea Maritime generalized cost (€/ton) to major intercontinental terminals (New York)

- 1 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- 451 - 500
- 501 - 550
- 551 - 600
- 601 < ...
- n.a.

• *Capital cities*

○ *Intercontinental Container Seaport (>250000 TEU/year)*

Figure 6.5. Maritime access to global hubs freight – New York hub



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Source: TRUST Accessibility Model (TRT 2012), Maritime Network: TRUST Model, Road/Rail Network: TransTools (2005), IWW network: RRG GIS Database, Intercontinental container throughput of ports (Eurostat data 2007-2009)
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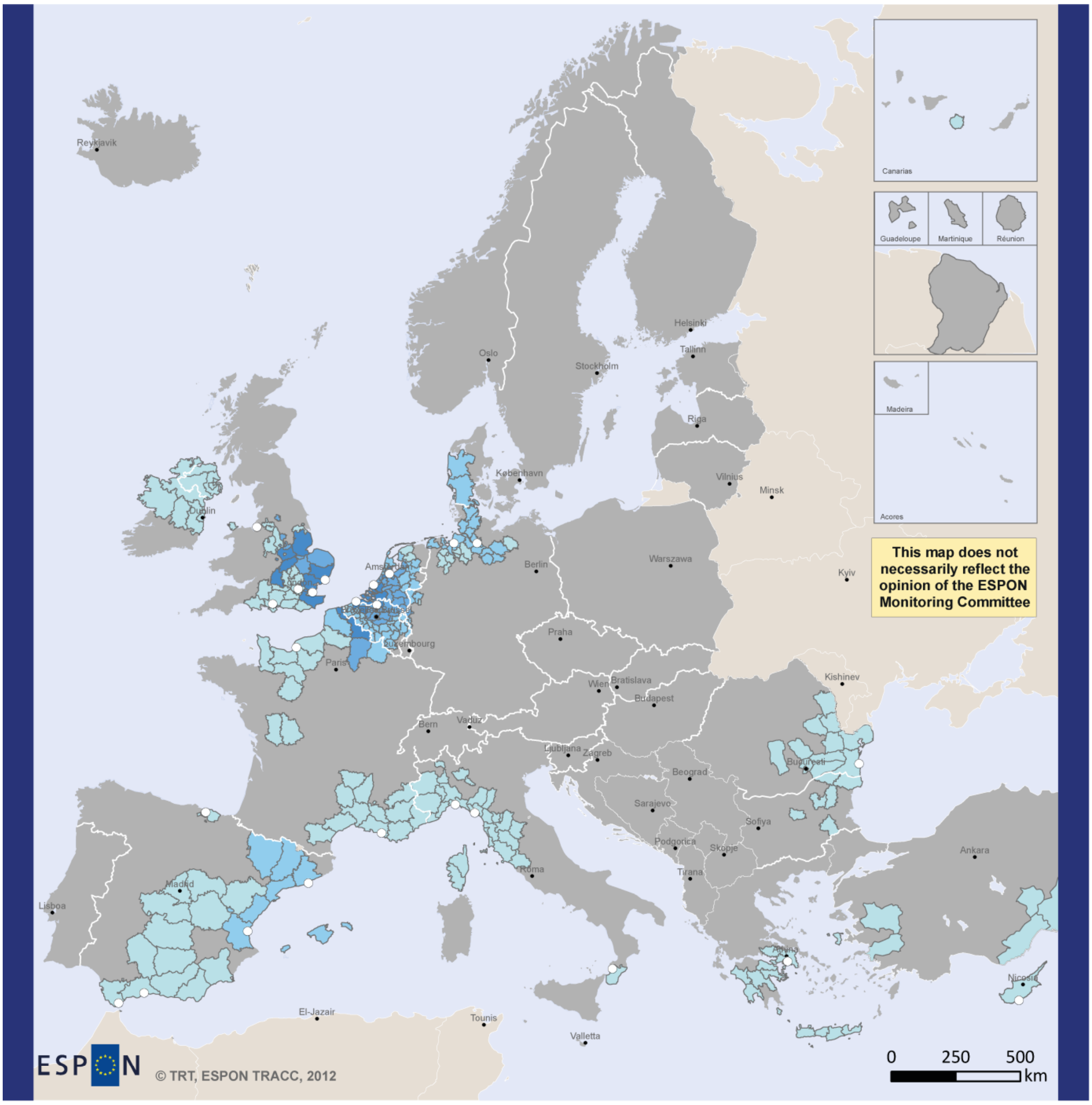
Access to global freight hubs (2011):
Sea Maritime generalized cost (€/ton) to major intercontinental terminals (Shanghai)

- 1 - 600
- 601 - 650
- 651 - 700
- 701 - 750
- 751 - 800
- 801 - 850
- 851 - 900
- 901 < ...
- n.a.

- • *Capital cities*
- ○ *Intercontinental Container Seaport (>250000 TEU/year)*

Figure 6.6. Maritime access to global hubs freight – Shanghai hub



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Source: TRUST Accessibility Model (TRT 2012), Maritime Network: TRUST Model, Road/Rail Network: TransTools (2005), IWW Network: RRG GIS Database, Intercontinental container throughput of ports (Eurostat data 2007-2009)
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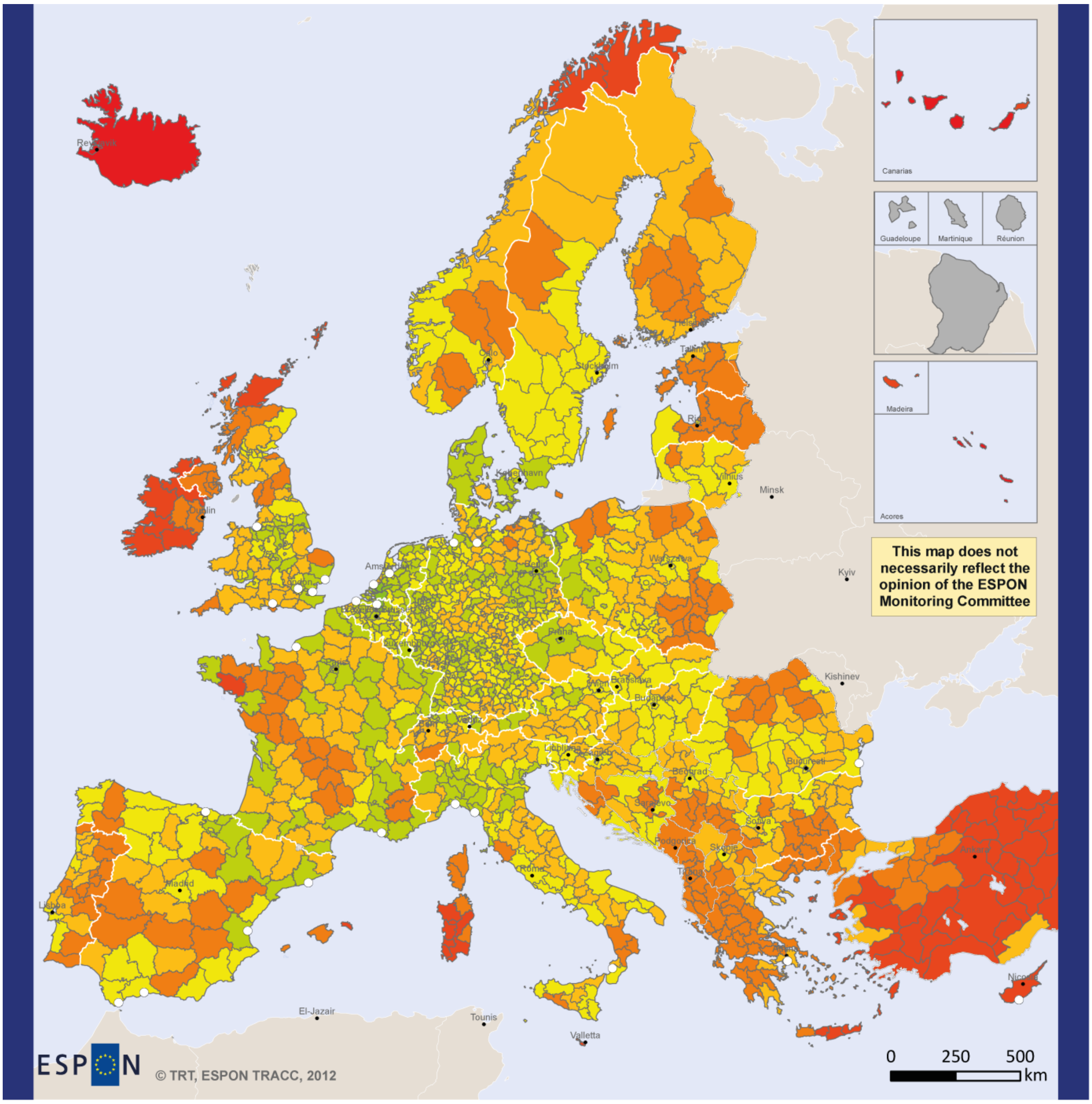
Global freight connectivity (2011):
Intercontinental container throughput (Ths. TEU) of European sea ports reachable within 72h Sea Shipping/Inland Waterway travel time (3 days)

- 0 - 4 000
- 4 001 - 10 000
- 10 001 - 15 000
- 15 001 - 20 000
- 20 001 - 25 000
- 25 001 - 30 000
- 30 001 - 35 000
- 35 001 < ...
- n.a.

- • *Capital cities*
- ○ *Intercontinental Container Seaport (>250000 TEU/year)*

Figure 6.7. Global freight connectivity – water



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Source: TRUST Accessibility Model (TRT 2012), Road/Rail Network: TransTools (2005), Intercontinental container throughput of ports (Eurostat data 2007-2009)
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Global potential accessibility freight (2011):
by rail to intercontinental container throughput of European sea ports
(percentage of average accessibility by rail of all areas)

0 - 25.0	• *Capital cities*
25.1 - 50.0	○ *Intercontinental Container Seaport (>250000 TEU/year)*
50.1 - 75.0	
75.1 - 100.0	
100.1 - 125.0	
125.1 - 150.0	
150.1 - 175.0	
175.1 - 200.0	
200.1 < ...	
n.a.	

Figure 6.8. Global potential accessibility freight – rail

7 Accessibility to European destinations

European accessibility indicators are expected to provide assessments of the attractivity and competitiveness of European regions in the European context based on their location and their integration in the transport networks. Compared to existing indicators, the TRACC set of European accessibility brings value-added as traditional accessibility indicators such as the accessibility potential have been updated to a current point in time, as additional new types of accessibility indicators and in particular of indicators addressing freight transport enable new insights into European accessibility conditions.

7.1 European travel accessibility

The first example for European travel accessibility reflects the access to the top level of European metropolitan areas, the MEGAs. For each NUTS-3 region the fastest travel time of road, rail and air transport to reach the top level of MEGAs has been calculated. The top level of MEGAs consist of 27 MEGAs as identified by the ESPON project 1.1.1 of the ESPON Programme 2006, namely Madrid, Barcelona, Paris, Geneva, Zürich, Torino, Milano, Roma, Wien, Athens, München, Stuttgart, Frankfurt, Köln, Düsseldorf, Hamburg, Berlin, Brüssel, Amsterdam, London, Manchester, Dublin, Kopenhagen, Oslo, Göteborg, Stockholm and Helsinki. Figure 7.1 displays the average travel time value for the European regions. In correspondence with the location of top MEGAs across Europe, lowest average travel time are in regions located in the highly urbanised belt stretching from the UK via Benelux, western Germany and Switzerland to Northern Italy. From here, travel time continuously increase towards the regions at the edge of the ESPON space. However, remarkable exceptions are regions around top MEGAs in those remote areas. The range of average travel time is from less than five hours to about twelve hours.

How many people can be reached from a region within a day's round trip or how many people can visit my region within a day's round trip. This indicator of the cumulative opportunities group of accessibility indicators sums up the number of persons in other European regions that can be reached within a one way travel time of five hours (door-to-door).Five hours maximum travel time is used to allow for at least five hours of activities at the destinations before returning back in the evening, i.e. a maximum travel time of 15 hours; therefore the indicator is labelled as daily accessibility. Figure 7.2 shows for intermodal trip chains that the range of daily accessibility values is between a few thousand persons reachable in rather remote areas and up to about 180 million people reachable from the best connected metropolitan areas in the UK, France, the Benelux countries, Germany and Switzerland.

The huge disparities in European accessibility are also visible in the potential type of accessibility indicator. Accessibility potential to population is presented for three modes of transport, road, rail and air, as well as the combined working of these modes as multimodal accessibility (Figures 7.3 to 7.6). The accessibility indicators are standardised to the ESPON average which is set to 100. By doing so, the potential accessibility indicators allow to identify regions that have different degrees of peripherality or centrality or are intermediate regions around the European accessibility average. Thus, the accessibility pattern presented in the four maps can also be considered as accessibility typologies of European regions.

Accessibility potential by road and rail show the traditional core-periphery pattern in Europe with highest accessibility in Belgium and neighbouring regions of Germany. Because high-level road infrastructure serves all regions there, highest accessibility forms a plateau. High-speed rail serves hubs and corridors, so, highest accessibility is visible along major corridors. In addition, high-speed rail is able to extent the areas of high accessibility to the outside. This is in particular visible in France with the corridors of high accessibility towards the Atlantic and the Mediterranean Sea. For both transport modes, accessibility goes gradually down when coming to regions more apart from those high-accessibility areas.

Accessibility potential by air shows a distinct picture. The major airport regions and their close surroundings have highest accessibility. This is also true in countries that have lower accessibility for other modes. Disparities in accessibility are now visible between but also within countries. Multimodal accessibility as a combination of the three modal accessibilities shows a somewhat intermediate spatial pattern. It can be seen that regions that are not served by good air connection might be compensated by other good transport links for road and in particular rail. However, this is true for regions in France, Germany etc., but not for regions in Eastern Europe. In addition, accessibility potential based on intermodal trip chains for personal travel is presented in Figure 7.7.

The remaining part of this section on European travel accessibility is devoted to a somewhat different approach on analysing the opportunities or restrictions that transport infrastructure provide to city citizens? The more cities that can be reached from a city within five hours travel time, the greater the opportunities are for business activities, networking or for social interaction. Urban connectivity in the domestic domain (see Volume 4, Chapter 3.5) is highest for road and rail for the Benelux countries, Western Germany, Italy, England and for Northern France and for the relation Paris-Lyon. In the New EU Member States, only Hungary and parts of Poland yield high connectivity. The other East European countries, so as Scandinavia, Ireland and also Portugal show poorer levels of city connectivity, mostly due to on average much longer travel times. Adding domestic passenger flights changes the picture significantly. In particular connectivity of cities in the far North (mainly connecting the smaller cities with their capitals), in the UK (connecting Scottish cities and the islands with the cities in the south), in Spain, and in Portugal and Greece (adding connectivity between many far-distant cities and with the islands) increased drastically, leading altogether to a fairly good urban connectivity in Europe, where for most city-to-city relations the citizens can at least choose one of the modes to reach the destination in less than five hours.

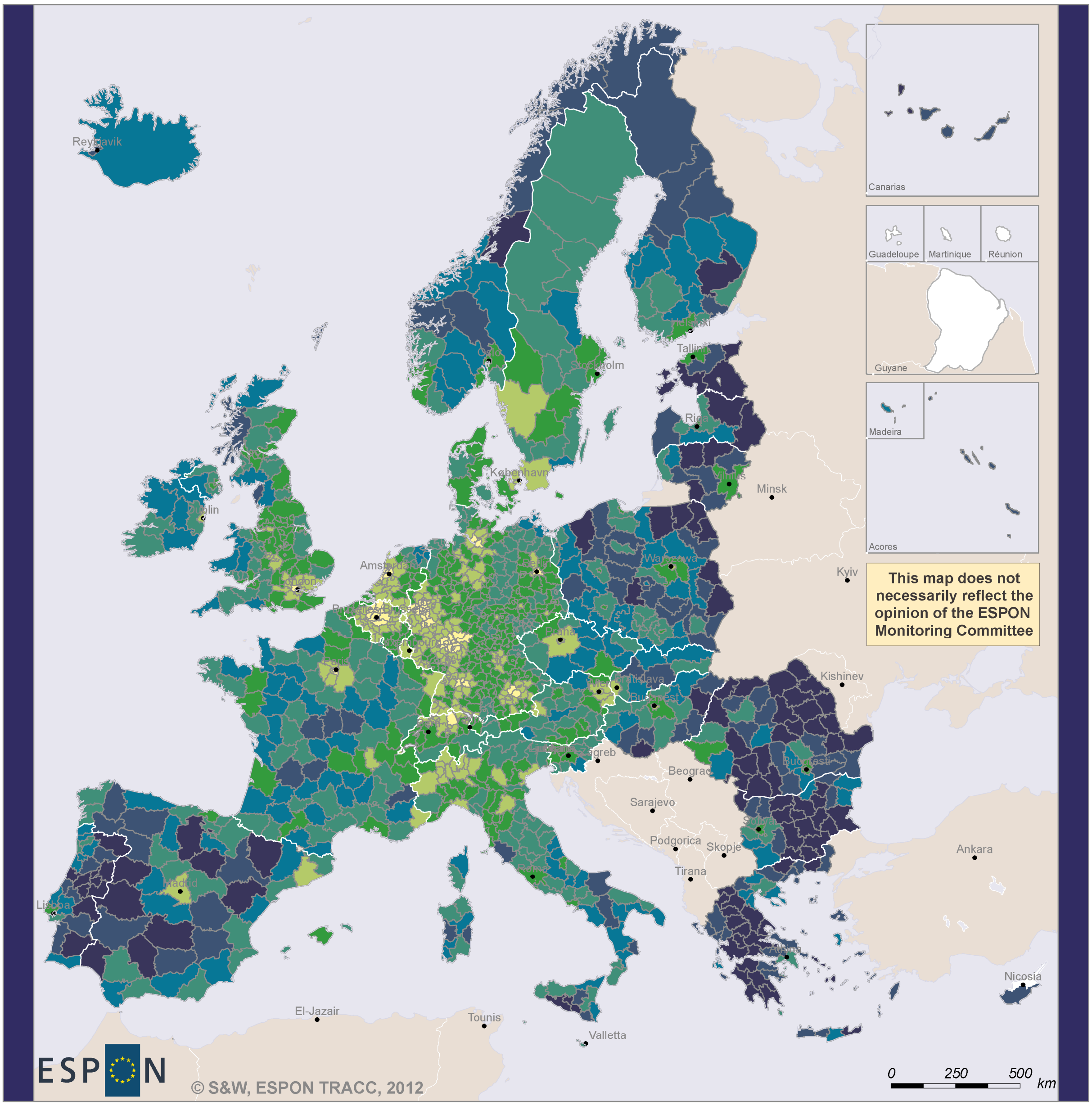
But also some negative evidences remain, even when looking at intermodal connectivity: Cities in the far North of Norway, Sweden and Finland only have air connectivity, and in most cases only to the capital. City-to-city relations to other cities than the capital from these origins are very scarce, limiting accessibility between the northernmost regions. Also, in many East European countries the urban connectivity is rather poor. Though many city-to-city relations lie within the five hours threshold, the travel time tend to be longer compared to Western Europe due to the relatively poor transport networks and the absence of high-level transport infrastructures. Thus, what would be a one-hour trip in the old EU Member States becomes a two or three hour or even longer trip in Bulgaria, Romania, or the countries of former Yugoslavia. Austria and Switzerland, on the other hand, having dense and high-quality transport networks, ensure high urban connectivity with rather low travel times, despite the difficult topographic situation in the Alps.

International urban connectivity for road and rail is mainly restricted to neighbouring countries: Relations within the Benelux countries and towards Northern France and Western Germany are those with highest accessibilities, so as relations between Portugal and Spain, Spain and France, France and Switzerland and Italy. For road (Figure 7.8), there are also many fast city-to-city relations along the former Iron Curtain between East Germany and Poland and the Czech Republic, between Austria and Slovakia and Hungary, as well as between Italy and Slovenia and Croatia. Interestingly, rail travel times for these latter connections are much longer compared to road illustrating the poorer cross-border rail connections in these areas. High-speed train services in turn also offer cities in great distance to national borders accessibility to other agglomerations within 300 minutes. For instance, cities in southern Italy are connected to cities in Southern France or in Slovenia, cities in the Brittany are connected through fast trains with cities in Belgium and Germany, and many Danish cities can for instance reach Stockholm, Gothenburg or even Oslo by fast train services. The Channel tunnel also connects many English cities by train to Benelux and to Northern France, including Brussels and Paris.

Passenger flights add another dimension of urban connectivity on top of fast train services. Within five hours, the majority of European cities can be reached with each other, ensuring connectivity of peripheral and outermost regions such as Northern Scandinavia and Iceland, Cyprus and Malta, Portuguese, Spanish and Greek islands, and cities in East Europe. Consequently, the intermodal international urban connectivity (Figure 7.9) is dominated by passenger flights and high-speed train services. Road mode is fastest in short-distance cross-border traffic, while fast train services ensure connectivity in medium ranges.

Even though the intermodal urban connectivity looks quite promising in general, in detail there are still some interesting observations:

- Even though many East European cities can be reached quite well from Western Europe, connectivity between cities in the East is significantly lower. The number of city-to-city relations below 300 minute threshold within Eastern Europe is much lower compared to Western Europe, and if they exist travel times are on average much longer.
- Similarly, international urban connectivity between the Nordic countries is poor. Cities in the northernmost territories are mainly well connected by flights to the capitals, but not between themselves.
- For all modes results clearly visualise the 'blue banana', i.e. the area in Europe with highest accessibilities ranging from London via Benelux and Paris, along the river Rhine valley towards Northern Italy. Clearly for road and rail, but even for passenger flights origin-destination relations within this part of Europe show by far shortest travel times. This of course is first of all due to the rather dense network of cities (and consequently the short geographical distances between them), but also the high-standard transport infrastructures in these areas contribute to these high connectivities.
- Despite recent efforts to overcome the Pyrenees barrier, the Iberian Peninsula is still suspended from rest of Europe. For road and rail only very few origin-destination relations are below five hours threshold, but even for passenger flights average travel times from Portugal or Spain to other countries are quite long.



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Regional level: NUTS-3
Source: RRG GIS Database
S&W Flight Network
Origin of data: S&W Accessibility model, 2012
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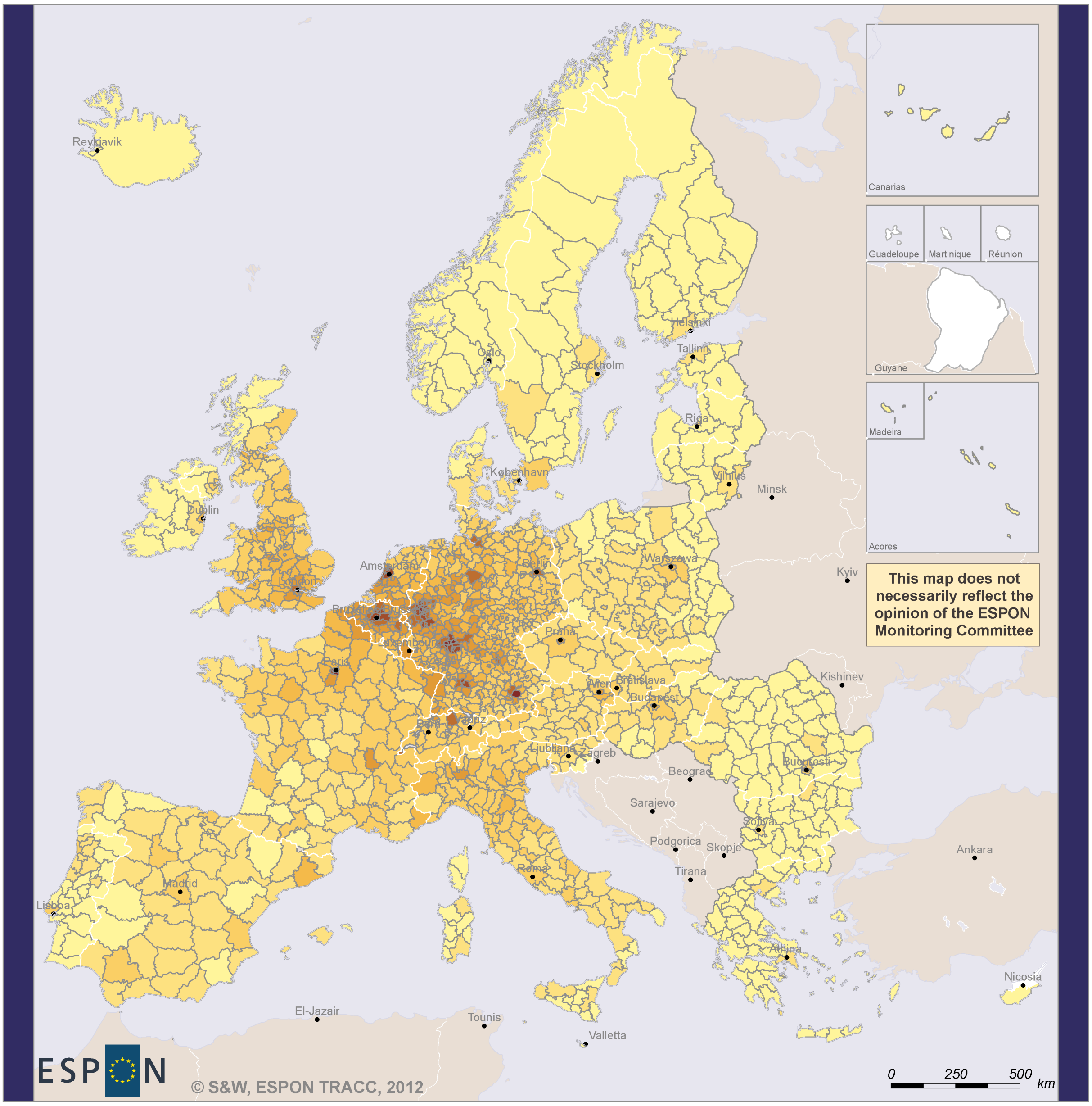
Average fastest travel time to top MEGAs

- **249 - 300**
- **301 - 360**
- **361 - 420**
- **421 - 480**
- **481 - 540**
- **541 - 600**
- **601 - 787**
- **no data**

Figure 7.1 Average travel time to reach top European MEGAs



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Regional level: NUTS-3
Source: RRG GIS Database
S&W Flight Network
Origin of data: S&W Accessibility model, 2012
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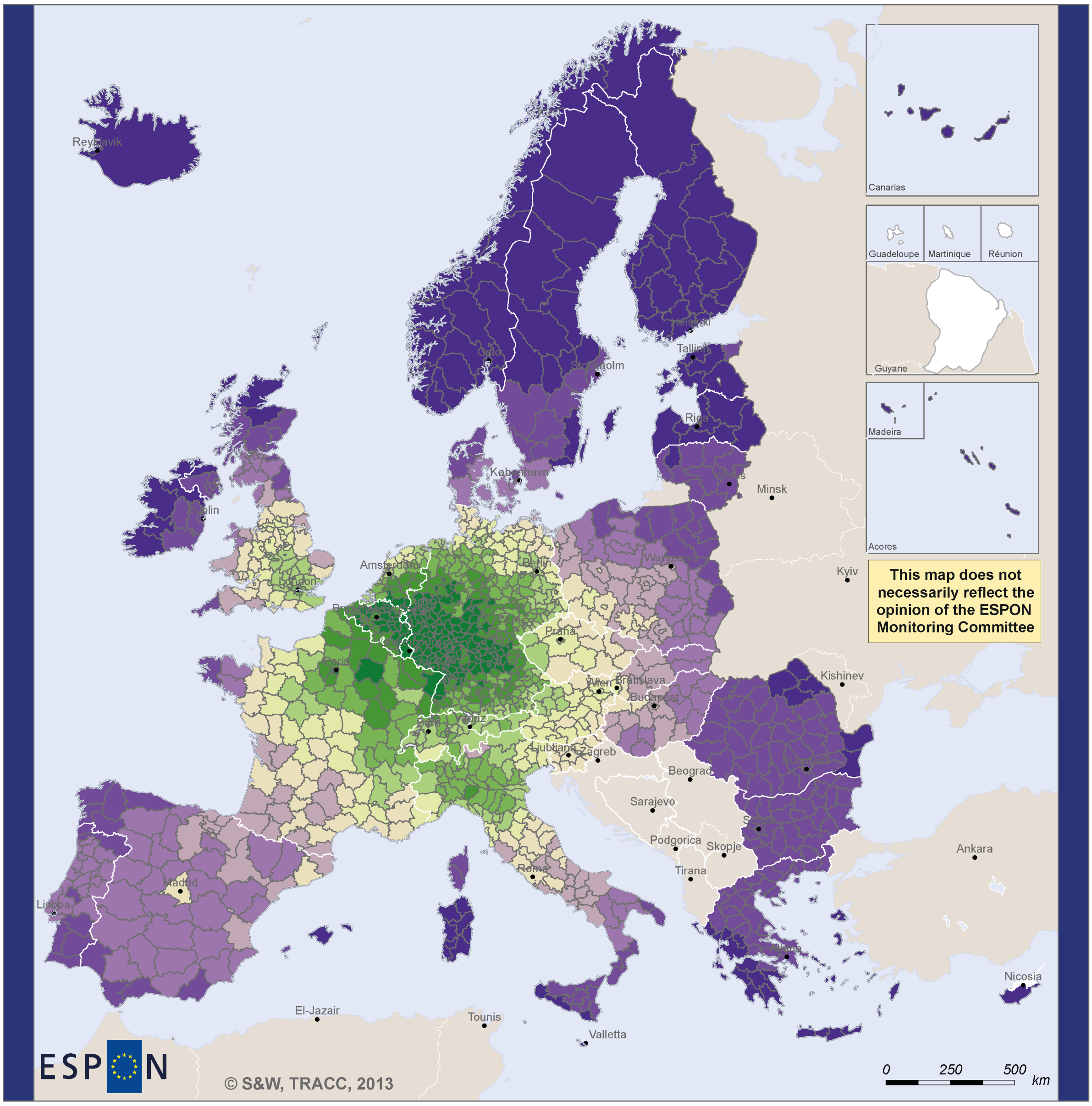
Population accessible within 5h by fastest mode

- 72800 - 10000000
- 10000001 - 25000000
- 25000001 - 50000000
- 50000001 - 75000000
- 75000001 - 100000000
- 100000001 - 125000000
- 125000001 - 150000000
- 150000001 - 182420560
- no data

Figure 7.2. Daily accessibility by fastest mode



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Regional level: NUTS 3
Source: Spiekermann and Wegener
Urban and Regional Research (S&W), 2013
Origin of data: S&W Accessibility Model, 2013
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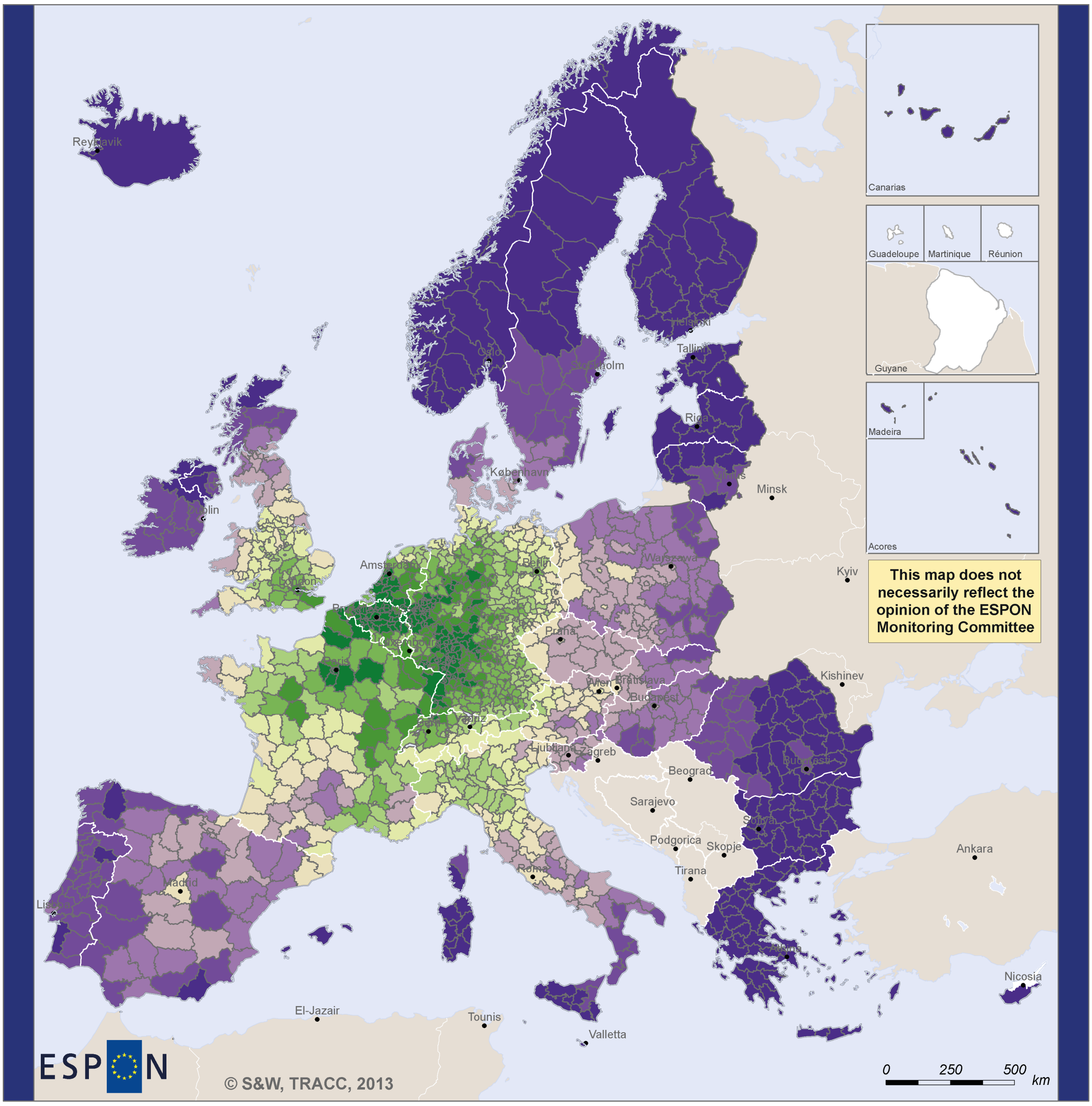
Accessibility potential, road (ESPON = 100)
2011

0 - 20	very peripheral
21 - 40	
41 - 60	peripheral
61 - 80	
81 - 100	intermediate
101 - 120	
121 - 140	central
141 - 160	
161 - 180	very central
181 - ...	

no data

Figure 7.3. Accessibility potential to population by road, 2011



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Urban and Regional Research (S&W), 2013
Origin of data: S&W Accessibility Model, 2013
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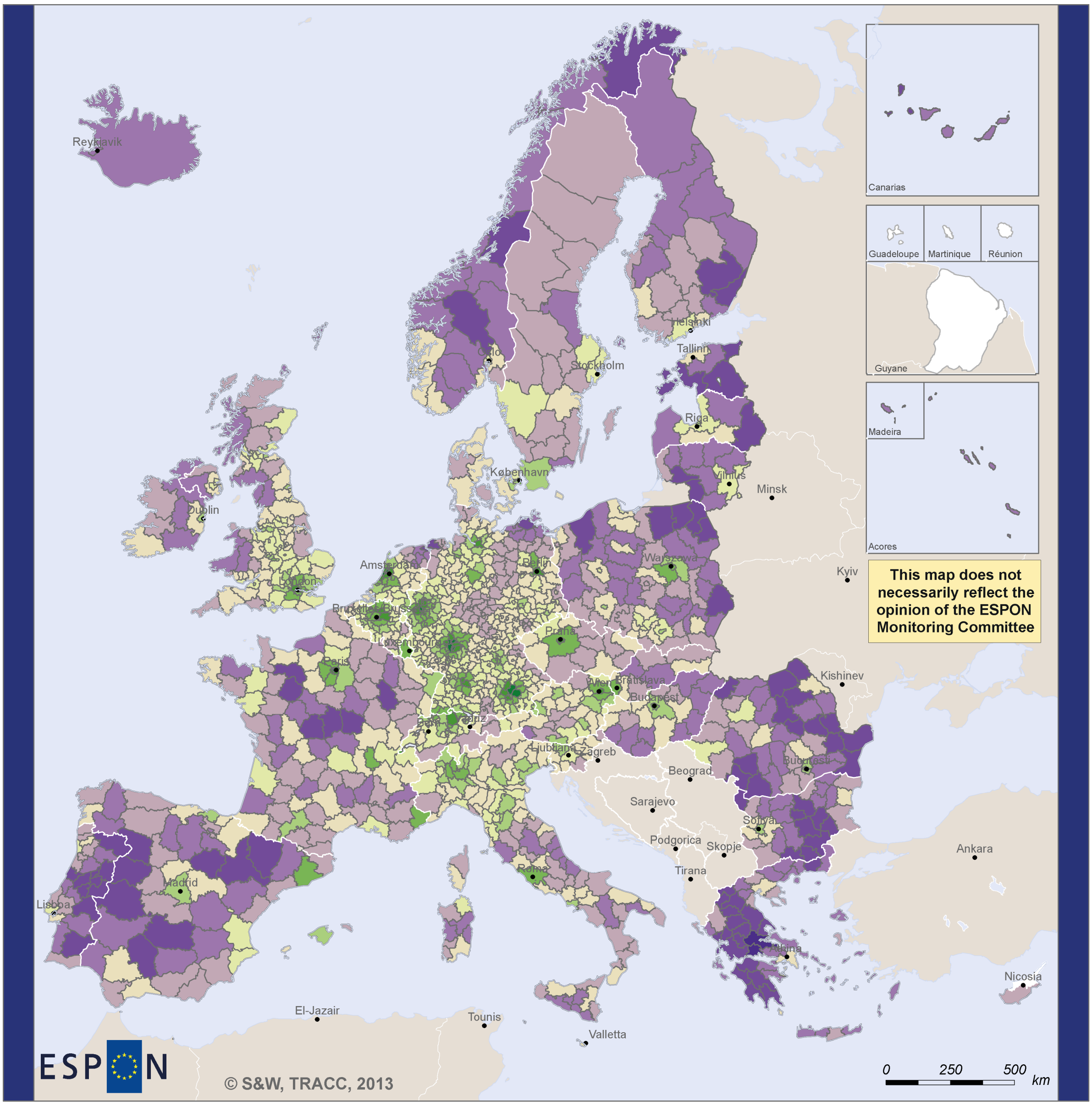
Accessibility potential, rail (ESPON = 100)
2011

0 - 20	very peripheral
21 - 40	
41 - 60	peripheral
61 - 80	
81 - 100	intermediate
101 - 120	
121 - 140	central
141 - 160	
161 - 180	very central
181 - ...	

no data

Figure 7.4. Accessibility potential to population by rail, 2011



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Regional level: NUTS 3
Source: Spiekermann and Wegener
Urban and Regional Research (S&W), 2013
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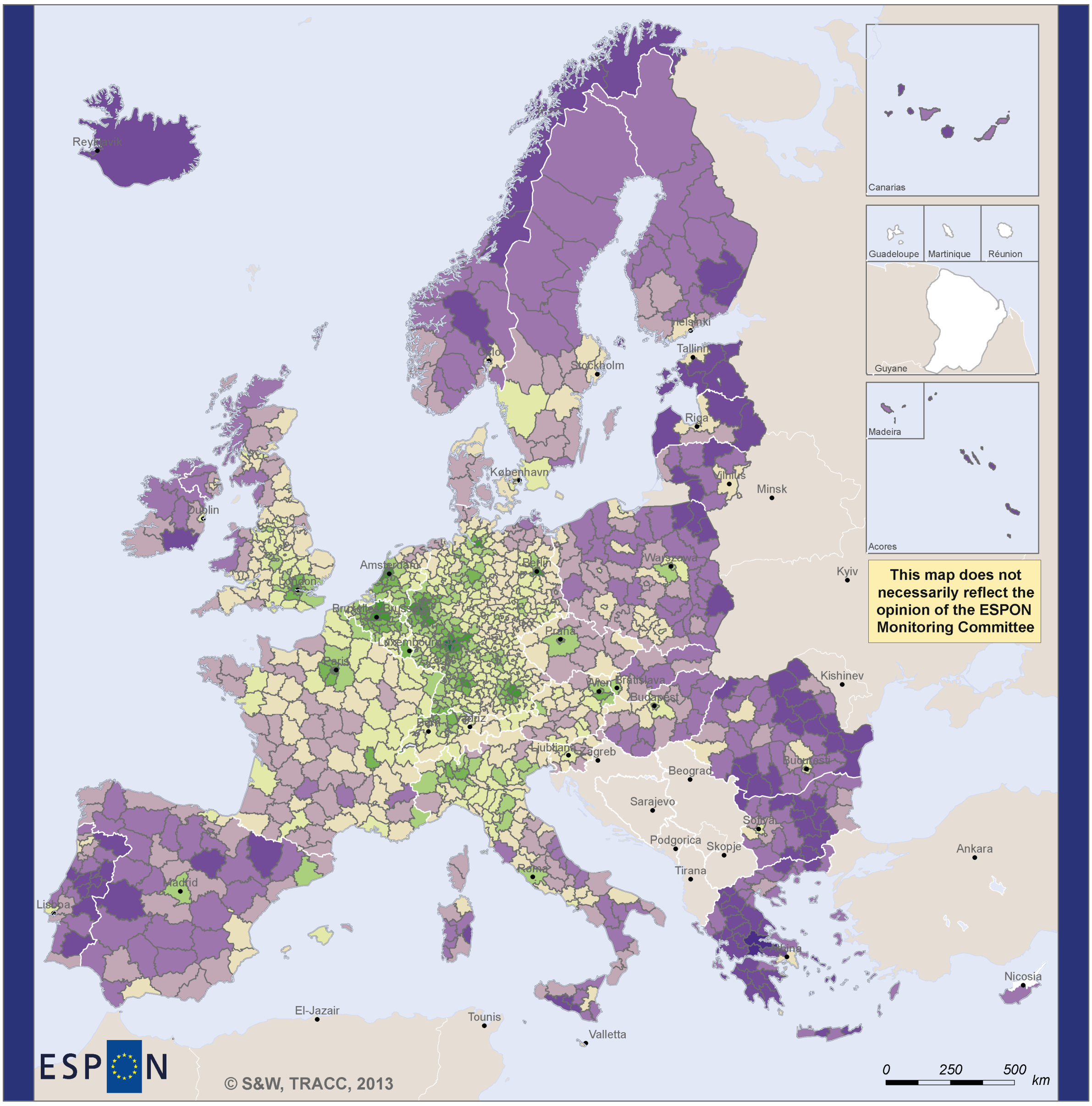
Accessibility potential, air (ESPON = 100)
2011

0 - 20	very peripheral	no data
21 - 40		
41 - 60	peripheral	
61 - 80		
81 - 100	intermediate	
101 - 120		
121 - 140	central	
141 - 160		
161 - 180	very central	
181 - ...		

Figure 7.5. Accessibility potential to population by air, 2011



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Regional level: NUTS 3
Source: Spiekermann and Wegener
Urban and Regional Research (S&W), 2013
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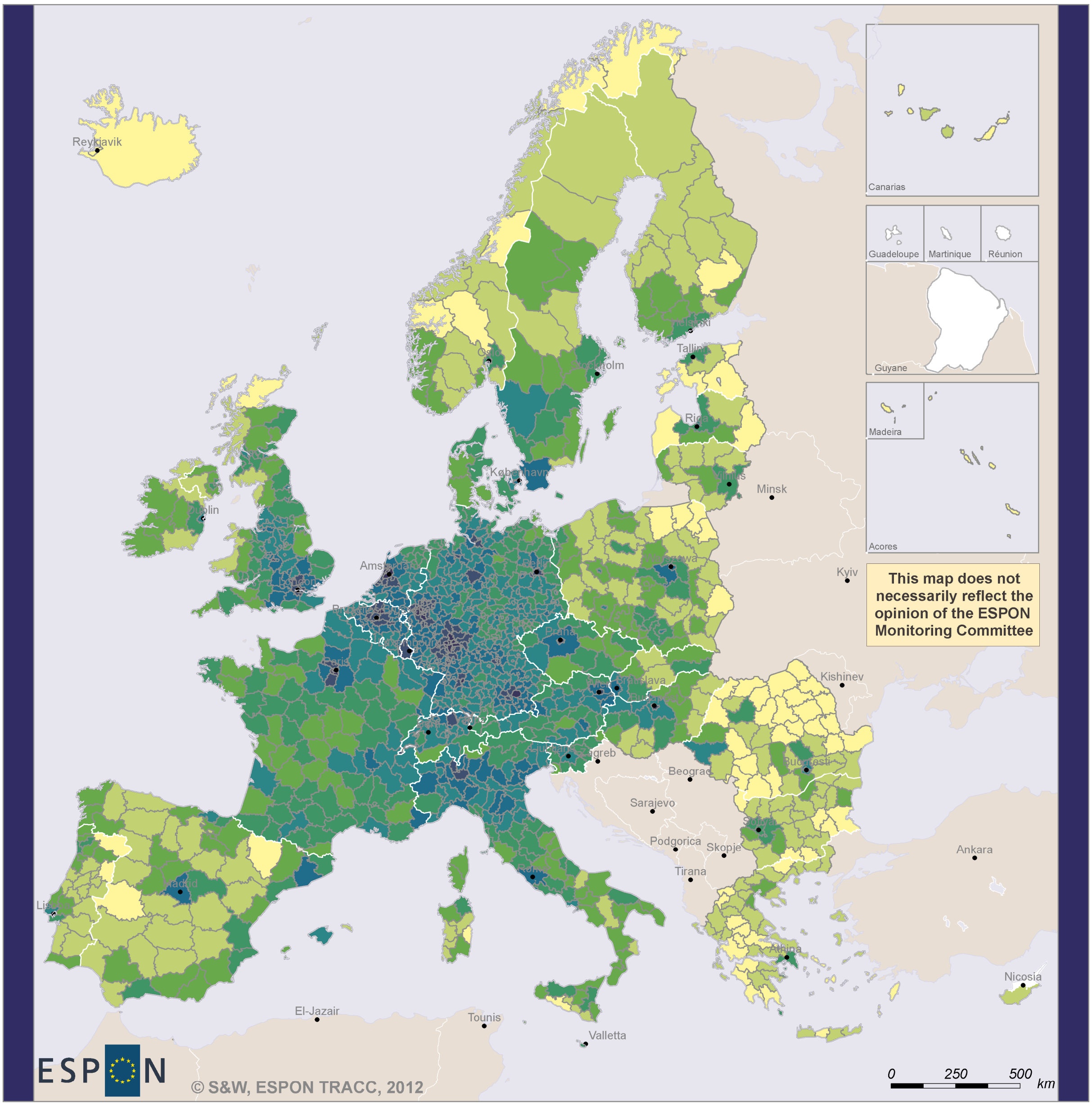
Accessibility potential, multimodal (ESPON = 100)
2011

0 - 20	very peripheral	no data
21 - 40		
41 - 60	peripheral	
61 - 80		
81 - 100	intermediate	
101 - 120		
121 - 140	central	
141 - 160		
161 - 180	very central	
181 - ...		

Figure 7.6. Accessibility potential to population multimodal, 2011



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Regional level: NUTS-3
Source: RRG GIS Database
S&W Flight Network
Origin of data: S&W Accessibility model, 2012
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European potential accessiblity, intermodal (ESPON = 100)

- **0 - 40**
- **41 - 60**
- **61 - 80**
- **81 - 100**
- **101 - 120**
- **121 - 140**
- **141 - 160**
- **161 - 187**
- **no data**

Figure 7.7. Potential accessibility to population, intermodal

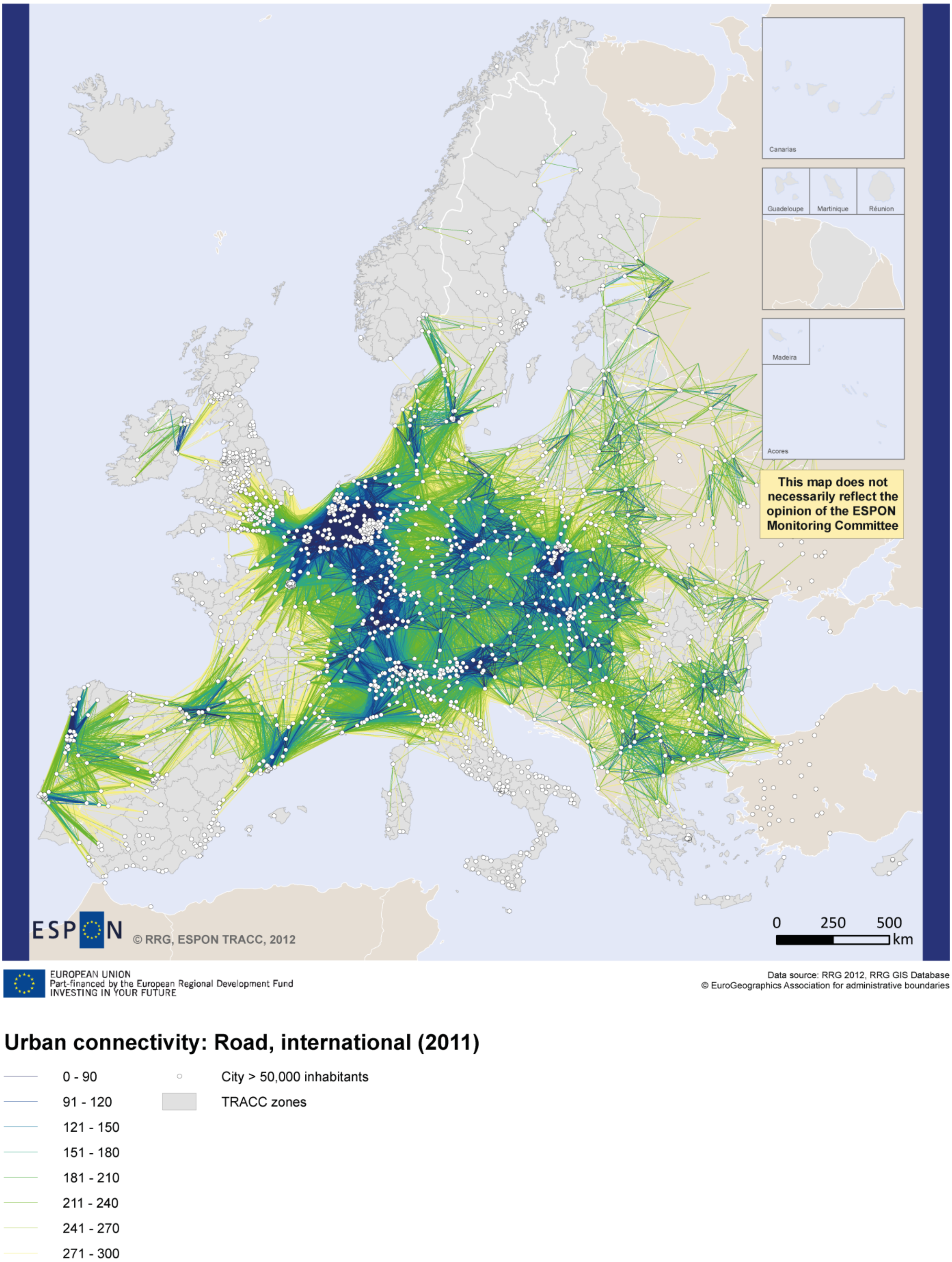


Figure 7.8. Urban connectivity, road, international

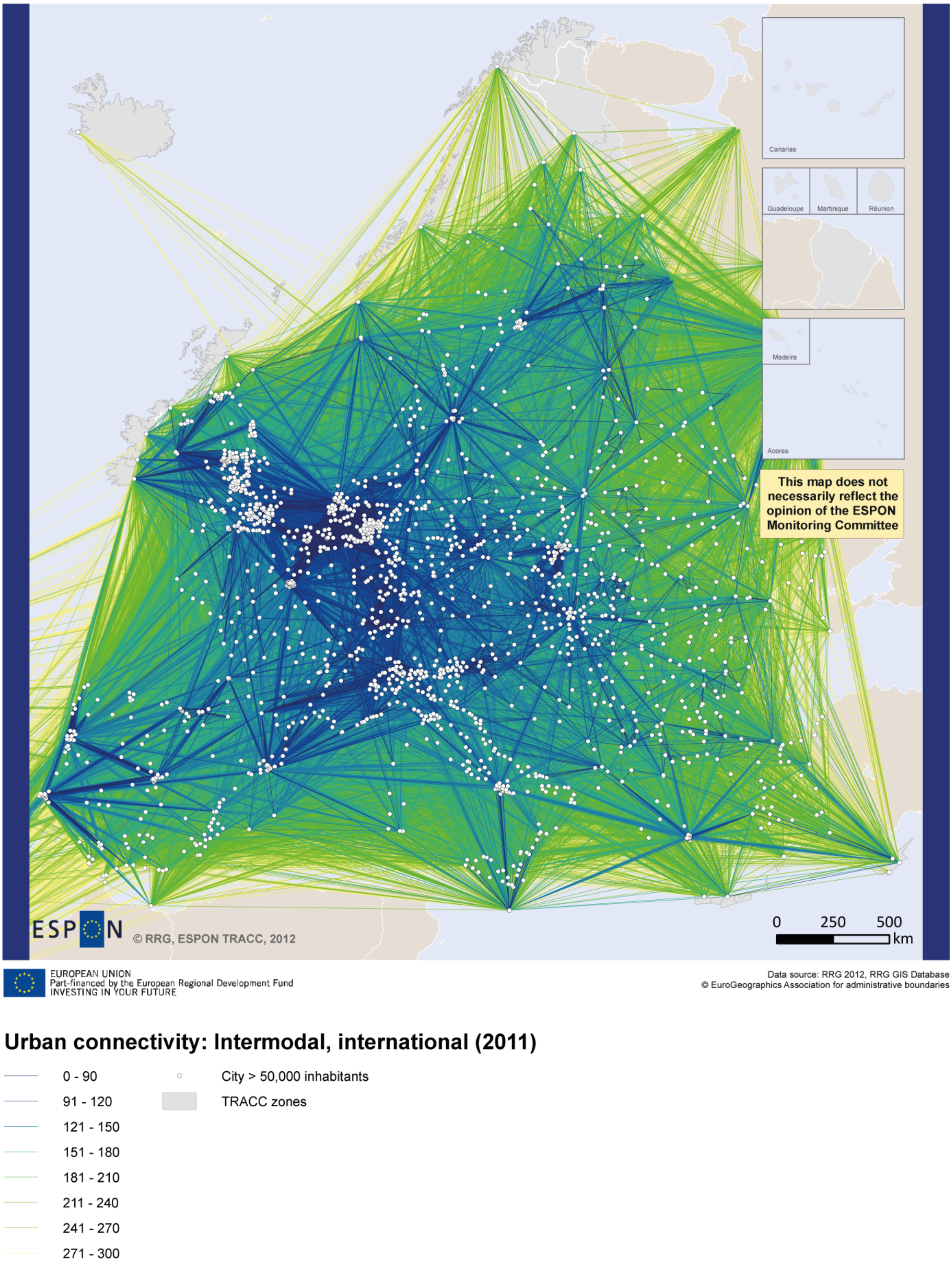


Figure 7.9. Urban connectivity, intermodal, international

7.2 European freight accessibility

Three indicators illustrate freight accessibility of NUTS-3 regions at the European level. A travel cost type accessibility indicator provides a measure of the closeness to the nearest maritime ports. Cumulated opportunities type accessibility is measured by the size of GDP which can be reached within the legal daily driving time. Both these two indicators are related to one specific mode (water and respectively road). Potential accessibility is examined for all the alternative modes.

A large volume of freight concerning intra-Europe trade is moved by ships, however most of this volume consists of large shipments of bulk goods. As far as daily shipments of intermediate as well as final products are concerned, inland modes are however dominant. Therefore a representative picture of European freight accessibility needs to consider all modes.

The accessibility to closest ports provides an integrated measure of the level of accessibility of regions with respect to maritime freight terminals, as an important element in the economy to allow exports of local commodities and imports. In this respect, the indicator is computed with reference to ports with a throughput of at least 4 million tonnes yearly, i.e. those ports which actually play a role as gates towards other regions. Not surprisingly, coastal zones are generally more accessible (see Figure 7.11). Nevertheless, geographical position is not enough and even coastal zones may have a poor accessibility if infrastructures (ports) are not adequate (i.e. only minor ports are located nearby or connections are expensive).

The message coming from the spatial pattern of the cumulated opportunities indicator (which is computed for trucks only, but road is the dominant inland freight transport mode) and of the potential accessibility indicators is that a group of regions in the central-western part of Europe have a clear advantage in terms of freight accessibility. This group of regions covers the Benelux , the western side of Germany, the northern edge of France and the southern side of UK. Around this core area, other neighbouring regions may be very well positioned according to one or more indicators even if there is always at least one measure for which they are significantly weaker than the core area. For instance, Denmark has good accessibility levels by water and also by unitised rail, but it is well below the average for road. The multimodal indicators reflect the prevailing role of the core area both for unitised and for non-unitised goods (Figures 7.12 and 7.13 below).

The separation between unitised and non-unitised goods is especially relevant for rail transport (Figure 7.14 and 7.15). Non-unitised goods represent pure rail transport, which does not need intermodal centres, but just of the rail network, which is quite homogenously available over the whole European territory. Instead, for combined transport (road + rail) of unitised goods the proximity to intermodal centres becomes a very significant accessibility factor. Thus, despite an overall decrement moving from the centre to periphery can still be observed, there are some regions e.g. in Italy or south France or Czech Republic with levels of European potential accessibility higher than e.g. some German regions thanks to the availability of intermodal facilities. The position of intermodal centres is also detectable in the differences of accessibility of regions in western France or in Italy.

Combined transport is the most dynamically growing segment of rail freight (Burkhardt, 2011) so promoting the accessibility for unitised rail could be considered a key strategy for the development of regions. However, it is relevant to observe that, unless a large growth of rail freight volumes is expected in the future, there are organisational reasons for intermodal centres not covering all the European territory in a homogenous fashion. Below a certain threshold of throughput, intermodal centres – which are usually private facilities – are not economically sustainable. It is therefore reasonable that they collect freight from a catchment area which can extend beyond a specific region. This means that the current pattern of unitised rail accessibility is correlated to a picture of those zones that have built a competitive advantage in infrastructural and logistical terms. This advantage could not be easily reduced by other regions in the future.

The graph in Figure 7.10 shows how the different countries perform in terms of European accessibility. For each indicator, the height of the bar is proportional to the share of NUTS-3 zones in the country with a value above the European average. This analysis is very simplified but provides a rapid overview of the strongest and the weakest countries. The advantage of the central-European area – Benelux, Germany and UK – emerges clearly. France and Switzerland are also in the upper side of the ranking, with Italy, Austria and Denmark to follow. The graph also shows that eastern Europe countries have a low rank, very often lower than countries in the northern periphery of Europe, such as Finland, Norway and Sweden. The strength of the central Europe countries is in their high accessibility by all modes. Road, rail, water and air are available in these countries which often host some of the major European terminals. Other countries, instead, may be strong from some perspective (e.g. for water accessibility) but are weak from another perspective (e.g. unitised rail accessibility). This is reflected in the multimodal potential accessibility, whose value is generally below the average outside the central regions in Europe. The low rank of the Eastern European countries is not just matter of travel cost or connectivity but is also explained by their lower economic activity, since especially road and rail potential accessibility are affected by the level of activity of the closest regions.

In brief, geographical position, availability of infrastructures and strength of the economy are the three key elements which describe the pattern of European accessibility. There is no need to say that these elements are correlated to each other.

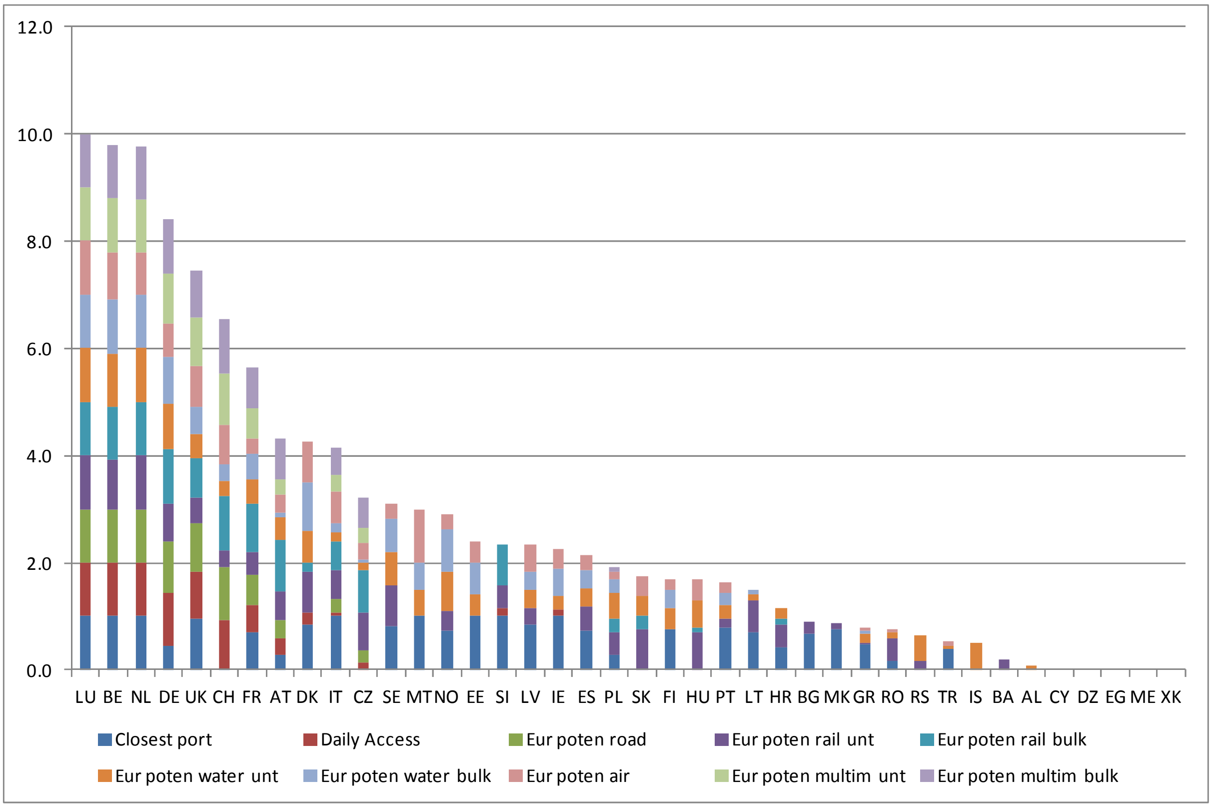
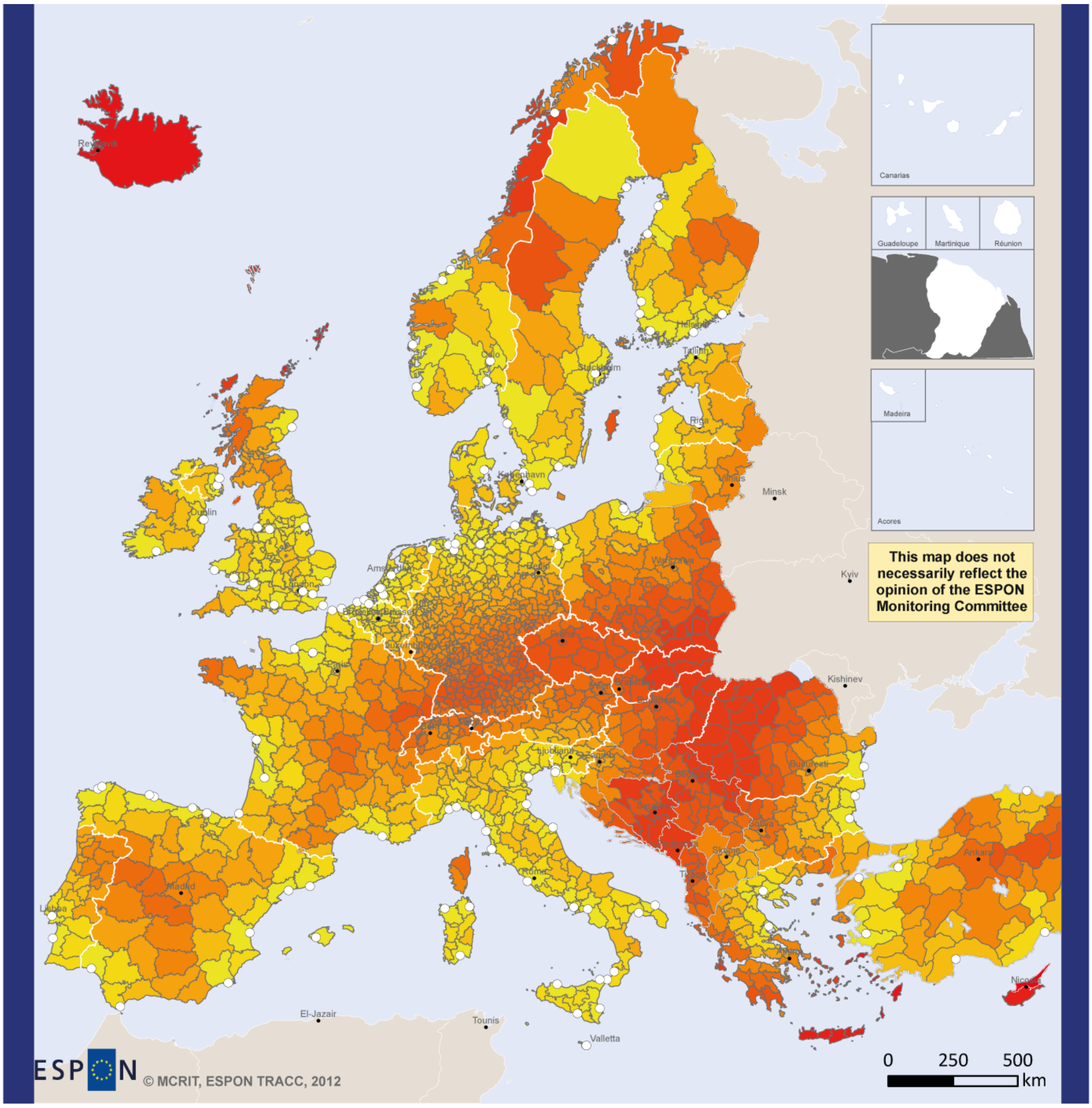


Figure 7.10. Performance of countries on European accessibility



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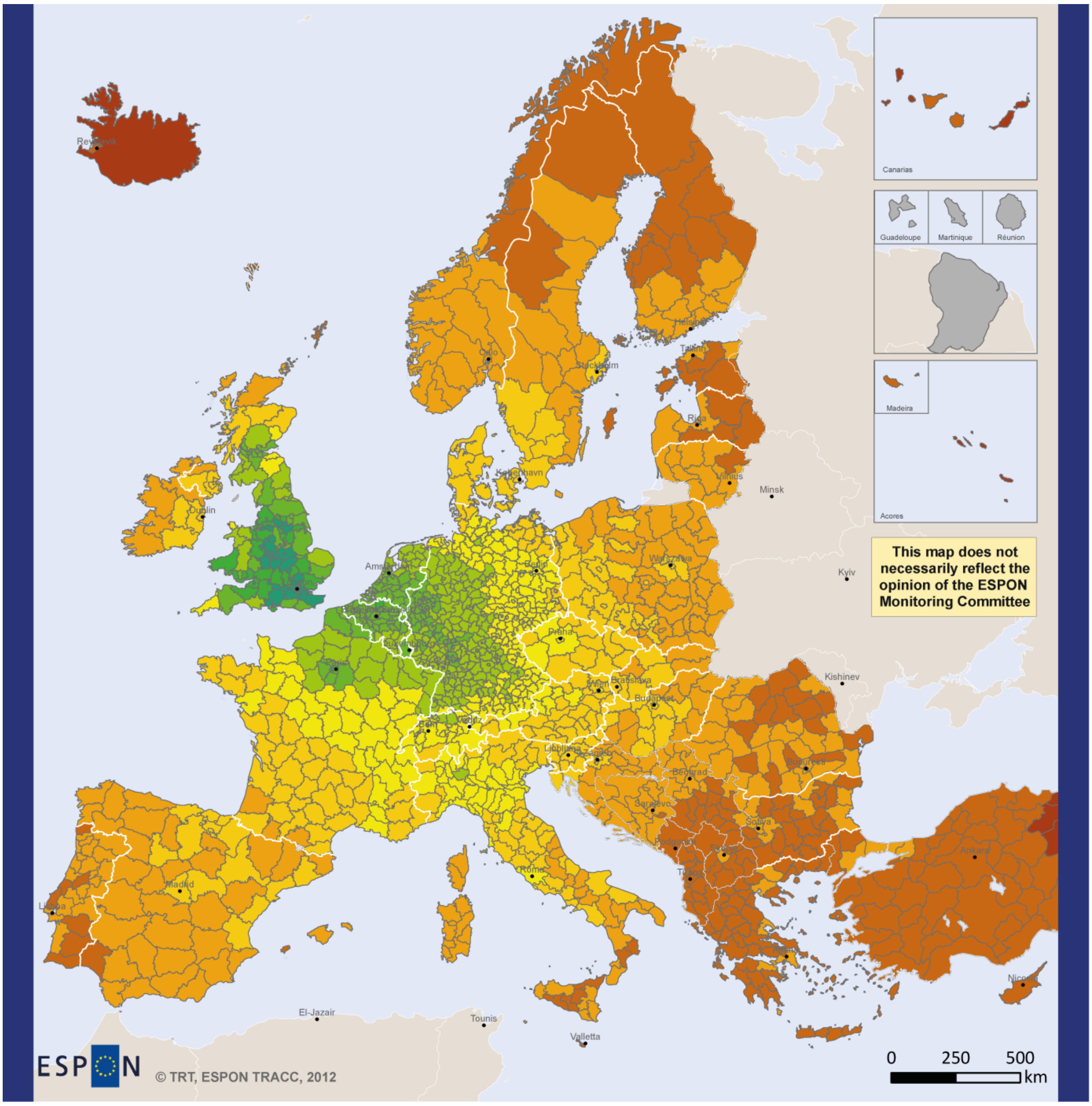
Travel Cost to access nearest maritime port (euros)

1 - 39	225 - 284	ports
40 - 79	285 - 379	Capital cities
80 - 124	380 - 569	no data
125 - 169	570 - 949	
170 - 224	950 < ...	

Figure 7.11. Access to nearest maritime port



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Source: TRUST Accessibility Model (TRT 2012), Maritime Network: TRUST Model, Road/Rail Network: TransTools (2005), IWW/Air Network: RRG GIS Database, GDP regional data (ESPON data 2005/2006, TransTools data 2005, Statistical Offices data)
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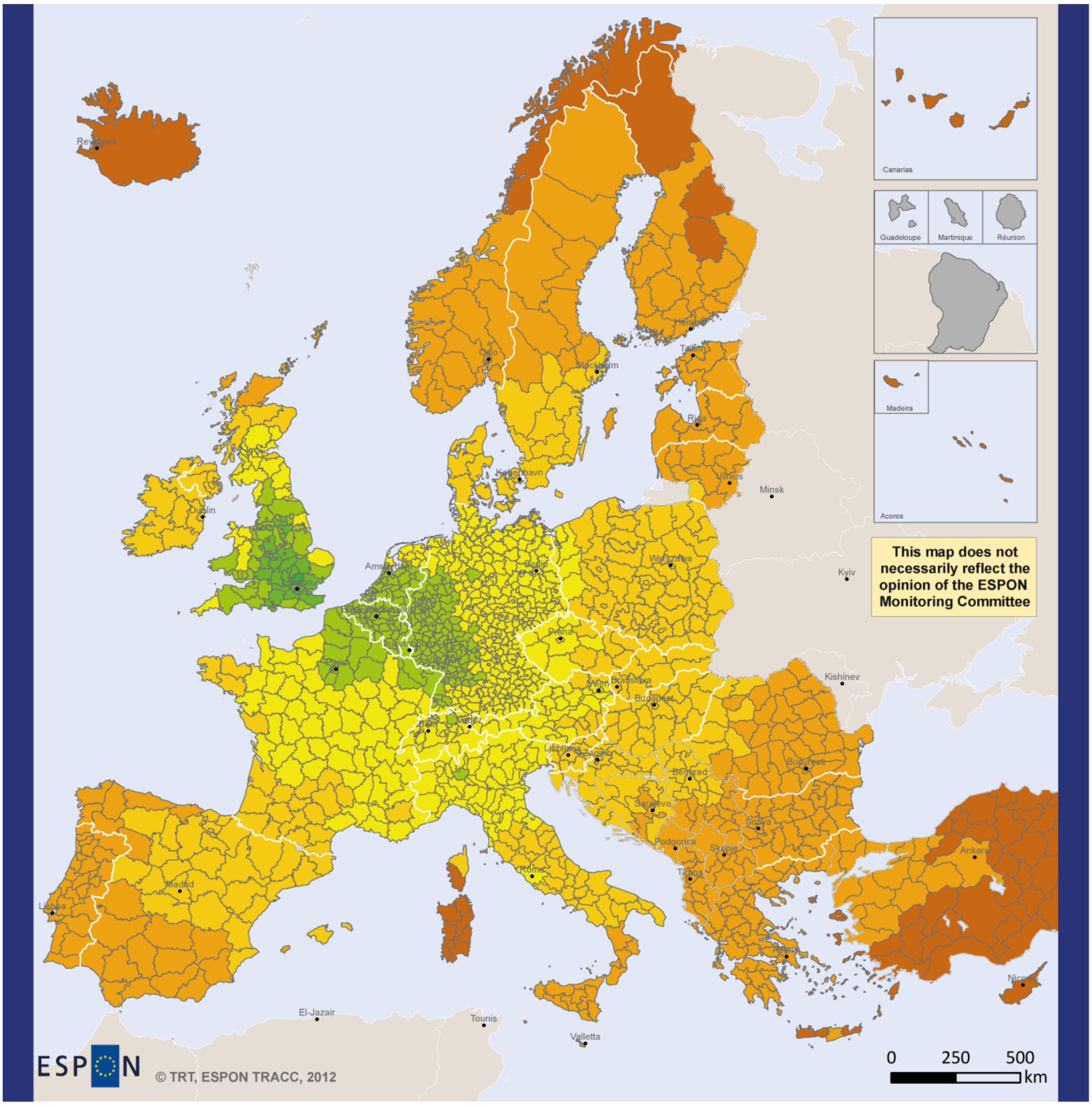
Multimodal European potential accessibility freight (2011):
Accessibility potential to GDP (unitised)
(percentage of average accessibility of all areas)

- 0 - 25.0
- 25.1 - 50.0
- 50.1 - 75.0
- 75.1 - 100.0
- 100.1 - 125.0
- 125.1 - 150.0
- 150.1 - 175.0
- 175.1 - 200.0
- 200.1 < ...
- n.a.

• *Capital cities*

Figure 7.12. European potential accessibility freight – multimodal unitised



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Source: TRUST Accessibility Model (TRT 2012), Maritime Network: TRUST Model, Road/Rail Network: TransTools (2005), IWW/Air Network: RRG GIS Database, GDP regional data (ESPON data 2005/2006, TransTools data 2005, Statistical Offices data)
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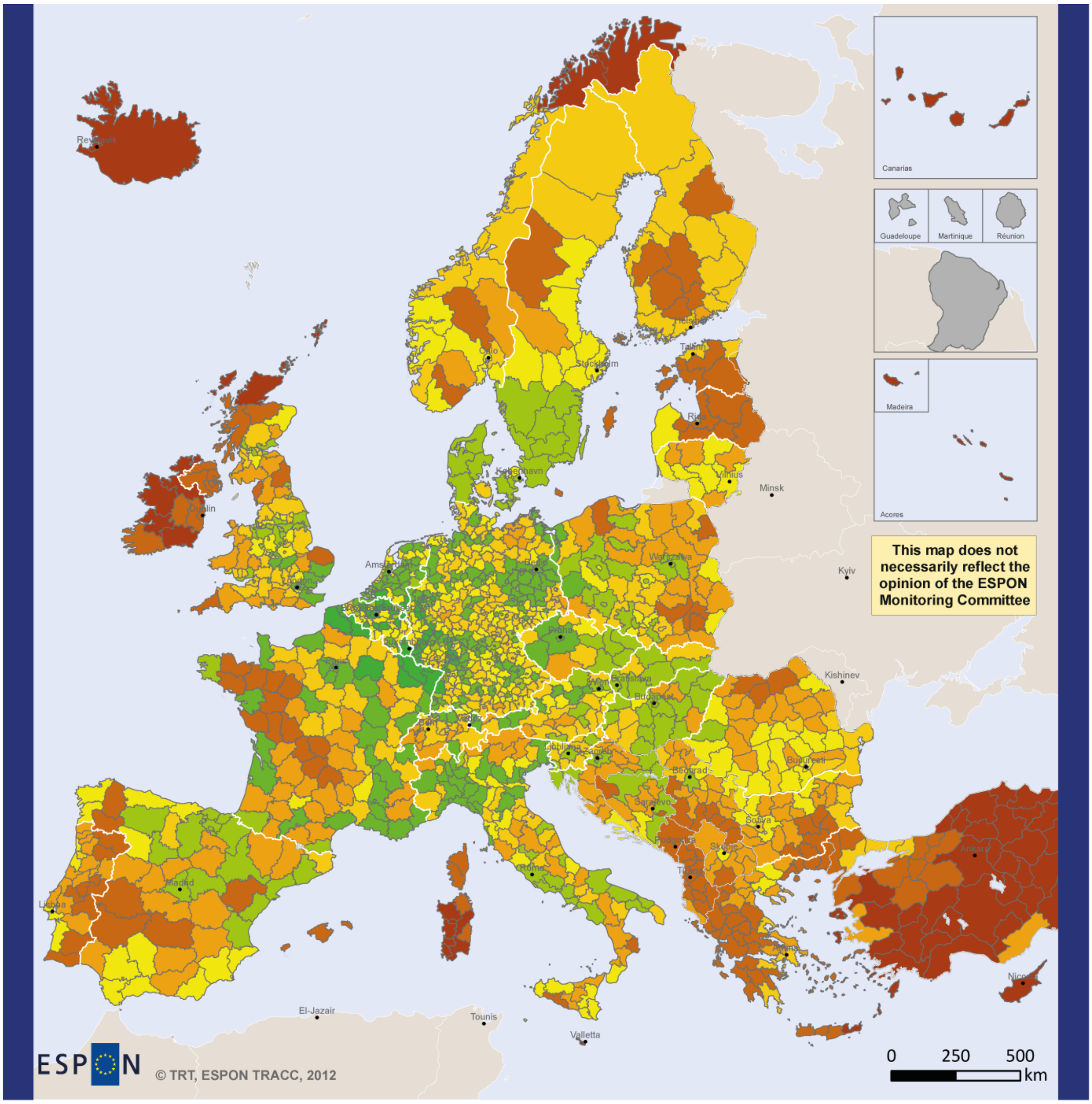
Multimodal European potential accessibility freight (2011): Accessibility potential to GDP (non unitised) (percentage of average accessibility of all areas)

- 0 - 25.0
- 25.1 - 50.0
- 50.1 - 75.0
- 75.1 - 100.0
- 100.1 - 125.0
- 125.1 - 150.0
- 150.1 - 175.0
- 175.1 - 200.0
- 200.1 < ...
- n.a.

• *Capital cities*

Figure 7.13. European potential accessibility freight – multimodal non unitised



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Data source: TRUST Accessibility Model (TRT 2012), Road/Rail Network: TransTools (2005), GDP regional data (ESPON data 2005/2006, TransTools data 2005, Statistical Offices data)
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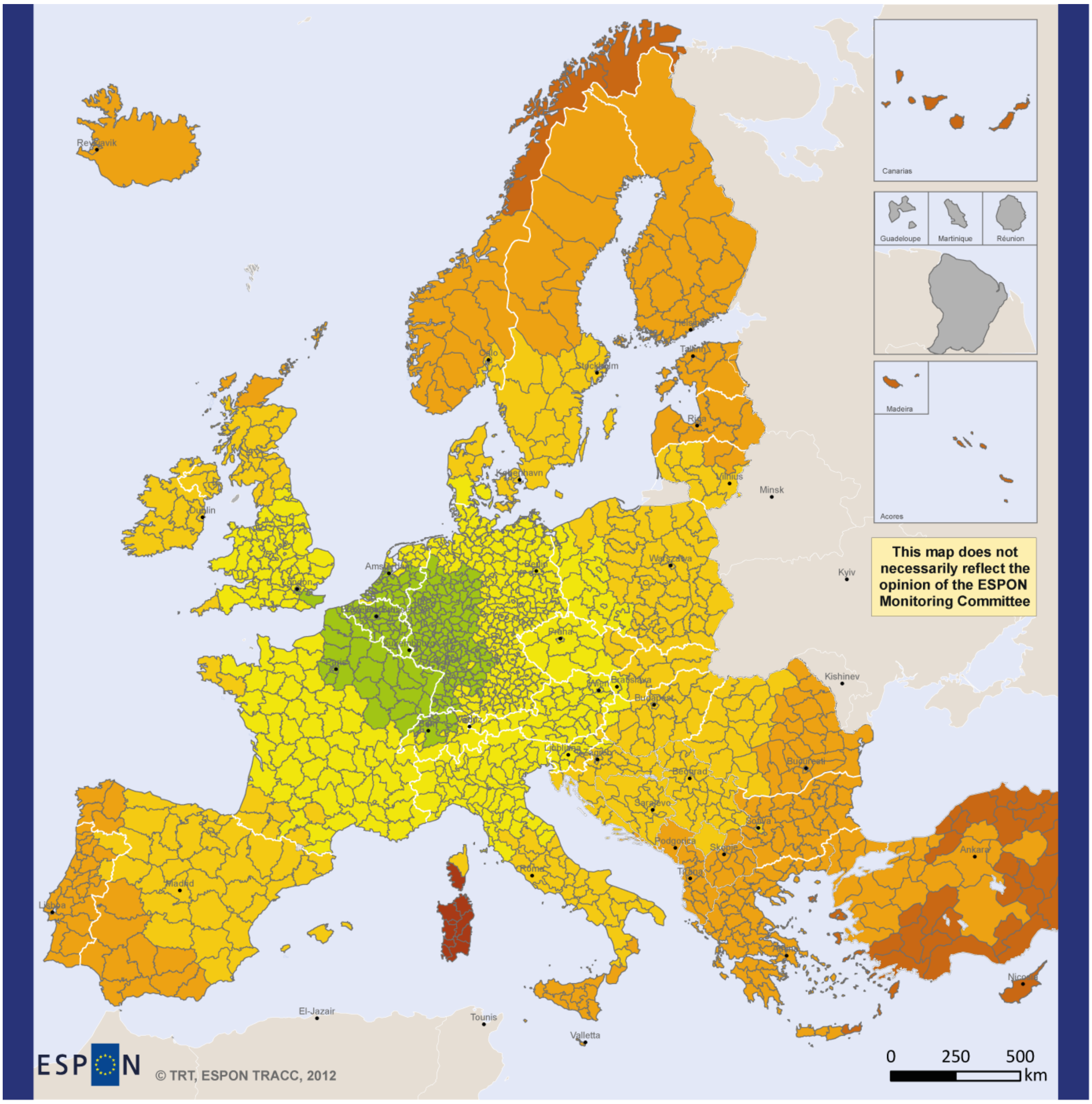
European potential accessibility freight (2011):
Accessibility potential to GDP by rail (unitised)
(percentage of average accessibility by rail (unitised) of all areas)

- 0 - 25.0
- 25.1 - 50.0
- 50.1 - 75.0
- 75.1 - 100.0
- 100.1 - 125.0
- 125.1 - 150.0
- 150.1 - 175.0
- 175.1 - 200.0
- 200.1 < ...
- n.a.

• *Capital cities*

Figure 7.14. European potential accessibility freight – rail unitised



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Data source: TRUST Accessibility Model (TRT 2012), Road/Rail Network: TransTools (2005), GDP regional data (ESPON data 2005/2006, TransTools data 2005, Statistical Offices data)
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European potential accessibility freight (2011):
Accessibility potential to GDP by rail (non unitised)
(percentage of average accessibility by rail (non unitised) of all areas)

- 0 - 25.0
- 25.1 - 50.0
- 50.1 - 75.0
- 75.1 - 100.0
- 100.1 - 125.0
- 125.1 - 150.0
- 150.1 - 175.0
- 175.1 - 200.0
- 200.1 < ...
- n.a.

• *Capital cities*

Figure 7.15. European potential accessibility freight – rail non unitised

8 Accessibility to regional destinations

8.1 Regional accessibility to long-distance transport networks

The development of transportation systems as integrated networks at different scales is deeply changing their operation and the way they induce urban and regional development patterns. The conventional definition of "distance between places" seems not sufficient anymore. A connectivity approach, focused on measuring the "distance to the networks" is needed to measure how transportation networks influence locational decisions and induce spatial development, in the context of current economic and technological changes.

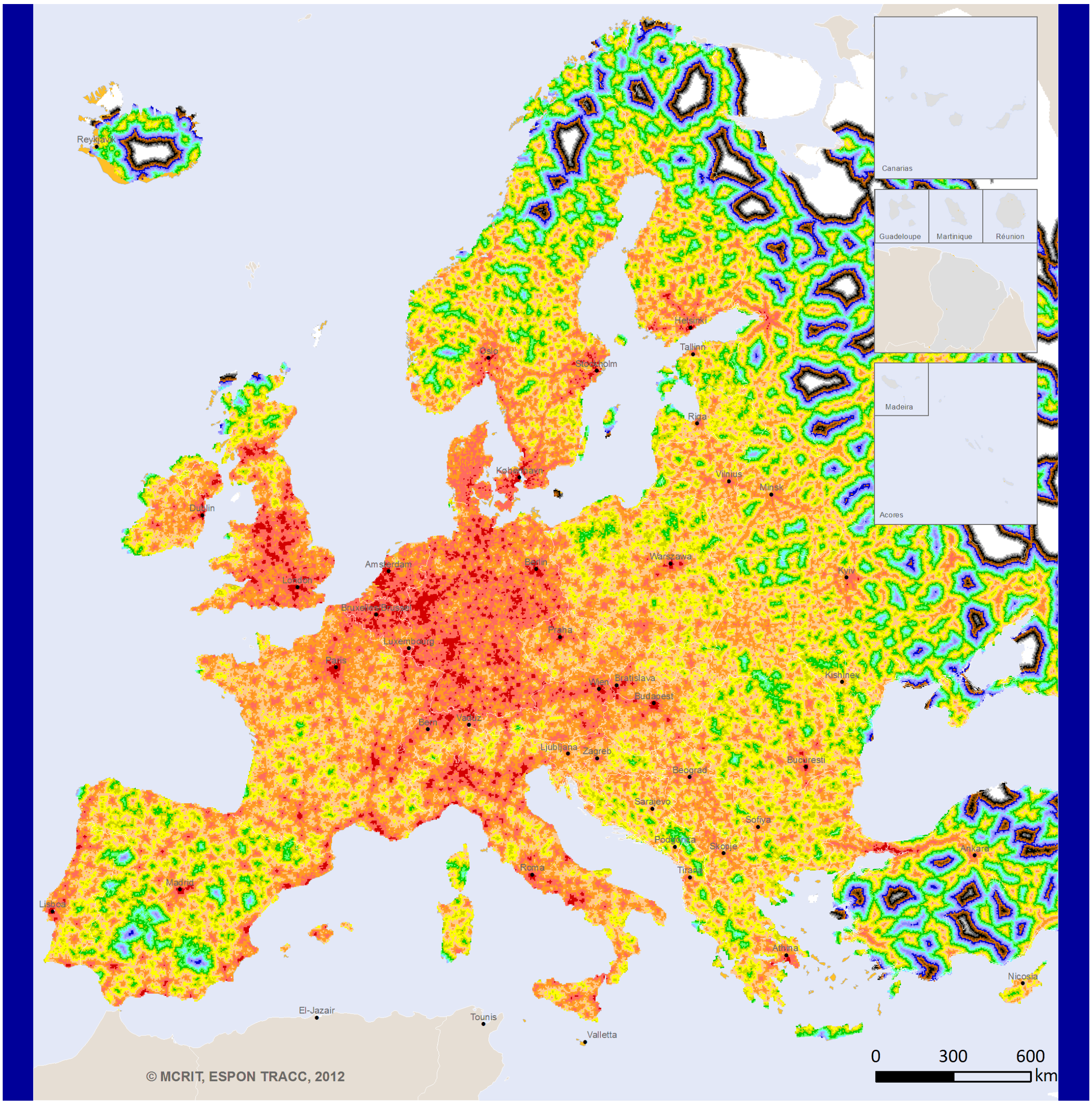
According to many transportation analysts (e.g. Chisholm, 1992) one of the most common fallacies about transport costs is that they vary with location to the extent that geographical peripherality implies a substantial cost burden over more central locations. Empirical observations (e.g. Diamond and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

As a result, the distance between two places (in time, cost or psychological perception), and the opportunity to establish relations between them, is increasingly dependent on the kind of transport and communication networks to which they are connected rather than the physical distance between them (Distler, 1986). Contemporary economic landscape can be therefore represented by the superimposition of two increasingly independent geographies: the geography of places and the geography of communication networks (Beauchard, 1991).

More sustainable and efficient interurban travel requires according to EC Transport White Paper a systematic choice in favour of the most efficient mode among the different transport alternatives, even a choice between the public and private transport means in terms of efficiency. Better modal choices will come from greater integration of the modal networks, but also from the promotion of increasing levels of territorial connectivity to passenger transport infrastructure

Today, core areas in Europe clearly show higher levels of connectivity to passenger transport networks than peripheral areas (Figures 8.1 and 8.2). The denser network of motorways in Germany, the Benelux and Northern Italy, also in the UK, and the fact that most intercontinental air hubs are located in this area (with million passengers in 2011: Heathrow 69, Paris Charles-de-Gaulle 61, Frankfurt 56, Amsterdam 50, Munich 38) is the main reason for these higher levels of regional connectivity. Beyond the European core areas, major regional corridors can still be tracked, as they concentrate population, economic activity and logically transport infrastructure: the Mediterranean arch from Southern Spain to Italy; the Rhone valley, the Scandinavian west coast corridor from Copenhagen to Gothenburg and Oslo, with extensions to Stockholm. In France and Spain, it is possible to identify the major HSR and motorway corridors linking intermediate cities.

The European transport policy aims at increasingly substituting aviation by high speed rail for journeys of up to 3-4 hours, while regional aviation can remain a sensible option for peripheral areas that do not have enough critical mass. The hub-and-spoke model continues to be promoted by the airline industry for long-howl connections, with a centralised airline locale providing an anchor where a wide range of its passengers can connect to the rest of the country or world. These two trends are likely to further increase the size of core European transport hubs, increasing their global connectivity, while point-to-point strategies promoted by low cost carrier tend to reinforce regional attractively of intermediate regions.



Data source: MCRIT 2012, TRANSTOOLS Transport Network
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Access to high-level passenger transport infrastructure

ICON indicator,defined as relative connectivity to available transport networks (in minutes)

http://www.mcrit.com/IGIS/ICON.htm

0 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
101 - 110
111 - 120
121 - 130
131 - 140
141 - 150
151 - 160
161 - 170
>170
no data

Figure 8.1. Access to high-level passenger transport infrastructure by 5x5 grid cells

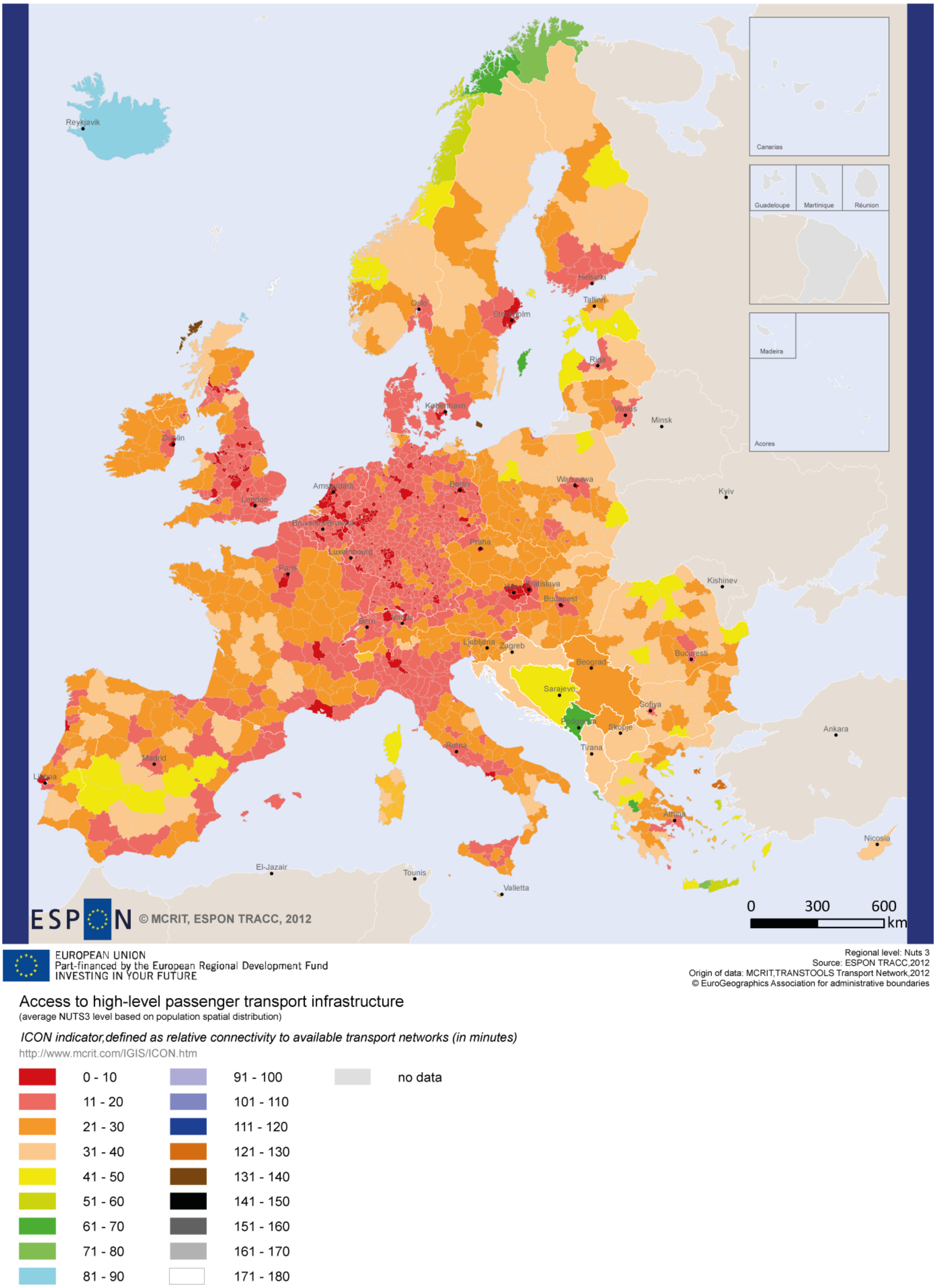


Figure 8.2. Access to high-level passenger transport infrastructure by NUTS-3 region

Countries having on average lower travel times to high-level transport infrastructure than mean values for all NUTS-3 regions in Europe (countries performing better) belong all to the European core: Luxemburg, the Netherlands, Belgium, Denmark, Switzerland, the UK, Austria, Lichtenstein, and Italy. 10 European countries have at least 50% of their NUTS-3 regions performing better than average in connectivity to passenger transport networks. These states are all located in the Core of Europe: Luxembourg, Lichtenstein, the Netherlands, Belgium, Germany, Denmark, the UK, Switzerland, Italy and Austria. On the other side of the spectrum, 10 European countries have more than 80% of their NUTS-3 regions performing worse than average: Cyprus, Estonia, Island, Bulgaria, Greece, Romania, Lithuania, Czech Republic, Slovenia and Poland

Regional accessibility to freight networks is a precondition for competitive local economies in a globalised economy. Intra-EU freight transport is mostly carried by trucks (47.3%), followed by seagoing ships (37.8%), rail (11.2%) and inland waterways (3.7%). Air cargo has a marginal share of volumes but it carries a significant share of value. According to EC Transport White Paper (2011), an increasing separation between passenger and freight traffic can be expected in the future to facilitate the optimisation of traffic flows with different needs and characteristics. Intercontinental trade will continue to rely almost exclusively on maritime transport, which will continue to be a global business, therefore accessibility to ports is of much relevance. The entry points into European markets will multiply. Certain ports will develop or become major intercontinental hubs along the northern and southern coastlines, avoiding at the same time unnecessary traffic crossing Europe. Ports have a major role as logistics centres and require efficient multimodal connections.

The analysis of regional accessibility to freight networks reveals, not surprisingly, that best results are recorded in the Atlantic rim between the Benelux and Germany (Figures 8.3 and 8.4). This is mostly due to the fact that the four busiest container ports in Europe are all located in the area (Rotterdam 11.1 MTEU (million twenty foot equivalent units, a measure for cargo capacity based on 20-foot-long intermodal container); Antwerp 8.5 MTEU; Hamburg 7.9 MTEU; Bremen 4.9 MTEU; in 2010), while at the same time, motorway, and rail and freight village networks are denser than in other areas of Europe. The Mediterranean rim may use the opportunity granted by the presence of large container ports (Valencia 4.2 MTEU; Gioia Tauro 2.8 MTEU; Algeciras 2.8 MTEU; Marsaxlokk 2.3 MTEU; Barcelona 1.9 MTEU; in 2010), but less dense motorway and freight village networks in the hinterlands of this area limit highest connectivity values only to coastal areas, to a large extent.

Most Mediterranean ports were undergoing extensions in the decade of the 2000 with the aim of increasing their share of the Far East traffic entering Europe, which is still mostly handled through Northern European ports (over 75% of total), often even for commodities bound to Southern Europe. Currently, Antwerp is the port handling the highest volume of Asian goods with destination in the South of Europe. The efficient handling of goods in ports and logistic platforms and high-performance transport links with the hinterland are essential conditions the competitiveness of the Mediterranean maritime front of the EU and the development of a more balanced and sustainable transport system.

Almost all countries having on average lower average travel times to high-level freight transport infrastructure than mean values for all NUTS-3 regions in Europe (countries performing better) belong to the European core: the Netherlands, Belgium, Denmark, the United Kingdom, Italy (especially northern areas), Luxemburg and Germany. Maritime countries show in general better freight connectivity values than landlocked countries. Seven European countries have at least 80% of their NUTS-3 regions performing better than European connectivity average to freight transport networks: Luxembourg, the Netherlands, Belgium, Denmark, the United Kingdom, Slovenia and Italy, mostly core and maritime countries. On the other side of the spectrum, 13 European countries have more than 80% of their NUTS-3 regions performing worse than average in terms of connectivity to freight transport networks, mostly Eastern and landlocked countries.

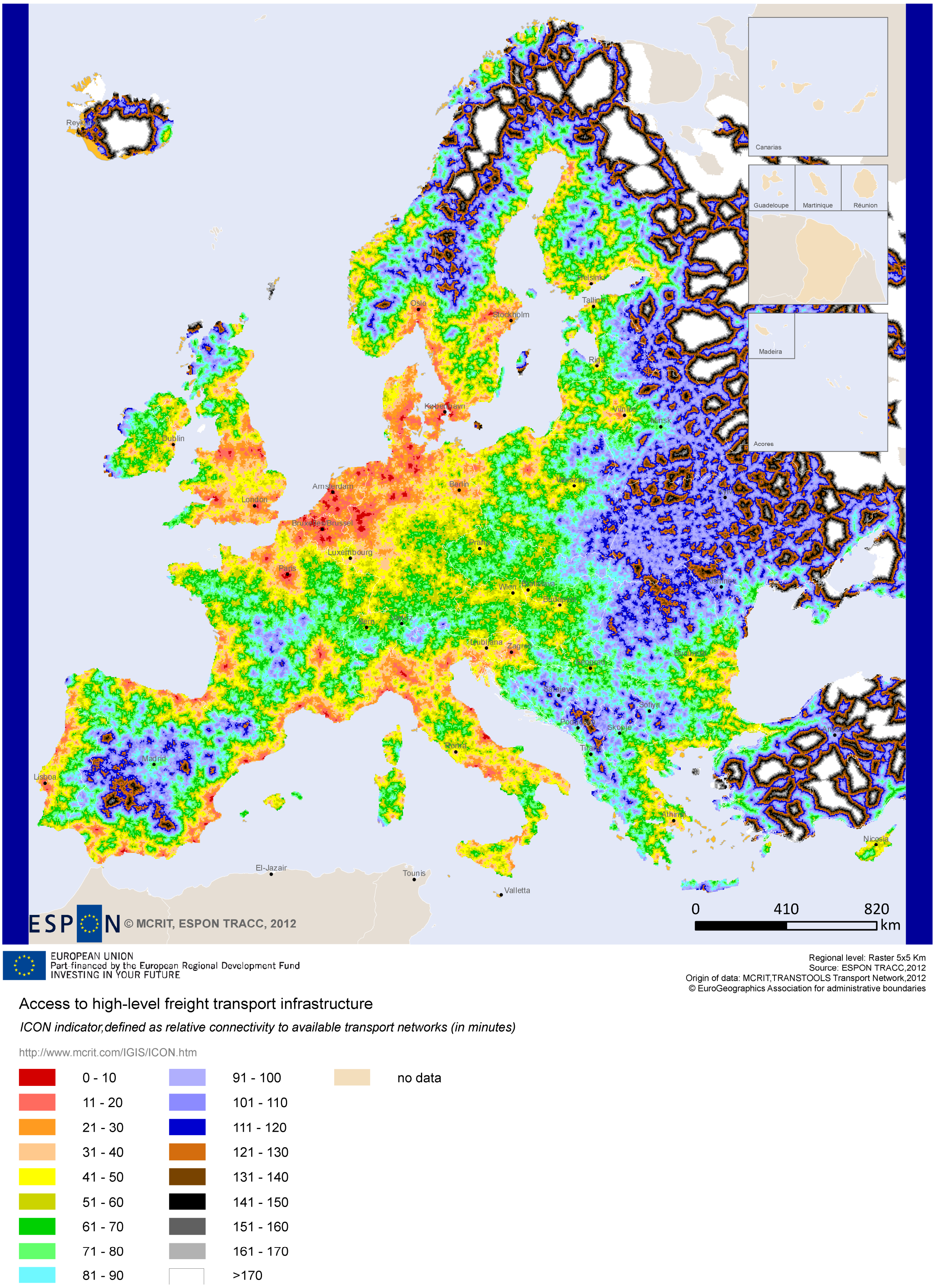
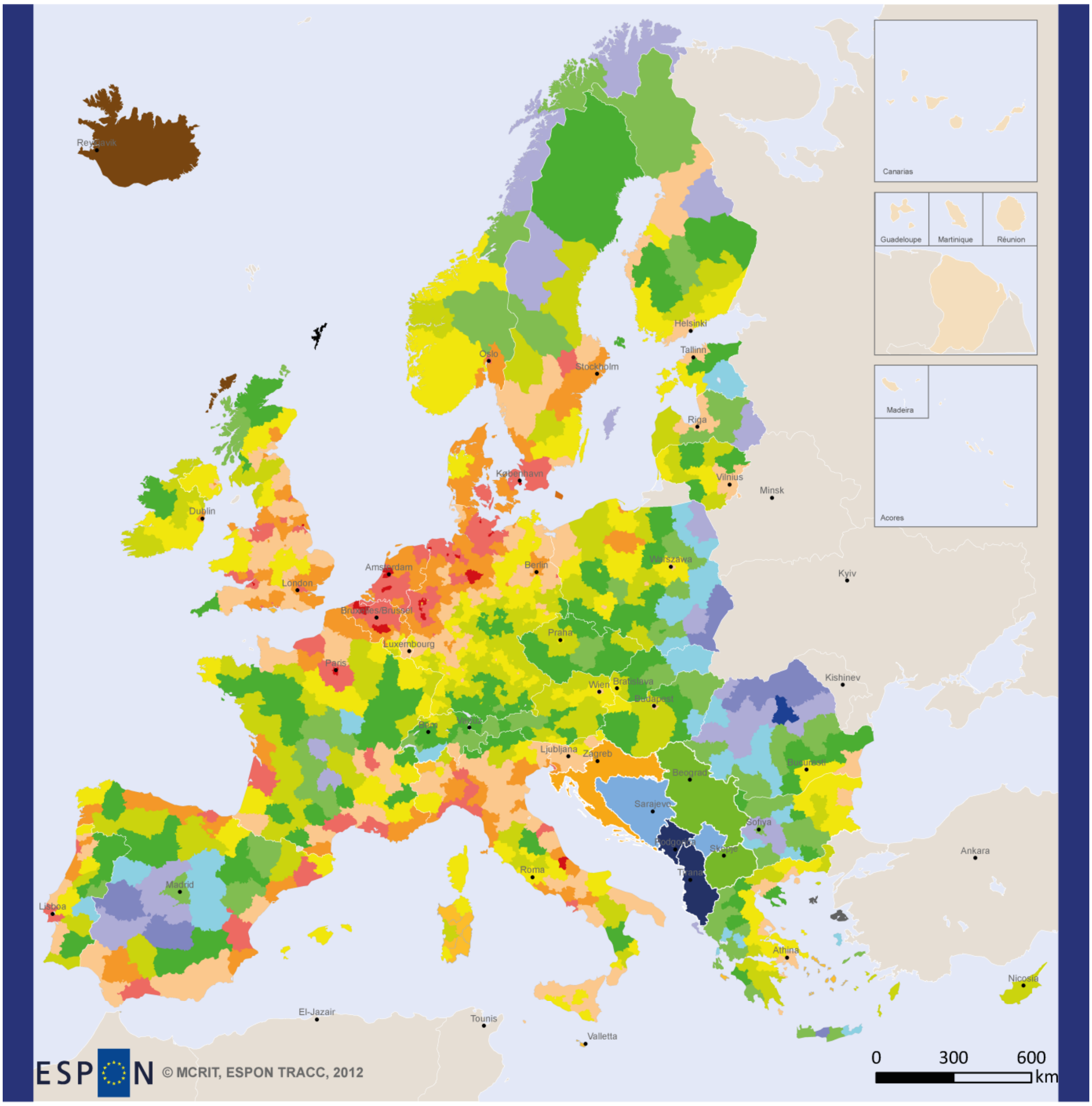


Figure 8.3. Access to high-level freight transport infrastructure by 5x5 grid cells



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Regional level: Nuts 3
Source: ESPON TRACC,2012
Origin of data: MCRIT,TRANSTOOLS Transport Network,2012
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Access to high-level freight transport infrastructure
(average NUTS3 level based on population spatial distribution)

ICON indicator,defined as relative connectivity to available transport networks (in minutes)
http://www.mcrit.com/IGIS/ICON.htm

- 0 - 10
- 11 - 20
- 21 - 30
- 31 - 40
- 41 - 50
- 51 - 60
- 61 - 70
- 71 - 80
- 81 - 90
- 91 - 100
- 101 - 110
- 111 - 120
- 121 - 130
- 131 - 140
- 141 - 150
- 151 - 160
- 161 - 170
- 171 - 180
- no data

Figure 8.4. Access to high-level freight transport infrastructure by NUTS-3 region

50% of European population resides within 18 minutes or less (on average) of high-level passenger transport infrastructure (Figure 8.5). This population is comprised in 16% of the European territory.

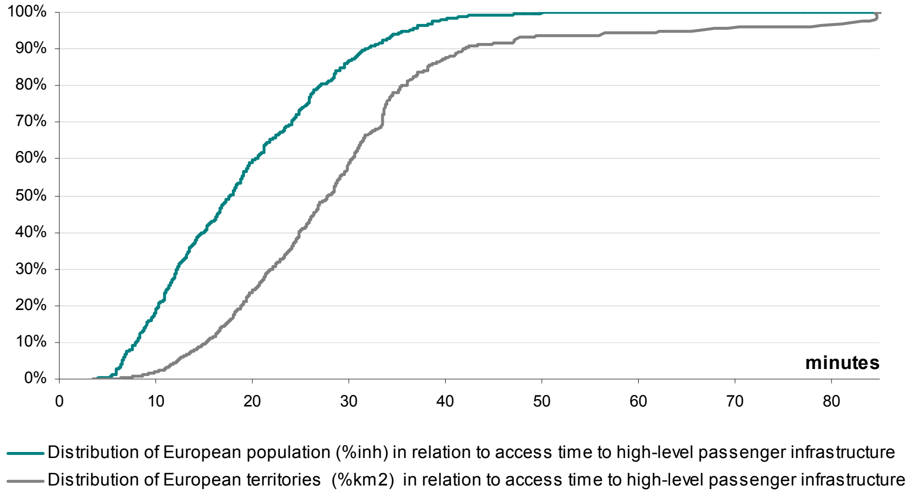


Figure 8.5. Access to high-level passenger transport infrastructure by population and territory

50% of European population resides within 40 minutes or less (on average) of high-level freight transport infrastructure (Figure 8.6). This population is comprised in 22% of the European territory

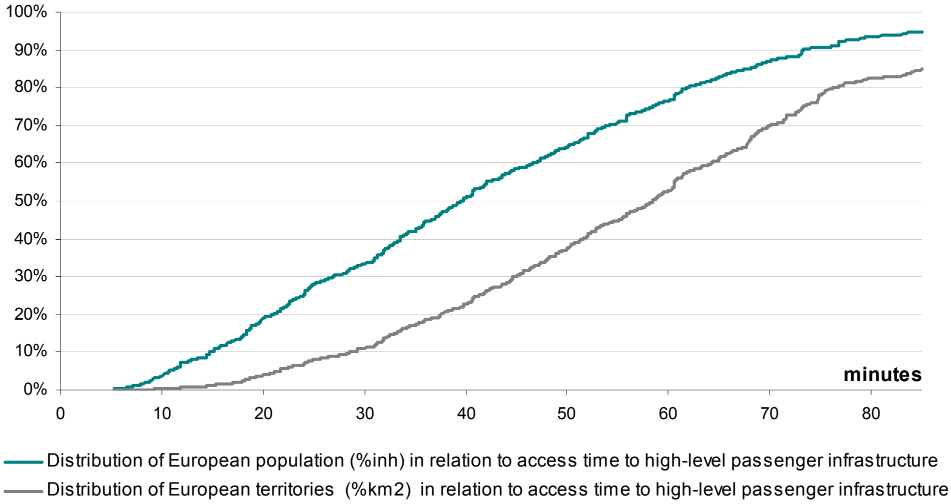


Figure 8.6. Access to high-level freight transport infrastructure by population and territory

8.2 Availability of urban functions and freight terminals

Access to and availability of public and private services and functions provided in urban nodes is crucial for daily life of citizens. If such functions are not offered in small towns and villages, or in the countryside, people require easy access to them in nearby cities. The higher the number of cities is that can be reached from a given location in reasonable time, the greater the opportunities are provided for economic and social activities and for general interactions.

This indicator looks at the number of regional cities that can be reached from any location within 60 minute travel time. The higher the number of such regional cities is, the higher the accessibility and thus the higher the attractiveness of a location is. Cities with at least 50,000 inhabitants are selected as destinations, assuming that only cities of that minimum size provide a full basket of public and private services and functions.

For both road and rail (Figures 8.7 and 8.8), this indicator highlights the agglomerated areas in Europe. Accessibility is highest in the Ruhr area, England, Paris, in the Benelux countries and in Northern Italy. Some capital city regions in other countries (for instance, Stockholm, Madrid, Budapest or Athens) also stand out, so as other selected regions such as Oslo-Gothenburg-Malmö-Copenhagen, Barcelona-Valencia-Murcia, Lyon, Saxony, Naples, Upper Silesia with city systems.

From most locations in Western and Central Europe, at least one regional city can be reached by road within 60 minutes, from many places even more than ten. In Eastern Europe, mostly only one or two cities are within reach. Locations from where only one city can be reached provide basic urban services. Usually, people from there do not have any option to go to one or the other cities to enjoy certain facilities, but they are bound to just one closest city. Locations from where more than one city can be reached, offer options to visit different cities offering a wider range of services, i.e. these locations provide more freedom of choice and thus more opportunities.

The raster results furthermore clearly highlight those regions in Europe that do not have access to urban functions at all in reasonable time. Interestingly, such areas are not only located in the far North (Northern peripheral sparsely populated areas) or in the Alpine space, as expected, but they also cover so-called 'inner peripheries' which for road (Figure 8.7) can be found basically in all European countries. Prominent examples of these are Mecklenburg-Vorpommern (Germany), many parts in France or Spain, or areas in Poland or Czech Republic. For rail (Figure 8.8) the extent of these areas is even bigger in almost all countries. In consequence, while the road indicator tends to form seamless coverages at raster level (Figure 8.7), for rail the major railway axes become clearly visible (Figure 8.8).

The aggregated maps at NUTS-3 level (see Figures 4.4 and 4.6 of Volume 4 of the TRACC Final Report) basically show the same results. The high availability of urban functions in the well-known agglomerations is visually even more pronounced in this map type. In the contrary, the rather poor availability in many East European regions becomes also more evident, i.e. for many NUTS-3 regions on average only one urban centre can be reached within 60 minutes travel time – for both road and rail. Interestingly, even at NUTS-3 level, although to some degree levelled out compared to the raster maps, some inner peripheries persist: For road NUTS-3 regions in Norway, Finland, but also at the Balkans lack access to urban functions. For rail additional regions in Spain, Portugal, Austria, Croatia, Latvia or Lithuania do not have access to regional cities.

As by intention this indicator was defined in a way to look at regional cities (and not just major agglomerations) which offer daily and medium-term public and private services to the people, a lack of access to such cities even at NUTS-3 level should be alarming, as the supply of important public and private services may not be guaranteed, forcing people to accept long travel times if they want to enjoy or if they need certain types of services.

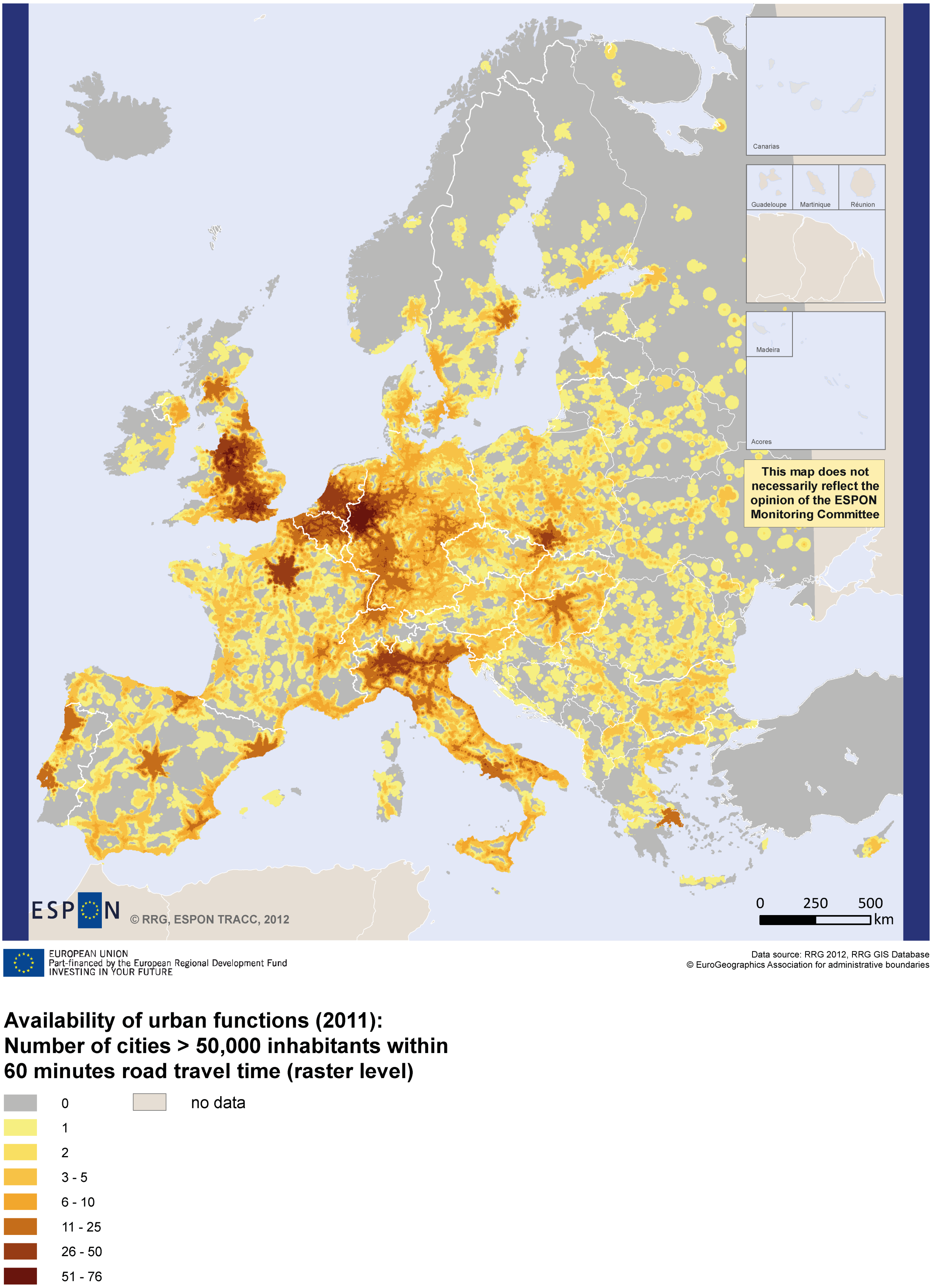


Figure 8.7. Availability of urban functions, road

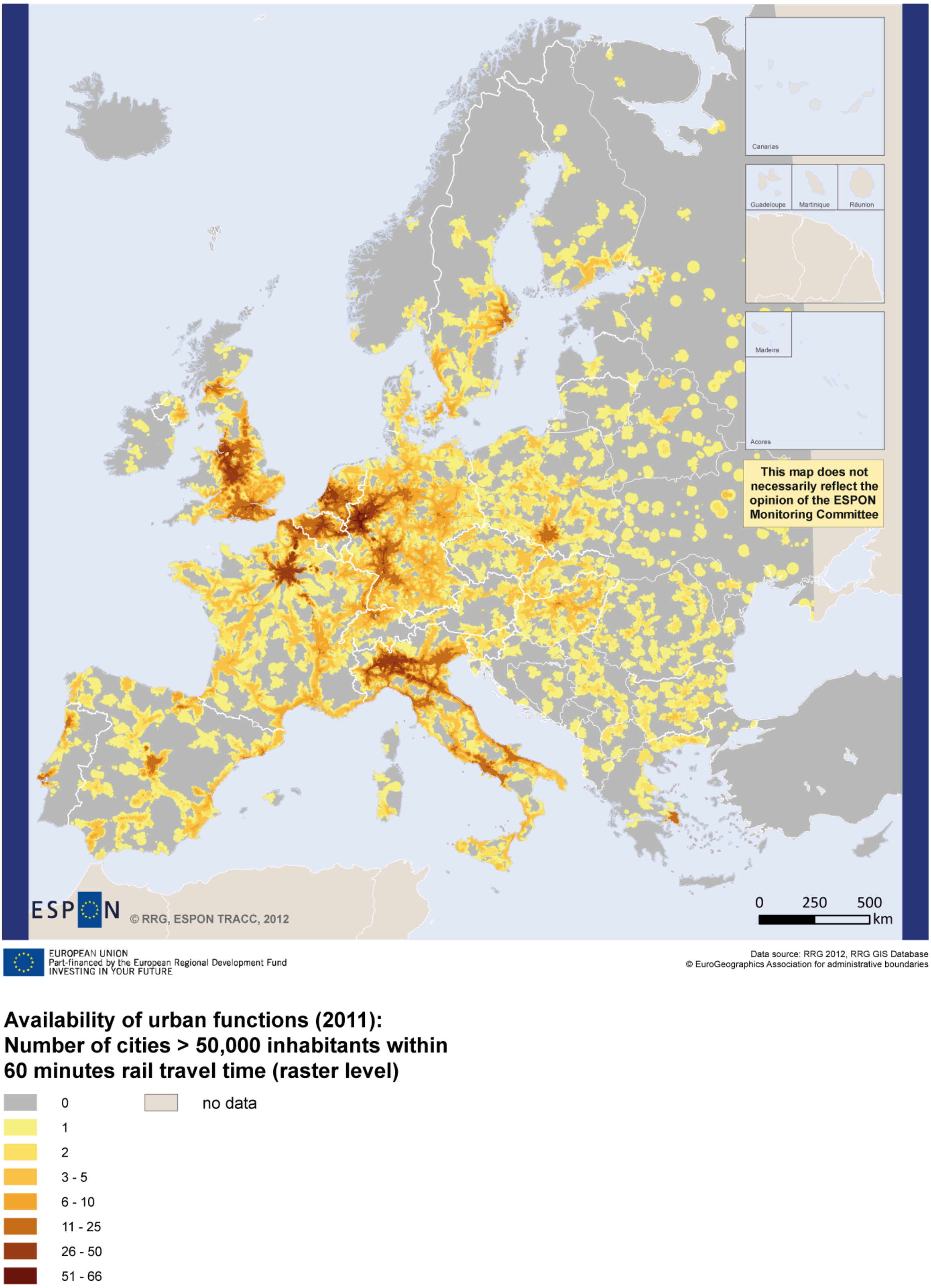


Figure 8.8. Availability of urban functions, rail

What amount of options do have regions with respect to freight logistic centres? By looking at road transport, it is assessed which number of freight terminals can be reached within a lorry travel time of two hours maximum. A wider definition of freight terminals is used, including all transhipment points from one cargo mode to another. Thus, freight terminals used for this indicator comprise cargo seaports and cargo inland ports, airports with cargo turnover, freight villages, and specific road-rail interchange terminals.

Freight terminals are not only important employers, but all the more they act as gateways for the local and regional economy to market their products national, European or worldwide, and to obtain fabricated materials from world markets for producing their own products. Successful freight terminals are thus considered as triggers for the regional economy.

The range of numbers of freight terminals throughout Europe is quite significant. While many areas have access to one or two terminals (mainly coastal areas), most accessible areas in Europe have access to more than 120 freight terminals within 120 minutes travel time (Figure 8.9). The latter ones are concentrated in the Benelux countries, Rhine-Ruhr area and Rhine-Main area in Germany, as well as in Northern Italy (Torino). Other important logistic regions are the Greater Stockholm area, the area between Turku and Helsinki, the coastal area between Oslo and Copenhagen, Greater Paris area, and the Midlands area in England (Liverpool, Manchester, and Sheffield).

Furthermore, main inland waterway axes such as Rhine, Danube and Elbe river corridors, and the canal systems in North Germany including main seaports of Bremerhaven and Hamburg, and the further canal system in East Germany all the way to Odra river, also provide high accessibilities for the regions due to its dense network of inland ports.

In contrary, there are also large territories that do not have access at all to any freight terminal. Such areas are mainly sparsely populated, landlocked hinterland regions in Scandinavia, France, Portugal and Spain as well as the Balkans. Aggregates at NUTS-3 level (Figure 8.10) hide these inner peripheries, as they are levelled out through averaging.

Results of this indicator confirm the expectation that the Benelux countries and West Germany are the main logistic turntables in Europe. Interestingly, with some exceptions the correlation of this indicator with potential population indicator is significant, supporting the assumption that logistic activities follow population concentrations.

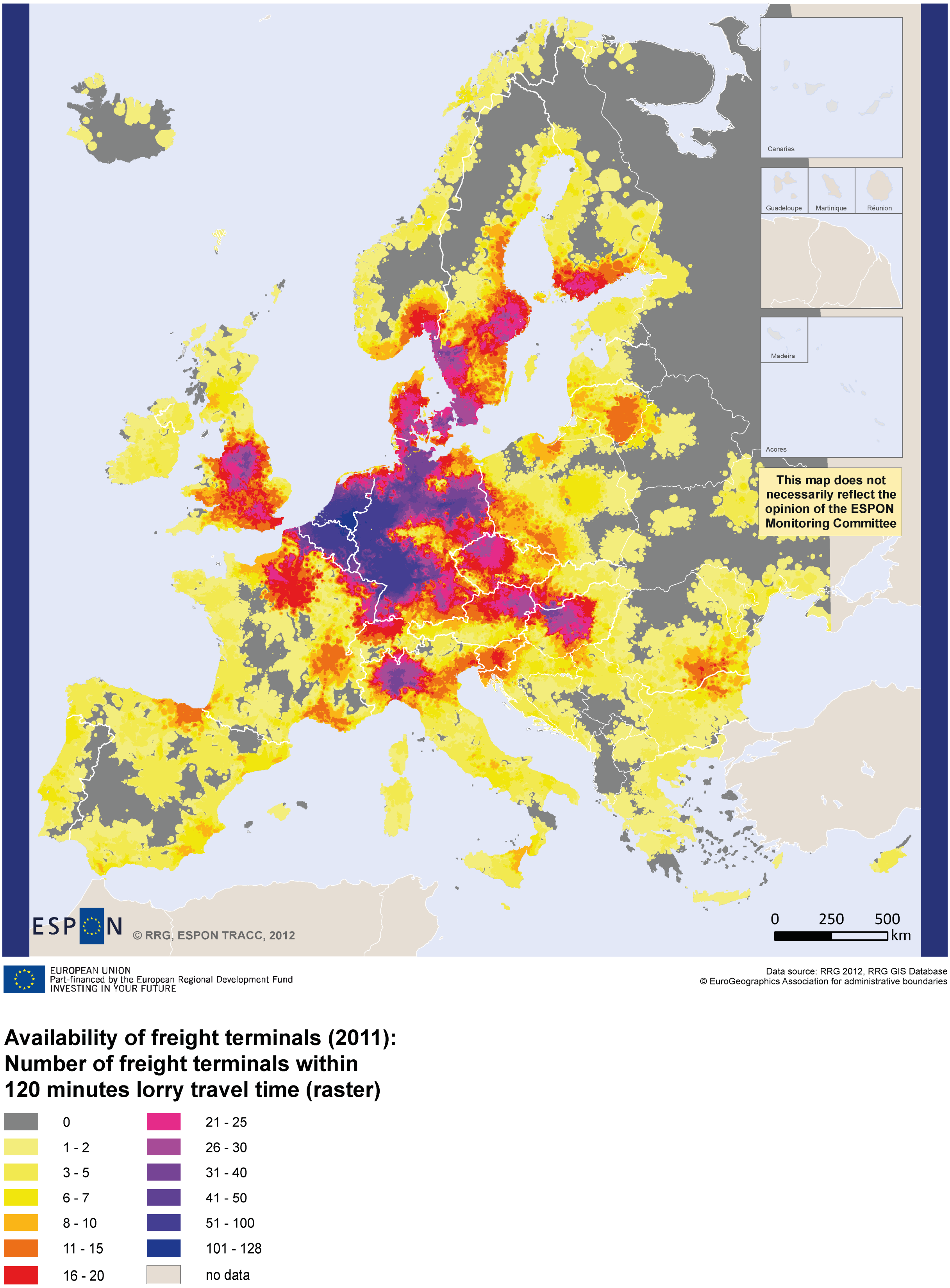
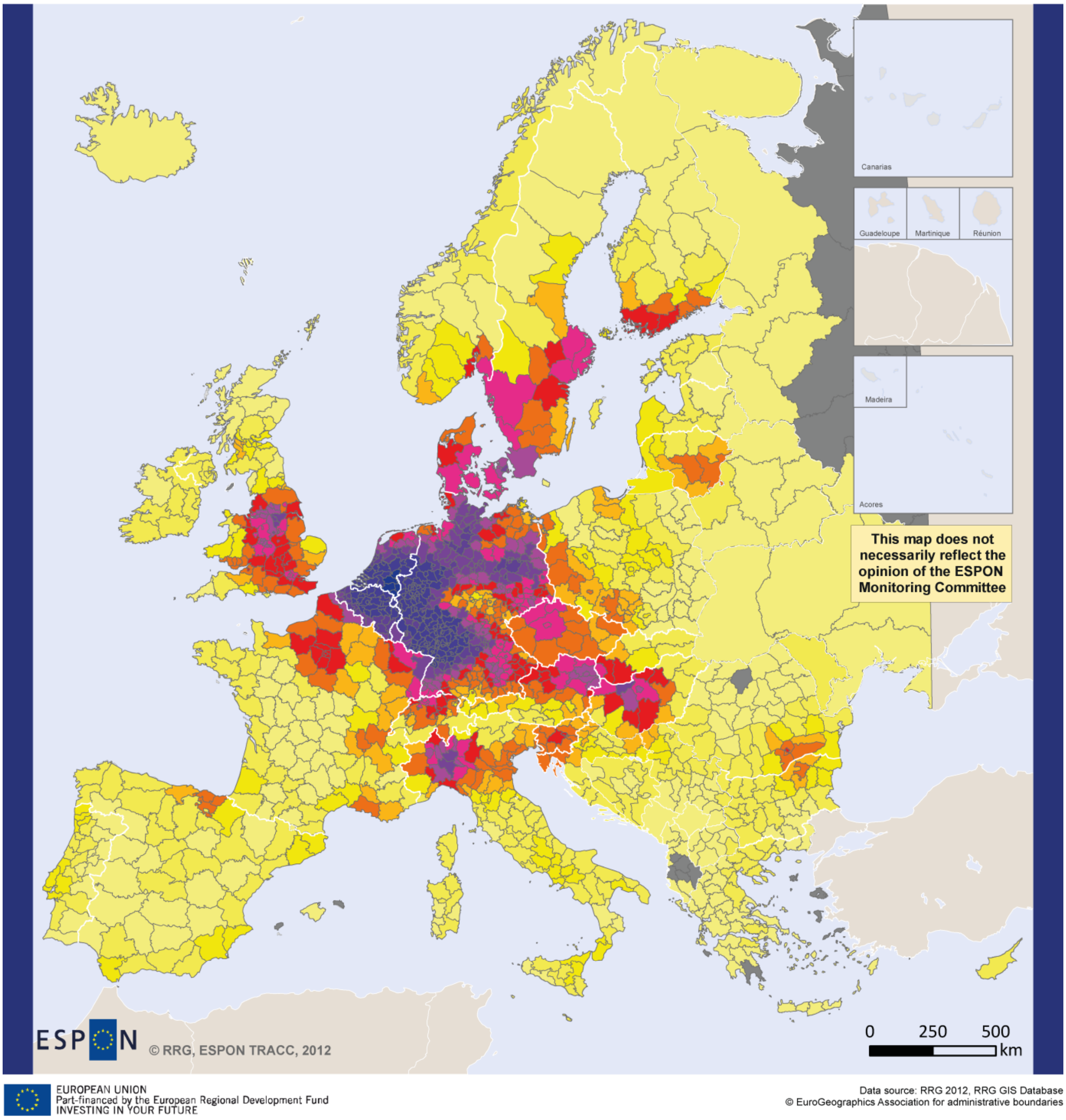


Figure 8.9. Availability of freight terminals, lorry, grid



Availability of freight terminals (2011):
Number of freight terminals within
120 minutes lorry travel time (NUTS-3 level)

0	21 - 25
1 - 2	26 - 30
3 - 5	31 - 40
6 - 7	41 - 50
8 - 10	51 - 100
11 - 15	101 - 128
16 - 20	no data

Note:
Indicator calculated based upon 2.5x2.5 rastrer grid. Raster results aggregated to NUTS-3 level as average numbers.

Figure 8.10. Availability of freight terminals, lorry, NUTS-3

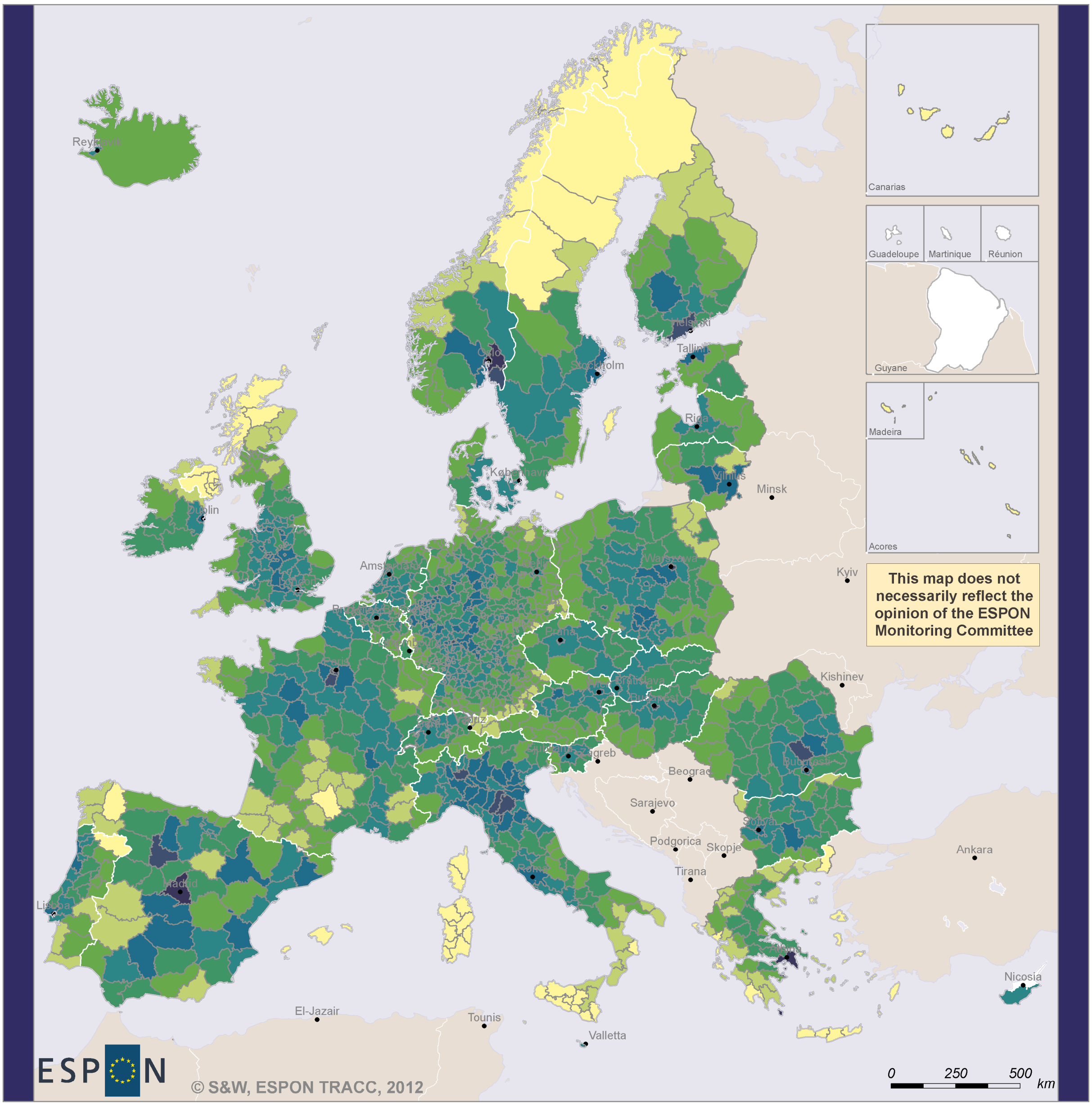
8.3 National Potential Accessibility

National Potential Accessibility for a specific NUTS-3 region is a construct of attractiveness of all other NUTS-3 regions in the country and generalised costs needed to reach these regions from the origin region. As the analysis is performed on a strict national basis, country borders are forced impermeable so foreign NUTS-3 regions become inaccessible from another country. In doing so, this indicator allows identifying a ranking of the regions within each country according to their proximity to the higher levels of national economic activity. Regions with a high potential accessibility have more opportunities to arrange a spatially distributed value chain in the domestic economy, have more alternatives in terms of national supply and demand market and so on.

Figure 8.11 shows the spatial pattern of national potential accessibility using rail as illustrative example. Each country has its highly accessible areas and its own peripheral areas. However, the pattern differs across Europe. Most of the countries in eastern and northern Europe have a clear core periphery pattern in which mostly the capital region performs best and the border regions have lowest accessibility. In other countries, there are larger corridors of higher accessibility; a consequence of a more polycentric distribution of population and network design or a consequence of the effects of high-speed rail services. In some countries such as Italy or Germany, highest accessibility is not to be found in the capital regions but around other important agglomerations. In some countries such as Poland or the Czech Republic areas that are located closer to the European core and thus have a fairly good European rail accessibility are rather peripheral when considering the national context.

For freight transport, the spatial pattern of national potential accessibility shows very clearly the position of the economic heart of each country (Figure 8.12). This indicator accounts for the amount of economic activity (i.e. GDP) accessible within each national market using only freight transport networks. This heart corresponds to the capital region in most countries, but there are remarkable exceptions like Germany – where the highest potential accessibility is in the western part – or Italy – where the highest potential accessibility belongs to the northern regions.

The differences in national freight accessibility between regions of a country vary a lot across Europe (Figure 8.13). The average level of GDP per capita does not seem correlated to the variability. Instead, smaller differences are found especially in smaller countries closer to central Europe –e.g. Germany, Netherlands, Switzerland, Lithuania – while larger differences show up mainly in bigger peripheral countries – Norway, Turkey, Finland. There are some exceptions. Iceland is an exception as it is the most peripheral but also the most homogenous country (but it includes just two NUTS 3 regions). Latvia and Croatia are exceptions, being small countries but with significant variability.



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Regional level: NUTS-3
Source: RRG GIS Database
S&W Flight Network
Origin of data: S&W Accessibility model, 2012
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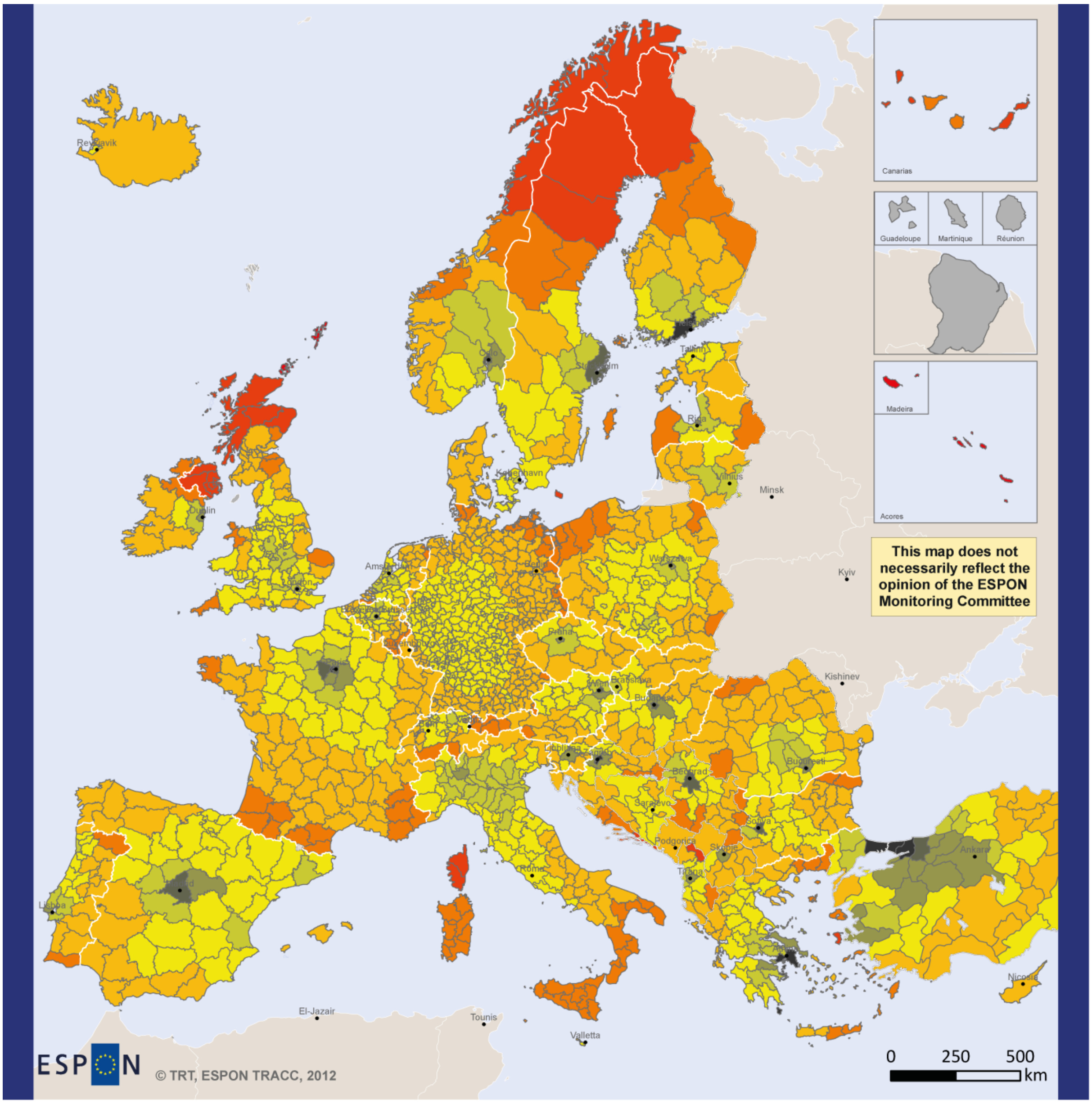
National potential accessibilty, rail (ESPON = 100)

- **0 - 40**
- **41 - 60**
- **61 - 80**
- **81 - 100**
- **101 - 120**
- **121 - 140**
- **141 - 160**
- **161 - 187**
- **no data**

Figure 8.11. National potential accessibility, travel by rail to population



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Source: TRUST Accessibility Model (TRT 2012), Road Network: TransTools (2005), GDP regional data (ESPON data 2005/2006, TransTools data 2005, Statistical Offices data)
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National potential accessibility freight (2011):
Accessibility potential to National GDP by road
(percentage of average accessibility by road of all areas of the same country)

- 0 - 25.0
- 25.1 - 50.0
- 50.1 - 75.0
- 75.1 - 100.0
- 100.1 - 125.0
- 125.1 - 150.0
- 150.1 - 175.0
- 175.1 - 200.0
- 200.1 < ...
- n.a.

• *Capital cities*

Figure 8.12. National potential accessibility by road freight to GDP

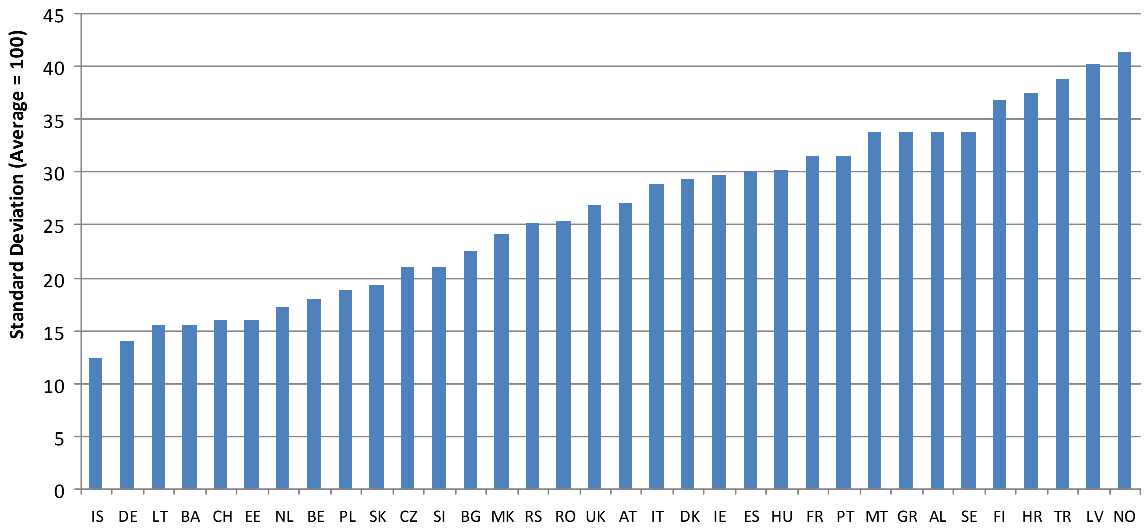


Figure 8.13. Variation of national potential accessibility freight

Conclusions

Territorial Connectivity: regional accessibility to European long-distance transport networks

As transportation networks influence location decisions and induce spatial development, the measure of generalised time access to transport networks (or connectivity) is relevant to measure the opportunities that regions are granted in terms of attracting population and economic activity and in providing fast access to its citizens and businesses to European and Global transport networks.

In relation to passenger transport, core areas in Europe have better access to high-level transport infrastructure than peripheral regions, as they tend to have denser motorway networks, good rail networks and concentrate most air hubs. This implies that citizens in core regions are more likely to seamlessly travel in Europe or easily access global transport gateways (higher availability of transport services, of direct point to point connections to other European cities, and shorter trip legs on local and regional road and rail networks). Outside the Core, national capitals (e.g. Warsaw, Madrid, Helsinki) and reference touristy regions (e.g the Spanish Mediterranean coast and islands, Naples) provide areas of increased regional connectivity.

In relation to freight transport, best connectivity is recorded in the Atlantic rim between the Benelux and Germany due to the presence of largest container ports in Europe, in addition to denser motorway and freight village networks. The Mediterranean rim has large container ports as well, even if well behind Northern European ones, but less dense motorway and freight village networks in their hinterlands limit high connectivity scores only to coastal fringes, to a large extent. As Mediterranean ports are better positioned in the international shipping routes to Asia, should expansions of capacity be undertaken in these ports as planned and better connections provided with the European hinterland, overall connectivity of the Mediterranean rim could increase sensibly in the future.

Availability of urban and freight (regional cities and freight terminals)

Access to and availability of public and private services and functions provided in urban centres is crucial for daily life of citizens. Freight terminals act as gateways for local and regional economies to market their products national, European or worldwide, and to obtain fabricated materials from world markets for producing their own products. Successful freight terminals may be considered as triggers for the regional economy.

The overall pattern of availability of urban functions is similar to that of passenger connectivity discussed above. Capacity of reaching large numbers of regional centres within limited travel time (cities lager than 50.000 inhabitants accessed in up to 60 minutes) is once again highest in the Core of Europe, in selected capital city regions in other countries, and in other prominent regions such as south-western Scandinavia (Oslo-Gothenburg-Copenhagen), the Spanish Mediterranean corridor (Murcia to Barcelona), the Rhone valley, Saxony, Southern Italy, and Upper Silesia city district

From most locations in Europe, at least one regional centre can be reached in less than 60 minutes travel time, but only people in western Europe have options to visit more than five different cities in that time. Inner peripheries with low accessibility values are not only located in the far North or in the Alpine space, as expected, but also in most European countries. The extent of these inner peripheries is substantially larger for rail than for car.

The range of numbers of freight terminals throughout Europe is quite significant. Again, the overall pattern is similar to that of freight connectivity discussed before, but northern Europe performs substantially better in this indicator than Southern Europe, due to the lack of freight terminals besides maritime ports in the later. With some exceptions, the correlation of this indicator with potential population indicator is also significant, supporting the assumption that logistic activities follow population concentrations. Main inland waterway axes (Rhine, Danube, Elbe) and the canal systems in Germany provide high accessibilities for the regions due to its dense network of inland ports.

National Potential Accessibilities

As the analysis is performed on a strict national basis for this set of indicators, country borders are forced impermeable so foreign NUTS-3 regions become inaccessible from another country. This indicator offers a much contrasted picture in relation to all previous indicators, where opportunities in Europe where accessible from any territory regardless of the country they belong.

The most significant finding in relation to the set of travel and freight national potential accessibilities is the large amount of regions that are likely to loose out substantially when they are restricted to access only national activities. This is especially important in regions such as Western Poland (at the German Border), North-eastern Germany (Danish and Polish borders), Southern Germany (Swiss, Austrian and Czech borders), Eastern France (German and Italian borders) and Southern France (Spanish borders).

This exercise, despite being fictitious up to a certain extent, reflects the potential opportunities lost from decreased or even from insufficient European integration (often due to cultural, social and even language issues). For instance, lack of integration in health and educational systems around Europe may force citizens in border regions to travel more (e.g. to national capitals) for certain higher education options or for complex health treatments that would otherwise do if integration was greater. Language obstacles may force citizens to move further within their countries for better job opportunities than would otherwise do if labour markets were more integrated and language barriers were lower. Seen it the other way round, border regions are largely benefitting in terms of accessibility of the diminishing importance of those borders and the gain in opportunities available to their citizens.

9 Accessibility to regional and local destinations

Global and European accessibility are important location factors for firms and working and leisure travel of people. However, for the daily life of citizens, regional/local accessibility to jobs, services and public facilities may be more important than global or European accessibility. One part of the TRACC project was therefore concerned with regional accessibility in a set of regional/local case studies in order to gain systematic knowledge on accessibility patterns in different types of regions throughout Europe.

One of the technical objectives for the regional case studies was to implement the methodologies as similar as possible in order to allow a comparison of the resulting accessibility patterns not disturbed by artefacts induced by methodological differences. In each case study, the set of regional accessibility indicators as defined in the TRACC set of accessibility indicators was implemented, calculated and analysed in a highly comparable way. Case studies are presented in detail in Volume 3 of the TRACC Final Report. This chapter provides summaries of the main findings.

Accessibility indicators for case study analysis

The common accessibility indicators for case study analysis can be grouped in two sets of accessibility indicators for travel. The first set follows the traditional set of accessibility indicators calculated at the European level. All indicators are calculated for municipalities, i.e. at the LAU-2 level. However, in same case studies the calculation was done first for smaller raster cells and then also aggregated to LAU-2:

- *Access to regional centres*. How distant or how far away is the nearest regional centre? Proximity to an urban centre has often been used as a proxy for accessibility to jobs and different services such as higher education, health care or commerce. The access to regional centre indicator is defined as minimum travel times by road and public transport to the nearest urban centre.
- *Daily accessibility of jobs*. How many jobs can be reached from the places of residence? This indicator approaches the opportunities of the regional labour market from the point of view of the population. The indicator is defined as the number of jobs reachable within a maximum commuting distance of 60 minutes by car and by public transport.
- *Regional potential accessibility.* What is the regional potential accessibility of a municipality using population as activity of interest? Such a population potential is useful to evaluate the different locations within a region from the viewpoint of economic actors, e.g. firms assessing the regional labour market, or retail industries assessing the market area. As for the other spatial levels the regional potential accessibility to population is defined as the sum of people in all destination areas weighted by the travel times to go there. Modes considered are road and public transport.

The second set of indicators for the regional case studies considers destinations of specific relevance for daily life, namely services of general interest:

- *Access to health care facilities*. What is the travel time to go to the nearest hospital? Travel times for each municipality or raster cells by road and by public transport are able to show the spatial diversity in access to this important health care facility.
- *Availability of higher secondary schools*. Are higher secondary schools offering degrees to access a university available within reasonable travel time? Is there even a freedom of choice to select between different options? The indicator is defined as the number of higher secondary schools that can be reached within 30 minutes.

- *Potential accessibility to basic health care.* What is the locational quality with respect to basic health care? Using medical doctors as destination activity in a potential accessibility indicator allows to assess the relative distribution of health care provision of different areas within the case study region. The indicator is defined as sum of medical doctors located in the case study region weighted by travel times by road and public transport.

Case study regions

The TRACC project aimed at an exploratory analysis of regional accessibility patterns across Europe. To do so, three considerations have guided the selection of the regional case studies.

- The case study areas for regional accessibility modelling in TRACC should cover a wide range of different types of regions in different parts of Europe. This asks either for a relative large number of case study regions or for relatively large case study areas that incorporate different types of regions.
- The comparison of regional/local accessibility patterns in different parts of Europe would be difficult if case study regions would be limited to one or very few NUTS-3 regions. These could be analysed in an isolated manner only without having information on regional accessibility in the surrounding regions. Therefore, case study areas should be larger in size.
- There are data constraints which are mainly related to network data. It is currently impossible to set up a harmonised network database for Europe, in particular for public transport, with the level of detail from which subsets could be extracted for regional case studies. Consequently, regional case studies have to be developed from existing regional network databases.

Based on these considerations the TRACC project has developed a specific concept for the case study regions. Each regional case study in TRACC consists of two integrated spatial levels, the total case study and a set of zoom-in areas.

- The regional case study area is usually defined at NUTS-0 or NUTS-1 level, i.e. contains a large number of NUTS-3 regions of different types.
- A number of zoom-in areas usually defined at NUTS-3 level should represent different types of regions within each case study region.

The regional accessibility models of the case studies were requested to be set up in a way that they are able to calculate the accessibility indicators at least for LAU-2 regions, if possible for smaller raster cells. This allows on the one hand to analyse accessibility pattern for the wider area of the macro region with different types of regions and on the other hand more in-depth analyses for specific types of regions by looking into the zoom-in areas.

In order to implement this spatial concept for the regional case studies, a pragmatic component had to be part of the case study selection process. Only those areas could be selected as case studies for which project partners had already a fairly good database for accessibility modelling. Figure 9.1 shows the seven TRACC case study regions selected: West Mediterranean in Spain and France, Northern Italy, Bavaria in Germany, the Czech Republic, Poland, the Baltic States and Finland. Together, they form an arc stretching from the Mediterranean Sea in south-western Europe up to the far north of the Nordic countries.

Figure 9.1. TRACC regional case studies

The case study regions selected forming almost a continuous arc across Europe offer the possibility of an additional contrast of results along neighbouring case study regions. Transitions from one case study region to the next are to be expected relatively smooth because of the role of common geographies and socio-cultural and historical linkages. Such a cross-section of Europe allows a continuous analysis from south to north:

- The West Mediterranean region and seaside Northern Italy are coastal corridor regions fringed by mountainous back areas in the Mediterranean framework.
- Northern Italy and Bavaria are densely populated regions located in flatlands topped by major mountain ranges, in this case the Alps.
- Bavaria, Czech Republic and Poland are part of the Central European plain, characterised by polycentric city structures.

- Czech Republic, Poland and the Baltic States, like many other new EU member states, have infrastructure deficits under way of amendment.
- Poland, the Baltic States and Finland form the south-eastern fringe of the Baltic Sea region.
- The Baltic States and Finland are peripheral regions with low density figures and conditioned by rigorous climates.

The case study regions cover a wide range of different types of regions in different parts of Europe. They cover both core and peripheral areas, inland, coastal and insular territories, urban and rural territories, densely populated and sparsely populated areas, flat and mountainous territories, territories located both in the old EU15 countries and in the new EU member states. Contrasting the case study regions with the nine standard ESPON territorial typologies, urban-rural, metropolitan regions, border regions, island regions, sparsely populated regions, outermost regions, mountainous regions, coastal regions, regions and regions in industrial transition, yields that the 275 NUTS-3 regions of the case study regions have almost for each regional typology the same share of regions of each type of region as the whole ESPON space (Table 9.1):

- In the case studies, there are slightly more rural regions and little less urban regions than in the ESPON average. Northern Italy and Poland are those case study regions with the highest share of urbanised regions; the Western Mediterranean, Northern Italy, Bavaria and the Czech Republic have above-average shares of intermediate regions close to a city.
- The classification of the case study NUTS-3 regions in terms of metropolitanisation is very close to the overall ESPON average. Twelve percent of the NUTS-3 regions are small metropolitan, six percent are medium size metropolitan and 20 percent are big metropolitan regions.
- Also with respect to border regions, the case study regions with half of the regions classified as border regions closely follow the ESPON average.
- The share of island regions is slightly lower for the case studies than for the ESPON average. The EURAM and Finland case study have islands included.
- With the inclusion of Finland as case study, the share of sparsely populated regions of the case studies is almost two percent and such equals the ESPON space average.
- The share of mountainous regions is slightly lower for the case study regions than for the ESPON space. Northern Italy and Poland have the highest shares of regions falling in one of the mountainous categories.
- The share of coastal regions is slightly higher for the case study regions. Highest shares are in the Western Mediterranean region, the Baltic States and Finland, whereas Bavaria and the Czech Republic do not have coastal regions at all.
- The share of regions in industrial transition is slightly higher for the case study regions than for the ESPON average.

Within each case study region, between three and six zoom-in areas have been defined. The selection results in a good distribution of in total 30 zoom-in areas over different types of regions ensuring the in-depth analysis of different kinds of territorial typologies with different accessibility patterns associated.

One aspect of the analysis of the results for the case study regions is to look at the accessibility performance of different types of regions of the urban-rural typology. As this typology is defined at NUTS-3 level and the case study analyses are performed at LAU-2 level, a matching of municipalities to regional types was necessary. This allocation was simply done by seeing all LAU-2 areas of a certain NUTS-3 region as of the same type as the NUTS-3 region, i.e. no further differentiation within the NUTS-3 region was done.

Table 9.1. Case study regions and ESPON regional typologies

ESPON Typology of region	West Mediter-ranean	Northern Italy	Bavaria	Czech Republic	Poland	Baltic States	Finland	**All case studies**	**ESPON Space**
NUTS-3 regions (total number)	11*	46	96	14	66	22	20	**275**	**1351**
Urban-rural regions *(% of NUTS-3 regions)*									
1 Predominantly urban	18,2	23,9	9,4	14,3	24,2	13,6	5,0	**16,0**	**23,2**
21 Intermediate, close to a city	54,5	45,7	43,8	42,9	33,3	22,7	20,0	**38,5**	**36,7**
22 Intermediate, remote	9,1	4,3	0,0	0,0	0,0	4,5	10,0	**2,2**	**1,6**
31 Predominantly rural, close to a city	9,1	23,9	44,8	42,9	37,9	31,8	30,0	**36,0**	**26,1**
32 Predominantly rural, remote	9,1	2,2	2,1	0,0	4,5	27,3	35,0	**7,3**	**12,4**
Metropolitan regions *(% of NUTS-3 regions)*									
1 Small metropolitan	18,2	10,9	10,4	7,1	16,7	9,1	10,0	**12,0**	**12,4**
2 Medium size metropolitan	0,0	10,9	3,1	7,1	7,6	9,1	0,0	**5,8**	**7,6**
3 Big metropolitan	18,2	19,6	20,8	21,4	28,8	9,1	10,0	**20,7**	**17,4**
0 Not a metropolitan region	63,6	58,7	65,6	64,3	47,0	72,7	80,0	**61,5**	**62,6**
Border regions *(% of NUTS-3 regions)*									
1 In eligible border program	27,3	58,7	27,1	92,9	65,2	86,4	50,0	**51,3**	**42,7**
0 Not in eligible border program	72,7	41,3	72,9	7,1	34,8	13,6	50,0	**48,7**	**57,3**
Island regions *(% of NUTS-3 regions)*									
1 Major island < 50 000 inhabitants	0,0	0,0	0,0	0,0	0,0	0,0	5,0	**0,4**	**0,9**
2 Major island between 50 000 – 100 000	9,1	0,0	0,0	0,0	0,0	0,0	0,0	**0,4**	**0,4**
3 Major island between 100 000 – 250 000	9,1	0,0	0,0	0,0	0,0	0,0	0,0	**0,4**	**0,5**
4 Island with 250 000 – 1 mill inhabs	9,1	0,0	0,0	0,0	0,0	0,0	0,0	**0,4**	**1,2**
5 Island with >= 1 mill	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**0,0**	**2,2**
0 Not an island region	72,7	100,0	100,0	100,0	100,0	100,0	95,0	**98,5**	**94,7**
Sparsely populated regions ***(% of NUTS-3 regions)***									
1 Sparsely populated	0,0	0,0	0,0	0,0	0,0	0,0	25,0	**1,8**	**2,0**
0 Not sparsely populated	100,0	100,0	100,0	100,0	100,0	100,0	75,0	**98,2**	**98,0**
Mountainous regions *(% of NUTS-3 regions)*									
1 Predominantly mountainous, remote	0,0	6,5	2,1	0,0	0,0	0,0	0,0	**1,8**	**6,5**
2 Predom. mountainous under urban influence	9,1	23,9	9,4	21,4	4,5	0,0	0,0	**9,8**	**13,7**
3 Moderately mountainous, remote	27,3	0,0	0,0	0,0	1,5	0,0	0,0	**1,5**	**1,9**
4 Moderat. mountainous under urban influence	0,0	10,9	10,4	21,4	1,5	0,0	0,0	**6,9**	**8,6**
0 Areas not covered by classification	63,6	58,7	78,1	57,1	92,4	100,0	100,0	**80,0**	**69,3**
Coastal regions *(% of NUTS-3 regions)*									
1 Coastal with low share of coastal population	0,0	10,9	0,0	0,0	3,0	9,1	10,0	**4,0**	**4,2**
2 Coastal with medium share of coastal pop.	9,1	4,3	0,0	0,0	3,0	9,1	0,0	**2,5**	**4,2**
3 Coastal with high share of coastal population	36,4	4,3	0,0	0,0	3,0	4,5	25,0	**5,1**	**6,5**
4 Coastal with very high share of coastal pop.	45,5	13,0	0,0	0,0	3,0	18,2	20,0	**7,6**	**15,2**
0 Areas not covered by classification	9,1	67,4	100,0	100,0	87,9	59,1	45,0	**80,7**	**69,9**
Regions in industrial transition *(% of NUTS-3 regions)*									
1 With industrial branches losing importance	36,4	73,9	69,8	57,1	25,8	31,8	40,0	**52,7**	**47,0**
2 With industrial branches gaining importance	0,0	4,3	3,1	0,0	28,8	9,1	5,0	**9,8**	**3,7**
3 With internal industrial structural change	27,3	4,3	8,3	35,7	9,1	18,2	10,0	**10,9**	**12,1**
0 Area not covered by typology	36,4	17,4	18,8	7,1	36,4	40,9	45,0	**26,5**	**37,2**

* Andorra not included in ESPON typologies

9.1 Case study results by indicator

This section summarises results of the case studies. This is done by discussing the six indicators and pointing to the main specifics of each case study.

9.1.1 Access to regional centres

This indicator analyses the travel time to the next regional centre by road and by public transport. All cities with more than 50.000 inhabitants or capitals of NUTS-3 regions are considered as relevant destinations for this indicator. For a given municipality, proximity to an urban centre is relevant in terms of labour supply and services provide (banking, education, health care, commerce, leisure, etc).

For all case studies, accessibility to regional centres is in general good in most populated areas. In Finland almost 50% of the population lives in municipalities located within 30 minutes of a regional centre; in Northern Italy, this share goes even up to 81% of the population; in the West Mediterranean region, one out of every five inhabitants (19%) lives within 15 minutes from a regional centre and half of the population lives within 30 minutes (52%). The pattern is similar for all other case studies, indicating that accessibility is granted with current transport infrastructure in most population areas of Europe. Not surprisingly, in all case studies accessibility to regional centres by public transport is substantially less good than by car. Sample maps for case study results are presented in Figures 9.2 and 9.3 for the Baltic States and in 9.4 and 9.5 for Poland.

Travel times to **Finnish** regional centres vary remarkably. Remote peripheries exist in Central and Eastern Finland, where the travel time to the next regional centre is mainly over 60 minutes, and particularly in Northern Finland, where the travel time may be over three hours. With public transport, even in Southern Finland there are peripheries between cities. Particularly the grid-based assessment shows that travel times of over two hours are common in central and eastern Finland. Regions in northern and north-eastern Finland are particularly distant to regional centres.

In the **Baltic States**, major road arteries extend highly accessible areas far into the hinterland generating star-shaped accessibility surfaces. However, there are extensive parts in the Baltic States where travel times to regional centres exceed 100 minutes, mostly in border areas (Lithuania / Latvia, Latvia / Estonia, but also Russian and Belarus borders), but there are also some ‘inner peripheries’ in the middle of the countries. Unlike road, public transport does not span plateaus of high accessibility, but there are only individual service areas and axes. Most areas in Lithuania and Latvia, and to a lesser degree in Estonia, yield travel times by public transport of more than 100 minutes to the next regional centre. In the rural parts of the countries there are individual distinct ‘spots’ of high accessibilities around coach or railway stations, which are surrounded by areas of extremely low accessibility.

In **Poland**, the average access time to the regional centres (population weighted) is about 20 minutes by car and 40 minutes by public transport (30min by car and 65min by public transport taking into consideration median values). Only few areas of the country located beyond 80 minutes by car from a regional centre (Bieszczady mountains, north of Mazuria), but by public transport most municipalities are located beyond this 80 minutes threshold. Inner peripheries can be identified in areas in the north of Poland (e.g. internal zone of Pomorze region) as well as in the east. The existence of such inner peripheries is determined by the settlement structure: in the Pomorze region there is a lack of large cities, while areas lying close to the German border are cut off from their historical regional centres located on the western side of the Oder river. In other regions low performance is due to acute shortages in transport infrastructure (e.g. in the Warsaw-Kraków and Warsaw-Gdańsk corridor). The spatial range of peripheral zones is distinctively greater in case of public transport, and concerns primarily the north Poland.

In the **Czech Republic**, accessibility patterns imply significant geographic differentiation of communities. Disparities in time accessibility are heavily affected by the current state of the road infrastructure. The areas located at the borders with Poland and Bavaria have clearly lower accessibility values. There are also inner peripheries mostly around the borders of NUTS-3 regions, in areas often with decline in the resident population. The transport-related exclusion of the residents is an important factor, for example in the interface of the Central Bohemian and South Bohemian Regions or the border between the Pardubice and Vysočina Regions. Public transport accessibility shows a similar spatial pattern.

In **Bavaria**, about 60 percent of the population reach the next regional centre by car in less than 20 minutes and about 90 percent in less than half an hour. The percentages for rural areas are only slightly lower; in urban areas more than 80 percent live less than 20 minutes from a regional centre. For public transport, the travel time is much worse. Only twelve percent of the population lives closer than 20 minutes to the regional centres; for many of them this is the pure walking time. But 55 percent of the population has a public travel time of more than half an hour, ten percent need even more than one hour. The performance of public transport is slightly worse in rural areas, but somewhat better in urban areas. Here, 80 percent of the population need less than half an hour. The analysis of access to regional centres for Bavaria shows at first the balanced distribution of administrative centres across the area and secondly the much higher travel times by public transport compared to car travel times. There exist differences between low and high travel times for both modes considered, however, the disparities in travel times are much more pronounced for public transport than for car use. For the latter, the differences between different types of regions are very low but high for public transport. To conclude, for a car user, the different locations in Bavaria offer almost comparable access to the opportunities provided by regional centres. For people dependent on public transport, the overall situation is much worse than for car users in all areas and the disadvantage becomes much higher in rural areas.

In **Northern Italy**, only some very peripheral municipalities generally in mountain areas and very sparsely populated (2% of the overall population in the study area) show larger travel times to regional centres than 60 minutes. Such peripheral municipalities are comparatively disadvantaged because of their position not because of lack of road infrastructures. Public transport accessibility is comparatively lower in mountain areas, and in some portions of the study region where the rail infrastructure is underdeveloped in comparison to the rest of the region. The decreasing level of accessibility when moving from urban regions to intermediate regions to rural regions is clear as well.

In the **West Mediterranean**, worse accessibility conditions are driven by geographical constraints, and usually happen in areas with sparsely populated conditions, like in the innermost areas of the western Pyrenees, in the backcountry mountains of Valencia, in the area around the Ebre delta, and in the smallest islands. Low public transport accessibility is found in these same areas, but also in those portions of the study region where the rail infrastructure is underdeveloped or simply inexistent (i.e. most of the interior areas).

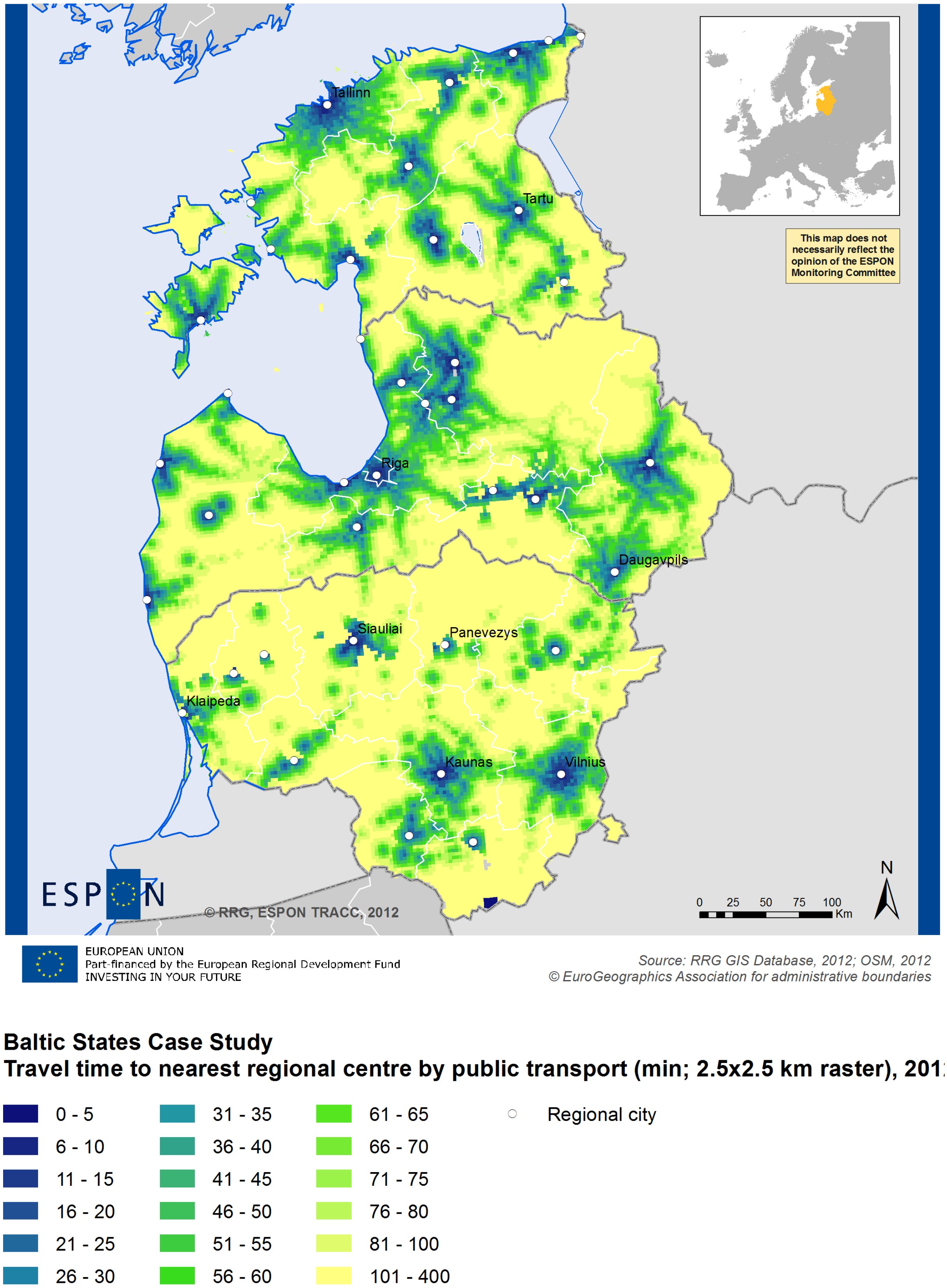


Figure 9.2. Baltic States case study, travel time to nearest regional centre by public transport

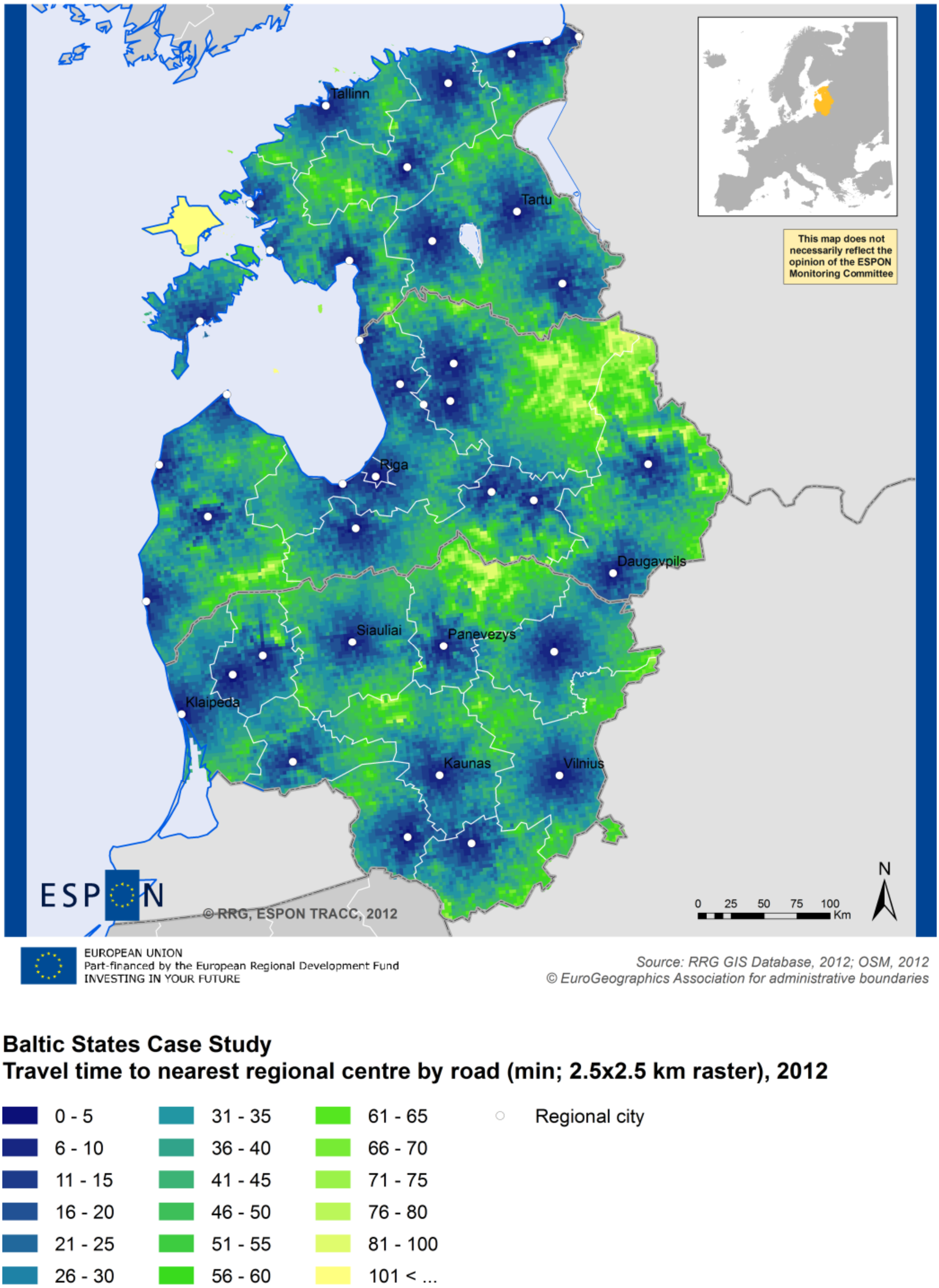
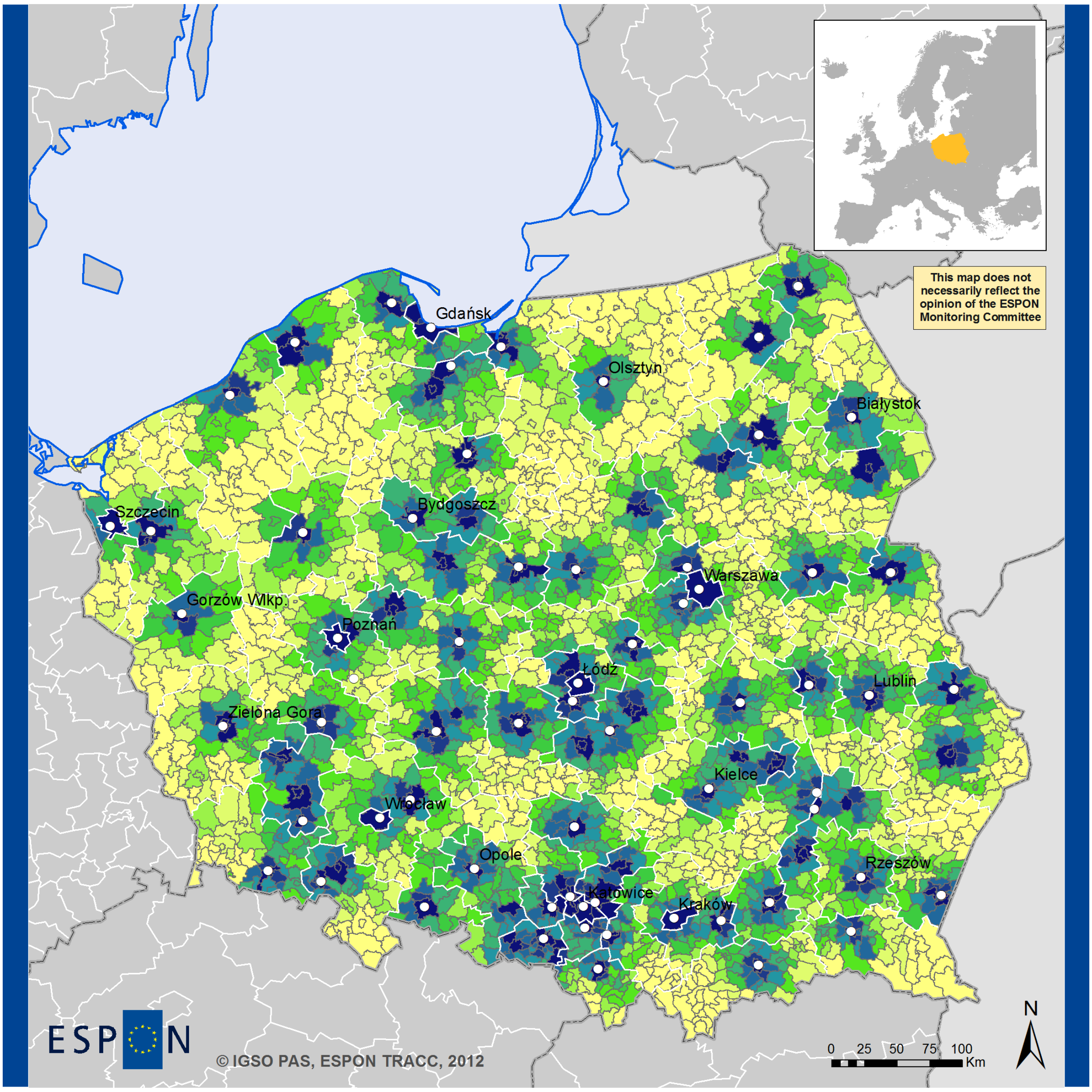


Figure 9.3. Baltic States case study, travel time to nearest regional centre by road



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Source: IGSO PAS, 2012
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Poland Case Study
Travel time by public transport to next regional centre

- 0 - 10 min
- 11 - 20 min
- 21 - 30 min
- 31 - 40 min
- 41 - 50 min
- 51 - 60 min
- 61 - 70 min
- 71 - 80 min
- 81 - 100 min
- 101 - 230 min

○ NUTS 3 Capitals

Figure 9.4. Poland case study, travel time to nearest regional centre by public transport

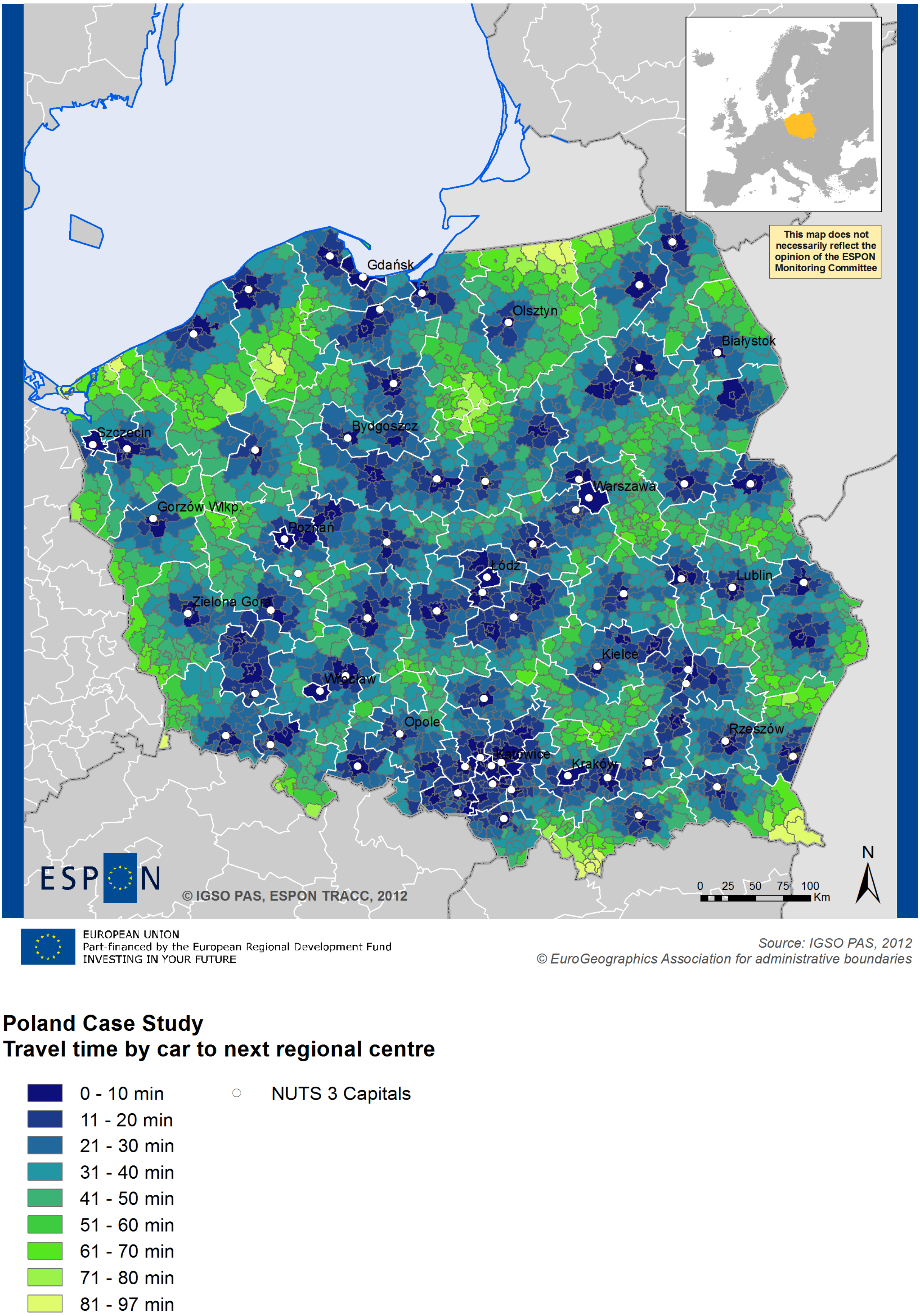


Figure 9.5. Poland case study, travel time to nearest regional centre by road

9.1.2 Daily accessibility of jobs

The accessible jobs indicator is defined as the amount of activity reachable from each LAU-2 region in less than 60min travel time. This indicator approaches the opportunities of the regional labour market from the point of view of the population. Using 60 minutes as a threshold for the daily accessibility indicator seems reasonable as it can be considered to represent usual maximum daily commuting time. Sample maps for case study results are presented in Figures 9.6 and 9.7 for Northern Italy and in 9.8 and 9.9 for the Western Mediterranean.

In **Finland**, the Helsinki region has a clear dominance in job accessibility by car, reaching its effect far in the surrounding areas via radial motorway connections to all directions. By grid cell analysis it can be visualised that jobs are well accessible around the regional centres, whereas apparent peripheries exist in Central, Eastern and particularly in Northern areas. In general, by public transport the accessibility of jobs is considerably lower than that by car. The best accessibility can be found in the capital region but to a more limited extent. The grid cell map shows that public transport based job accessibility is decent only in the immediate surroundings of the regional centres. In the areas between the cities, accessibility is mainly at a poor level. Due to the limited coverage of the bus network, there are large areas with very low accessibility to jobs by public transport even in the southern part of the country. As the population density outside of centres is low, it is clear that population in these areas may not be served by public transport, due to low demand.

In the **Baltic States**, there are large differences in jobs accessibility, even for road. While from places along the borders people can only reach up to 5,000 jobs, in contrary from the highest accessible places people can reach more than 750,000 jobs within 60 minutes car travel time. The latter areas are the greater Riga agglomeration, as well as the area between Kaunas and Vilnius in Lithuania. Estonia has two labour market centres, which are Tallinn and Tartu. Apart from the two main labour market areas mentioned, the job accessibility in Estonia is rather low with most places yielding rather small numbers between 10,000 and 100,000 jobs. As expected, accessibility levels for public transport are generally lower. However, low accessibility areas are often interrupted by distinct axes of higher accessibilities along the public transport corridors (which are mainly rail corridors). Accessibility is highest in star-shaped axes connecting the agglomeration centres into their hinterland In brief, this accessibility indicator yields not only obvious differences and specific spatial patterns between the three Baltic States, but also between the two modes and the types of regions, with a strong concentration on the agglomerations.

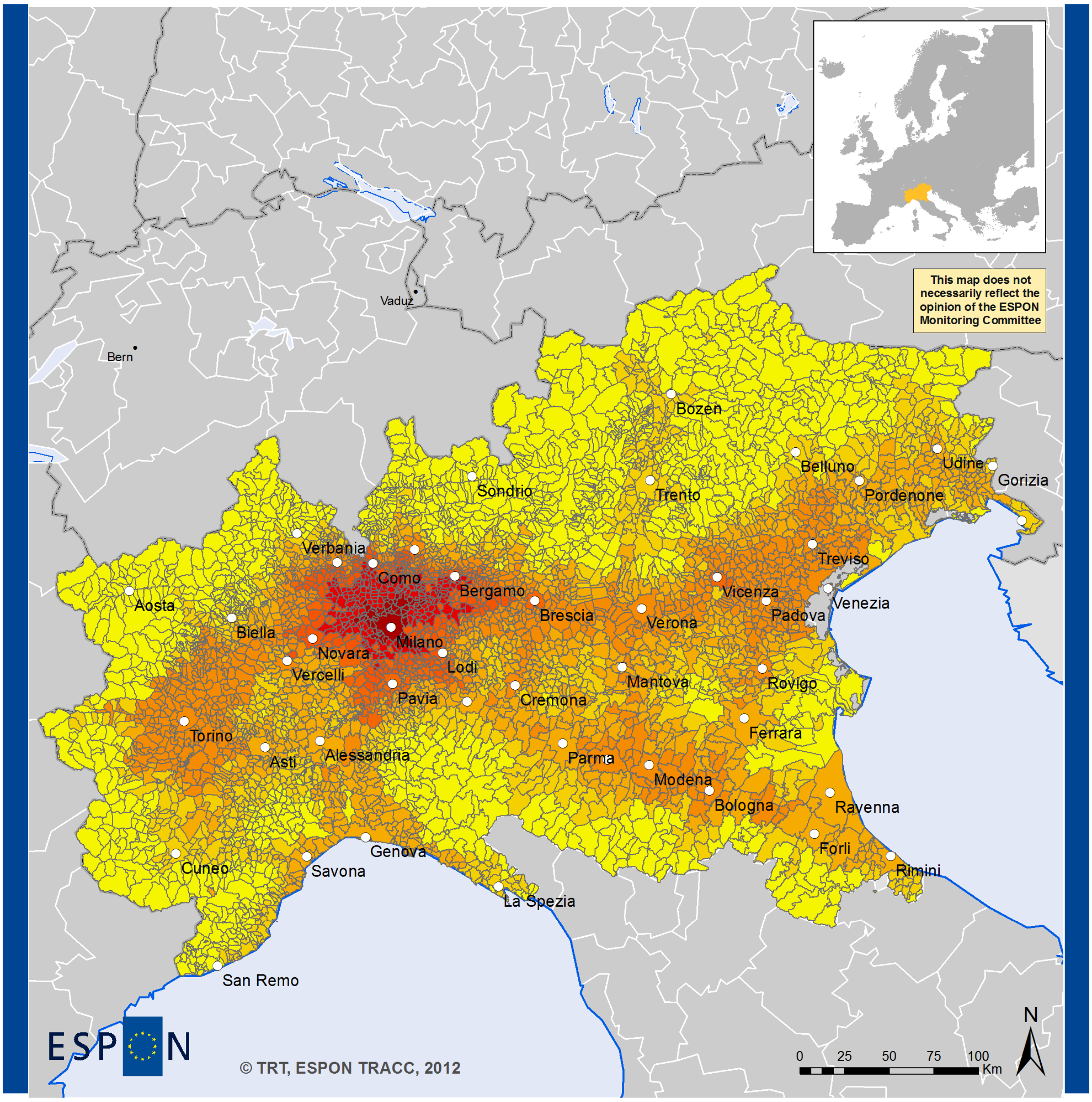
In **Poland**, the average number of jobs accessible by car within 60 minutes is around 550.000 (population weighted), 200.000 for public transport. As opposed to accessibility to regional centres, good accessibility to jobs is more concentrated in regions located close to cities. Best labour accessibility takes place in the metropolitan areas of Warsaw, Łódź, Wrocław, Poznań, Kraków and Upper Silesia conurbation, where most jobs are located. Around largest metropolitan areas, motorway axes provide high accessibility values along most important mobility corridors. Lagging regions are mostly located in border regions, especially on the outer Schengen border with Ukraine (Bieszady mountains), Belarus (south of Białystok, close to Białowieża forest) and Russia, areas suffering from migration outflows. The good accessibility to jobs by public transport is reserved only for the municipalities located close to the big cities. The poor public transport connections lead to relatively small catchment areas and long commuting travel times, during the peak hours in particular, with the presence of several inner peripheries.

In the **Czech Republic**, during the transformation period job opportunities were concentrated in hierarchically more important residential centres, supported by the fall of often artificially maintained employment in agriculture in areas with inconvenient nature and in small rural industrial plants established or promoted within so-called socialist industrialization. Job opportunities in the smallest communities have been decreasing on a long-term basis. Most significant potential for job opportunities is in the broad hinterland of Prague as there is more than one million of theoretically available job opportunities at an hour´s distance. Radial express roads can be observed here as well. Border areas, inner peripheries at regional borders have a minimum amount of available job opportunities. Expressing accessibility as a cumulated opportunity provides a new view over some peripheral areas, especially for relatively lagging areas between Prague, Hradec Králové and Liberec which can benefit from the offer of job opportunities in all three centres. The importance of regional capitals as the centres of employment is highlighted by expressing cumulated accessibility via public mass transport. Population relying on public transport is more strongly dependent on job opportunities in regional capitals or near to their home.

The analysis of accessibility to jobs for **Bavaria** shows a very unbalanced spatial distribution. On the one hand, there are urban areas in which several hundred thousand jobs are in reach within one hour travel time by car and also by public transport. On the other hand, there are rural regions from which only a few ten thousand jobs are available. This is even worse for people that are depending on public transport, here from most of the municipalities located in rural regions clearly less than 5,000 jobs are in reach. That means that people in rural regions without a car are almost excluded from the labour market, at least in terms of variety of job opportunities and in terms of flexibility.

The **Northern Italy** area has spread economic activities, even if the density of activities is especially high in the sub-region surrounding the metropolitan area of Milan. As result of this level of density, nearly one half of zones and two thirds of population can reach more than 1 million of jobs in less than one hour by car. Only a small share of population, living in a minority of zones mainly located in mountain areas, can reach less than 100,000 jobs within 60 minutes. Jobs accessibility by public transport follows basically the same pattern but with a distribution shifted downwards. Not surprisingly, the difference of accessibility to jobs between zone types is dramatic. The median of the distribution or urban zones and other zones close to a city is several times larger than the median for the remote areas. Another advantage of urban areas is that public transport accessibility is not that worse than car accessibility. Instead, in intermediate zones the difference is much larger and moving by public transport means a clear drop in median accessibility. In remote areas the difference between car and public transport accessibility is small just because even car accessibility is low.

The **West Mediterranean** region has economic activities spreading over most of its territory but the density of activities (as well as of population) is clearly higher in the coastal areas and especially high in the areas around Barcelona, Valencia and Alacant. As result of this level of density, around 65% of the population of the region have more than 1 million jobs accessible in less than 1h by car, and more than 40% of the population has 2 million jobs accessible within 60 minutes drive. Only a small share of population, living in a minority of zones mainly located in mountain areas, can reach less than 100.000 jobs within 60 minutes. Territories around the largest cities in the area logically show the greatest values for job accessibility by public transport, because of geographical proximity and because of having more rail services available. Levels of occupation accessible in interior territories are still relatively high except for mountain areas in the western Pyrenees and in interior Valencia and Castelló.



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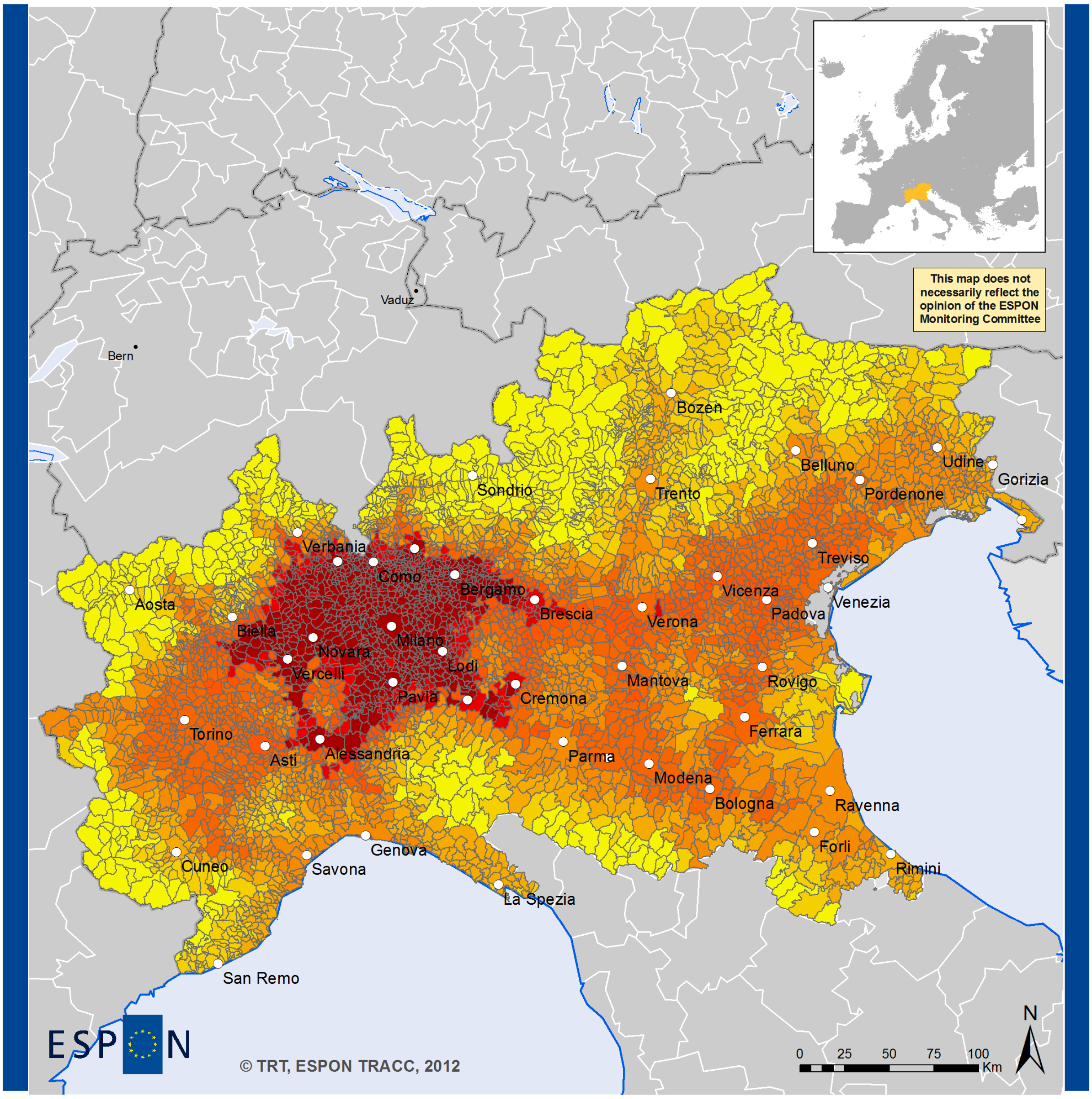
Northern Italy Case Study (2011)
Daily accessibility of jobs: Jobs (ths.) accessibile within 60 minutes by public transport

- 0 - 100
- 101 - 250
- 251 - 500
- 501 - 1 000
- 1 001 - 1 500
- 1 501 - 2 000
- 2 001 - 2 500
- 2 501 < ...

○ *NUTS3 Capital*

Figure 9.6. Northern Italy case study, daily accessibility of jobs by public transport



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Source: TRT Accessibility model (2012), Rail Network: RRG GIS Database (2011), Road Network: OSM (2011), Italian Statistical Office (ISTAT)- Workplaces (2001)
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Northern Italy Case Study (2011)
Daily accessibility of jobs: Jobs (ths.) accessibile within 60 minutes by road

- 0 - 100
- 101 - 250
- 251 - 500
- 501 - 1 000
- 1 001 - 1 500
- 1 501 - 2 000
- 2 001 - 2 500
- 2 501 < ...

○ *NUTS3 Capital*

Figure 9.7. Northern Italy case study, daily accessibility of jobs by road

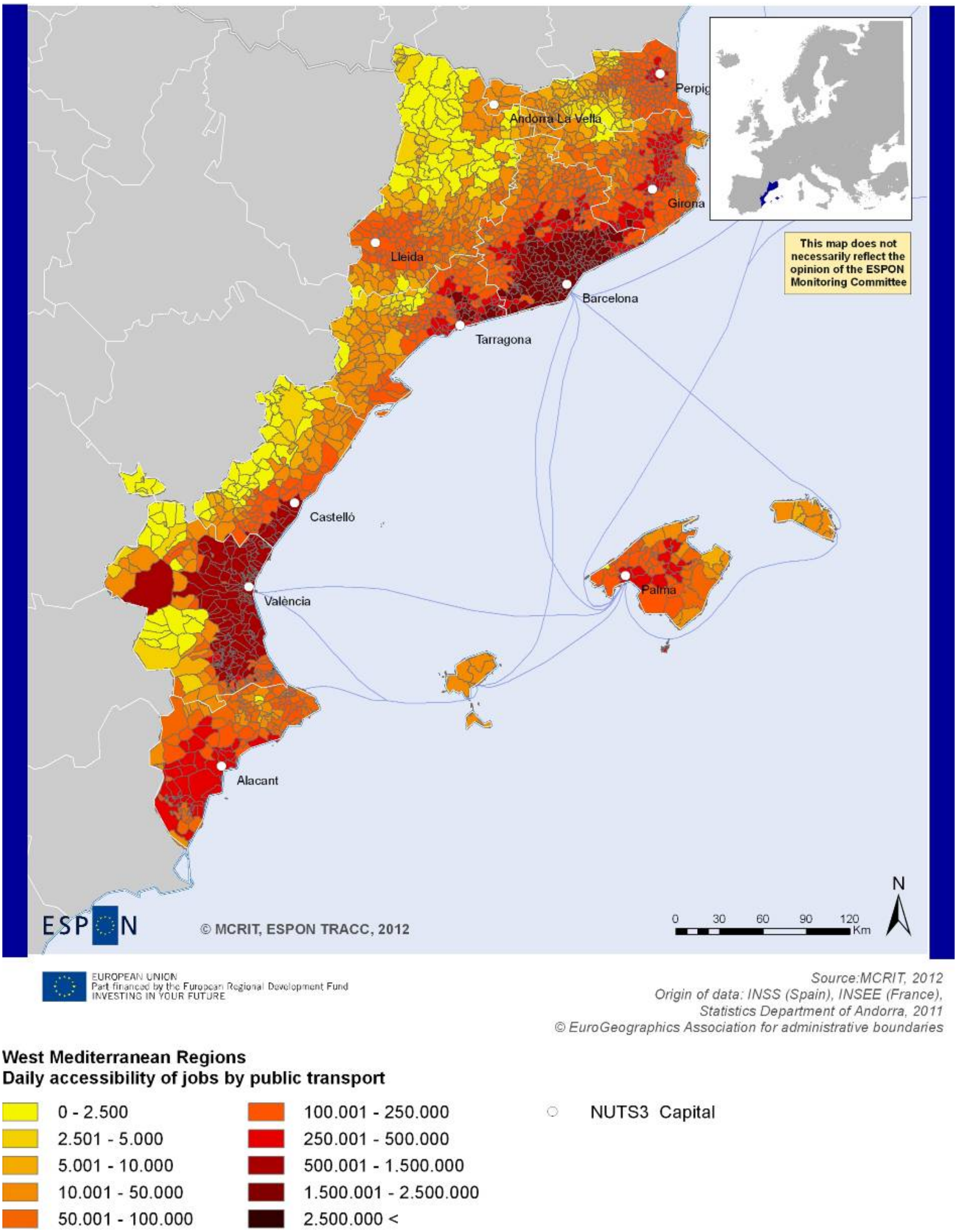


Figure 9.8. West Mediterranean case study, daily accessibility of jobs by public transport

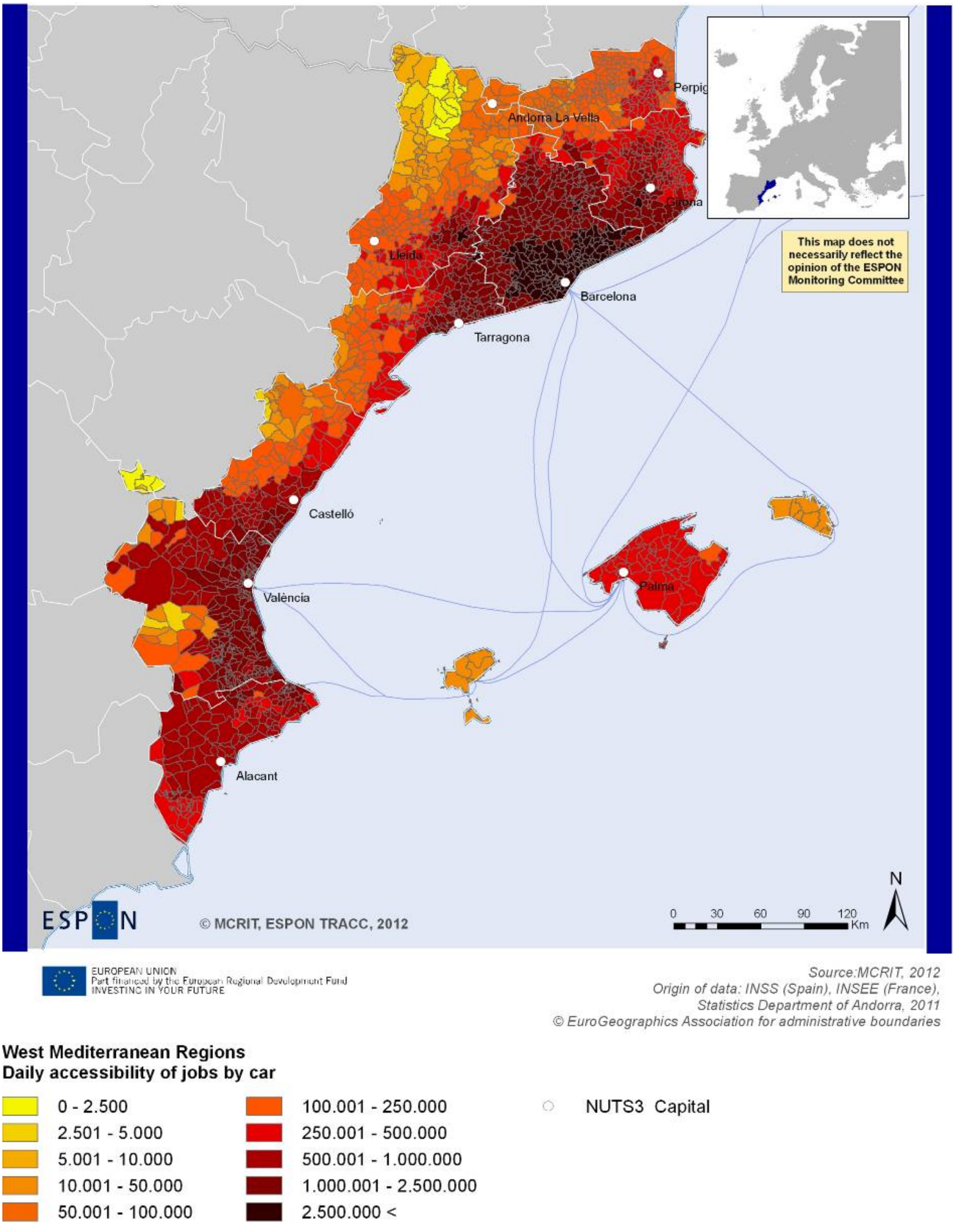


Figure 9.9. West Mediterranean case study, daily accessibility of jobs by road

9.1.3 Regional accessibility potential

What is the regional population potential of any point in space? In order to evaluate the different locations within a region from the viewpoint of economic actors, e.g. firms assessing the regional labour markets and locational advantages, or retail industries assessing the market area, the population potential of each municipality within a case study region is analysed. The population potential is calculated as the sum of people in destination areas weighted by the travel times to reach them.

In aggregate, the results of the accessibility potential show the main concentration areas and their locations in the transport networks. Accessibility potential to population somehow makes visible the “enlarged cities” in the case study areas, the metropolitan areas at large. By public transport, the accessibility potential tends to reflect the functional commuting areas of greatest urban regions. Sample maps for case study results are presented in Figures 9.10 and 9.11 for Finland and in 9.12 and 9.13 for the Czech Republic.

In **Finland**, the dominance of a few cities in the South, particularly the capital region, forms the major pattern in the regional accessibility potentials. The centre-periphery polarisation in Finland is particularly evident. Only the accessibility around regional centres is an exception to the pattern in remote peripheries. All municipalities in the Lapland region belong to the most peripheral category. Eastern regions are also characterised by low accessibility. The grid cell analysis also shows the significance of the main roads between the capital and major cities. Accessibility potentials by public transport are even more polarised than that by car. Most of the territory is poorly accessible by public transport, while the population centres are served pretty well. The Oulu region is in the most accessible class by public transport.

In the **Baltic States**, for both modes the regional potential accessibility to population is much higher in Latvia and Lithuania compared to Estonia, due to the generally lower population densities in Estonia. The capital city regions clearly dominate the accessibility patterns in all three countries. For road, the accessibility surface around the major cities (Riga, Kaunas and Vilnius) form plateaus of high accessibility, with stretches into the rural parts along main transport axes. Apart from the four leading agglomerations areas of average potential accessibility can be found around the regional cities. All other territories of the three Baltic States show accessibility levels far below the average, reaching only up to a quarter of the Baltic States average. Public transport accessibility only shows significant accessibility levels for urban regions and for intermediate regions close to a city, while for intermediate remote and for rural regions public transport accessibility is very poor yielding only small portions of road accessibility.

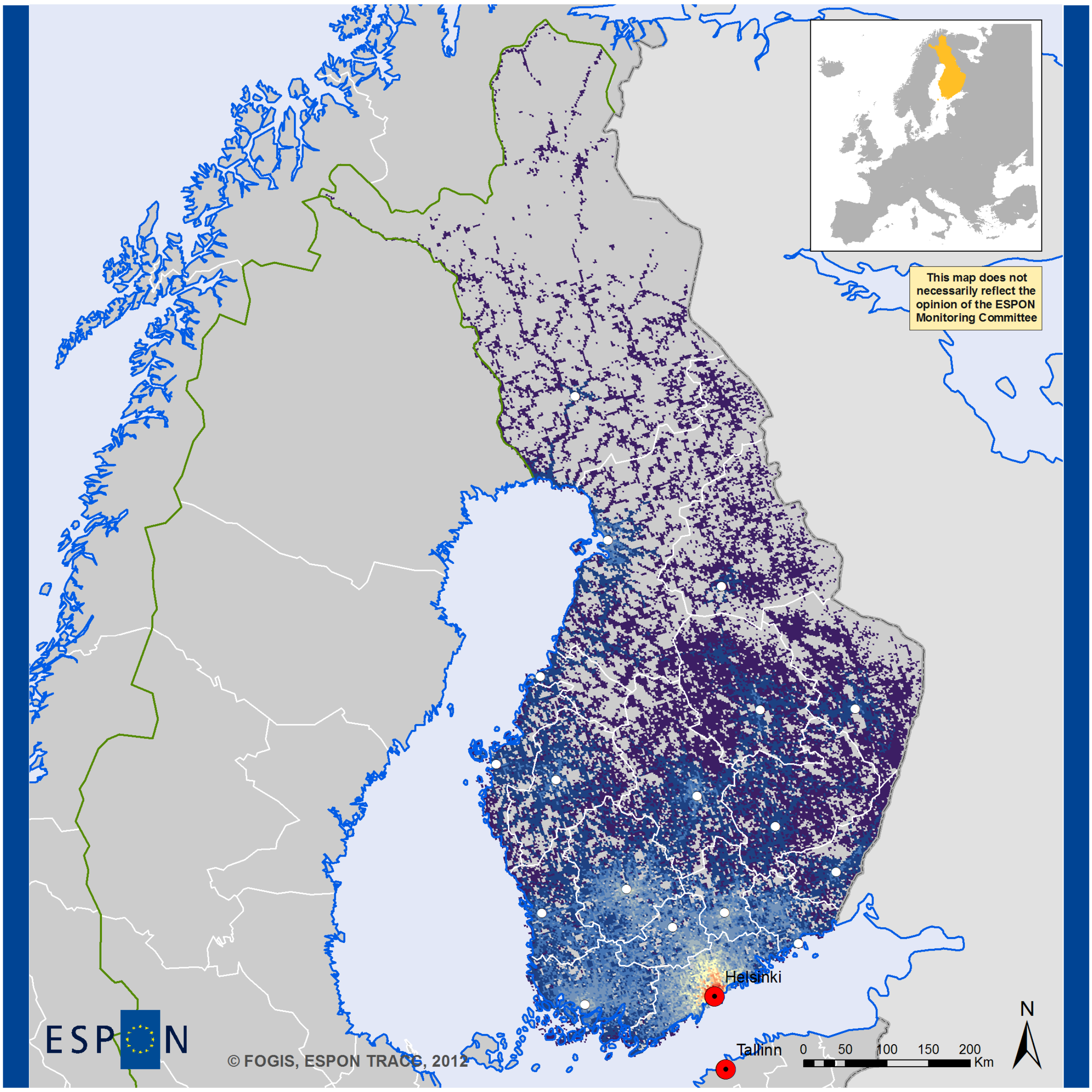
In **Poland**, areas with best potential accessibility are the metropolitan area of Warsaw, in Upper Silesia and Kraków, and along motorway axes. The worst accessible regions are those located near the border, the outer Schengen border in particular but also, fragmentarily, along the border with Germany and Czech Republic. The compact areas of poorer potential accessibility occur in the Pomorze region (except for the Gdańsk subregion). The average accessibility potential to population by public transport (population weighted) is less than 40% of the same indicator for car. Accessibility potential by public transport shows the general weakness of the railway system in Poland, with only major cities and their suburban areas performing well. Compared to road, investments in the rail network (upgraded segments) have not been able to improve substantially the magnitude of accessibility potential in any particular direction. The north-eastern Poland (with the exception of the municipalities along the railway line between Warsaw and Białystok) is at the worst situation. Historically falling behind in terms of railway infrastructure this area is waiting for the implementation of the Rail Baltica project.

In the **Czech Republic**, the analysis clearly illustrates the relative separation of the two historically independent areas of the country (Morava and Bohemia). The Moravian system is dominated by the axis Brno – Olomouc/Zlín – Ostrava, while Bohemia is dominated by Prague situated in the centre of the radial system of roads. The analysis shows also the importance of unfinished motorway axes and first-class roads: some agglomerations appear isolated as they are not connected yet to the national motorway network (e.g. South Bohemian centre of České Budějovice, or the relatively weak NUTS-3 centres of Karlovy Vary and Jihlava). If relations to the neighbouring states had been considered in the analysis, the potential accessibility of North-Western Bohemia would be even higher thanks to the presence of Dresden, and the region of Ostrava communicating with the region of Polish Katowice would also stand out.

In **Bavaria** highest accessibility potential by car can be found in the Munich agglomeration. In the city of Munich the indicator value is more than twice the average. Due to the dense road network, the area of above average accessibility around Munich is relatively wide. The radial motorways push the areas of higher potential accessibility to the outside and form corridors with high market potential. The Nuremberg region forms the second accessibility peak in Bavaria, however, the maximum values are much lower due to less population living in that agglomeration. From the two agglomerations, accessibility potential goes down when moving to more remote areas. But due to the more smoothing character of the indicator definition, the disparities are less pronounced and the average of rural areas is about 70 percent of the Bavarian average. The situation for public transport users is much worse. When using the car average as benchmark (i.e. car average is set to 100 and is used for public transport accessibility), no municipality is above car average, even Munich is slightly below. The average accessibility potential by public transport is only about 30 percent of the car average. Even in urban agglomerations, the public transport average goes only up to 70 percent. In rural areas it is as low as 15 percent of the Bavarian accessibility potential by car. However, the spatial pattern is rather similar.

In **Northern Italy**, despite some polarisation there is a relatively even distribution of potential accessibility in the core of the area: only 20% of the zones (accounting for more than 30% of population) are over the average. There is an apparent continuity in the (above the average) level of potential accessibility throughout the Padan region and in the northern part of the corridor between Turin and Bologna. Of course, potential accessibility of very peripheral LAU-2 areas is well below the average, but they account for only 6% of population. Also for potential accessibility, on average public transport performs worse than car. Nevertheless there are a few zones (where about 10% of population lives) whose potential accessibility by public transport is above the average potential accessibility by car. These zones are basically those which are very well connected by train to Milan and its metropolitan area. Outside this area, the potential accessibility by public transport is generally lower than the average accessibility by car.

In the **West Mediterranean** region, the fairly concentric network of motorways around Barcelona becomes perceivable as potential accessibility diminishes from the capital onto the backcountry following the major transport corridors. The influence of Barcelona can be perceived in the four Catalan NUTS-3 capitals, in addition to Perpignan in France. In the south, the influence of Valencia is also very high, almost merging with the metropolitan area of Alacant-Elx, even Murcia –to the south of the case study area-. Accessibility potential by public transport shows the major corridors around largest cities in the region. In Barcelona, the map reflects the corridors of the suburban rail lines and express busses to Igualada, Manresa and Vic in the interior and to Girona and Tarragona in the corridor parallel to the coast –Tarragona performs better due to the high speed rail-. The values for potential accessibility in the islands are limited.



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Data source: Finnish Transport Agency, 2012, Statistics Finland, 2011, 2010, Oy Matkahuolto Ab, 2012
Origin of data: ESPON Databank Project, 2010/2011
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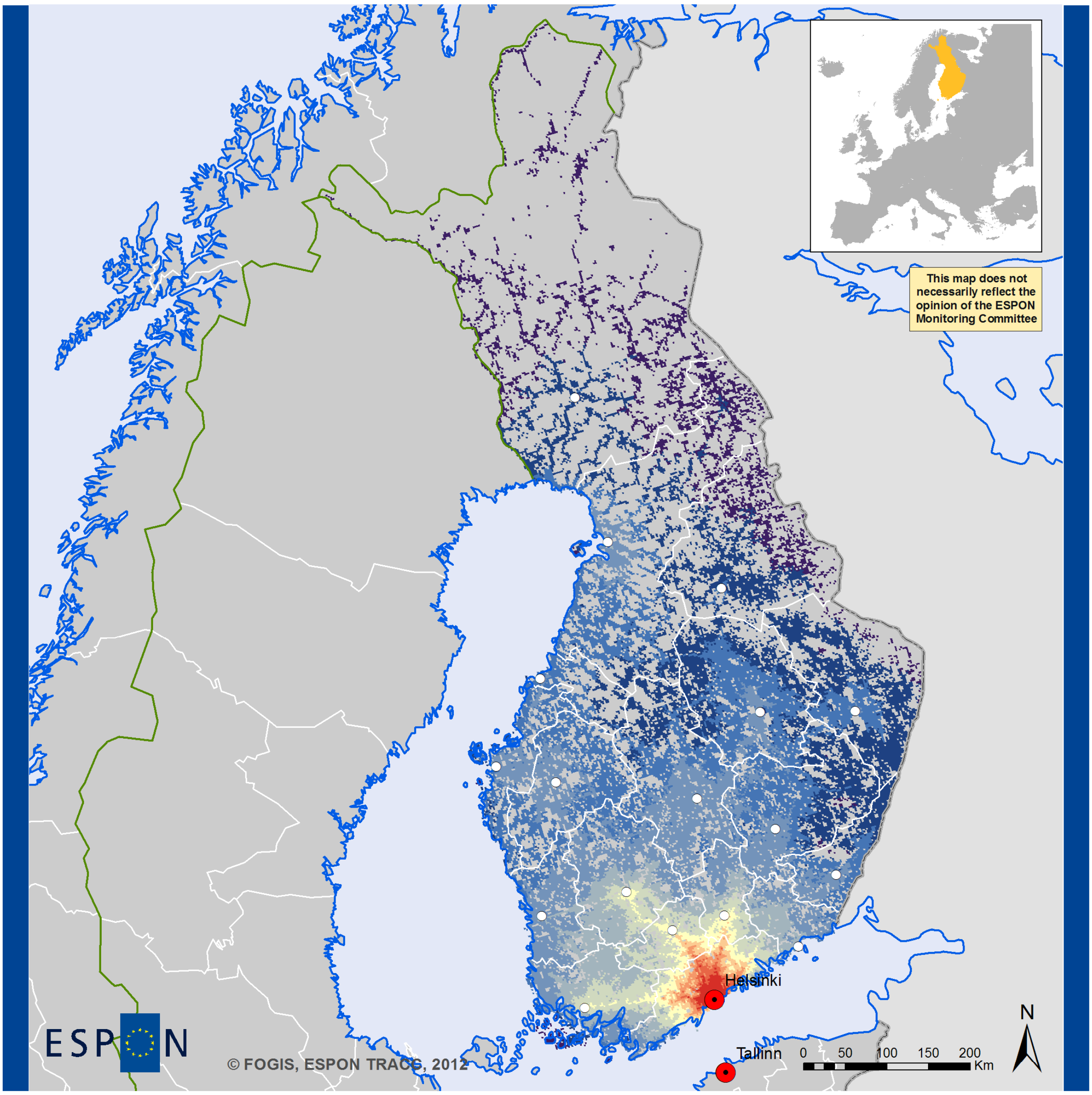
Finland Case Study
Potential accessibility to population by public transport (raster level)

- 0.0 - 5.0
- 5.1 - 15.0
- 15.1 - 25.0
- 25.1 - 50.0
- 50.1 - 75.0
- 75.1 - 100.0
- 100.1 - 125.0
- 125.1 - 150.0
- 150.1 - 175.0
- 175.1 - 200.0
- 200.1 < ...

100 (population weigted average, car) = 302283.4
Maximum: 664740.9
Minimum: 0.008

Figure 9.10. Finland case study, potential accessibility to population by public transport



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Data source: Finnish Transport Agency, 2012, Statistics Finland, 2011, 2010
Origin of data: ESPON Databank Project, 2010/2011
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Finland Case Study
Potential accessibility to population by car (raster level)

0.0 - 5.0
5.1 - 15.0
15.1 - 25.0
25.1 - 50.0
50.1 - 75.0
75.1 - 100.0
100.1 - 125.0
125.1 - 150.0
150.1 - 175.0
175.1 - 200.0
200.1 < ...

100 (population weigted average) = 302283.4
Maximum: 870217.3
Minimum: 127.2

Figure 9.11. Finland case study, potential accessibility to population by road

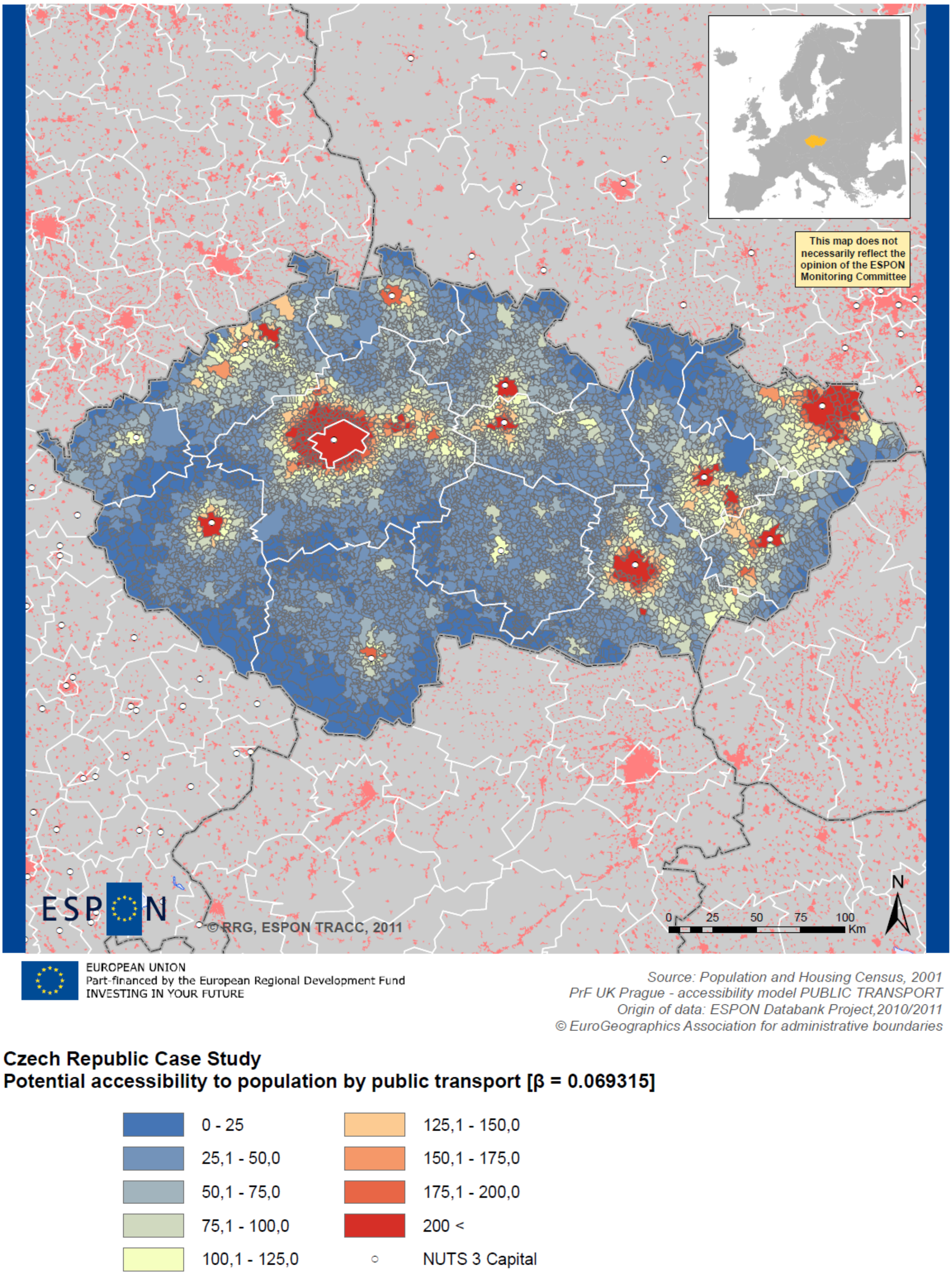


Figure 9.12. Czech Republic case study, potential accessibility to population by public transport

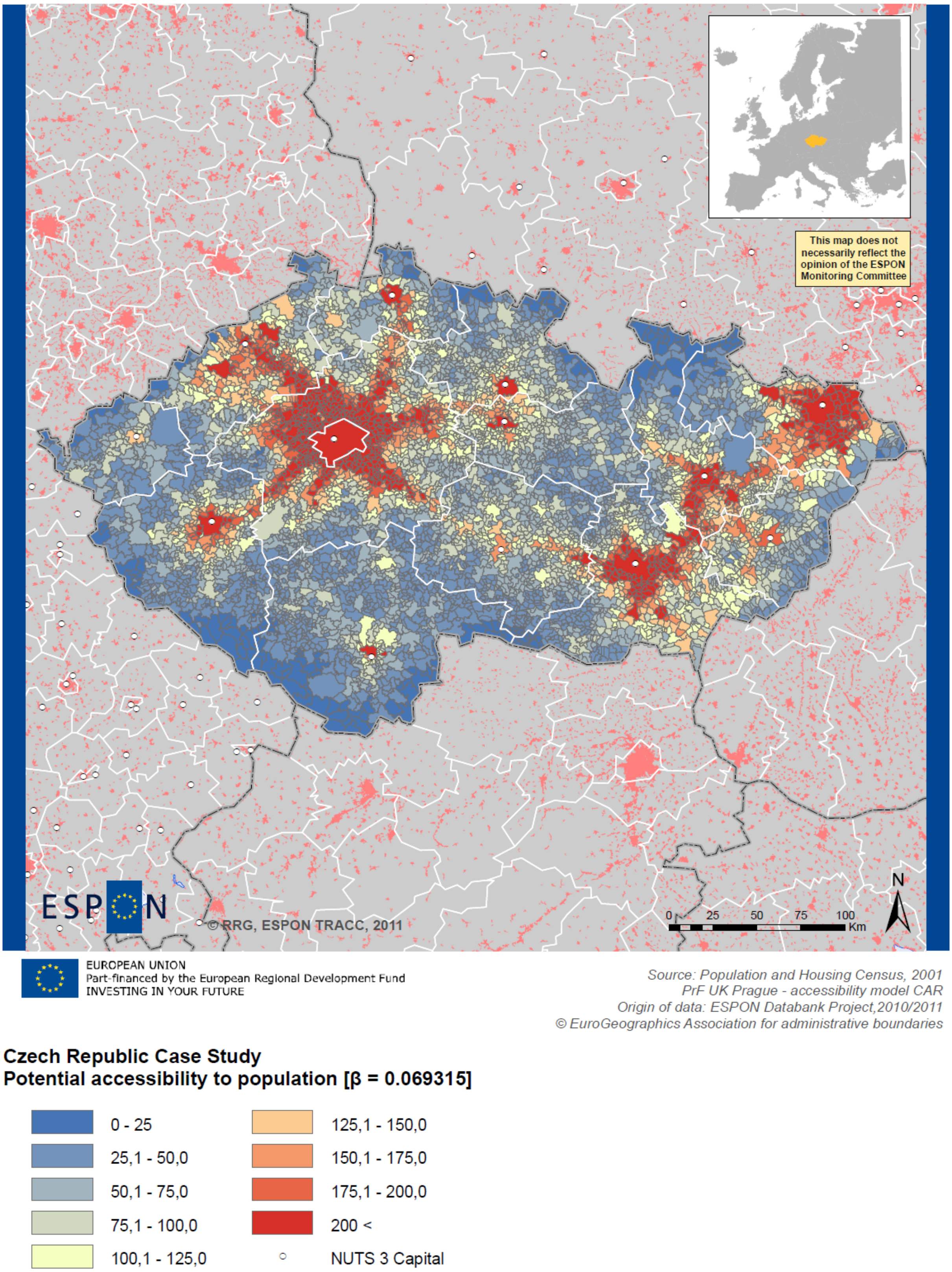


Figure 9.13. Czech Republic case study, potential accessibility to population by road

9.1.4 Access to health care facilities

Hospitals are one of the main general services of public interest. This indicator measures the travel time required to access the closest hospital from a given point. Travel times by road and by public transport from each LAU-2 region show the spatial diversity in access to reference health care facilities. Reference hospitals are defined as those allowing at least for surgery, regardless of being publicly or privately managed. Specialised clinics are not considered.

In general, the levels of accessibility to hospitals in Europe are much better than those of accessibility to regional centres reported above, reflecting that hospital endowment is generally available to municipalities which are below the 50.000 inhabitant criteria established by ESPON TRACC as threshold to consider regional centres. Sample maps for case study results are presented in Figures 9.14 and 9.15 for the Baltic States and in 9.16 and 9.17 for Poland.

In **Finland**, health care facilities are accessible within 40 minutes in most parts of the country. Only in the eastern and northern parts of the country, the travel time may be close to or longer than 60 minutes. Considering the long distances and sparse population that are typical of Finland, the level of accessibility can be considered to be relatively good. The grid-based map clearly indicates how the access to health care facilities is very good in close proximity to large or medium-sized towns in all parts of Finland. The results of the access to health care facilities by public transport indicate that accessibility can be considered to be reasonably good only in southern Finland and in the most populated municipalities in the rest of the country.

In the **Baltic States**, Lithuania and Latvia have a rather dense and equally distributed network of general hospitals, even in rural parts. The situation in Estonia is different as hospitals are concentrated in selected regional cities. Car travel time to the next hospital is less than 40 minutes for almost all parts of the Baltic States, except small areas along some borders and on some Estonian islands, yield travel times of more than 40 minutes. For public transport travel times to hospitals form more complex spatial patterns, as cities and bigger towns are well covered with short travel times, so as some public transport corridors between them, but hospitals in smaller towns are often difficult to reach by public transport from the countryside. Hospitals in small towns mainly serve local needs but they do not span any form of service areas into their rural hinterland. Trains or busses are no real option for getting to the next hospital.

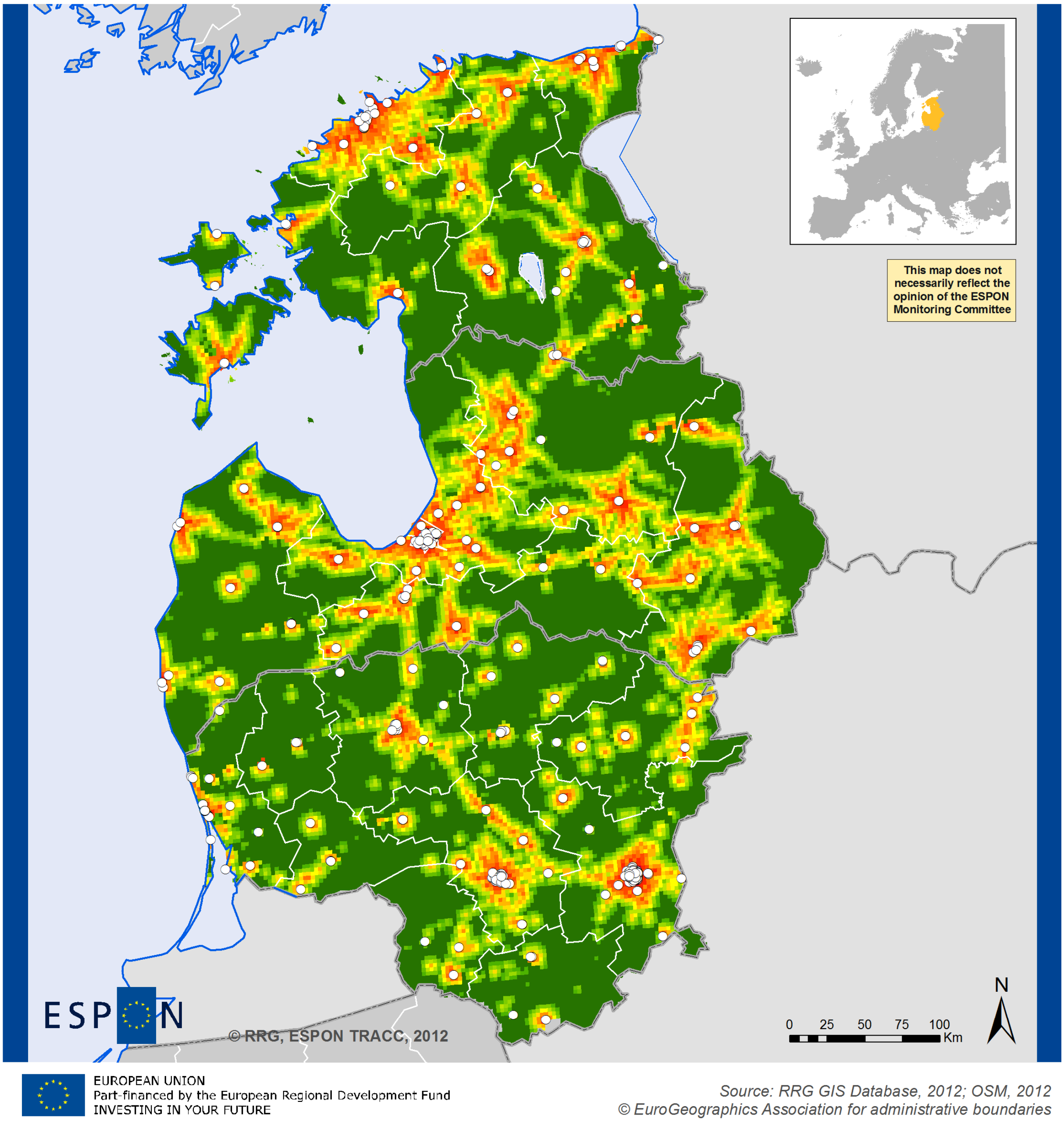
In **Poland**, hospitals are in general much more equally distributed among the whole country than other services; travel time to hospitals rarely exceeds 30 minutes and the situation in the urban areas is only a little better than for the rural ones. The population weighted average travel time to the nearest hospital by car is 10 minutes and only slightly more than 30 minutes for public transport. Lagging regions are mostly located in borderland regions and areas on Baltic coast. To the south-east of Warsaw the zone of poor accessibility to hospitals is adversely affected by shortage of bridges on the Vistula River. Even if by public transport accessibility to hospitals is worse than by car, it is still relatively good as most of the hospitals in Poland are traditionally located close to railway stations. However, quite vast areas have access-times to hospitals exceeding 60 or even 90 minutes, generally driven by local shortages of transport infrastructure.

In the **Czech Republic**, the accessibility pattern is still relatively balanced in individual regions but this might change subject to ongoing health care system restructuration. Today, a large majority of communities is within a 40-minute distance from a hospital. The worst accessibility is from communities in the border area of the Czech Republic. Most hospitals are located in the major residential centres situated inland. Time accessibility of the closest hospitals by public transport is worse than time accessibility by individual car transport, especially for communities which are not situated on major roads. This concerns primarily communities in South-Western Bohemia, being more distant to regional capitals, with fewer public transport connections and less express roads.

In **Bavaria**, the distribution of hospitals across the territory is relatively even. Travel times by car to municipalities are for many municipalities rather short with less than 15 minutes (Figure 18). However, there are also areas in Bavaria that are more apart from hospitals with car travel times up to half an hour or even slightly above in some smaller areas. The Bavarian average travel time to a hospital by car is about 16 minutes. The variation across types of regions is very little. The average of urban areas is twelve minutes, the average of rural areas is 18 minutes. Access to hospitals by public transport is for most areas in Bavaria much longer. Even for most of the urban areas, public transport travel time is more than 20 minutes. The map shows a majority of green coloured municipalities indicating that the next hospital is almost one hour or even more apart by public transport. Access times by public transport might not so relevant for patients, but it is an important issue for relatives and friends without a car available. The Bavarian average is beyond half an hour. Lowest average is in urban areas with about 25 minutes, the average access time value goes up to about 35 minutes in rural areas. Similar to car access, the variation across types of regions is relatively little.

In **Northern Italy**, public health system has been dominant for the last decades, resulting on a dense network of public hospitals providing a wide range of therapies. In Northern Italy, 82% of zones and 97% of population need no more than 30 minutes to reach a hospital by car. By public transport, the results differ especially for the interval below 10 or 20 minutes, but the difference is much smaller for a time threshold of 30 minutes. 24% of zones and 62% of population can reach a hospital in less than 20 minutes by bus or train. It could be noted that in recent years some forms of privatisation have been introduced in the health system: plans for closing smaller hospitals have been periodically presented, which might have an impact on current accessibility trends.

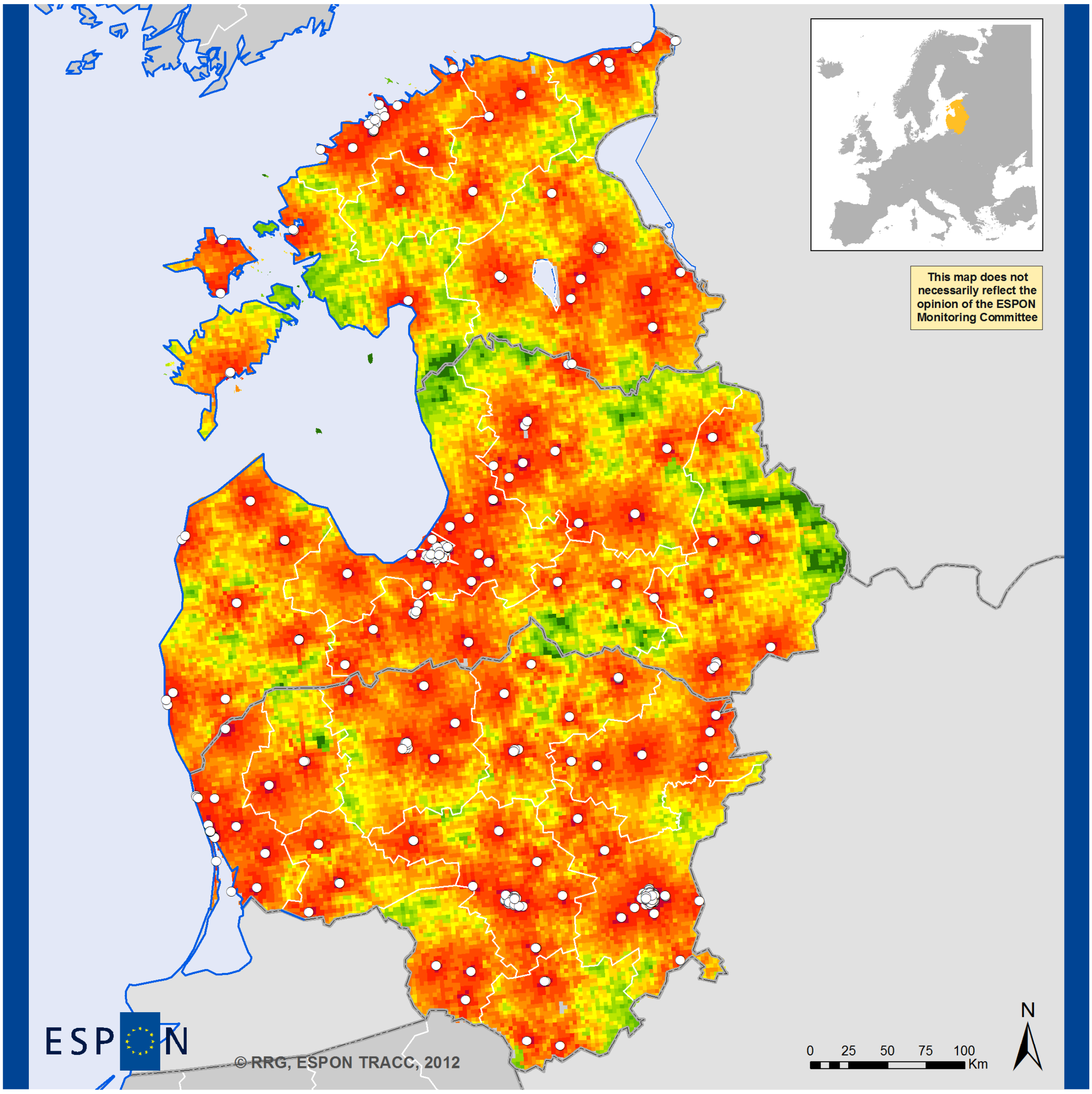
In the **West Mediterranean** region, the levels of accessibility to hospitals are much better than those of accessibility to regional centres. 39% of population lives within 15 minutes to hospital (against 18% to regional centres), 81% of population lives within 30 minutes (against 52% to regional centres), and 95% of population lives within 45 minutes (against 78% to regional centres). The territorial pattern shows a higher territorial homogeneity than the pattern for accessibility to regional centres, revealing the important role county hospitals in the case study region. The pattern obtained with public transport is similar to the one obtained by private transport, but the influence of hospitals in the territory is more limited, especially in most peripheral regions.



Baltic States Case Study
Travel time to nearest hospital by public transport (min; 2.5x2.5 km raster), 2012

0 - 5	26 - 30	51 - 55	○ Hospital
6 - 10	31 - 35	56 - 60	
11 - 15	36 - 40	61 - 65	
16 - 20	41 - 45	66 < ...	
21 - 25	46 - 50		

Figure 9.14. Baltic States case study, travel time to nearest hospital by public transport



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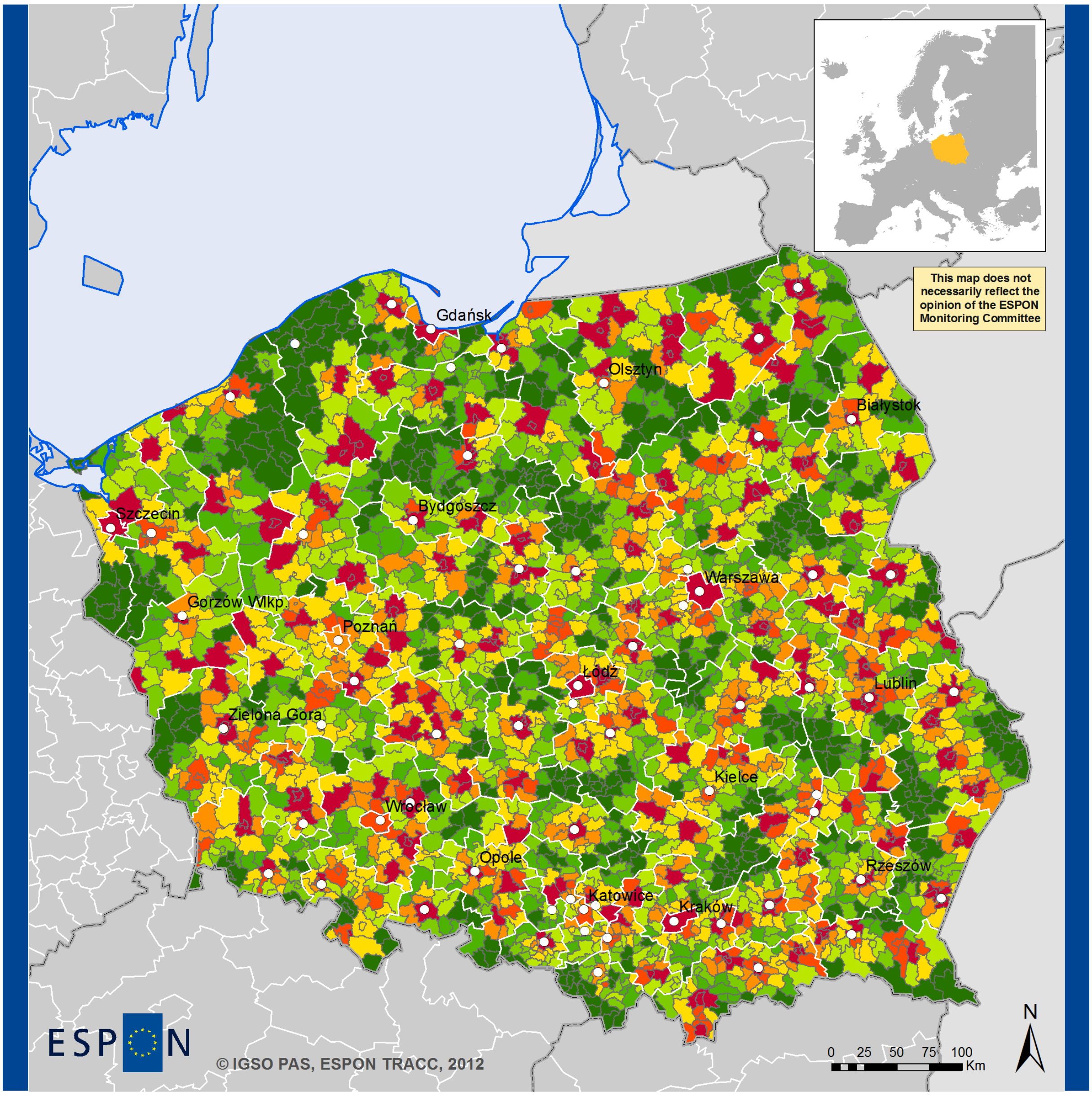
Baltic States Case Study
Travel time to nearest hospital by road (min; 2.5x2.5 km raster), 2012

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 35
- 36 - 40
- 41 - 45
- 46 - 50
- 51 - 55
- 56 - 60
- 61 - 65
- 66 < ...
- ○ Hospital

Figure 9.15. Baltic States case study, travel time to nearest hospital by road



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Source: IGSO PAS, 2012
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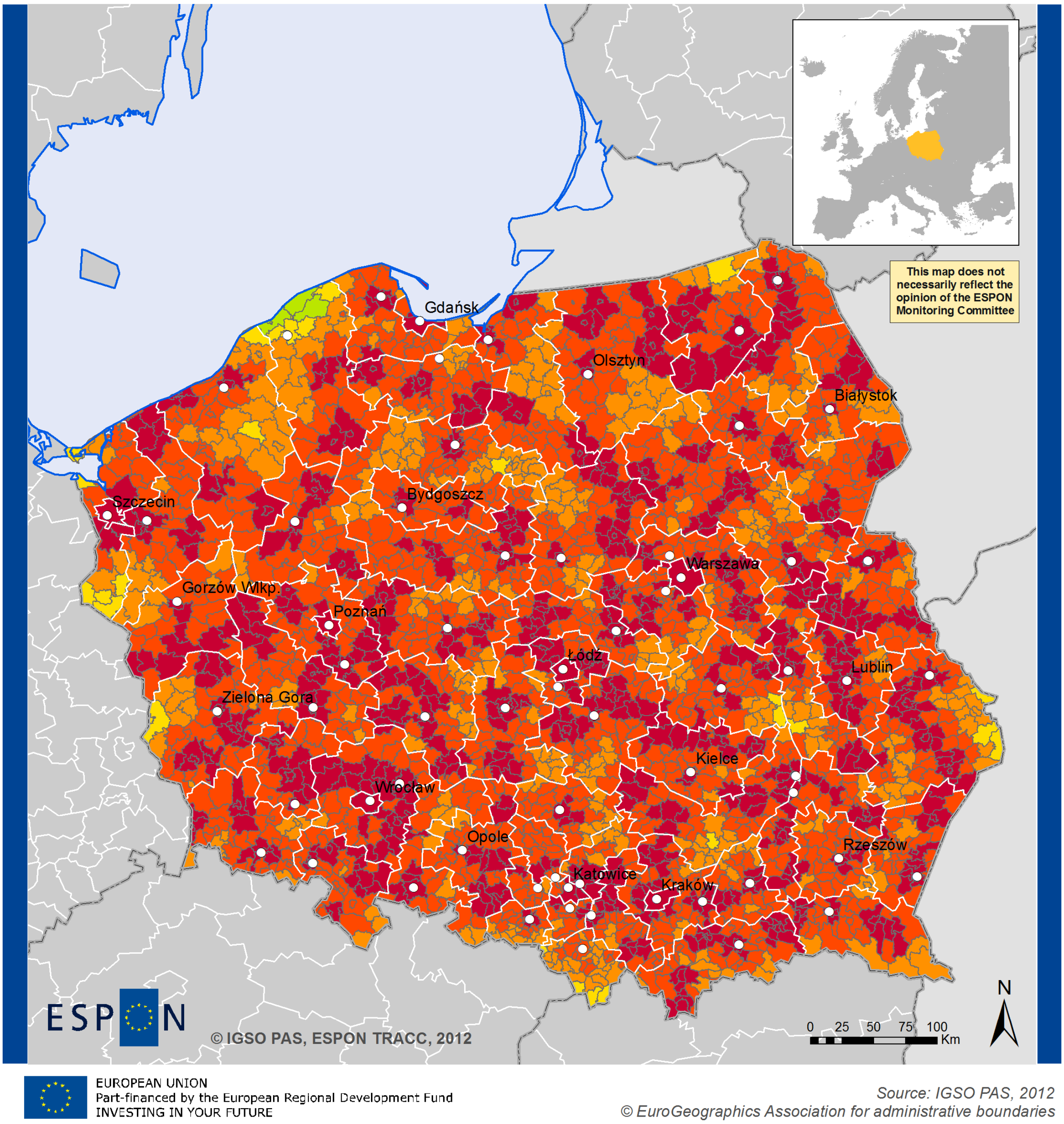
Poland Case Study
Public transport travel time to next hospital

- 0 - 10 min
- 11 - 20 min
- 21 - 30 min
- 31 - 40 min
- 41 - 50 min
- 51 - 60 min
- 61 - 70 min
- 71 - 149 min
- ○ NUTS 3 Capitals

Figure 9.16. Poland case study, travel time to nearest hospital by public transport



Poland Case Study
Car travel time to next hospital

- 0 - 10 min
- 11 - 20 min
- 21 - 30 min
- 31 - 40 min
- 41 - 47 min
- ○ NUTS 3 Capitals

Figure 9.17. Poland case study, travel time to nearest hospital by road

9.1.5 Availability of higher secondary schools

Do pupils have access to higher secondary schools in reasonable travel time and do households have a freedom of choice to select between different options? Access to one school ensures a basic supply, while several options allow families to select that school deemed best for their children. Sample maps for case study results are presented in Figures 9.18 and 9.19 for Northern Italy, in Figures 9.20 and 9.21 for the Western Mediterranean and in Figures 9.22 and 9.23 for Bavaria.

Accessibility to higher secondary schools is relatively good by car all over in Europe, except for most peripheral areas (including inner peripheries within countries) and in general for sparsely populated areas. Public transport is the major mode of transport for students to attend to higher secondary schools, as driving is not allowed in Europe under the age of 18 years. As public transport is in general slower and scarcer than private car, the accessibility to higher secondary schools is more limited by public transport than by car, and a relatively important number of communities may not have secondary education options accessible by public transport in less than 30min. Some regions overcome this gap by providing dedicated public transport services to students, while in some other regions it might be necessary for students to move onto more accessible areas to attend secondary education (moving with relatives, boarding schools).

In **Finland**, only in the major urban areas accessibility to higher secondary schools provides a substantial possibility to select between schools. In most municipalities in Finland, students have no more than two options to choose from. In the eastern and northern parts of the country there are even areas with no school accessible within 30 minutes by car. The discrepancy between municipalities is therefore very large. By public transport, the accessibility to higher secondary schools is very low, with large areas in Finland where no higher secondary schools are accessible by public transport within 30 minutes.

The 30 minutes road isochrones to higher secondary school do not cover the entire **Baltic States** territory. For all three countries, there are large areas where no higher secondary schools can be reached below this threshold. These areas are most extensive in Latvia and smallest in Estonia. However, since most of the population in all three countries is concentrated in the four main agglomerations, 50% of the population can reach 10 higher secondary schools within 30 minutes by car and 6-7 schools by public transport. In the capital cities even more than 100 higher secondary schools can be reached within 30 minutes. In fact, from most places in Latvia and Lithuania at least one or two higher secondary schools can be reached by car, sometimes even up to five. In case of Estonia, from many places households can choose between more than three higher secondary schools. This eventually results in substantial disparities between the rural and urban territories. While intermediate regions more or less correspond to the average performance, the cumulative population graph illustrates that 50% of the population in rural regions can only reach 1 or 2 schools by either mode, therefore only a basic supply of services is ensured.

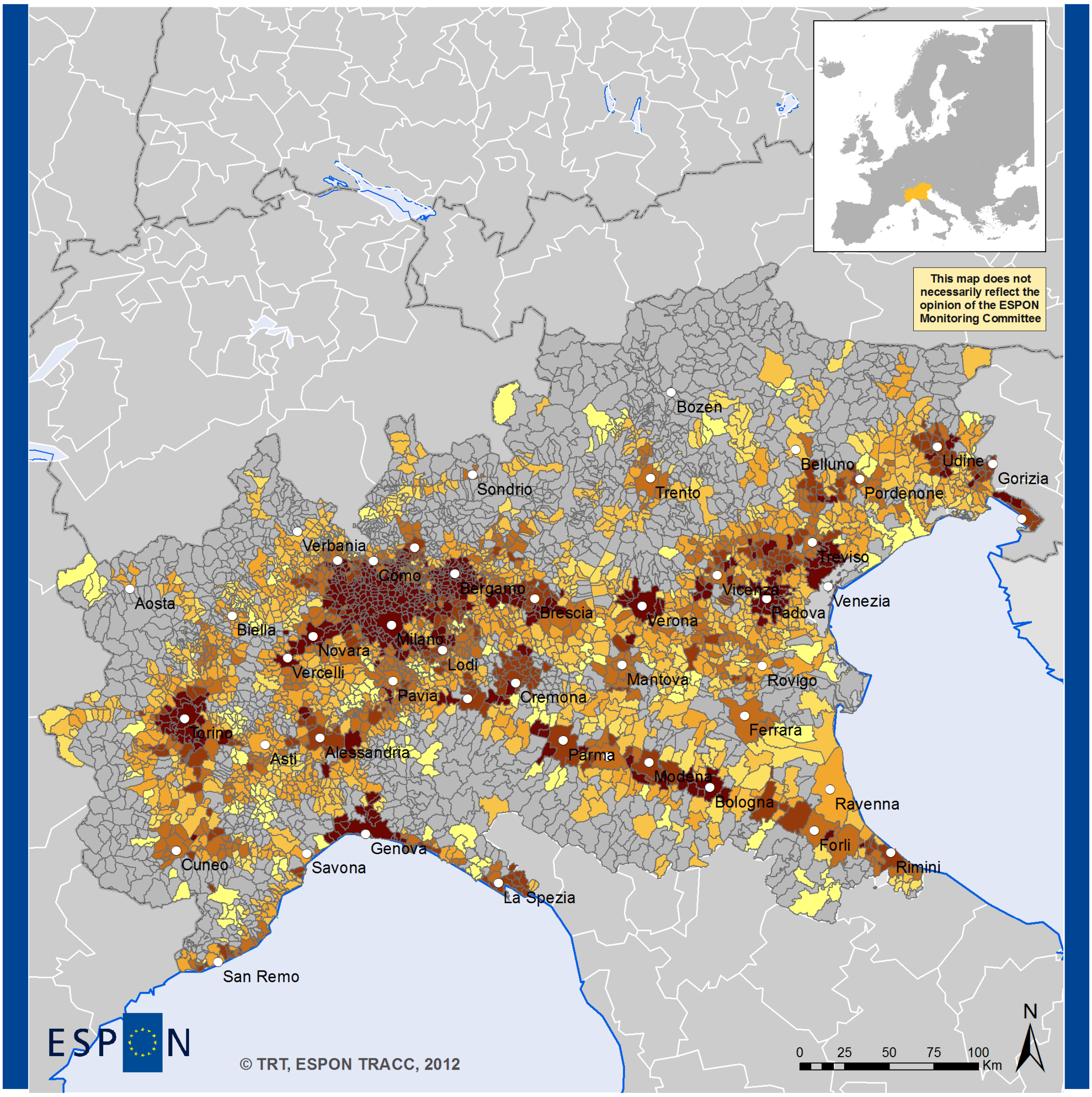
In **Poland**, the educational endowment is relatively good. Only inhabitants in the north-east and areas along the Polish-German and eastern borders have relatively less choice when travelling by car to higher schools. The wide choice of more than 20 higher secondary schools within 30 minutes travel time is reserved only for the inhabitants of regional centres. Accessibility to higher secondary schools by public transport is noticeably poorer and zones of its low level much vaster, even in the central and southern Poland. A wide choice of higher secondary schools is typical for urban municipalities, but there is a huge difference between urban and rural areas in terms of choice of higher secondary schools, irrespective of the remoteness of the rural area.

Secondary schools in the **Czech Republic** are mainly situated in communities of at least micro-regional importance (about 10.000 residents and more). Highest accessibilities are in the hinterland of the largest Czech agglomerations (Prague, Brno, Ostrava, Olomouc), being in better position the agglomerations in the eastern part of the Czech Republic (Brno, Olomouc, and Ostrava) than communities in Bohemia. As expected, the results of accessibility by public transport are poorer, even when most higher secondary school commuters rely on public transport. It is possible to identify several dozens of communities which do not have any higher secondary schools within the 30-minute distance, especially in border communities and, surprisingly, in some inland areas (in so-called inner peripheries) which are distant from major residential centres.

In **Bavaria,** there is a very distinct spatial pattern for the availability of higher secondary schools within 30 minutes travel time by car. Highest values are in the large agglomerations, including the suburban municipalities. Number of Gymnasiums goes up to more than 80 in Munich and some neighbouring communities. Second peak is in and around Nuremberg with up to 40 options. The Augsburg, Würzburg and Regensburg urban agglomerations form the next peaks with about 10 to twenty Gymnasiums. Most other municipalities have at least two options available, only for a handful of municipalities, there is no Gymnasium at all in reach within half an hour car travel time. The Bavarian average is slightly above 20, the average in rural municipalities is about 8. However, a car is not the standard transport mode to go to school. When looking at availability of higher secondary schools within half an hour by public transport the picture becomes much worse. Given the spatial distribution of the locations of the Gymnasiums, the overall spatial pattern in terms of accessibility is similar, however, on a much lower level concerning the number of available options. Now, outside the agglomerations, the better-off municipalities have only one Gymnasium within 30 minutes public transport travel time, but from most of the rural communities a Gymnasium is not reachable by public transport within that travel time maximum at all. Though the population weighted average is about 9 Gymnasiums in reach, but this is mainly due to the population concentration in the urban parts. So, for the accessibility to higher secondary schools it is first of all decisive in which type of region a pupil lives. Then, it is relevant whether one might go (or will be driven) to school by car which is superior to be dependent on public transport.

In the **Northern Italy** region, higher secondary schools exist not only in the bigger cities, but also in most of the medium centres. Many alternatives are available for a large part of the population. Only 4% of the population (living in 12% of the territory) has no schools available within 30 minutes reach by car, 11% by public transport (30% of the territory). Additionally 13% of the population has just one school within reach by public transport. Instead 87% of the population can reach 11 higher secondary schools or more in half an hour by car, and 60% by public transport (as higher secondary schools offer in part different courses, availability of more schools does not necessarily imply availability of more schools of the same sort). Urban NUTS-3 regions show less homogenous results for this indicator than for others, meaning that the usual correspondence between “living in an urban area = accessibility much better than the average) depends in this case on the specific urban zone.

In the **West Mediterranean** region, car accessibility to higher secondary schools is high in most of the zones. Only 0,3% of the population, about 46.000 inhabitants living in 108 municipalities (6% of total) has no higher secondary schools available within 30 minutes drive, and just 1,1% can reach only one higher secondary school in less than 30 minutes, about 150.000 inhabitants and 216 municipalities (12% of total). Instead 89,0% of the population can reach 20 higher secondary schools or more in one half an hour drive. Public transport accessibility is much lower resulting in 2,0% of the total regional population, about 285.000 inhabitants in 497 municipalities (28% of total) having no schools accessible within 30 minutes drive, and 3,8% can reach only one school in less than 30 minutes, a set of 540.000 inhabitants living in 728 municipalities (41% of total). Still, 64,3% of the population can reach 20 higher secondary schools or more in half an hour by public transport, that is 9,1 million inhabitants living in the 319 municipalities (18% of the total).



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Source: TRT Accessibility model (2012), Rail Network: RRG GIS Database (2011),
Road Network: OSM (2011), Italian Ministry of Education (2010/2011)
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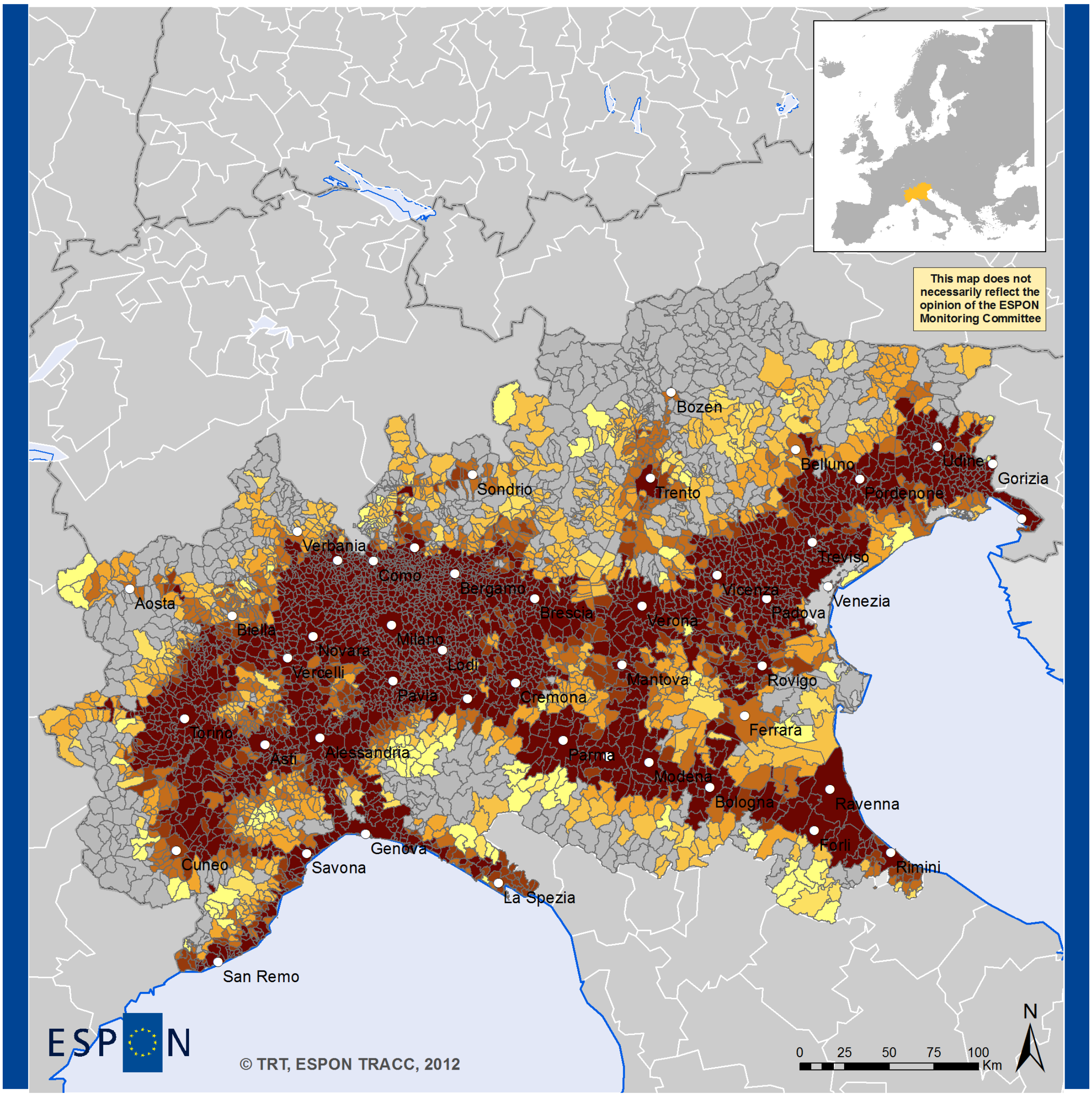
Northern Italy Case Study (2011)
Availability of secondary schools: Number of secondary schools within 30 minutes of public transport travel time

- 0
- 1
- 2
- 3 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 < ...

○ *NUTS3 Capital*

Figure 9.18. Northern Italy case study, availability of secondary schools by public transport



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Source: TRT Accessibility model (2012), Rail Network: RRG GIS Database (2011), Road Network: OSM (2011), Italian Ministry of Education (2010/2011)
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Northern Italy Case Study (2011)
Availability of secondary schools: Number of secondary schools within 30 minutes of road travel time

- 0
- 1
- 2
- 3 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 < ...

○ *NUTS3 Capital*

Figure 9.19. Northern Italy case study, availability of secondary schools by road

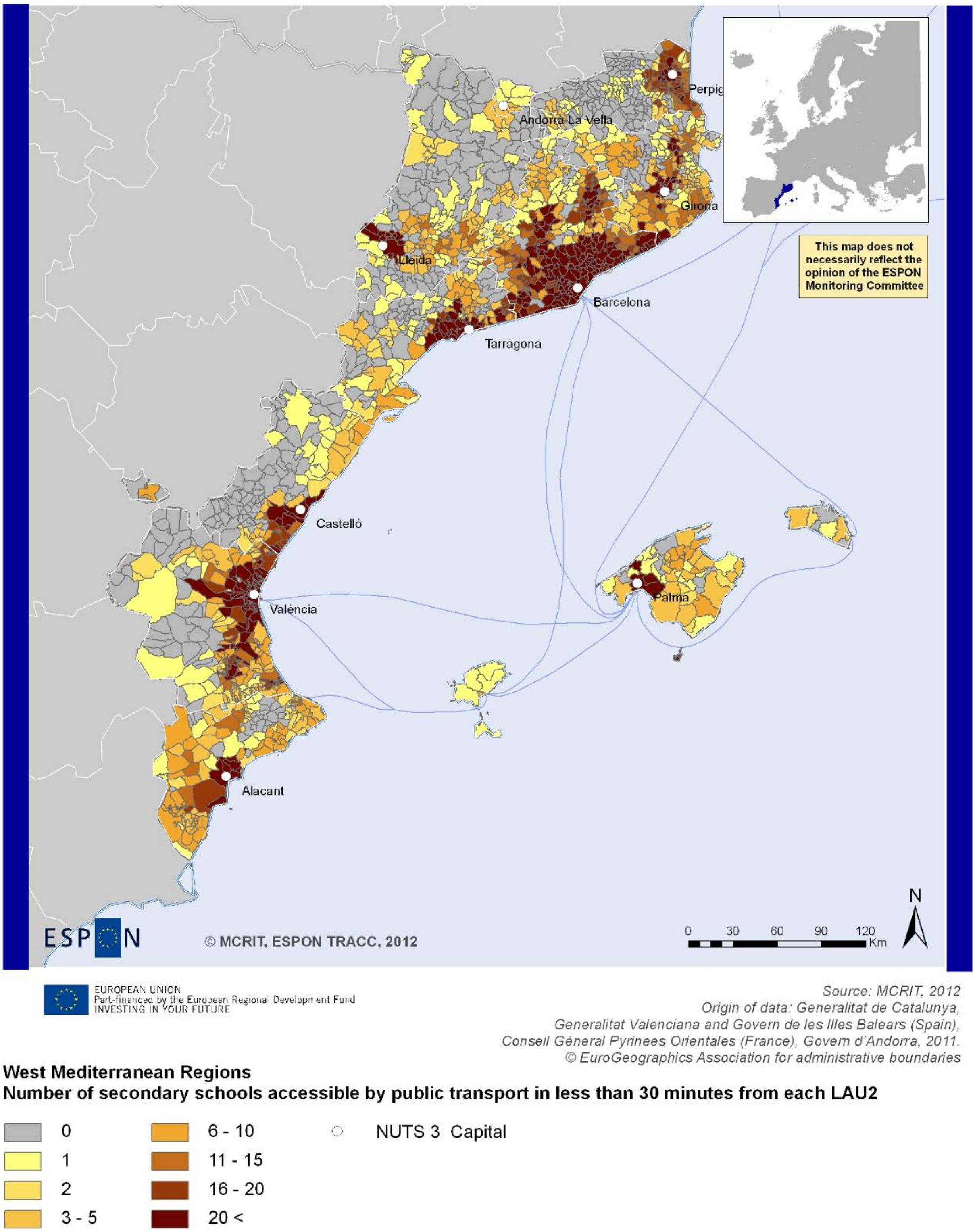


Figure 9.20. West Mediterranean case study, availability of secondary schools by public transport

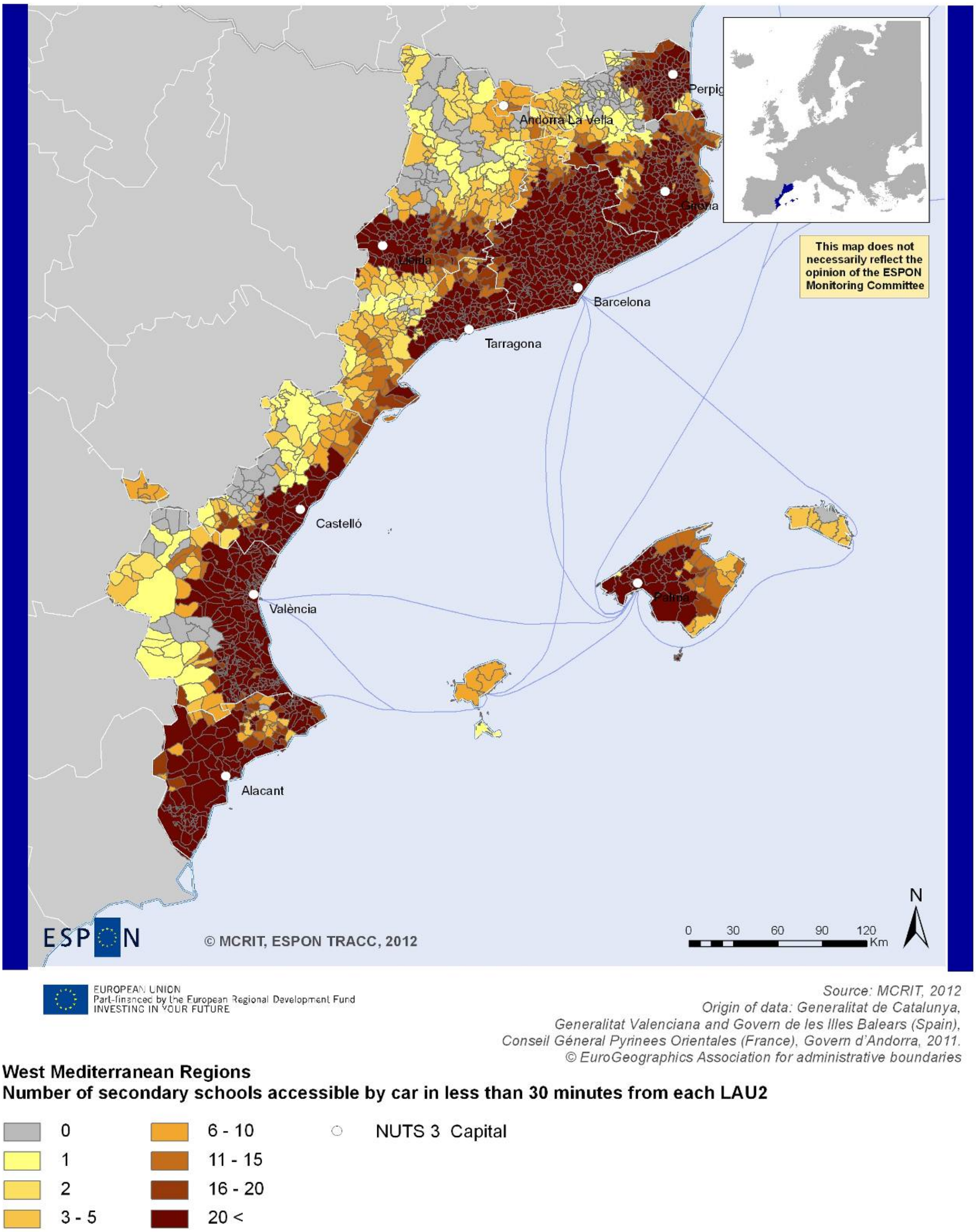
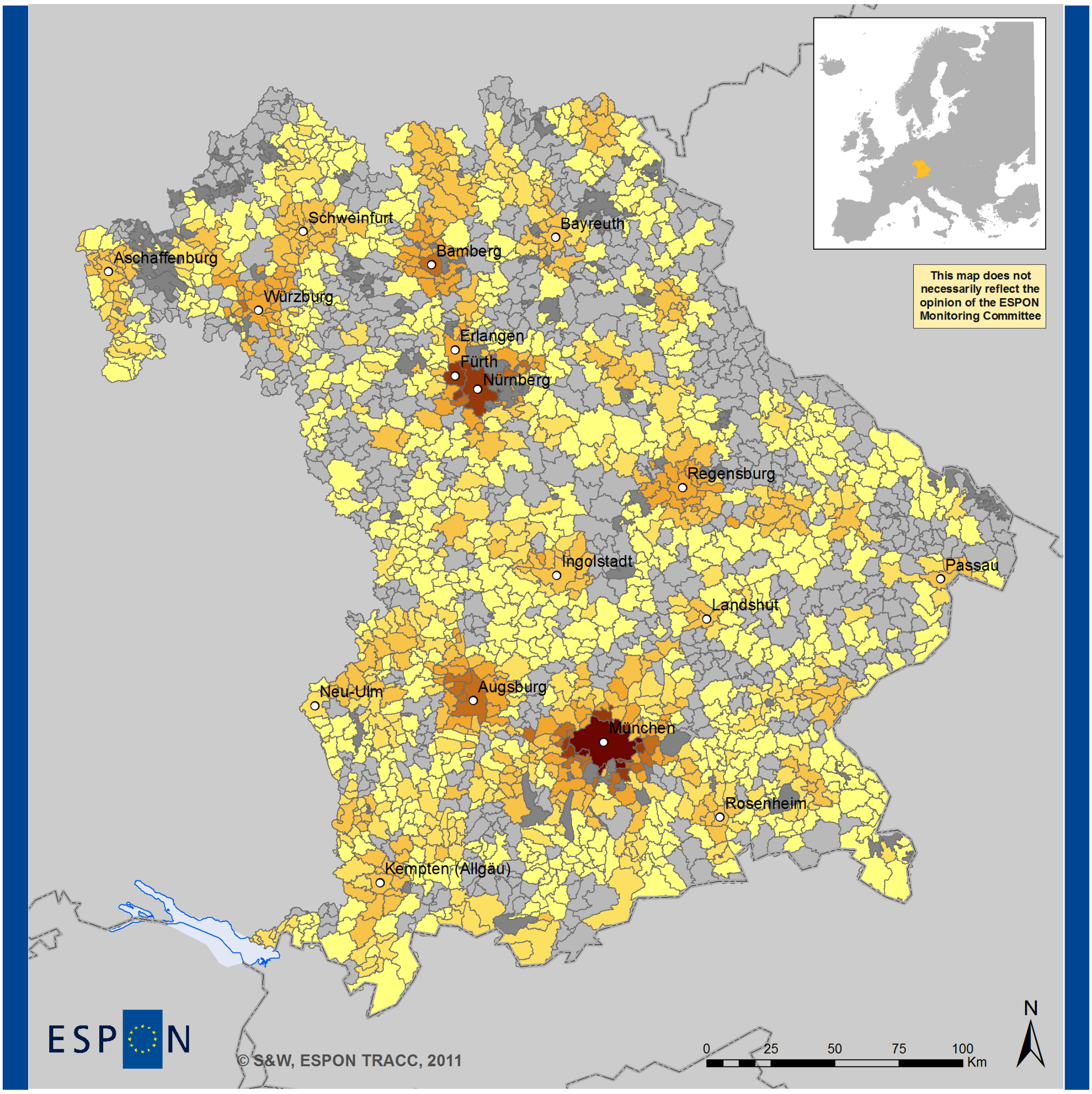


Figure 9.21. West Mediterranean case study, availability of secondary schools by road



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Source: S&W Bavaria Accessibility Model, 2012
Origin of local data: StMWIVT
Origin of map data: ESPON Database 2013
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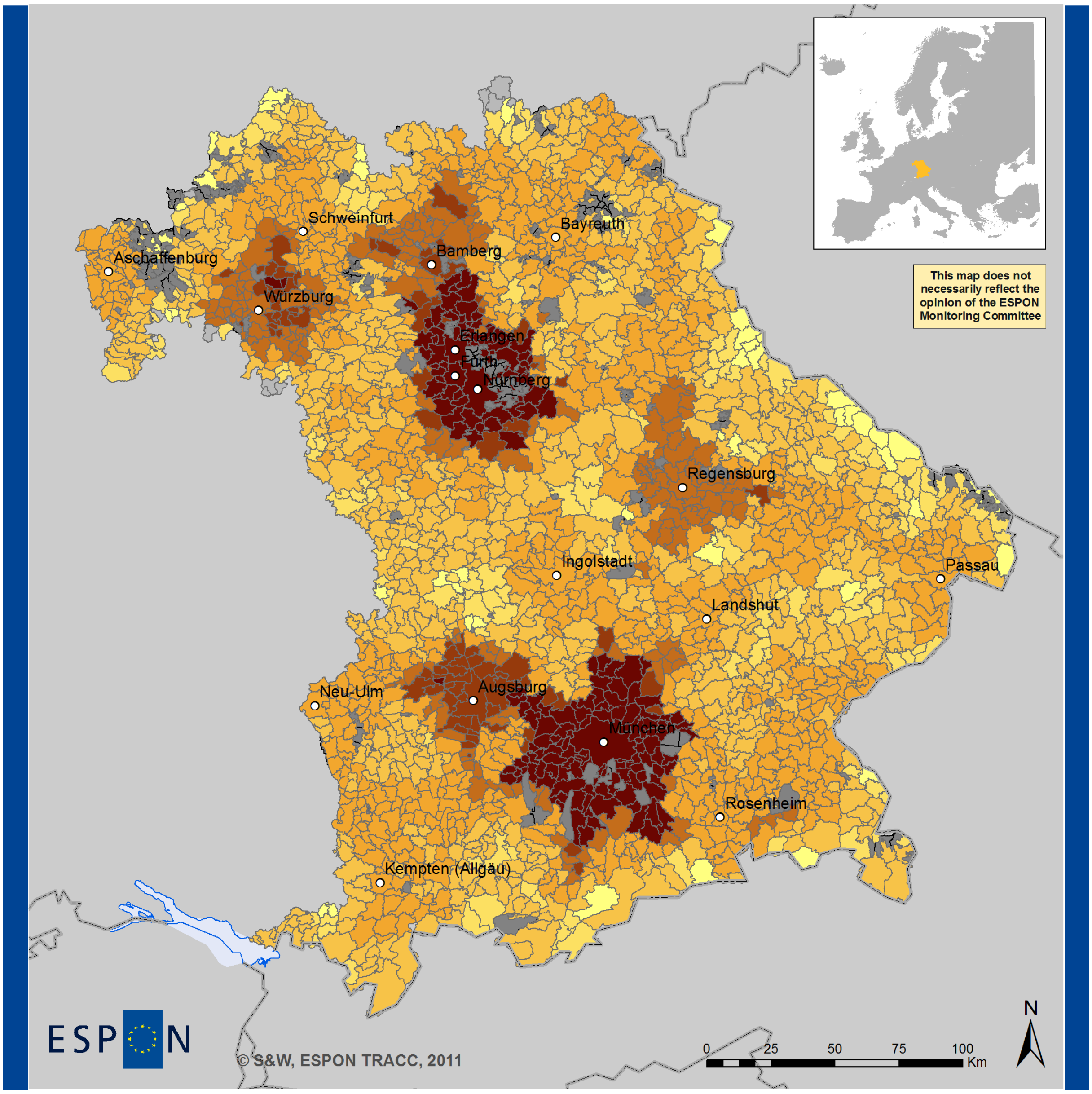
Bavaria Case Study
Higher secondary schools within 30 minutes travel time by public transport (number of schools)

- 0 - 0,5
- 0,5 - 1,5
- 1,5 - 2,5
- 2,5 - 5,5
- 5,5 - 10,5
- 10,5 - 15,5
- 15,5 - 20,5
- 20,5 <
- Unincorporated area

Figure 9.22. Bavaria case study, availability of higher secondary schools by public transport



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Source: S&W Bavaria Accessibility Model, 2012
Origin of local data: StMWIVT
Origin of map data: ESPON Database 2013
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Bavaria Case Study
Higher secondary schools within 30 minutes travel time by car (number of schools)

0 - 0,5	5,5 - 10,5	Unincorporated area
0,5 - 1,5	10,5 - 15,5	
1,5 - 2,5	15,5 - 20,5	
2,5 - 5,5	20,5 <	

Figure 9.23. Bavaria case study, availability of higher secondary schools by road

9.1.6 Accessibility potential to basic health care

What is the locational quality with respect to basic health care? Using the number of medical doctors in general practice surgeries as destination activity in a potential accessibility indicator allows assessing the relative distribution of health care provision of different areas within case study regions.

Using public transport to go to doctor puts additional burdens upon people compared to using a car. Assuming that elderly people visit general surgeries more often than other groups of people, who for various reasons stronger rely on public transport systems, one can imagine that these groups experience some problems in organizing their daily life facing such access obstacles. In general, the patterns of potential accessibility to basic health care (doctors) by car are somewhat similar to the patterns of potential accessibility to population. Sample maps for case study results are presented in Figures 9.24 and 9.25 for Finland and in 9.26 and 9.27 for the Czech Republic.

In **Finland** there are marked differences in the accessibility potential to basic health care. In the South-Western of the country, the potential accessibility to medical doctors by car is relatively good, while the situation is considerably worse in the eastern and northern parts of Finland. This is related to the longer distances and lower availability of medical services in the peripheral parts of the country. The analysis of accessibility potential by public transport provides a very similar picture. The accessibility potential is good in the south-western part of Finland and in the biggest municipalities, while remaining low in regions poorly served by public transport.

In the **Baltic States**, the analysis for Estonia and Latvia for both road and public transport illustrate areas of high accessibility around main regional centres and along main transport axes, while the situation in Lithuania is more complex. While for road a seamless plateau of high accessibilities is formed around the agglomerations of Kaunas and Vilnius, supplemented by areas of high accessibility around Klaipeda and Panevezys, for public transport a lot of local hotspots appear around each medical centre, even in small towns and villages, reflecting the service quality even in rural and peripheral parts of the country. Accessibility levels for public transport are only fractions of those for road, since most parts of all three countries show huge underperforming. Only areas around Riga, Tallinn, Tartu and Daugavpils lie above the average.

In **Poland**, once again the Warsaw metropolitan region, Upper Silesia conurbation and Kraków are much more visible as areas of the best accessibility to health care by car. In the other cities with more than 500.000 inhabitants, like Poznań, Wrocław, Tricity (Gdańsk, Gdynia and Sopot) and Łódź the access to the basic health care is also at the very high level. In general, the cities in the eastern part of Poland seem to have relatively better access to basic healthcare in comparison with the general accessibility to population. The worst situation is for sparsely populated areas of the Zachodniopomorskie and Warmińsko-Mazurskie voivodeships. In comparison with individual transport, accessibility potential by public transport is rather poor and needs to be improved. Areas with better accessibility to primary health care by public transport are limited to an immediate neighbourhood of large and some of the medium-sized urban centres. Only in the southern Poland (region of Upper Silesia, Kraków and Częstochowa) these areas form a more compact zone.

In the **Czech Republic**, the analysis of potential accessibility to basic health care (doctors) shows the concentration into main agglomerations, its hinterland and along main transport networks. As many inhabitants are dependent on public transport, this indicator could also be important for regional policy improvements.

Also in **Bavaria**, accessibility potential to medical doctors is high in agglomerations and goes down to rather low values in rural areas. Accessibility by public transport is much beyond accessibility by car. This similarity with accessibility population to population is due to the fact, that more or less the density of medical doctors follows the population distribution.

In **Northern Italy**, The relevance of the metropolitan area of Milan and of the “enlarged city” connecting Turin to Venice is almost more apparent as doctors are slightly more concentrated than population. Given this concentration, there are group of regions also outside the mountain areas whose potential accessibility to basic health care is significantly lower than the average. These more disadvantaged regions are mainly located in the south-east of the study area, where population density is lower. 80% of the zones and 60% of the population are ranked below the average. Potential accessibility to doctors by public transport is generally well below the average accessibility to doctors by car. The profile of the “Padan megalopolis” is clearly recognisable. Outside of it, only the Genoa metropolitan area is not too far away the reference level of average accessibility. For all other zones the public transport accessibility is less than 25% of the average car value.

In the **West Mediterranean** region, the pattern of potential accessibility to basic health care (doctors) by car is similar to the pattern of potential accessibility to population. Largest urban agglomerations concentrate most the largest hospitals, but also most regional centres have country hospitals, and medium-small municipalities have primary health centres and smallest municipalities may have health services only at certain days of the week. The influence of Barcelona metropolitan region reaches the four Catalan NUTS-3 capitals, but not Perpignan in France (as opposed to population potential). Large potential accessibilities to doctors by public transport are limited to largest cities in the case study area: in Barcelona and Valencia. Tarragona and Castelló show some positive values, indicating mostly that they benefit from the health endowment of the Barcelona and Valencia metropolitan areas.

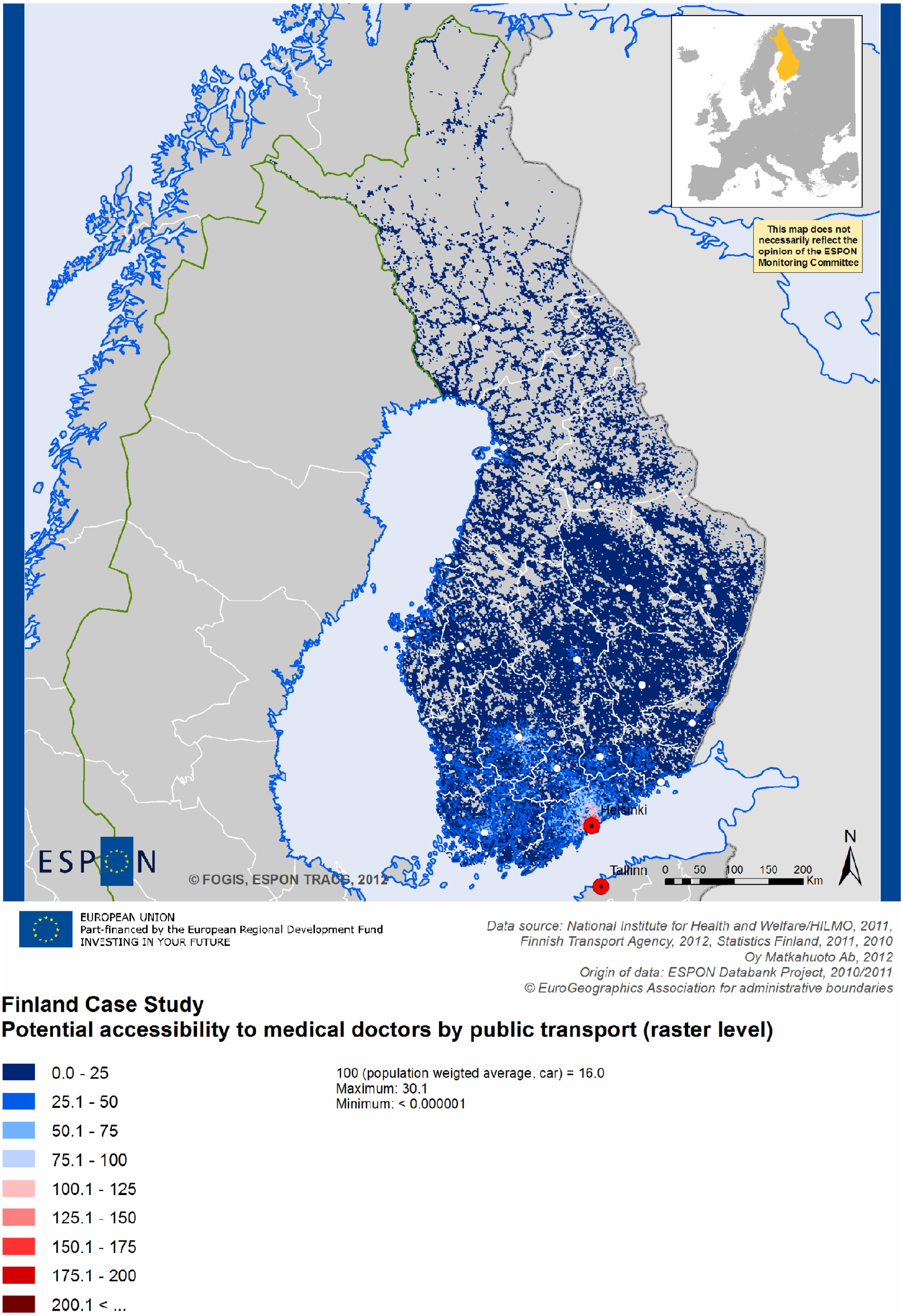


Figure 9.24. Finland case study, potential accessibility to medical doctors by public transport

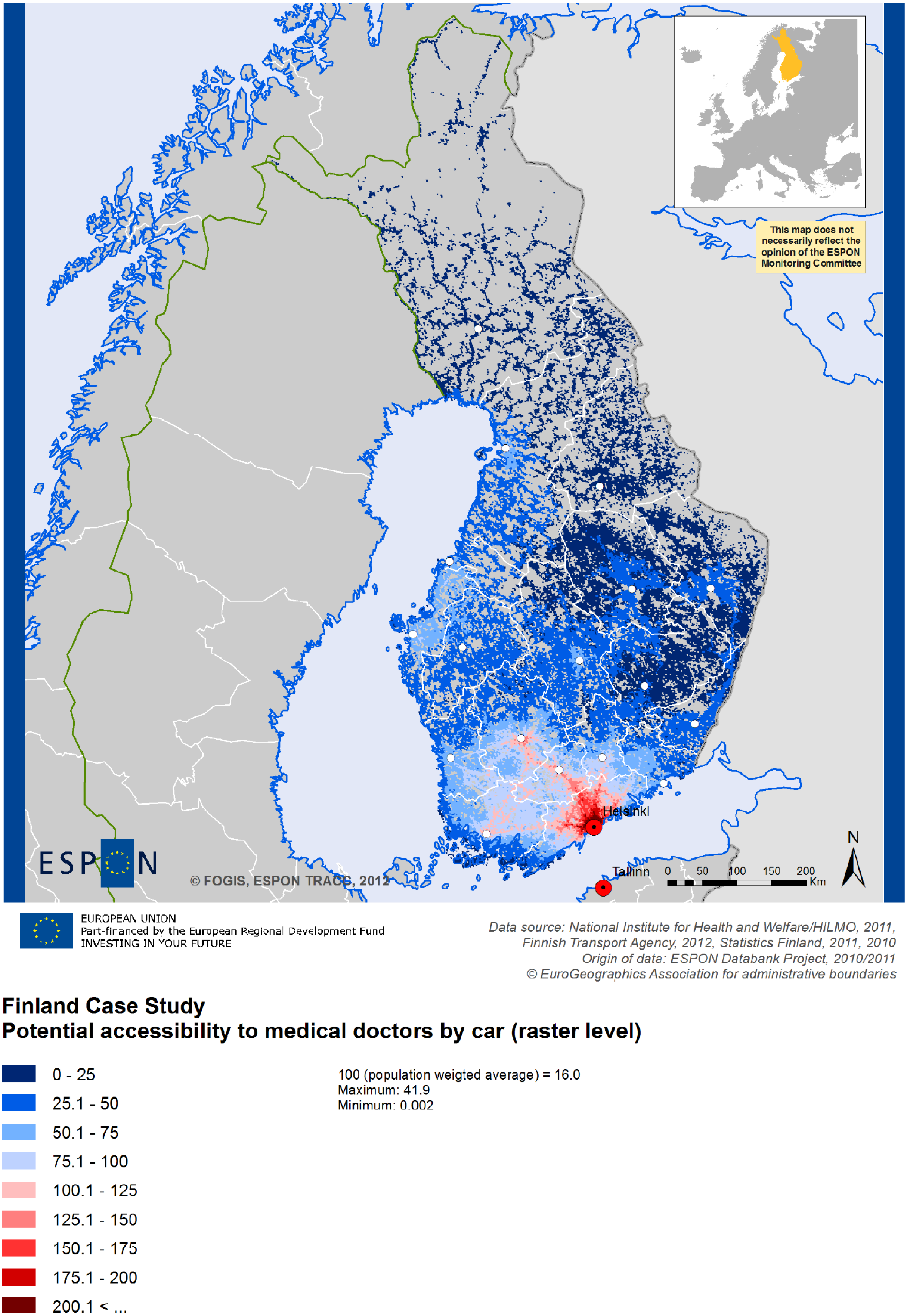


Figure 9.25. Finland case study, potential accessibility to medical doctors by road

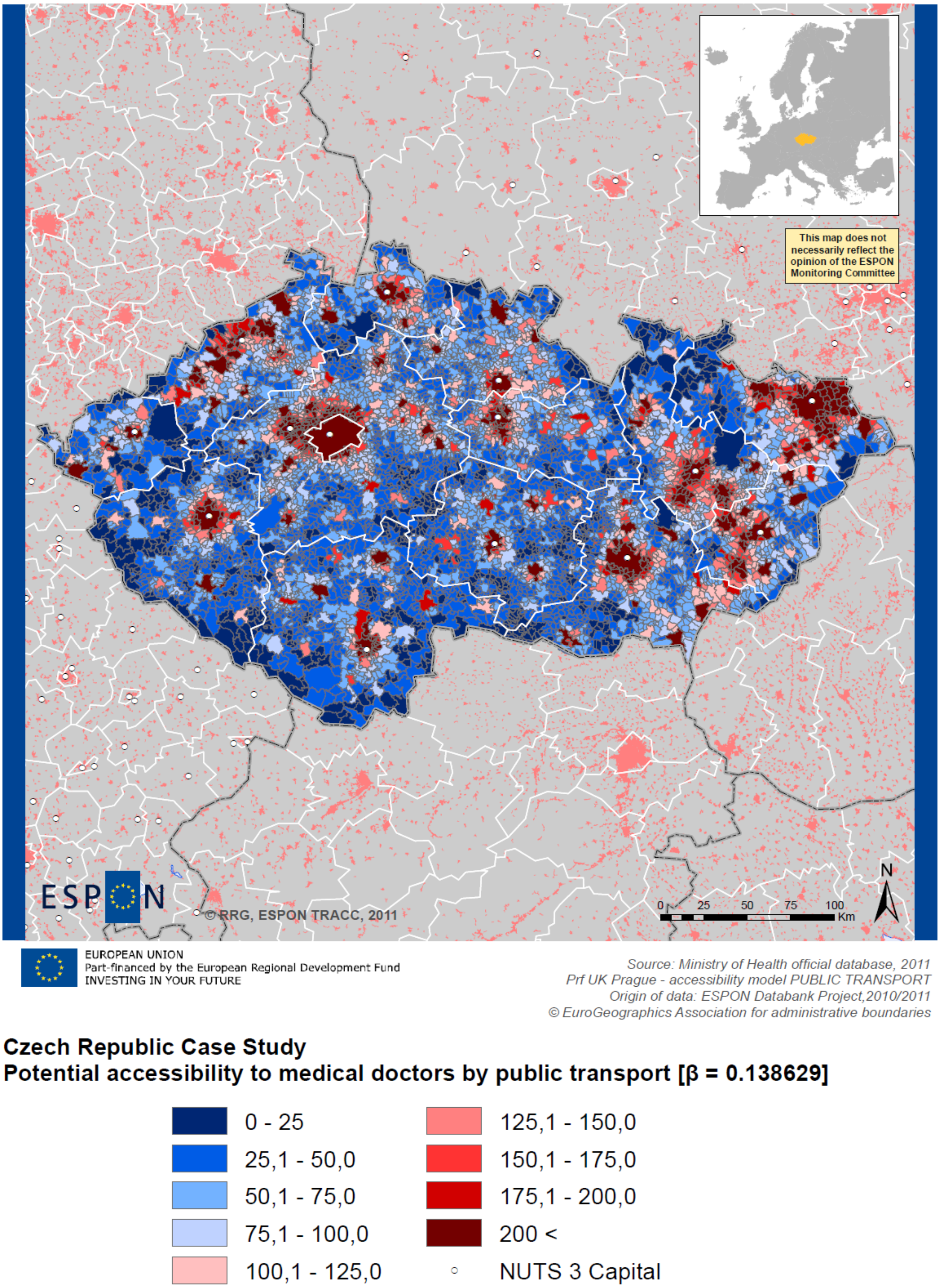


Figure 9.26. Czech Republic case study, potential accessibility to medical doctors by public transport

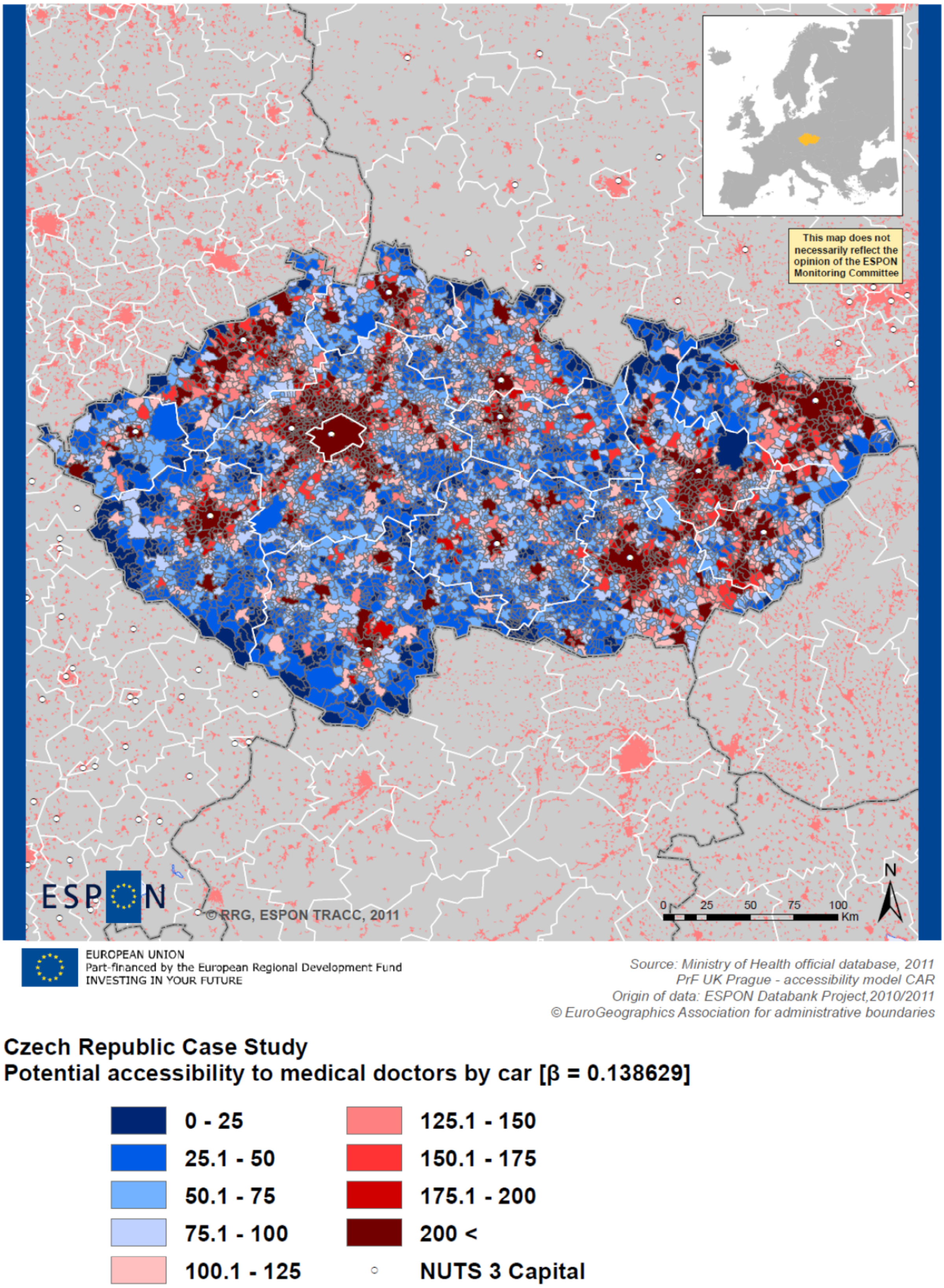


Figure 9.27. Czech Republic case study, potential accessibility to medical doctors by road

9.2 Main findings by case study region

The subsequent section gives for each case study a summary of the main findings.

Finland Case Study

Finland, as a whole, is one of the most sparsely populated countries in Europe. In the spatial divisions of the population and jobs, the presence of both urban densities and extremely sparsely populated areas having long distances to major population centres is evident in the analyses of accessibility. Polarisation is intense in the centre-periphery axis, when compared to European standards, and the division is deepening due to the location choices of companies and the overall urbanisation process.

The availability of services is relatively good even in peripheral areas, but naturally the number of choices decreases along with lower demand. This is evident in the case of health care accessibility. There are hospitals in every major city and town, and accessibility to basic health care corresponds to population distribution. Most municipalities in Finland have at least one higher secondary school, but in many parts of the country, students have no real choice concerning their school, and travel times are long. Only in the sparsely populated peripheries, accessibility to services can be considered to be poor.

This regional structure favours travelling by car in areas outside urban densities, and car is clearly the dominating travelling mode in Finland. As for all indicators of accessibility, it appears that the use of public transport significantly reduces the accessibility in all parts of the country, with the exception of the capital city and its surrounding areas, and the core areas of other major cities. Outside of the immediate surroundings of centres, accessibility by public transports decreases rapidly and is non-existent in the deepest peripheries. Because of the geography of Finland, distances are generally long, transport flows are thin, and there is not enough population in many areas to ensure adequate demand for public transport.

The capital region and its surroundings, constituting the Uusimaa zoom-in area, clearly stand out as areas of good accessibility, compared to any other parts of the country. The other major population centres, especially regional capitals, constitute the second best category of accessibility, while large peripheral regions are generally characterised by low accessibility. However, rural areas exhibit different levels of accessibility in different parts of the country. Especially in the eastern and northern regions, the accessibility of services is extremely poor for the rural population, while in some predominantly rural regions, the presence of strong regional centres may be associated with improved indicators of accessibility. In the Finnish case study, the Lapland zoom-in area represents the case of remote periphery with poor accessibility, while the Northern Ostrobothnia zoom-in area represents a combination of remote periphery and a major regional centre having positive implications on the accessibility for the adjacent areas.

Transport corridors and networking between urban regions and centres within their zones of influence, have been a key element of the Finnish transport policy (Ministry of the environment, 2006). In order to secure the needs of foreign trade, functional transport connections must exist to all parts of the world. Indeed, in economic terms, the most important elements of the Finnish transport system are connections to abroad (harbours and aviation in particular), the capacity and the level of service of the trunk roads and railways, the internal transit system of Helsinki, and the connections between the most important regional centres. A fundamental requirement of a functioning logistic chain is that the services of the road and railway infrastructure, as well as harbours, are available. In the case of Finland, it has to be noted that the availability of services is critical also in winter. This is something that cannot be taken for granted especially at high latitudes. With this regard, a special need of the Finnish transportation system, also affecting international accessibility, is the use of ice-strengthened ships and ice breakers in maritime transport during the winter season.

In early 2012, the Finnish government gave an extensive report on the national transportation policy (Liikenne- ja viestintäministeriö, 2012). The Finnish transport policy and the transport system are tightly connected to the other functions of the society, including particularly the requirements of the industry, economy and employment, as well as regional development, since good accessibility is a key factor in the economic development and prosperity of regions. At contrast, improving the accessibility of remote rural areas will not be in the focus of Finnish transport policy. This effectively signifies that these areas will remain in a disadvantaged position also in the future, as the development measures will be mostly directed to the regions having the most favourable conditions with regard to economic activity and population.

The components of accessibility are the accessed place or object and travel for reaching in general, population distribution changes slowly and transport networks maybe even more slowly, particularly in Finland, where the network have reached a sort of maturity. Thus, the service supply, location choices of companies and population change will evidently affect more to accessibility development in Finland, than any foreseen transport investment.

A majority of the findings of this study are based on grid cell maps, free of administrative divisions. Several particular areas and patterns can be noticed only on the grid cell basis. The LAU-2 division, i.e. the municipal structure of Finland is sparse in some areas and municipal consolidations have been common. There are significant political efforts in reducing the amount of municipalities even more. Therefore, it is important to acknowledge that the spatial analysis based on the municipal classification loses accuracy, and comparability between different years is poor. This underpins that the LAU-2 classifications need supplemental regional classification systems, which could be based on grid cells. In Finland, this type of regional typology is in a pilot stage (Finnish Environment Institute (2012)).

Baltic States Case Study

The accessibility indicators reveal different spatial patterns in the Baltic States. While the travel time to the nearest regional centre by car is quite short for all parts of the case study area, service quality by public transport is generally poor for most areas, except for the main agglomerations. In fact, many parts of the Baltic States do not have any public transport accessibility to regional cities. The indicator daily accessibility by jobs marks the dominance of few labour market centres with extremely high job numbers opposed to extensive rural areas where only a fraction of jobs are within reach – for both modes. The absence of jobs in the rural and peripheral areas may, by way of consequence, reinforce migration processes from the peripheral regions towards the main centres. Potential accessibility to population is dominated by the areas Kaunas-Vilnius and Riga. Estonia, due to its generally lower population density, falls behind the performance of the southern parts of the Baltic States[1]. Also, accessibility by public transport is much poorer than accessibility by car, for all parts of the case study area. Riga, Kaunas and Vilnius are the largest market areas in the Baltic States, in terms of population potential. The divide in market potentials to the rural regions is that high that one expects all future economic and demographic developments concentrate in these agglomerations. Due to the even spatial distribution of hospitals across the Baltic States, there is good car access to health care facilities through all parts of the case study area. Only some small areas along the border suffer insufficient access times. In case of public transport the cities and town are well served, covering the largest share of population, while the hinterland often experience some difficulties in getting to a hospital by bus or train. Altogether, this indicator confirms a fair and balanced accessibility surface without any polarization between urban and rural parts. Results for the indicator availability of higher secondary schools come to some surprise. Even though a minimum access to at least one higher secondary school is main-

[1] Destinations abroad which are closer to Estonia such as Helsinki and St. Petersburg may, however, compensate for the missing domestic demand.

tained for the majority of population, from large parts of the study area no school at all can be reached within 30 minutes, even by car. Freedom of choice for the families between more than one school is basically only offered in agglomerations. Results for public transport are even poorer as for cars; however, they have to be interpreted with caution since specialised school busses are not considered due to a lack of data. Finally, while the potential accessibility to basic health care can generally be considered as good in most parts of the Baltic States, despite the fact that there are significant differences between areas with highest and lowest accessibility, the poor accessibility by public transport needs to be paid attention since many elderly people rely on busses or trains to go to their doctor.

Poland Case Study

The analysis carried out in Poland allowed for identification of basic differentiations in terms of spatial accessibility in one of the new EU member states, significantly backward in development of its transport infrastructure due to lack of investment between the 1980's up to recently. When Poland entered the EU in 2004, its transport infrastructure differed only marginally from that of 1989. The large amount of existing gaps entailed the necessity – to a higher degree than in other accession countries – to prioritise investments.

In the above described conditions, a distribution of spatial accessibility still remains (independently of the indicator used) a by-product of settlement network pattern, distribution of places of working and services of public utility. Influence of transport infrastructure itself is clearly discernible in public transport, which results from its uneven density (many closed rail lines), and primarily from the quality of rail routes. In the road transport a slightly different situation results from the fact that Poland has had a relatively evenly developed and quite dense network of roads, even before the transition period. However, there shortage of investment in motorways and express roads has caused accessibility deficits, as fast growth in car ownership caused a substantial overload of road network, road congestions, leading locally to deterioration in the accessibility level. Not until 2004, the development of reference projects has caused a differentiation in spatial accessibility indicators in view of the state of infrastructure.

At the same time, in the analysed range, the findings were overlapped by socio-economic processes going on in Poland which had a spatial dimension. In the first place, this concerns internal and external migrations (changes in a distribution of population), and investments in health care.

Accessibility to regional centres is in Poland conditioned by geographical and historical factors. Thereby it is much better in the south-central Poland and inferior in the north where population density is lower and cities/towns are sparse (especially in the Pomorze and Mazury regions). Only partially, it translated into the availability of public utility services (health care, education), since many of such functions are fulfilled in Poland by poviat centres, which are evenly distributed also in sparsely populated regions. Between some of the regional centres there are clearly visible internal peripheries. Existence of some of these peripheries is still tied to the borders left over from the historical period of the Partitions (for example, 19th century borders between Russian and Austrian rule between Rzeszów and Przemyśl and Lublin and Zamość or the prewar Polish-German border).

The obtained results have confirmed that there occurs acute spatial incompatibility between places of living and places of working throughout the entire territory of Poland. Concentration of places of working in major metropolises and in some medium-sized centres is markedly greater than concentration of population. This is a cause of large-scale commuting to work even from places lying far beyond what is conventionally perceived as the upper limit isochrone - 60-minute travel-time value. These trips in a considerable part are made by individual transport, which is entirely understandable after comparing of road accessibility indicators and those related to public transport.

New road investments (after 2004) to a large degree (on the basis of investigated indicators) have clearly become apparent during the analysis of potential accessibility to population (and also to medical doctors). A strongly positive effect is immediately perceptible in the long progression of constructed motorways and express roads (despite their formally lower technical standards and thus lower passing through speed adopted in a traffic model).

Within Poland, the analysis has revealed also a relatively satisfactory, evenly distributed development of public services, such as health care and secondary education. Despite that fact, disparities in accessibility to different public utility institutions (hospitals, medical doctors, schools) in the immediate vicinity of places of residence have become apparent (in the relevant isochrones). Concentration of medical doctors is clearly greater than concentration of population, which results in availability of better opportunities in terms of health care in large metropolitan areas. Also, as regards educational opportunities, metropolises and medium-sized centres are in a markedly better situation, since they are at disposal of a wider selection of educational institutions.

All analysed indicators have shown deficiencies and investment neglect of public transport. Such unfavourable picture is partly a consequence of the methodology that was adopted, but despite these shortcomings, it accurately reflects to a larger extent, the real situation, especially in the peripheral areas and those located away from the main rail lines. The better situation is noted in the intermediate vicinity of some of major centres. In external zones of metropolises as well in rural and peripheral areas, public transport is absolutely non-competitive in relation to individual transport. This concerns to a larger degree accessibility to places of work (flexible approach in searching for jobs above a 60-minute isochrone), and to a slightly smaller degree accessibility to services that are concentrated in the historically established centres, frequently in the vicinity of main railway nodes.

Czech Republic Case Study

The results of main regional centres accessibility imply significant geographic differentiation of municipalities in respect of time accessibility of key settlement centres in the Czech Republic. On one hand they highlight the hinterland, on the other hand the results show the most distant and peripheral areas located primarily at the borders with Poland and Bavaria. There are also so-called inner peripheries in the Czech Republic, which can be found around the borders of the NUTS-3 regions. Disparities in time accessibility are affected by the current state of the road infrastructure in the Czech Republic (mainly motorway network). The main difference between car and public transport accessibility is the size of the hinterland with time accessibility of up to 30 minutes and its concentric shape resulting from the lower transportation speed of public transport.

The results of job accessibility imply the most significant potential for the residents of communities in the broad hinterland of larger agglomerations. Radial express roads can be observed affecting the higher accessibility of job opportunities from more distant communities by car. The results also identify communities with a minimum amount of available job opportunities (border areas, inner peripheries at regional borders). Expressing accessibility as a cumulated opportunity provides a new view of some peripheral areas. Some municipalities laying in-between several regional capitals can benefit from the offer of job opportunities in all surrounding centres. Population relying on public transport is more strongly dependent on job opportunities in regional capitals or near to their home. The importance of suburban railroads is clearly evident.

In contrary to time and cumulated accessibility the potential accessibility take into account the weight of potentially origin destinations. The results of potential accessibility indicator considering population size of municipalities (LAU-2) shows the main concentration areas and their locations in the transport networks in the Czech Republic. There is relative separation of the two historically independent settlement areas of the Czech Republic (Moravia vs. Bohemia). A key role of motorways in the accessibility is clearly evident (NUTS-3 centres not connected to motorway system are relatively isolated). Areas with the worst potential accessibility include, first, the scarcely populated border area, and, second, so-called inner peripheries.

The results of time accessibility of hospitals show that a large majority of communities is within a 40-minute distance. The worst accessibility is from communities in the border area of the Czech Republic. Most hospitals are located in the major residential centres situated inland.

The importance of cities as the centres of secondary education is highlighted by expressing cumulated accessibility. The highest accessibility of higher secondary schools within the range of 30 minutes is in the hinterland of the largest agglomerations (Prague, Brno, Ostrava, Olomouc etc.). The results of accessibility by public transport have crucial importance, because it is not possible to obtain driving licence before 18 years of age in the Czech Republic. It is even possible to identify several zones of communities which do not have any higher secondary schools within the 30-minute distance. In particular, this is the case of border communities and, surprisingly, of some inland areas (in so-called inner peripheries) which are distant from major residential centres.

The results of potential accessibility indicator considering number of basic health care surgeries (doctors) in LAU-2 (municipalities) shows the concentration into main agglomerations, its hinterland and along main transport networks in the Czech Republic. As many inhabitants are dependent on public transport, this indicator could also be important for regional policy improvements.

Bavaria Case Study

The spatial differentiation of a case study region such as Bavaria from an accessibility point of view is very much depending on the type of destination opportunity under consideration. Accessibility of opportunities of basic needs seems to be rather balanced. However, accessibility of higher level services such as hospitals is less even distributed across the region. For such facilities, there are only some hundred locations in Bavaria and those are primarily located in cities that have a higher position in the city hierarchy. Between those central places there are often wide areas with a clearly lower accessibility situation. This is especially pronounced when talking about accessibility by public transport.

However, the spatial or temporal proximity, i.e. accessibility, is not the only criterion when deciding about travel and destination decisions. Other features of the destinations such as quantity and quality of the possible supply, individual evaluations and preferences of the potential users often prevent from travelling to the next opportunity. However, the degree to which the population has a real choice in selecting opportunities to visit varies strongly between services fulfilling basic needs and such matching advanced demand. For opportunities matching basic needs, population mostly has different choices, even in rural parts of Bavaria. However, for opportunities serving higher demand there is a clear differentiation of the Bavarian territory. Whereas the municipalities in urban agglomerations, in particular the core cities, offer a high degree of freedom to choose a certain facility, this does not exist in rural areas. Here, sometimes population must be happy if there is an opportunity in reasonable reach at all.

Remarkable are the huge accessibility differences between car and public transport. This is in particular true if longer trips have to be made to reach the destinations of interest. On average, public transport travel time are twice as high as those for trips by car. This gap is even higher in rural areas.

Northern Italy Case Study

Looking at the various index computed, the Northern Italy region can be described as an area with four main subzones; within the subzones accessibility is quite homogeneous while between the subzones the accessibility changes significantly. The first subzone is the metropolitan area of Milan and its surroundings. This subzone is significantly at the top of accessibility values thanks to the structure of the transport networks (and of the transport services) as well as to the concentration of activities. The second subzone is made of the subalpine area extending east and west of Milan (from Turin to Venice) and of the corridor from Turin to Rimini (at the south-east corner of the study area. This second subzone, broadly corresponding to the “Padan megalopolis”, also shows high level of accessibility, which are sometimes even as high as those of the metropolitan area of Milan. The third subzone includes the mountain part of the study area at its northern and southern borders. This subzone has generally quite a poor accessibility, but it is also very sparsely populated. Finally the fourth subzone is made of the remaining zones, which are located in between the other ones and present a medium level of accessibility. Zoom-in regions are significant samples of the four subzones.

There is a clear difference in terms of accessibility between private car and public transport in the Northern Italy region, the latter performing worse than the former. However, at least in the core subzones, also public transport allows for good levels of accessibility.

The analysis of zoom-in regions allowed to highlight different patterns of accessibility existing within the study area: the privileged situation of the metropolitan area of Milan, the peripheral position of Belluno, the high dependency on local destinations for La Spezia and the gap between car and public transport accessibility for Piacenza.

West Mediterranean Case Study

The accessibility patterns in West Mediterranean region follow approximately the geographic constraints of the region, which being a narrow coastal corridor for most of the territory, it concentrates most of the population and activities next to the sea side. The backcountry is substantially less populated, especially in mountain areas; infrastructure endowment is more limited giving place to poorer accessibility patterns in comparison.

In terms of accessibility, the region is dominated by the two big metropolitan agglomerations of Barcelona and Valencia. Most of the maps show that the influence of Barcelona’s agglomeration at large reaches approximately all NUTS-3 capitals in Catalonia, and in some cases even Perpignan in France. In the south, the metropolitan agglomerations of Valencia and Alacant tend to merge one with each other in most of the cases, despite the fact that mountainous topography in the areas in between both agglomerations provides locally some areas of low accessibilities.

There is a clear difference in terms of accessibility between private car and public transport, the latter performing worse than the former, as expected. In this issue, it is especially relevant the impact of the new high speed rail lines all over the region, increasing the opportunities of medium cities in between largest agglomerations. These cities may be in position to offering better live standard conditions while allowing for everyday commuting onto main labour markets, but may also be threatened to become mere residential economies due to rising competition by more robust markets.

All over the region, accessibility to public services is more homogenous than accessibility to population and jobs, reflecting the fact that public services are relatively decentralised in the Western Mediterranean region, being the ratios of hospitals or schools per 1000 inhabitants higher in areas with relatively low populations than in the largest agglomerations.

The case of the Balearic Islands shows the impact of insularity on accessibility patterns. Each island is de facto an isolated region, despite the existence of fast ferries linking some of the islands to each other and frequent internal flights.

9.3 Main findings across regions

Comparable information on indicators based on access time is presented in figures 9.28 to 9.31. **Access time to next regional centre by car** is relatively similar in all case studies, with minimum values (25th percentile) around 20 to 30 minutes, and maximum values (75th percentile) around 40 to 60 minutes. More populated case studies tend to have better values (Poland, Northern Italy, Western Mediterranean), while case studies comprising sparsely populated regions tend to have higher access times (Finland, Baltic States, Czech Republic). **Access time to next regional centre by public transport** provides much more diversity of results. While minimum values (25th percentile) are fairly similar for all regions around 30 to 40 minutes (except in the Baltic States, with 60 minutes), maximum values (75th percentile) show a wider dispersion going from around 60 minutes for Northern Italy case study to 120 minutes for the Baltic States (Figure 9.28). For **access time to hospitals,** minimum access times (25th percentile) and maximum access times (75th percentile) are lower than those observed for accessing regional centres, in all case studies. This reflects that the threshold for providing hospital equipments in Europe is generally below 50.000 inhabitants. Therefore, the health system is more easily accessed than the network of medium sized cities in Europe would seem to intuitively provide a priori. The relative differences of access times between urban, intermediate and rural regions are similar for this indicator than those observed for accessing regional centres.

Availability of urban functions indicators (jobs and higher secondary schools the same) reveal in all case studies a more unbalanced performance between different territorial typologies than all other indicators. In all cases, except for Czech Republic, urban regions have a clearly differentiated behaviour in relation to intermediate and rural regions in terms of opportunities reachable. This is especially important by car, but also relevant by public transport. The overall magnitude of cumulated opportunities varies widely from one case study to another, mostly depending on the total amount of population (Figures 9.32 to 9.35).

Potential accessibility indicators both to population and to medical practitioners show a much more unbalanced pattern between urban and rural regions than access time indicators. As expected, all urban regions perform substantially better than intermediate and rural regions, and much better than overall case study averages. Differences between different territorial typologies are more visible by car accessibility than by public transport (Figures 9.36 to 9.41).

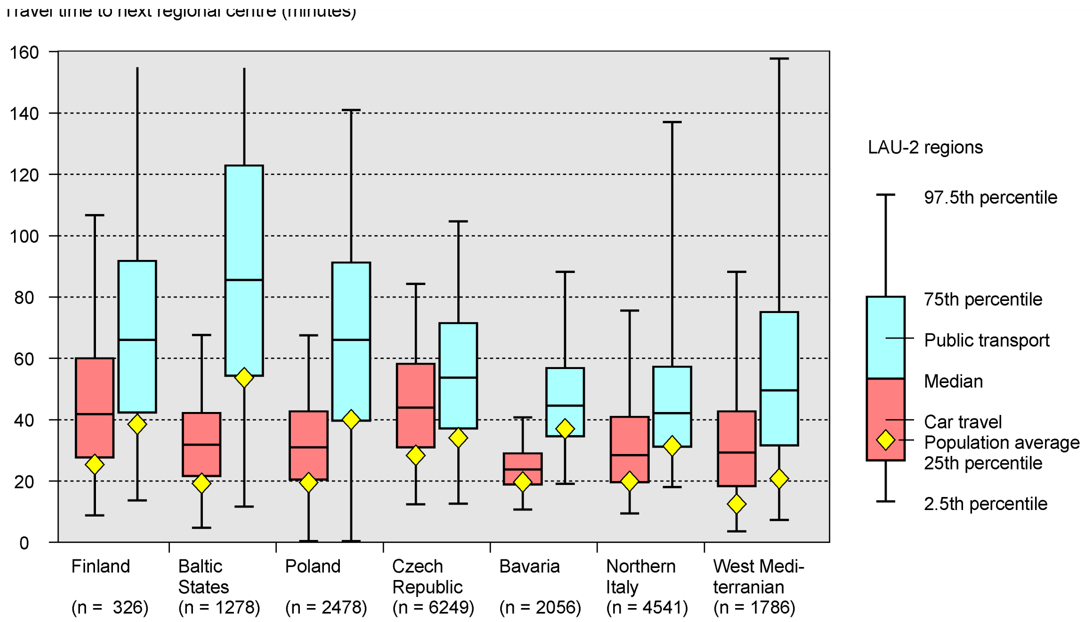


Figure 9.28.Travel time to next regional centre by case study region

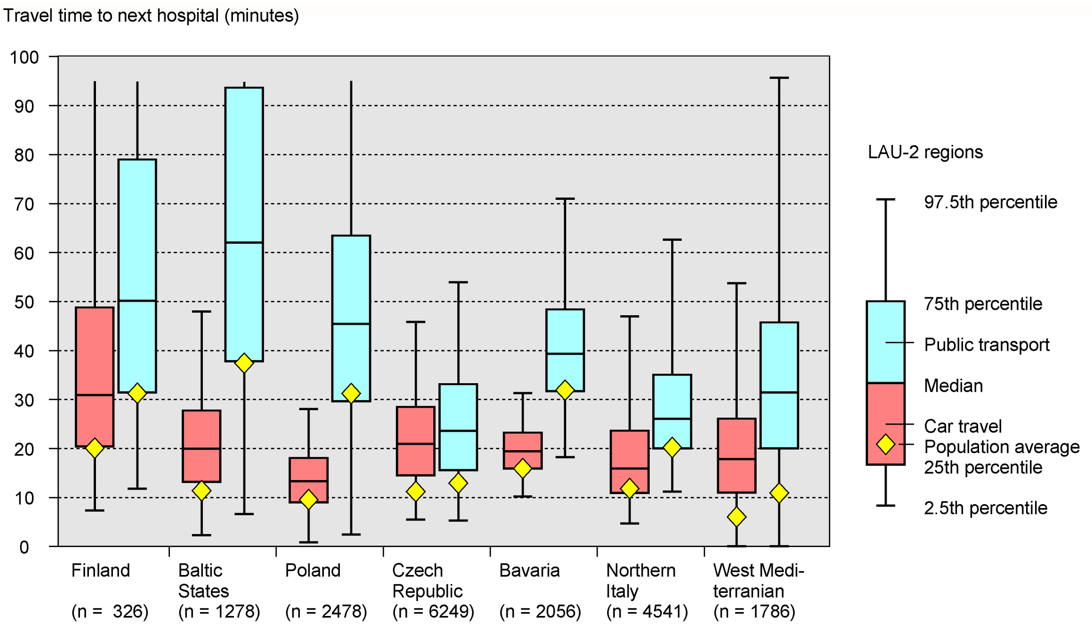


Figure 9.29. Travel time to next hospital by case study region

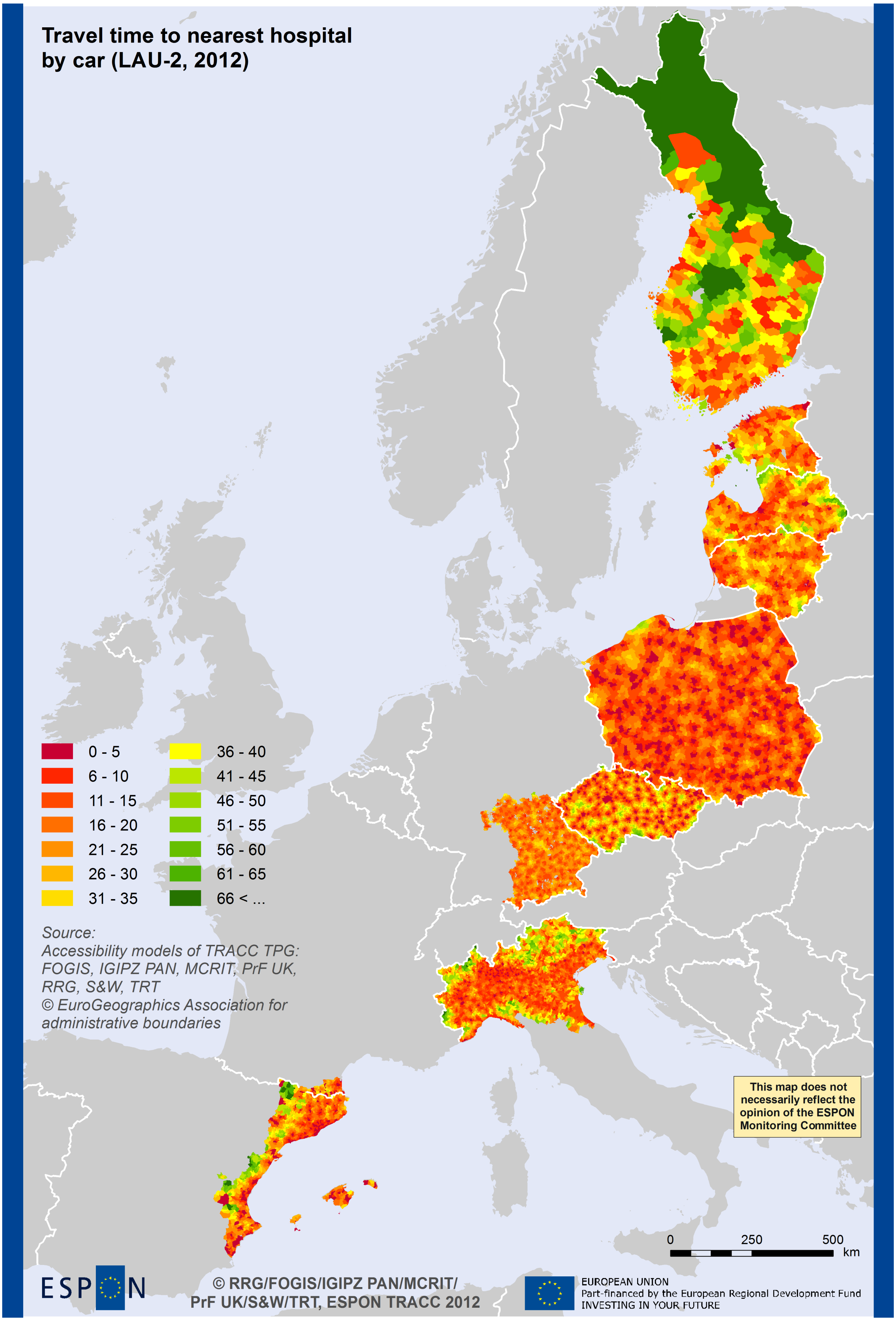


Figure 9.30. Car travel time to next hospital

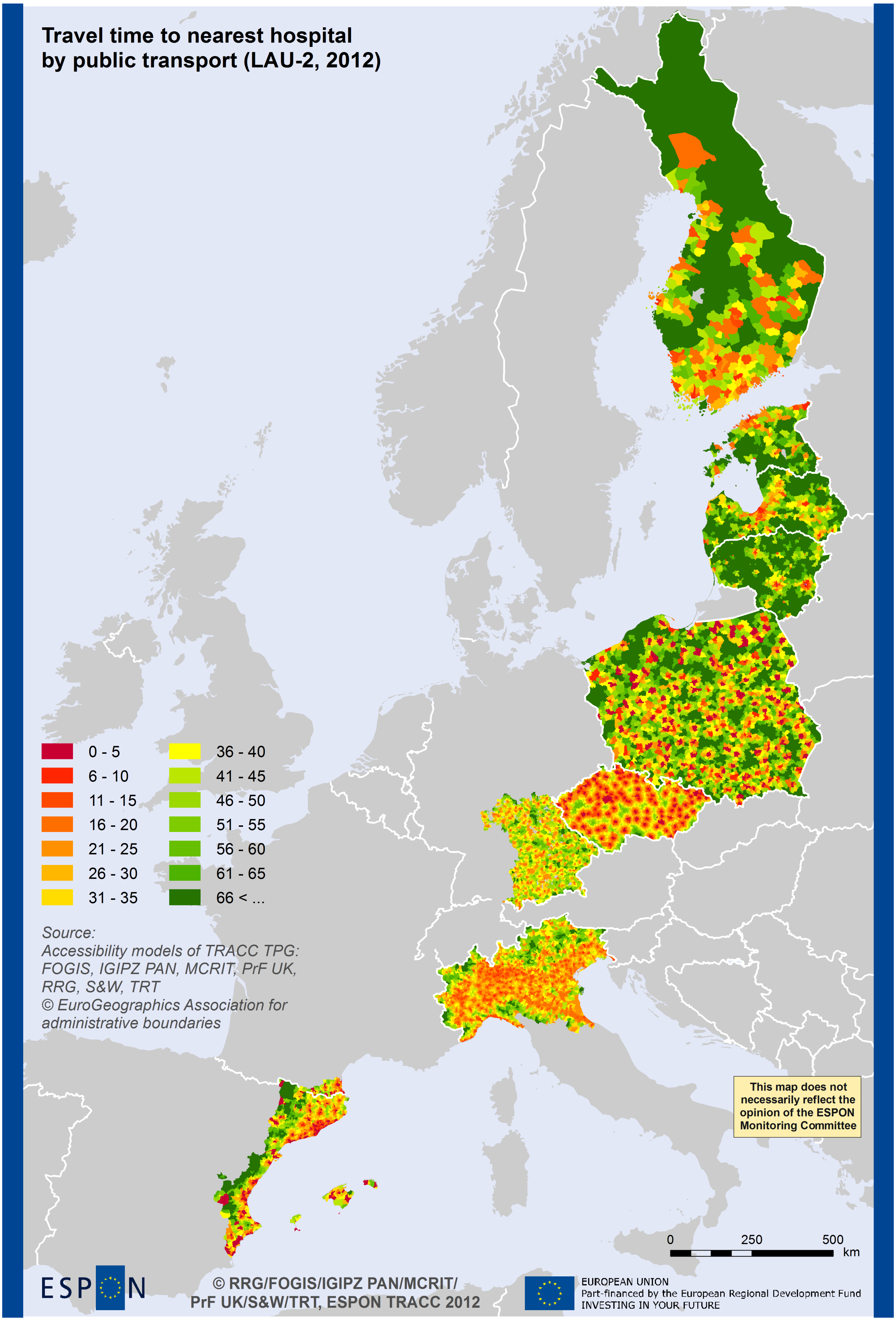


Figure 9.31. Public transport travel time to next hospital

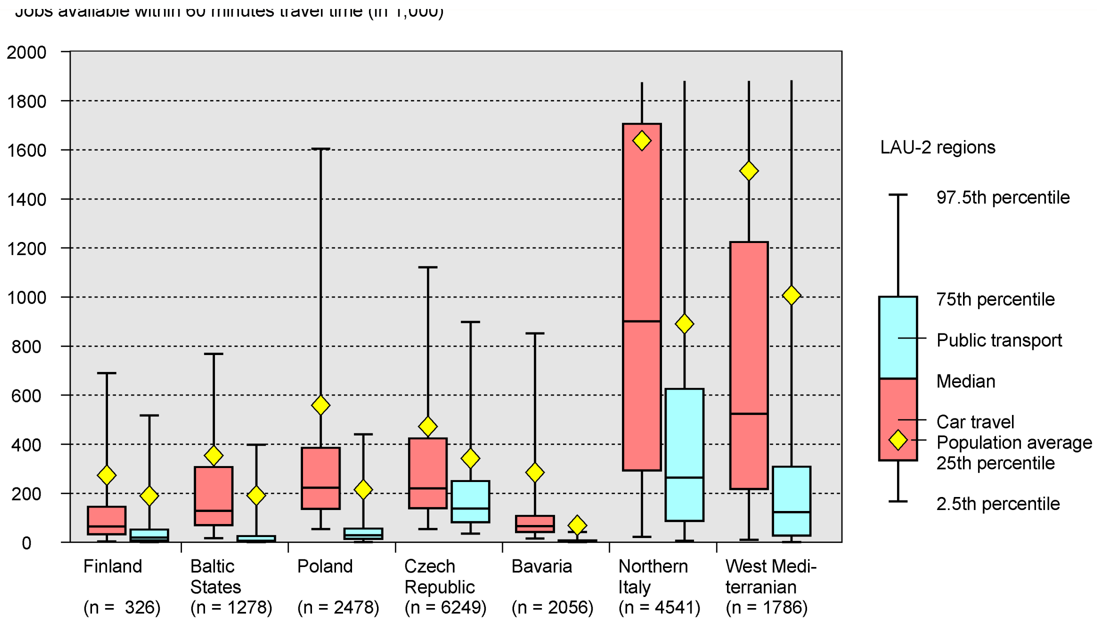


Figure 9.32. Jobs available within 60 minutes travel time by case study region.

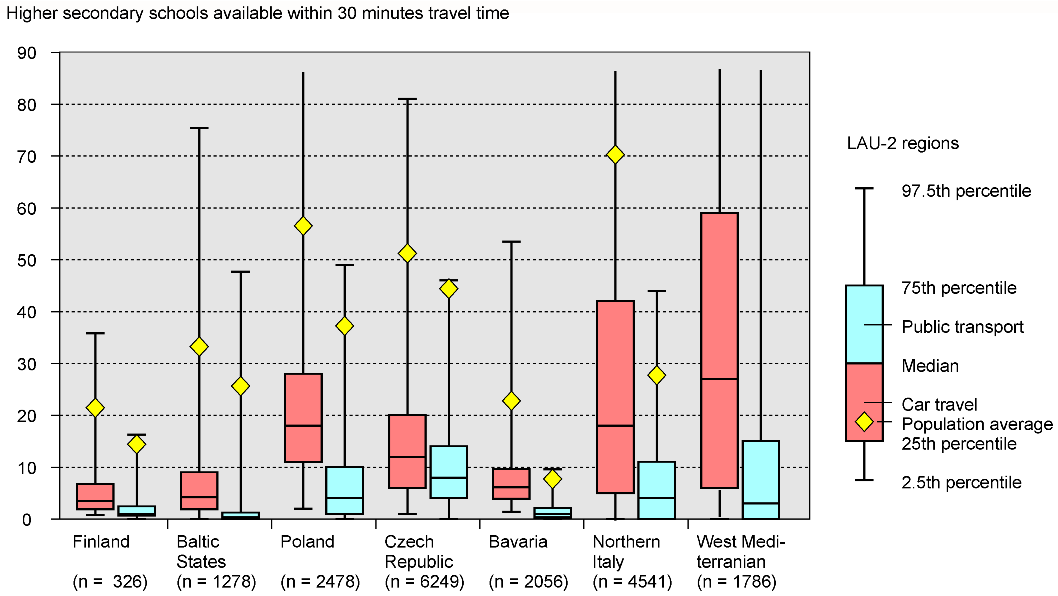


Figure 9.33. Higher secondary schools available within 30 minutes travel time by case study region

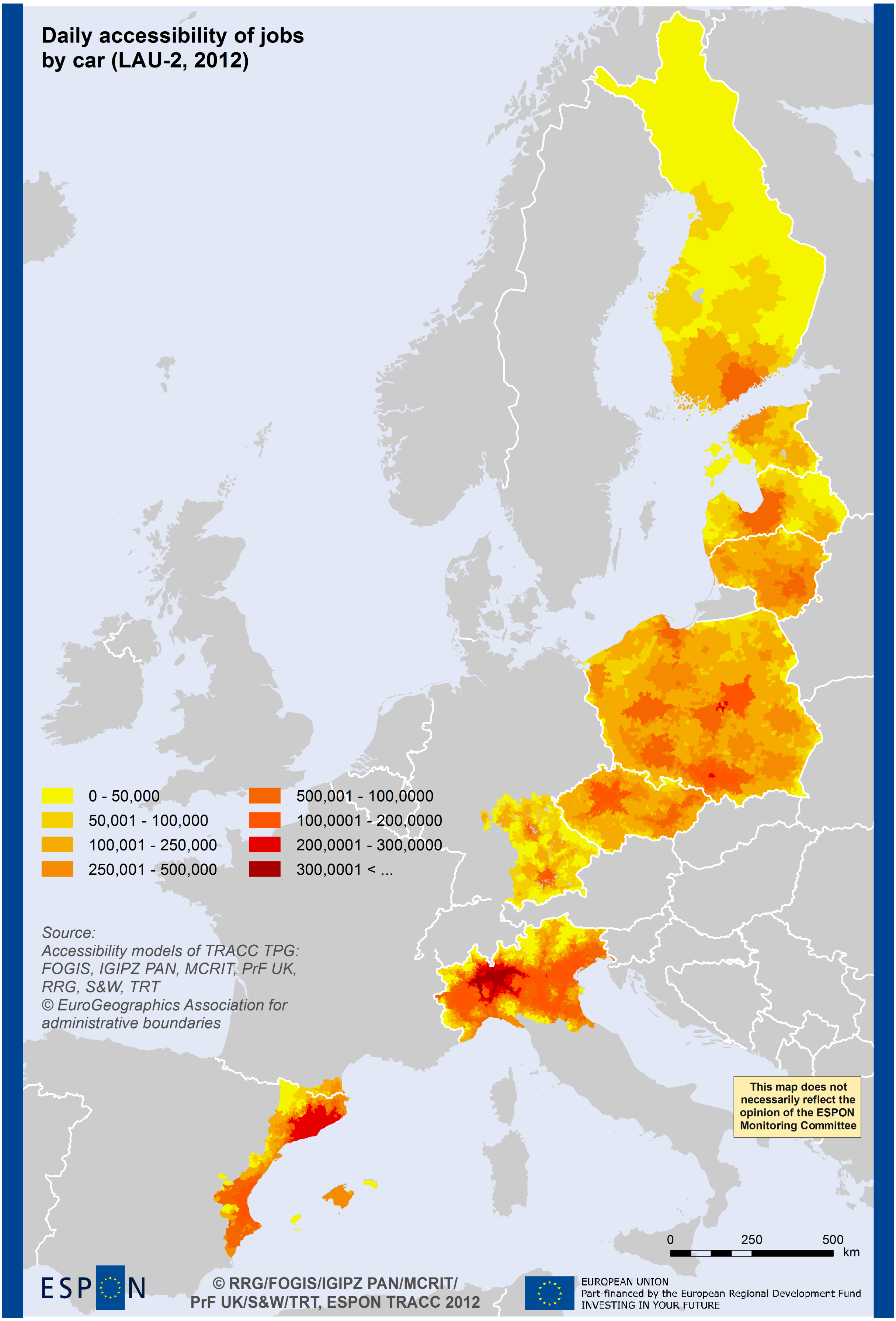


Figure 9.34. Jobs available within 60 minutes car travel time

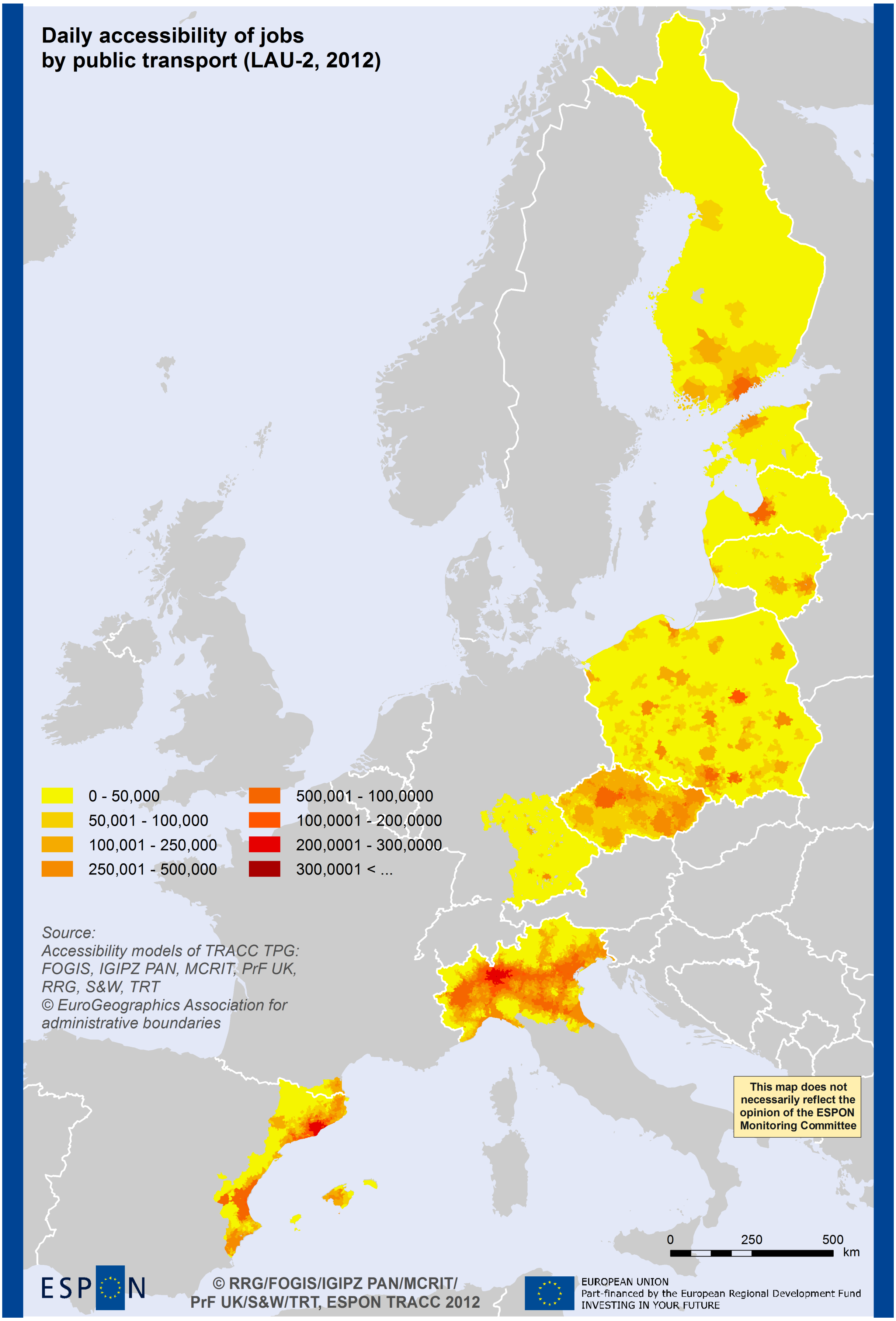


Figure 9.35. Jobs available within 60 minutes public transport travel time

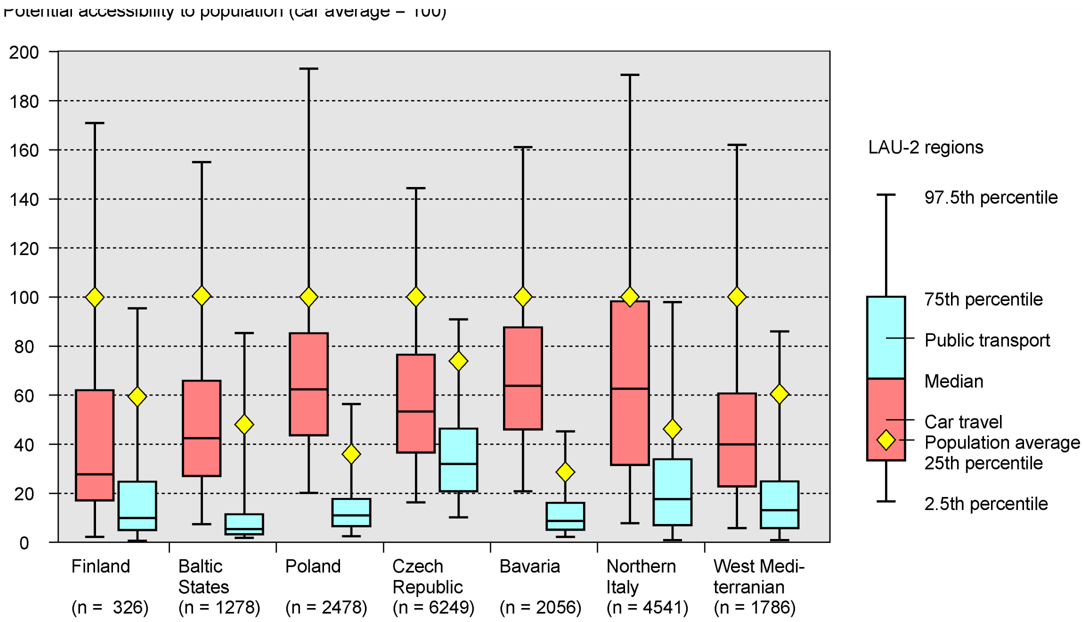


Figure 9.36. Potential accessibility to population by case study region

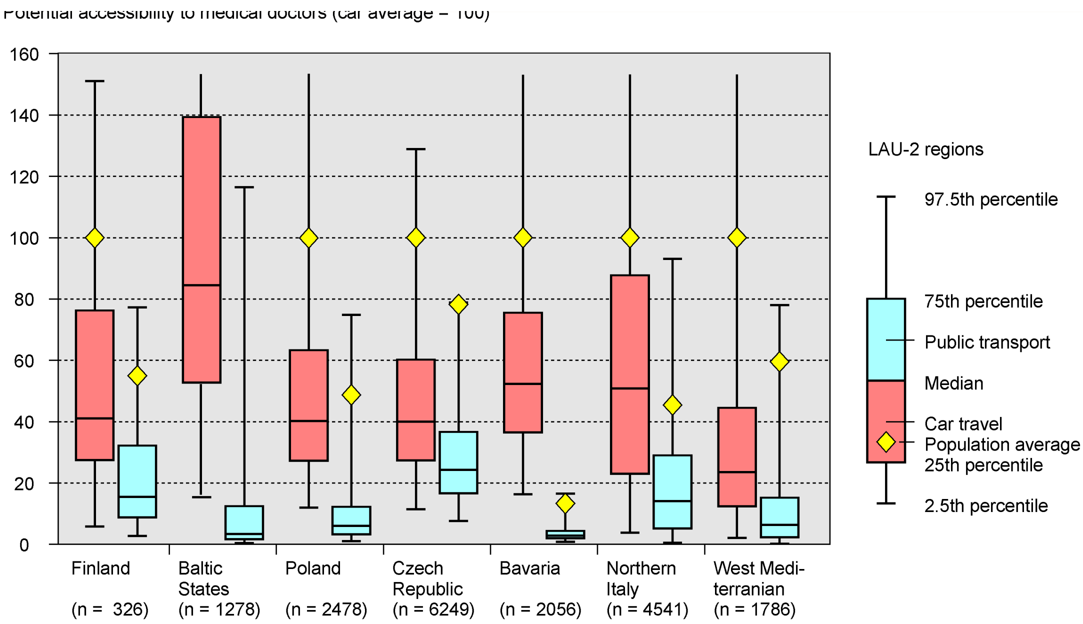


Figure 9.37. Potential accessibility to medical doctors by case study region

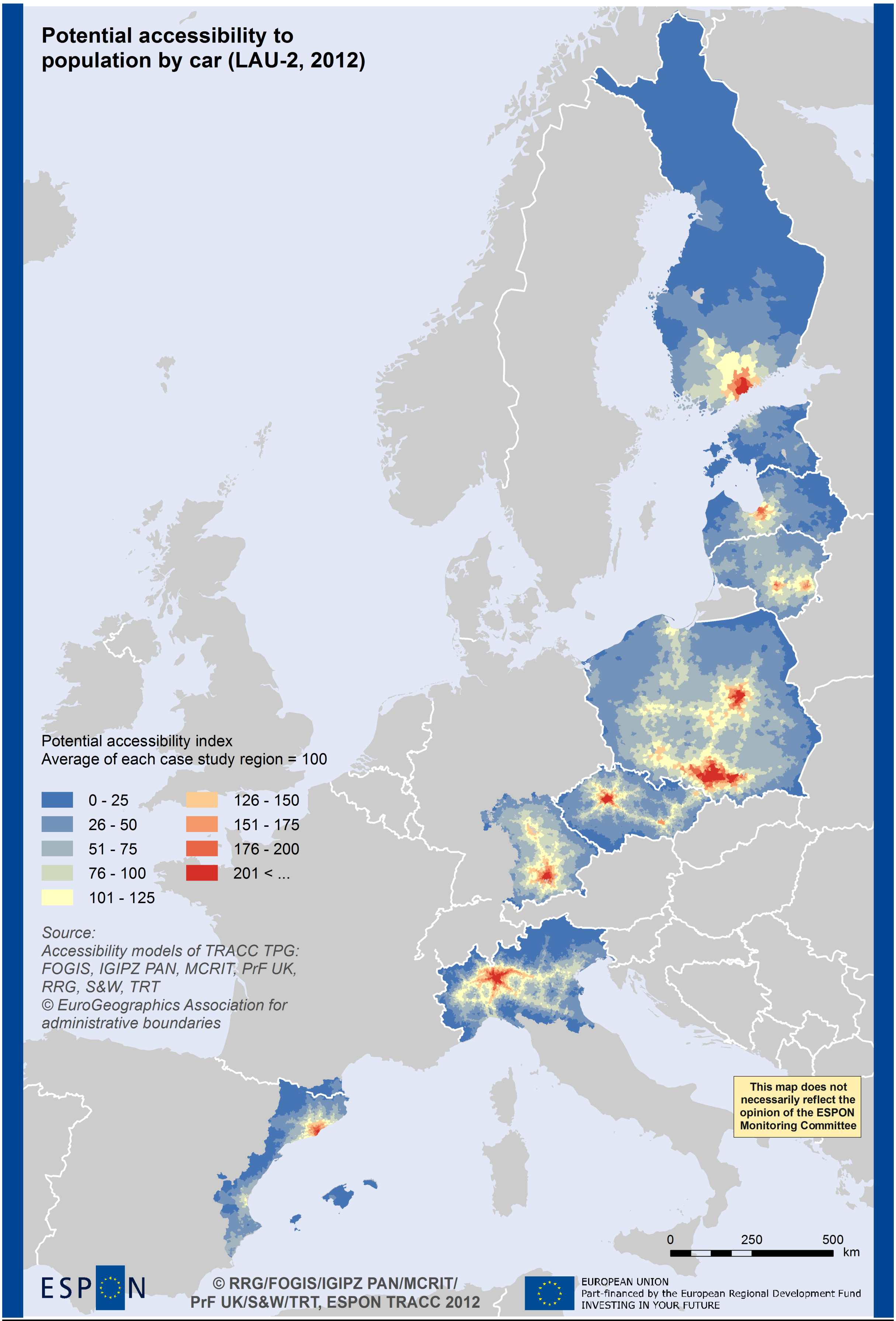


Figure 9.38. Potential accessibility to population by car (Index: each case study average = 100)

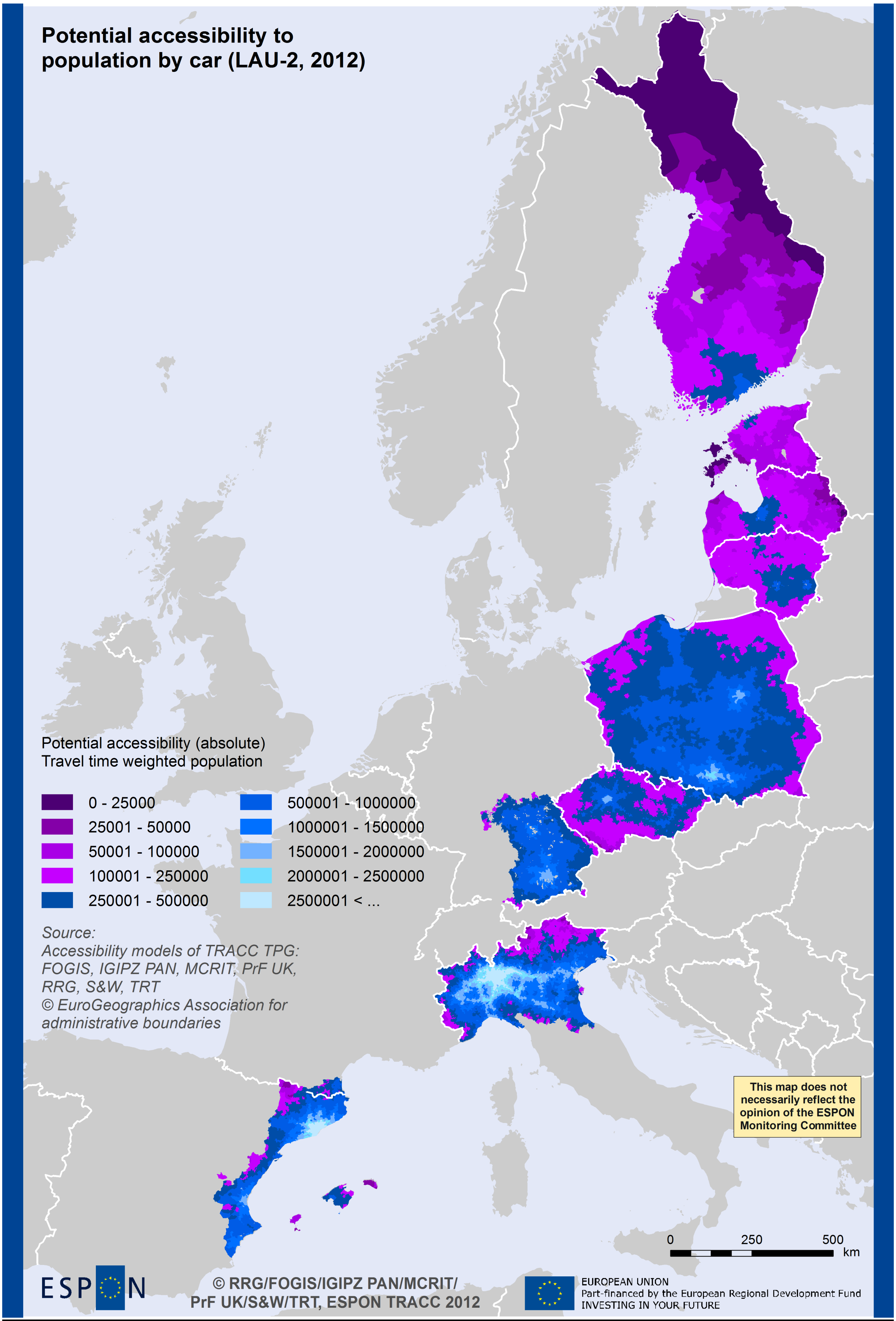


Figure 9.39. Potential accessibility to population by car (absolute values)

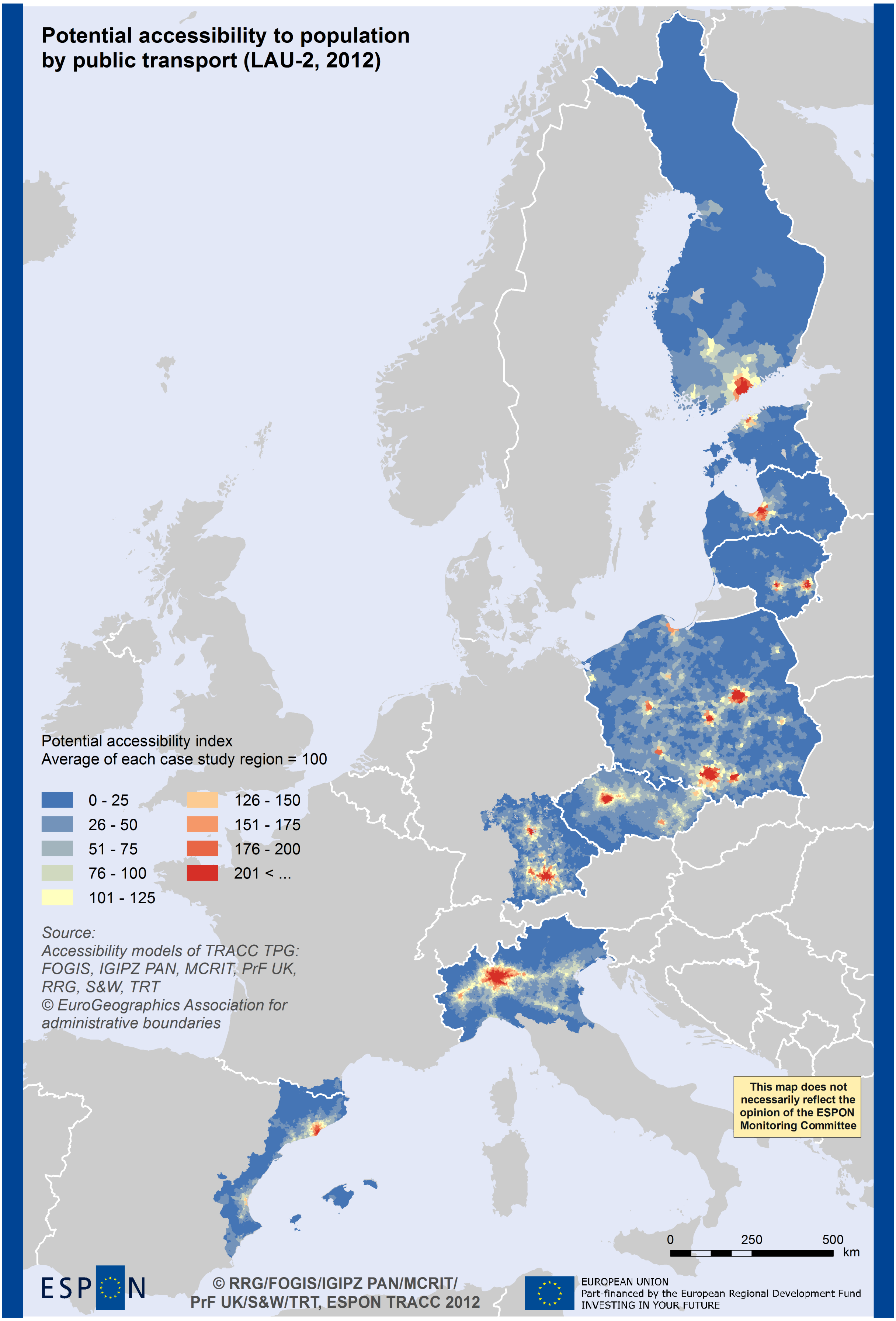


Figure 9.40. Potential accessibility to population by public transport (Index: each case study average = 100)

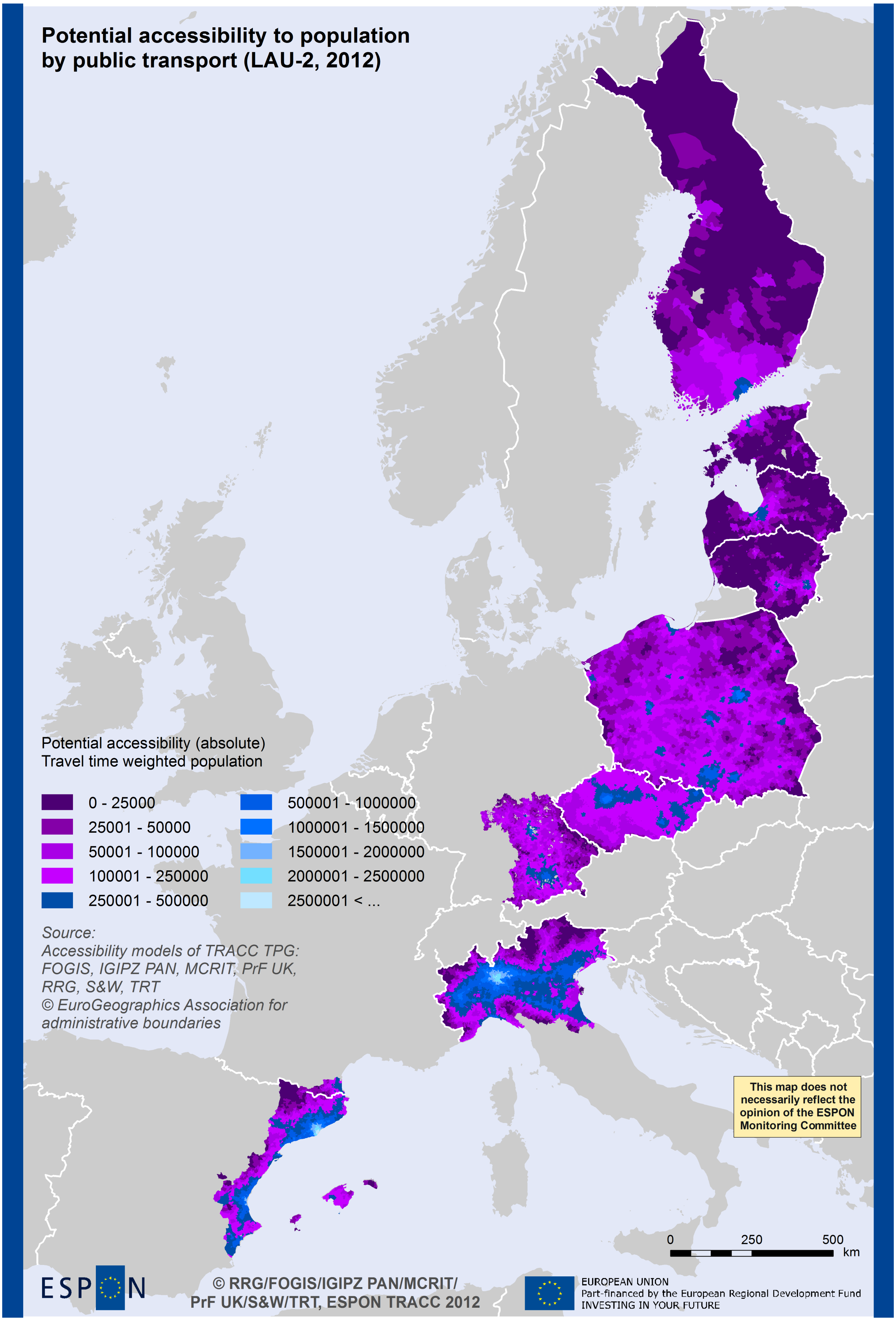


Figure 9.41. Potential accessibility to population by public transport (absolute values)

To conclude the case study analysis, the following points can be made.

Minimum availability of functions vs diversity of services and activity on offer. Indicators considering merely the availability of activities and services, i.e. travel time to the closest target activity or service (Ind1 and Ind4), provide more decentralised patterns on the territory than indicators accounting for the magnitude of available offer, regardless if they consider cumulated opportunities or total potential accessibility. The latter tend to reflect polarisation in largest metropolises and well deserved transport corridors and quickly diminish towards more remote areas, while the former tend to provide more balanced patterns across territories. This reflects that minimum service and administrative endowments are granted to a reasonable extent in most areas of Europe (e.g at least one hospital available, at least one regional centre available), but differences reveal to be more acute when analysing the amount of possible alternatives of choice for between most populated urban areas and more sparsely populated rural areas (e.g. number of jobs available, schools, doctors).

Public services endowment vs availability of economic / social activities and private services. In general, out from all case studies it seems to appear that the distribution of public services in Europe is much more balanced than the distribution of economic and social activity (population, jobs). This can be attributed to the nature of European welfare systems, where administrations care for minimum endowments of services in less accessible areas, e.g. in rural areas or in peripheries. A few case studies, however, have pointed out the danger of diminishing accessibility to public services driven by the financial crisis in Europe, due mostly to the withdrawal of the public sector and the process of recentralisation of services towards larger regional centres.

Public transport accessibility vs car accessibility. The results illustrate that a distinction between different modes is clearly needed. Accessibility patterns for cars and public transport differ to a large degree, both with respect to the level and also with the spatial patterns, so that modelling results for one mode cannot be used as proxy for the other mode. While accessibility indicators for cars tend to form different types of plateaus, the same indicators for public transport form 'stretches' and 'bands' of high accessibilities along certain transport axis, interrupted by areas of low accessibilities where public transport is missing. Apart from this, in general as demonstrated by the indicator calculations, the accessibility levels by car are higher than those for public transport, but still in city centres and for along some axes public transport is able to reach as high levels as cars do. Regarding public transport as such, one may furthermore think of even splitting 'public transport' mode into individual indicators for rail and bus/tram.

Lack of services vs lack of infrastructure. Accessibility is a matter of both transport infrastructure endowment and availability of services in destinations. In some case studies, low accessibility values tend to reflect most remote areas within regions, often substantially less populated (e.g. in interior regions of the Western Mediterranean case study or in northern regions of the Finland case study). In other case studies, low accessibilities are mostly driven by poor transport infrastructure endowment, more often in Eastern Europe than in Western Europe (e.g. in Poland, the Baltic States and Czech Republic). In this direction, reports on Economic and Social Cohesion by the DGRegio (2007, 2010) point out to the fact that improved accessibility tends to create new job opportunities for rural and urban areas but that potentialities from improving accessibility depend on the previous competitiveness of the regions concerned, being some regions liable to lose out as they become more open to competition from elsewhere. The reports claim the importance of combining investment in transport infrastructure with support for businesses and human capital development to achieve sustainable economic and social development.

Territorial Typologies. In all countries, accessibilities for capital regions or for main agglomerations differed significantly from those for rural, peripheral and landlocked regions, as well as for intermediate areas. Therefore, the aggregation of raster results to different types of regions or to what was called 'zoom-in' regions may provide additional insights into accessibility patterns of a study area. Even though in this study only six zoom-in areas and only five different types of regions were used, interesting findings were obtained. A combination of raster approach with a typology approach deems promising to obtain high-resolution results on the one hand and easy-to-communicate summary results on the other hand.

European peripheries VS European core. In general, no significant differences can be observed in terms of regional and local accessibility between case studies located in the European Periphery (e.g. Finland, Baltic States or West Mediterranean) and case studies located in the European Core. Regional and local accessibility in all case studies depends to a higher extent on the total level of population living in the concerned region and the level and quality of transport infrastructure endowment.

On accessibility indicators. Accessibility of a region cannot be assessed by just one indicator. In case studies a set of six different accessibility indicators were identified which should help analysing different aspects of access to markets and access to public services. In fact, the results for the different indicators have shown that this broad set is quite useful as the individual indicators are in fact able to depict different facets and different spatial structures. Only results of the last indicator, i.e. accessibility potential to basic health care, seem questionable since this indicator too much reflects the national health care systems rather than locational advantages or disadvantages. Moreover, the definition of this indicator as a potential indicator may be questionable, since one may discuss whether the number of doctors is really a good 'weight'.

On edge effects. For all case study regions, the areas of analysis were treated as "islands", meaning that opportunities outside the case study regions were not considered. This is different to the other analysis done in TRACC in which always destinations outside the area for which accessibility indicators were estimated are included. For the analysis of regional accessibility in the case study regions, in particular for those who form only a part of a country such as in Spain, Italy and Germany, border effects might occur. This means that the degree of accessibility in edge areas of the case study regions might be underestimated, because destinations across the fringe of those regions are not included.

On spatial resolution of indicators. A majority of the findings of this study are based on grid cell maps, free of administrative divisions. Several particular areas and spatial patterns can be noticed only on the grid cell basis. TRACC has proven that even at the level of zoom-in regions significant intra-regional disparities exist, which cannot be detected by the traditional, aggregated models. Such intra-regional disparities are often greater than those between regions, thus accessibility studies should acknowledge these disparities and should find ways how to capture them. For the Baltic States and for the Finland case studies, or for the EU connectivity analysis, the raster approach turned out to be very useful, and should be developed further. Raster approaches allow capturing the fine grained accessibility surfaces generated by public transport and also reflect the axial structures caused by high-level transport infrastructures. Raster approaches provide more accurate images which are not dependant on the size of territorial units (e.g. NUTS-3 or LAU-2), a recurrent problem in any mapping and modelling activity. Another advantage of the raster approach is that results can be afterwards easily aggregated to any spatial level, such as LAU-2 or NUTS-3 (as done in this study), or higher. Also, comparisons and cross-over correlations with other variables such as population distributions are easy to implement.

10 Integrated view on accessibility of European regions

The chapter will provide an aggregate overview on accessibility of European regions. First, the relationship between different indicators of the TRACC set of accessibility indicators will be explored (Chapter 10.1). Then, the results of the accessibility indicators will be analysed in terms of territorial cohesion (Chapter 10.2).

10.1 Accessibility indicators compared

The TRACC set of accessibility indicators is very comprehensive ranging from global to regional indicators, including different generic types of indicators and including indicators for personal travel and for freight transport and all for different modes of transport. This section analyses the relationship between those indicators by looking at correlations between them to depict which indicators have similar and which have different messages. The correlation analysis is done to compare different generic indicator types, to compare similar indicators for different modes, to compare indicators for different spatial contexts and to compare indicators for travel and freight accessibility.

Comparison between generic indicator types

The first comparison looks at the different generic indicator types (Table 10.1). Each row of the table contains the correlation (as coefficient of determination, r^2) for the relationship between two indicators of different generic type, however, for the same spatial context and basic characteristic. The coefficient of determination varies considerably across the different indicator pairs considered, lowest r^2 values are almost zero, highest go up to 0.9.

The relationship between travel cost indicators and indicators of cumulated opportunities is given, however, the coefficient of determination has middle-range values or rather low values. For instance, for the relationship between "Access to global cities" and "Global travel connectivity" r^2 is 0.47, for "Access to top MEGAs" and "European daily accessibility travel" it is 0.62. For freight indicators r^2 is much lower, for "Access to nearest maritime port" and "Daily accessibility freight" it is 0.02, for "Access to freight terminals" and "Availability of freight terminals" it is 0.27.

The relationship between travel cost indicators and accessibility potential type indicators is comparable to the previous group, i.e. it is fairly good for some of the indicator types reflecting personal travel, but it is almost not existing for the freight indicators.

Much better is the correlation between indicators measuring cumulated opportunities and potential type indicators. For travel indicators, r^2 is between 0.8 and 0.9 for global and European accessibility indicators, but r^2 is only around 0.2 at the regional level. Highest r^2 is for the relationship between "European daily accessibility travel" and "European potential accessibility travel" for road transport, lowest r^2 is for the relationship between the "Availability of urban functions" and the "National potential accessibility travel". The r^2 for freight transport are lower than for travel when comparing cumulated opportunities with potential type indicators. Highest correlation is for "Daily accessibility freight" and "European potential accessibility freight" for road transport (r^2 = 0.68).

Table 10.1. Correlation between generic accessibility indicator types

Spatial context	Basic characteristic	Indicator 1	Indicator 2	Correlation (r^2)
Global	Travel	**Access to global cities** (Travel time to New York)	**Global travel connectivity** (Number of intercontinental flights reachable in five hours)	0.47
		Access to global cities (Travel time to New York)	**Global pot. acc. travel** (Intermodal acc. to seat capacity of intercontinental flights)	0.61
		Global travel connectivity (Number of intercontinental flights reachable in five hours)	**Global pot. acc. travel** (Intermodal acc. to seat capacity of intercontinental flights)	0.85
	Freight	**Global freight connectivity** (Intercontinental container throughput reachable within 36 hours travel time by road)	**Global pot. acc. freight** (to intercontinental container throughput by road)	0.57
		Global freight connectivity (Intercontinental container throughput reachable within 48 hours travel time by rail)	**Global pot. acc. freight** (to intercontinental container throughput by rail)	0.41
		Global freight connectivity (Intercontinental container throughput reachable within 72 hours travel time by water)	**Global pot. acc. freight** (to intercontinental container throughput by water)	0.11
European	Travel	**Access to top MEGAs** (Average travel time to main MEGAs by fastest mode)	**European daily acc. travel** (population in 5 h by fastest mode)	0.62
		European daily acc. travel (pop. in 5 h by road)	**Europ. pot. acc. travel** (to population by road)	0.90
		European daily acc. travel (pop. in 5 h by by rail)	**Europ. pot. acc. travel** (to population by rail)	0.82
		European daily acc. travel (pop. in 5 h by fastest mode)	**Europ. pot. acc. travel** (to population by fastest mode)	0.82
	Freight	**Acc. to nearest maritime port** (Average generalised costs)	**Daily accessibility freight** (GDP within allowed lorry driving time of 13 h)	0.02
		Acc. to nearest maritime port (Average generalised costs)	**Europ. potential acc. freight** (to GDP by Road)	0.06
		Daily accessibility freight (GDP within allowed lorry driving time of 13 h)	**Europ. potential acc. freight** (to GDP by Road)	0.68
Regional	Travel	**Avail. of urban functions** (Cities in 60 minutes by road)	**National pot. acc. travel** (to population by road)	0.19
		Avail. of urban functions (Cities in 60 minutes by rail)	**National pot. acc. travel** (to population by rail)	0.23
	Freight	**Access to freight terminals** (ICON index)	**Avail. of freight terminals** (within 2 hours by lorry)	0.27
		Access to freight terminals (ICON index)	**National potential acc. freight** (to national GDP by lorry)	0.08
		Avail. of freight terminals (within 2 hours by lorry)	**National potential acc. freight** (to national GDP by lorry)	0.07

Comparison between transport modes

Several indicators in TRACC were calculated for different transport modes. Table 10.2 and 10.3 give the correlation between different transport modes for the same indicator.

For travel, there is mostly a relative high degree of similarity between road and rail accessibility, and the correlation of road and rail with air accessibility is much lower. Not surprisingly, correlation between those three modes with the multimodal aggregate is rather high with r² of between 0.7 and 0.9.

Table 10.2. Correlation between different transport modes for same indicator

Spatial context	Basic characteristic	Indicator	Mode 1	Mode 2	Correlation (r^2)
Global	Freight	**Access to global hub** (Generalised cost to New York)	maritime	air	0.00
		Access to global hub (Generalised cost to Shanghai)	maritime	air	0.04
		Global freight connectivity (Interc. container throughput reachable in 36 h by road, 48 h by rail, 72 h by water)	road	rail	0.69
			road	water	0.04
			rail	water	0.03
		Global pot. acc. freight (to intercontinental container throughput)	road	rail	0.34
			road	water	0.43
			road	multimodal	0.96
			rail	water	0.31
			rail	multimodal	0.47
			water	multimodal	0.48
European	Travel	**European daily acc. travel** (population within 5 hours)	road	rail	0.83
			road	fastest	0.73
			rail	fastest	0.85
		European pot. acc. travel (to population)	road	rail	0.93
			road	air	0.42
			road	multimodal	0.72
			road	intermodal	0.72
			rail	air	0.47
			rail	multimodal	0.78
			rail	intermodal	0.74
			air	multimodal	0.89
			air	intermodal	0.81
			multimodal	intermodal	0.93
	Freight	**Europ. potential acc. freight** (to GDP)	see next table		
Regional	Travel	**Avail. of urban functions** (Cities in 60 minutes by road)	road	rail	0.85
		National pot. acc. travel (to population by rail)	road	rail	0.83

Table 10.3. Correlation between different transport modes for European potential acc. freight

Mode	Road	Rail	Rail unitised	Water	Water unitised	Air	Multimo-dal	Multimo-dal uni-tised
Road		0.65	0.75	0.32	0.27	0.40	0.94	0.99
Rail	0.65		0.37	0.32	0.30	0.18	0.83	0.65
Rail unitised	0.75	0.37		0.25	0.30	0.12	0.33	0.34
Water	0.32	0.32	0.25		0.85	0.14	0.30	0.34
Water unitised	0.27	0.30	0.30	0.85		0.13	0.27	0.29
Air	0.40	0.18	0.12	0.14	0.13		0.36	0.41
Multimo-dal	0.94	0.83	0.33	0.30	0.27	0.36		0.94
Multimo-dal uni-tised	0.99	0.65	0.34	0.34	0.29	0.41	0.94	

For freight transport, the relationship between transport modes is in many cases much lower. This is in particular true for correlations with water transport and air transport. The correlation between road and rail freight transport accessibility indicators is higher and goes up to a r^2 of 0.75 for the European potential accessibility freight indicator. Road and rail freight accessibility explain to a very high degree multimodal accessibility freight, however road is even higher than rail.

Comparison between different spatial contexts

Another question to be addressed by this analysis is to what degree accessibility at a certain spatial levels is similar to accessibility in a different spatial context. Table 10.4 presents the correlation for indicators of same generic type, but calculated for different spatial contexts. When interpreting the results, one has to consider that the indicator definition is not always exactly the same for different spatial contexts.

Looking first at global v. European accessibility, there seems to be a high degree of similarity for travel as well as for freight accessibility. Lowest correlation for travel indicators is for "Access to global cities – New York" and "Access to top MEGAs" with a r^2 of 0.50 only. But for the cumulated opportunity indicator, the relationship is more closely. And, for the potential type of indicator, the correlation is very high, the r^2 for "Global potential accessibility travel" and "European potential accessibility travel" is 0.89 for multimodal and 0.94 for intermodal. That means that regions that have a good European accessibility usually have also a good global accessibility and vice versa. This finding is confirmed by freight accessibility indicators. In particular for the potential type of indicators, the correlation between global and European accessibility is very high with r^2 ranging from 0.75 to 0.96 for different modes of freight transport.

The relationship between regional and European accessibility is completely different, i.e. much weaker. It is still moderate when looking at the indicator type of cumulated opportunities. That means, if there are several cities within 1 hour travel time or freight terminals available within two hours travel time, the daily accessibility for travel or freight is also good. But r^2 for these relationships are only between 0.40 and 0.49 for travel and 0.56 for freight. Looking at the potential accessibility indicator, the correlation does almost not exist. The coefficient of determination between European and national potential accessibility goes down to 0.24 (road travel) and 0.21 (rail travel) and even down to 0.10 for road freight. That means that a region that has a low accessibility in the national context, does not necessarily has a low European accessibility. In particular, several border regions in Europe demonstrate the opposite, i.e. fairly good European accessibility compared to other parts of the country, but relatively low national accessibility.

Table 10.4. Correlation between indicators for different spatial contexts

Spatial context	Basic characteristic	Indicator 1	Indicator 2	Correlation (r^2)
Global v. European	Travel	**Access to global cities** (Travel time to New York)	**Access to top MEGAs** (Average travel time to main MEGAs by fastest mode)	0.50
		Global travel connectivity (Number of intercontinental flights reachable in five hours)	**European daily acc. travel** (pop. in 5 h by fastest mode)	0.66
		Global pot. acc. travel (Intermodal acc. to seat capacity of intercontinental flights)	**Europ. pot. acc. travel** (to population multimodal)	0.89
		Global pot. acc. travel (Intermodal acc. to seat capacity of intercontinental flights)	**Europ. pot. acc. travel** (to population intermodal)	0.94
	Freight	**Global freight connectivity** (Intercontinental container throughput reachable within 36 hours travel time by road)	**Daily accessibility freight** (GDP within allowed lorry driving time of 13 h)	0.69
		Global pot. acc. freight (to intercontinental container throughput by road)	**Europ. potential acc. freight** (to GDP by road)	0.75
		Global pot. acc. freight (to intercontinental container throughput by rail)	**Europ. potential acc. freight** (to GDP by rail unitised)	0.97
		Global pot. acc. freight (to intercontinental container throughput by water)	**Europ. potential acc. freight** (to GDP by water unitised)	0.96
		Global pot. acc. freight (to intercontinental container throughput multimodal)	**Europ. potential acc. freight** (to GDP by multimodal)	0.73
European v. regional	Travel	**European daily acc. travel** (pop. in 5 h by road)	**Avail. of urban functions** (Cities in 60 minutes by road)	0.40
		European daily acc. travel (pop. in 5 h by by rail)	**Avail. of urban functions** (Cities in 60 minutes by rail)	0.49
		Europ. pot. acc. travel (to population by road)	**National pot. acc. travel** (to population by road)	0.24
		Europ. pot. acc. travel (to population by rail)	**National pot. acc. travel** (to population by rail)	0.21
	Freight	**Daily accessibility freight** (GDP within allowed lorry driving time of 13 h)	**Avail. of freight terminals** (within 2 hours by lorry)	0.56
		Europ. potential acc. freight (to GDP by Road)	**National potential acc. freight** (to national GDP by lorry)	0.10

Comparison between travel and freight accessibility

How similar are the results of travel accessibility indicators compared to those for freight transport? Table 10.5 gives results for comparable indicators at global, European and regional scale. It can be seen that there is a certain relationship between travel and freight accessibility as there is no extremely low value for the coefficient of determination. Lowest r^2 is for "European potential accessibility" by air (0.32). Highest correlation are for "Daily accessibility" by road (0.84) and "European potential accessibility " by rail (0.86), all other relationships are between these extremes.

Table 10.5. Correlation between travel and freight accessibility indicators

Spatial context	**Indicator 1 (travel)**	**Indicator 2 (freight)**	**Correlation (r^2)**
Global	**Global pot. acc. travel** (Intermodal acc. to seat capacity of intercontinental flights)	**Global pot. acc. freight** (to intercontinental container throughput multimodal)	0.53
European	**European daily acc. travel** (pop. in 5 h by road)	**Daily accessibility freight** (GDP within allowed lorry driving time of 13 h)	0.84
	Europ. pot. acc. travel (to population by road)	**Europ. potential acc. freight** (to GDP by road)	0.59
	Europ. pot. acc. travel (to population by rail)	**Europ. potential acc. freight** (to GDP by rail)	0.86
	Europ. pot. acc. travel (to population by air)	**Europ. potential acc. freight** (to GDP by air)	0.32
	Europ. pot. acc. travel (to population multimodal)	**Europ. potential acc. freight** (to GDP multimodal)	0.67
Regional	**Avail. of urban functions** (Cities in 60 minutes by road)	**Avail. of freight terminals** (within 2 hours by lorry)	0.47
	National pot. acc. travel (to population by road)	**National potential acc. freight** (to national GDP by lorry)	0.74

To conclude the correlation analysis for the TRACC set of accessibility indicators it can be argued that there is some overlap between a few accessibility indicators, but that in general a set with different accessibility indicators is to be justified. The coefficients of determination are only for a few relationships very high, more often they are in a moderate range or even rather low, i.e. one accessibility indicator can only to a limited degree explain the variation in another accessibility indicator. Thus, there is no single accessibility indicator that might serve all purposes. That means that different analytical questions for different context require always the definition and implementation of appropriate customised accessibility indicators. So, it is important (i) to have indicators at different spatial contexts, ranging from the global down to regional or even local scale, (ii) to have different types of generic indicators with customised definitions ranging from easy to understand travel cost indicators to more complex potential type indicators, and (iii) finally, it is important to differentiate between different transport modes and between travel and freight indicators.

10.2 Disparities in accessibility

Finally, the results of the accessibility indicators will be analysed in terms of territorial cohesion. For all accessibility indicators calculated at NUTS-3 level for the ESPON space, the coefficient of variation gives an indication how disparate or how homogeneous the specific accessibility is distributed across regions in Europe (Table 10.6). This dispersion measure gives for a data set the ratio of the standard deviation to the mean; in the table this is expressed as percent of the mean. The higher the standard deviation the higher the disparities. To give a benchmark, the coefficient of variation for GDP per capita in the European Union is around 40 percent. That means that the GDP per capita of a region in the European Union deviates on average around 40 percent from the EU mean for GDP per capita.

Regional disparities for global accessibility depend on the indicator type. It is rather low for travel cost indicators, only about 14 percent for "Access to global cities" for travel and between 10 and 25 percent for "Access to global freight hubs". However, as for this travel cost indicator, the costs for the part of the transport outside Europe is much higher than the part within Europe, the average is high and the variation around the average is low, i.e. the dispersion measure gives no substantial dispersion in total costs. This is very different for cumulated opportunities for global accessibility. The coefficient of variation is at 77 percent for travel, for freight transport it is 58 percent for road, 47 for rail and 285 for water transport. Potential type indicators are inbetween with about 40 percent for travel and around 30 percent for freight.

Disparities for European accessibility travel are lowest for the travel cost indicator. The variation is only 23 percent for the "Access to top MEGAs". The disparities for the other two indicator types are much higher, between 70 and 90 percent depending on mode for "European daily accessibility travel". Also the "European potential accessibility travel" sees considerably disparities among European regions. The coefficient of variation is highest for road (60 percent) and rail (62 percent), and somewhat lower than 40 percent for air, multimodal and intermodal. The latter means that when considering several modes together, a deficit in one mode can be substituted by another transport mode.

European freight disparities are highest for the "Access to nearest maritime port" (106 percent), a consequence of the uneven spatial distribution of sea ports in Europe. However, also "European daily accessibility freight" sees considerable disparities between regions in Europe (73 percent). The potential accessibility indicators for freight show clear disparities, but they are below the value for daily accessibility. Interesting to note that for those modes that have a distinction between "normal" freight transport and unitised (container) freight transport, the disparities for unitised transport are much larger, an outcome of the differences in the availability of intermodal transshipment facilities in Europe.

At the regional level, disparities with respect to the availability of urban functions within 1 hour travel time (136 percent for road, 155 percent for rail) and availability of freight terminals (111 percent for road) is extremely high. On the contrary, national potential accessibility shows lower disparities with around 30 percent for travel by road or rail and of 24 percent for freight by road.

Overall, the degree of spatial disparities in accessibility varies substantially across different indicators. Indicators of the type cumulated opportunities tend to show much higher disparities than indicators of the potential type which are based on a more smoothing definition. For the travel cost type indicator, the degree of disparities depends very much on the selected types of destinations. Compared with the disparities in GDP per capita, cumulated opportunity indicators show in general much less cohesion than the economic performance. For potential type indicators this depends on the spatial context and the transport mode. Most of the indicators are in the range or somewhat below the disparities of GDP per capita, however, for important aspects such as European potential accessibility by road and rail, the coefficients of variation for accessibility are about 50 percent higher than for the economic performance, i.e. disparities in accessibility potential are much higher than disparities in economic performance..

Table 10.6. Coefficient of variation (in percent of the mean) for accessibility indicators

Spatial context	***Basic charac-teristics***	***Generic type of accessibility indicator***		
		Travel cost	***Cumulated opportunities***	***Potential***
Global	***Travel***	***Access to global cities*** Travel time to New York **13.8 intermodal**	***Global travel connectivity*** Flights to intercontinental destinations reachable in five h **76.7 intermodal**	***Global potential accessibility travel*** To seat capacity of inter-continental flights depart-ing in Europe **40.8 intermodal**
	Freight	***Access to global freight hubs*** Generalised travel cost to intercontinental hubs **9.5 maritime NewYork** **25.6 air New York** **17.3 maritime Shanghai** **22.8 air Shanghai**	***Global freight connectivity*** Intercontinental container throughput reachable within 36/48/72 hours **57.9 road** **46.9 rail** **285.7 water**	***Global potential accessibility freight*** To container throughput of European sea ports **27.1 road** **25.7 rail** **31.2 water** **25.5 multimodal**
Europe	***Travel***	***Access to top MEGAs*** Average travel time to top MEGAs **22.8 fastest mode**	***European daily accessibility travel*** to population **72.2 road** **87.1 rail** **84.6 fastest mode**	***European potential accessibility travel*** To population **59.5 road** **61.6 rail** **38.6 air** **39.0 multimodal** **35.5 intermodal**
	Freight	***Access to nearest maritime port*** Average generalised cost to nearest maritime port **106.4 all modes**	***European daily accessibility freight*** GDP accessible within allowed lorry driving time **72.9 road**	***European potential accessibility freight*** To GDP **42.7 road** **23.8 rail** **41.2 rail unitised** **30.4 water** **51.4 water unitised** **41.2 air** **26.6 multimodal** **40.6 multimodal unit.**
Regional	***Travel (Europe-wide)***	***Access to high-level transport infrastructure*** Weighted access time to motorway exits, rail sta-tions, airports	***Availability of urban functions*** Cities > 50.000 within 60 minutes travel time **135.9 road** **155.3 rail**	***National potential accessibility travel*** To national population **30.9 road** **31.5 rail**
	Freight (Europe-wide)	***Access to freight terminals*** Weighted access time to freight terminals **49.1 all modes**	***Availability of freight terminals*** Freight terminals within 2 h travel time **111.4 road**	***National potential accessibility freight*** To national GDP **23.7 road**

11 Accessibility dynamics

Accessibility is not static, but changes over time. According to the basic concept of accessibility underlying this report, changes can either be induced by change in the impedance term, i.e. infrastructure, transport services, transport costs etc., or by changes in the opportunities to be reached, e.g. population, GDP, jobs, services of general interest and other. In this chapter, such changes are analysed at the European level and at the local/regional level using accessibility potential indicators. First, accessibility changes at European level that happened during the period 2001 – 2011 will be presented for different transport modes. Then, the accessibility changes to be expected from the future trans-European transport networks at local and regional level will be presented by using the case studies as examples. Impacts of accessibility changes on regional development are subject of the chapter following this one.

11.1 Past changes of European accessibility

In Europe, the last decade has seen huge investments in the trans-European transport infrastructure and changes in transport services, but also regional population change, mainly due to migration. The combined working of these two factors has changed the European accessibility pattern. However, as seen in Chapter 7, the overall patterns have not changed substantially compared to accessibility pattern of previous studies. However, a closer look at the changes via analysing the differences shows substantial shifts of accessibility for European regions.

In the decade between 2001 and 2011, highest relative accessibility potential changes by road happened in regions outside the European core (Figure 11.1). Spain, Portugal and south-western France, regions in Ireland and the Nordic countries, and many regions in eastern European countries have experienced significant accessibility gains by road transport. Clearly visible are the accessibility impacts of new motorways such as the east-west motorway in Poland or the Via Egnatia in northern Greece.

The pattern of change of accessibility by rail is somewhat different due to other investment strategies of European countries (Figure 11.2). Clearly visible are the effects of investments in high-speed rail infrastructure in the Iberian Peninsula, France, Italy, Germany and Belgium. Gains in accessibility potential often exceed 50 percent. Very distinct to rail is the very modest development of accessibility by rail in eastern European regions. The main focus of transport infrastructure development in these countries was on road, not on rail, so the improvements are modest.

Another pattern of changes emerges for accessibility potential by air (Figure 11.3). Largest improvements are in regions that have smaller airports. This is particular true for the countries in Eastern Europe in which many airports have been developed outside the capital regions. The capital regions had already fairly good accessibility potentials by air a decade ago.

The combined working of the three transport modes is expressed in the multimodal accessibility indicator. The changes of multimodal potential accessibility are presented in Figure 11.4. The tendency is that higher relative gains did occur in less central areas, but not everywhere in the periphery. Central areas did grow less in relative terms in multimodal accessibility.

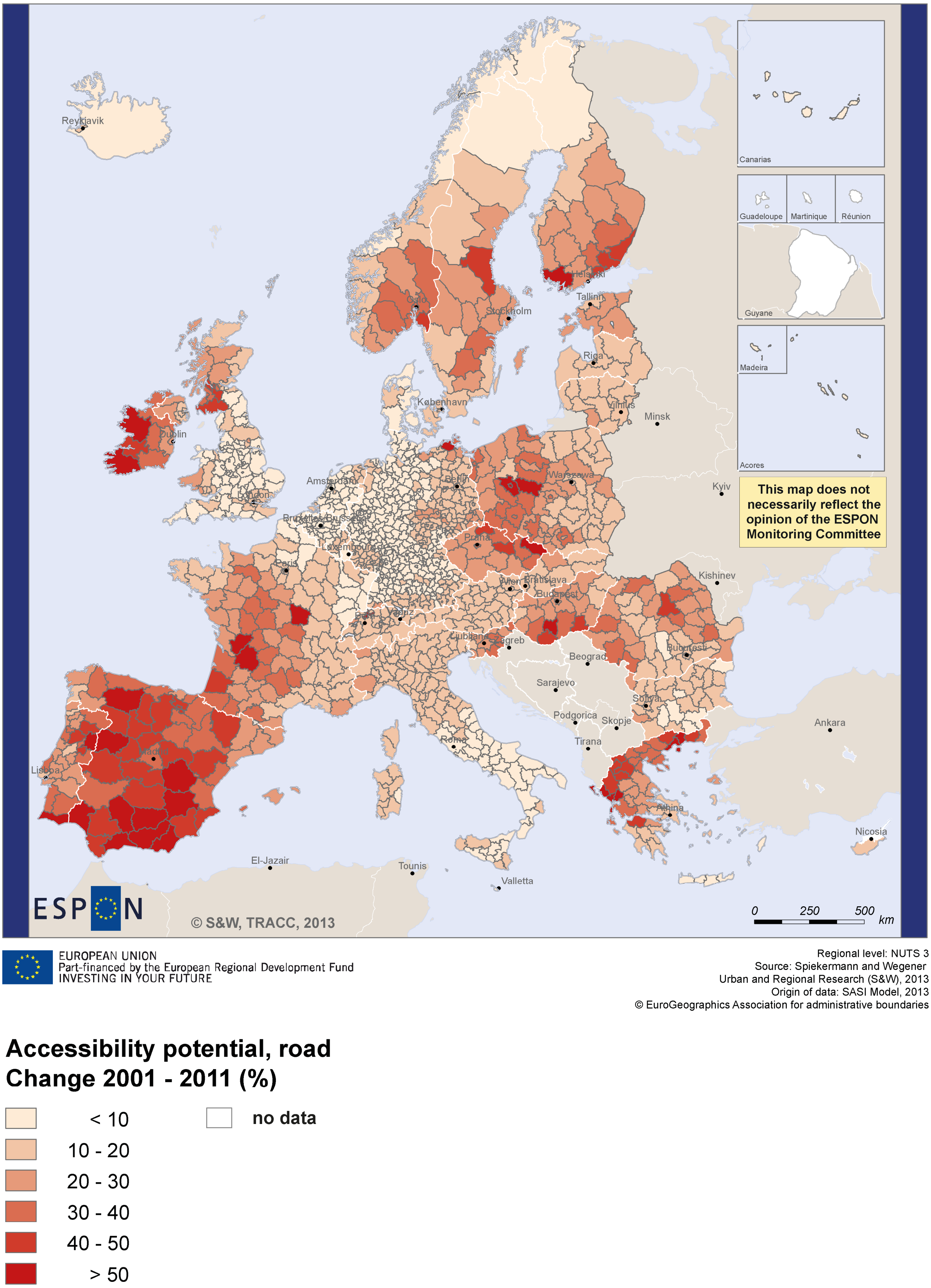
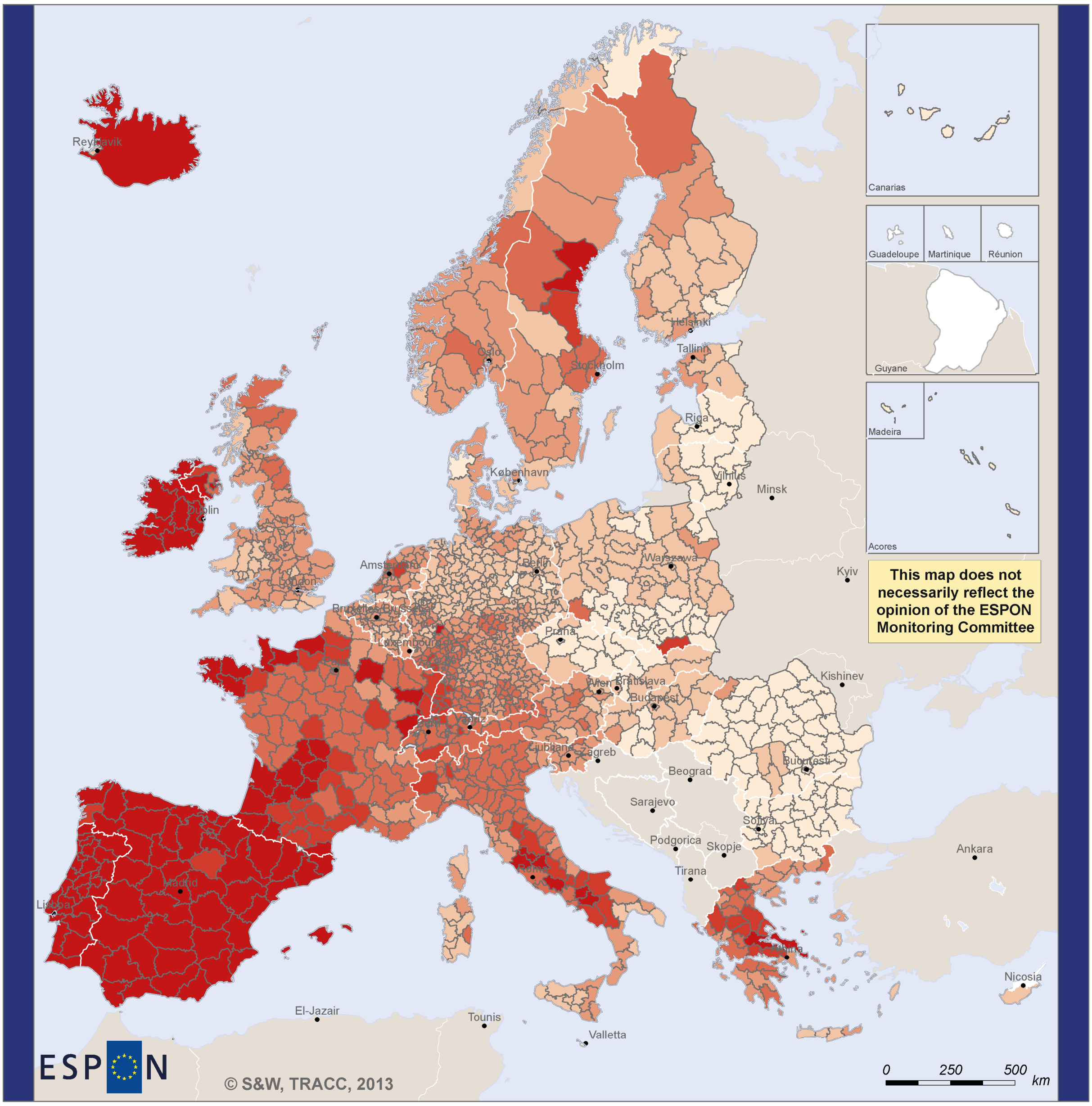


Figure 11.1. Potential accessibility to population by road, relative change 2001 – 2011



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Urban and Regional Research (S&W), 2013
Origin of data: SASI Model, 2013
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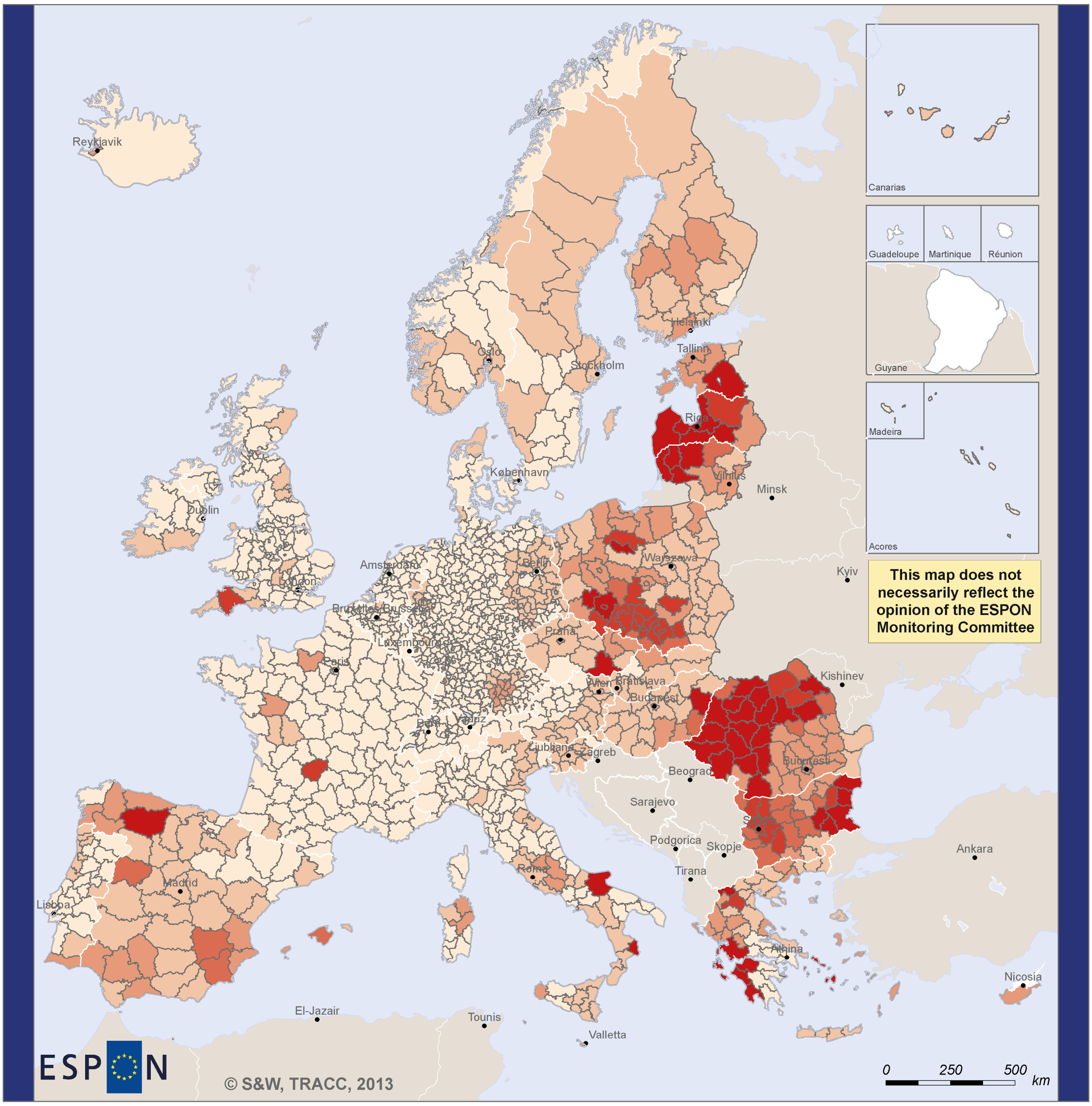
Accessibility potential, rail
Change 2001 - 2011 (%)

- < 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- > 50
- **no data**

Figure 11.2. Potential accessibility to population by rail, relative change 2001 – 2011



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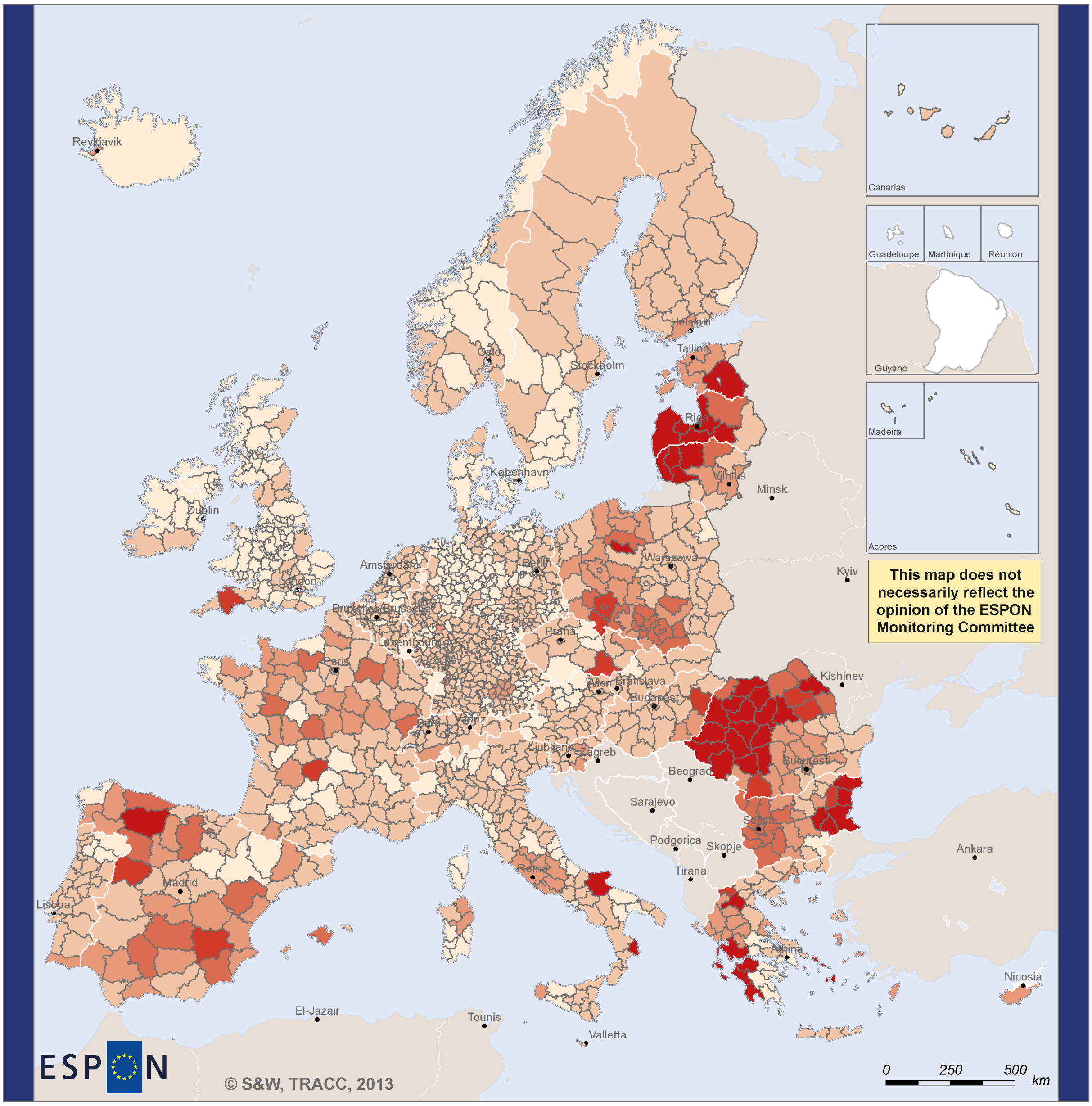
Accessibility potential, air
Change 2001 - 2011 (%)

- < 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- > 50
- no data

Figure 11.3. Potential accessibility to population by air, relative change 2001 – 2011



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Accessibility potential, multimodal
Change 2001 - 2011 (%)

- < 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- > 50
- no data

Figure 11.4. Potential accessibility to population multimodal, relative change 2001 – 2011

11.2 Local/regional accessibility effects of future TEN-T implementation

The analysis of the current accessibility conditions for car travel and for public transport is followed by an analysis of how the planned trans-European transport networks would change the regional accessibility pattern. For each region, the recent proposals of the European Commission for a TEN-T core network are implemented in the regional network databases. The local and regional accessibility impacts of the TEN-T developments are demonstrated by using the accessibility to population indicator. The potential by car and by public transport are presented for the future situation, the changes compared to today are analysed in relative and absolute terms.

The EU-wide multi-modal TEN-T ‘core network’ was presented along with the new TEN-T guidelines in October 2011 and eventually approved in December 2013. This Regulation for Guidelines for Trans-European Networks (TEN-T) will remove cross-border bottlenecks, upgrade infrastructure and streamline cross-border transport operations for passengers and businesses throughout the EU. Member States are committed to complete the TEN-T core transport infrastructure by 2030. In some areas of Europe, mostly in eastern countries, this will require substantial use of the European co-financing.

The TEN-T core network is aimed at ensuring efficient multi-modal links between the EU capitals and other main cities, ports, airports and key land border crossing, as well as other main economic centres. It focuses on 10 major transport corridors. It will address missing links -mostly cross-border sections and bottlenecks and bypasses- and the upgrading of existing infrastructure up to high technical standards (e.g. ERTMS in most core railways, intelligent infrastructure including VTI communications in most core motorways). The TEN-T core network is to allow a more focused and effective targeting of EU transport investments. The new core European transport network will connect by 2030 a set of 86 main European ports with rail and road links, 37 key airports with rail connections into major cities, 15,000 km of railway line upgraded to high speed and 35 major cross-border projects to reduce bottlenecks.

The core network will be complemented by a comprehensive transport network feeding into it, with a time horizon of 2050. This comprehensive network will provide full coverage of the EU and is aimed at granting EU accessibility of all regions. Both layers include all transport modes: road, rail, air, inland waterways and maritime transport, as well as intermodal platforms.

The implementation of the several TEN-T projects will triple the length of the existing high-speed rail network, and a dense railway network in all Member States should be maintained. By 2050, a complete European high-speed rail network should be in service. According to the Transport White Paper published in 2011, by 2050 the majority of medium-distance passenger transport should go by rail, and by 2050, all core network airports should become connected to the rail network, preferably high-speed. The quality, accessibility and reliability of transport services is to be increasingly important, requiring attractive frequencies, comfort, easy access, reliability of services, and inter-modal integration.

The TEN-T in the case study regions

ESPON TRACC has considered for the analysis of future accessibility in case studies all the projects included in the TEN-T core network, as presented in the 2011 proposal, and most representative TEN-T comprehensive network projects in each case. Partners have been responsible for the selection of specific projects to be considered in the analysis. The considered projects are presented for each case study in a dedicated map. For further information, consult individual case study reports in Volume 3.

In the different case study regions, the following projects have been considered:

- The majority of projects in **Finland** focused on to improve transport facilities and consequently did not improve traffic speeds of road or rail networks. The most relevant projects included were the rail upgrading between Central and Northern Finland, a local railway connection to Helsinki airport and road upgradings for extending the southern motorway network towards the eastern border and to the north-east
- Most of the TEN-T projects in the **Baltic States** concern improvements in the railway systems. The most important project will be the new high-speed train connection from Tallinn via Pärnu, Riga, Kaunas towards the Polish border, establishing for the first time a continuous rail connections from North to South, even though only few intermediate stops are foreseen. This project is part of the core network Corridor 1 (Baltic-Adriatic Corridor). The other railway projects are concerned with upgrading of existing lines. For Estonia and Lativa, TEN-Ts intervene in almost all main rail lines. There are no road projects foreseen in Lithuania, one major road project connecting Riga to the East in Latvia, and number of projects upgrading existing national roads are planned in Estonia.
- TEN-T projects in **Poland** cover most of the national area, but particular focus is given to road and rail connections between Warsaw and the rest of large metropolises where the majority of Poles live. TEN-T rail projects are prepared to improve the north-south railway axes linking by modern railway connections harbours of Gdańsk and Gdynia with the Upper Silesia conurbation and the Czech Republic. The other important axis is the Rail Baltica connecting Warsaw with Białystok to Baltic States and the modern railway line from Kraków to Ukraine. TEN-T road projects are aimed at completing the motorway network (missing parts of the A1, A2 and A4 motorways, and several express roads throughout the country).
- In the **Czech Republic**, most of the TEN-T projects are new or upgraded motorway stretches from Prague to the rest of the country, namely to the south to České Budějovice (Bohemia) and across into Austria towards Linz, to the east to Hradec Králové and across into Poland towards Wroclaw, to the north to Teplice and across into Germany towards Dresden; other motorways in the eastern part of the country, mostly around Brno and towards Slovakia; and a new west-east motorway corridor from Hradec Králové to Olomouc. Rail projects include upgrading to high standards of the stretches from Prague to Brno and Katowice, and from Prague to Wroclaw and to Dresden, plus several additional upgrading of conventional rail.
- In **Northern Italy**, the major TEN-T projects envisaged are rail projects, namely the new connection between Turin and Lyon (in France) and the new Brenner tunnel between Bolzano and Innsbruck (in Austria) -more relevant for long distance international traffic (especially freight) than for regional mobility within the Northern-Italy region-, and the completion of the high speed rail connections from Milan to Trieste and from Milan to Genoa. Comparatively, TEN-T road projects are more limited: the main project is probably the “New Romea” motoway in the southern-east part of the study area, aimed at reducing congestion in the current road, and the new “Pedemontana Lombarda” and “Pedemontana Veneta” motorways providing alternative west-east connections for the densely populated areas north of Milan and north of Venice.
- In the **West Mediterranean region**, most relevant TEN-T projects concern the high speed network under development (many projects are today developing with substantial delays due to funding shortage). Projects foreseen are the finalisation of the Madrid-Barcelona line up to the French border (expected to enter in service in 2014 up to Perpignan, and planned in the mid term to be extended to Montpellier); the interconnection in the Tarragona province of the existing high standard rail line along the

Mediterranean coast with the Madrid-Barcelona line, which will decrease the travel time between Barcelona and Valencia from 3h00 to 2h15 (just addressing a 20km bottleneck); and the finalisation of the Madrid–Alacant high speed link. The rail corridor from Valencia to Zaragoza is also included in the TEN-T, only foreseeing an upgrading of existing infrastructure. Road projects concern the upgrading of some of the existing TEN core corridors (mostly along the Mediterranean coast) and the upgrading of 3 trans-Pyrenees international crossings in the TEN-T comprehensive network linking Toulouse in France, to Barcelona, Lleida and Zaragoza in Spain.

Impacts of the TEN-Ts in the case study regions

The transport networks in **Finland** are at a today relatively good level, especially when compared to demand. The network investments may be considered as developing infrastructure, not establishing and hence, absolute improvements yielded by the investments are very low The impact of envisaged TEN-T projects was found to be very limited on a local basis. The accessibility pattern of Finland will be essentially similar after TEN-T investments by car and by public transport. A noticeable relative increase of accessibility by car is achieved with the motorway upgrade, but this effect is very local. The effect of the northern rail improvement is evident in the municipalities close to the railway, and remarkable improvements of accessibility may be found in municipalities having stations (Figures 11.5 and 11.6).

In the **Baltic States**, only marginal absolute differences in accessibility can be detected after implementation of TEN-T, both for road and rail (only some effects visible for public transport along specific axes, and localised increases in largest agglomerations). However, relative accessibility changes reveal that in fact the intended projects will have considerable effects on the accessibility levels of many parts of the study area (Figures 11.7 and 11.8).

For cars, the biggest effects can be found along the road corridor between Tallinn and Tartu, followed by the corridors Tallinn-Pärnu and Tallinn-Haapsalu/Hanila. Also accessibility along the corridor Tallinn-Narva will increase considerably. In Latvia there are only positive impacts measured along the Eastward corridor Riga-Laudona, while the rest of Lavia so as entire Lithuania does not benefit from the TEN-T outline plans due to absence of any road projects. Overall, accessibility by car will increase up to 20% for the most benefiting parts of Estonia.

For rail, the implementation of the TEN-T outline plans will lead to a step change in accessibility. Some areas in all three countries will double their accessibility, while others experience increases of more than 50%. Benefits basically appear along all major rail axes; they are strongest in areas North of Pärnu and in the Vöru region (both Estonia), as well as along the corridors Riga-Siauliai-Kaunas (Latvia and Lithuania) and Ventspils/Liepaja-Jelgava-Jekabpils-Daugavpils (Latvia). These findings reflect the two main political objections regards rail transport in the Baltic States:

(i) To establish an uninterrupted North-South link for the first time from Helsinki to Warsaw via the main agglomerations of the Baltic States (Tallinn, Pärnu, Riga, Kaunas);

(ii) To strengthen the hinterland connections of the Baltic seaports through rehabilitation of the existing East-West freight corridors.

While the maps of relative increases suggest that effects for public transport are larger than those for road, the corresponding maps of absolute change illustrate that the situation is more complex.

In case of Estonia, the effects for public transport are clearly restricted to small areas along the railway axes, while intermediate areas between these axes will not benefit. For road, effects of course are highest along the major road corridors, but also the intermediate regions will benefit considerably through spill over effects. As a result, almost all parts of the country gain accessibility improvements. In case of Latvia, effects for rail are clearly larger than those for road, since almost all rail corridors will be improved or rehabilitated. However, even though the relative difference map for road suggests only small impacts along the Eastward corridor of Riga, absolute increases will not only appear in this corridor but also in corridors Riga-Pärnu and Daugavpils-Laudana-Rauna-Valka-Tartu. Even territories south of Riga towards the Lithuanian border will benefit from the corridor project.

Since the TEN-T outline plans do not include any road project in Lithuania, accessibility improvements focus on improvements in public transport accessibility. These are clearly concentrated in the Kaunas area and along the corridor Riga-Siauliai-Kaunas-Polish border. Interestingly, the capital city of Vilnius will only benefit to a lesser degree from these infrastructure projects, so that in future Kaunas will become the location in Lithuania with the highest accessibility – not only for road but also for public transport.

However despite all positive impacts on accessibility for rural areas in the case study region and for areas along the major transport axes, the existing agglomerations in all three countries clearly benefit the most from the foreseen infrastructure projects so that in total the accessibility patterns with the Baltic States are consolidated and spatial disparities in accessibility are solidified. For Estonia and Latvia, the capital regions of Tallinn and Riga continue to be the main economic and demographic hubs, by far with the highest market potential and highest accessibility. In case of Lithuania it will be interesting to see if and how Kaunas makes use of its improved accessibility (for instance, acting as logistics hub at the crossroads of all North-South and West-East axes) in relation to Vilnius as being the demographic and political centre of the country.

In **Poland,** the implementation of the TEN-T projects lead to significant changes in the accessibility pattern of the country. Investments of express roads in all directions around Warsaw improves significantly the accessibility of the eastern Poland and its big cities of Lublin and Rzeszów which still today lack of adequate modern road connections to the capital. North-western Poland, where the traffic needs are the lowest, has the poorest gains of accessibility. The potential accessibility to population by public transport shows that new railway axes are easily visible as corridors of better accessibility. The accessibility between largest agglomerations significantly improves both by individual and public transport. Changes in rail potential accessibility are mostly perceived in the western part of Poland, thanks to the improvement of major passenger and freight railway axes located in the CETC corridor connecting Szczecin with Lower and Upper Silesia. The already modernised line Gdańsk to Warsaw leads also to significant accessibility improvements (Figures 11.9 and 11.10).

In the **Czech Republic** the impacts of new TEN-T infrastructure significantly enlarge potential accessibility in the hinterland of the most important agglomerations and it supports transport connection among key settlement centres in the Czech Republic. Car accessibility is improved in most of the Czech territory. For public transport, impacts are more localised. TEN-T would strengthen public transport relations of Prague with north and east Bohemia regions and cities, and positively influence the transport situation in Moravia-Silesia regions (especially among cities Brno, Ostrava and Olomouc). The most important benefit from the public transport point of view is possible to expect in north and east Bohemia, furthermore in south hinterland of Prague and in the South-Moravia and Zlín regions (partially in the South part of Olomouc regions as well) (Figures 11.11 and 11.12)..

In **Northern Italy,** the overall picture of car potential accessibility is not significantly changed , as new road projects are not expected to alter the potential current accessibility pattern in the study area. Even if they can improve accessibility locally, the benefits are either too limited as to reduce the accessibility gap with respect to the most accessible areas in the region (e.g. “now Romea”), or benefit zones which are already above average (e.g. “Pedemontana Veneta”). Regarding to public transport, improvements can be noted in some spots like Bologna or Genoa, but in general the pattern is unchanged. Looking especially at relative differences one can see clear advantages for the Brenner axis, for the Liguria region and for other zones in the north-west and south-east of the study area, where rail improvements are concentrated (instead the new Fréjus tunnel towards Lyon is basically irrelevant for the regional accessibility) (Figures 11.13 and 11.14)..

In the **West Mediterranean** region, impacts of the TEN-T are especially important in the public transport domain. Substantially increased values of accessibility to population are recorded in all the cities having HSR stations, namely (from north to south) Perpignan, Figueres, Girona, Barcelona, Tarragona, Tortosa, Castelló, Valencia and Alacant, and in the interior, Lleida. Impacts are very high in all provinces, only slightly lower in Barcelona and Lleida provinces and partly in Valencia province. The car scenario locally shows the impact of new transport infrastructure in the Lleida-Toulouse road axis through Vielha, increasing accessibility in the western Pyrenees (allowing reaching previously inaccessible Toulouse labour market, and making accessible the tourist offer of Val d'Aran to Toulouse). In the Castelló province, finalising the new second Mediterranean Corridor motorway (new A-7 motorway parallel to existing Ap-7) allows for interior municipalities to more easily reach the coastal labour markets (tourist economies), and the Catalan labour market to some extent (Figures 11.15 and 11.16)..

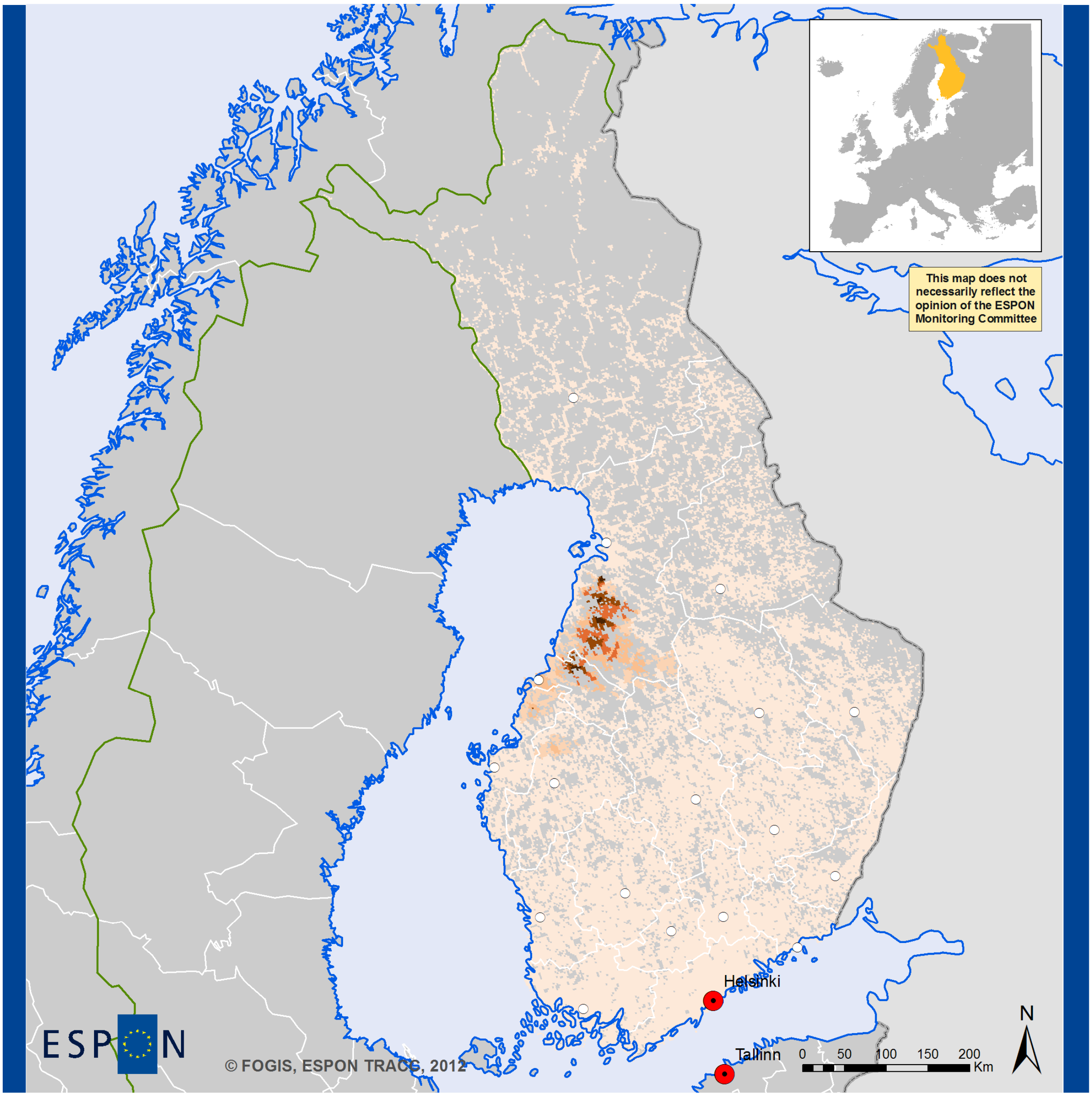
Conclusions

The overall quantity of projects foreseen varies largely form one case study to another. The volume of projects in Eastern Europe is generally higher than in Western Europe, with the exception of the Western Mediterranean region where the large development of the high speed rail network is included in the TEN-T programme.

Rail projects dominate over road projects in most of the case studies, especially in regions in Western Europe. Rail projects often consist in implementation of high standard rail stretches. In the Eastern European case studies, namely in Poland and the Czech Republic, a higher balance between road and rail projects can be identified. In the Baltic States, the picture varies substantially from country to country, road projects dominating in Estonia, and rail projects in Latvia and Lithuania.

No clear patterns can be observed for the integrity of case studies, impacts varying largely from one case to another. The diversity of typologies of projects in each case, and the use of particular hypothesis for final performance of envisaged infrastructures (e.g. speeds in new rail links) may be in part responsible for these differences.

In a number of case studies, largest metropolitan areas and urban regions tend to win less in relation to intermediate and rural regions (e.g. in the Czech Republic, in the Baltic States, and to some extent in the Western Mediterranean and in Finland). In Poland, road projects benefit to a higher extent the Warsaw – Katowice region, but also important gains can be observed in the far less populated eastern regions bordering with Belarus and Ukraine.



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Data source: Finnish Transport Agency, 2012, Statistics Finland, 2011, 2010
Origin of data: ESPON Databank Project, 2010/2011
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Finland Case Study
Relative increase of potential accessibility to population by public transport with TEN-T projects (raster level)

- 0 - 5.0
- 5.1 - 10.0
- 10.1 - 15.0
- 15.1 - 20.0
- 20.1 - 25.0
- 25.1 < ...

Figure 11.5. Finland case study, relative increase of potential accessibility to population by public transport with TEN-T projects

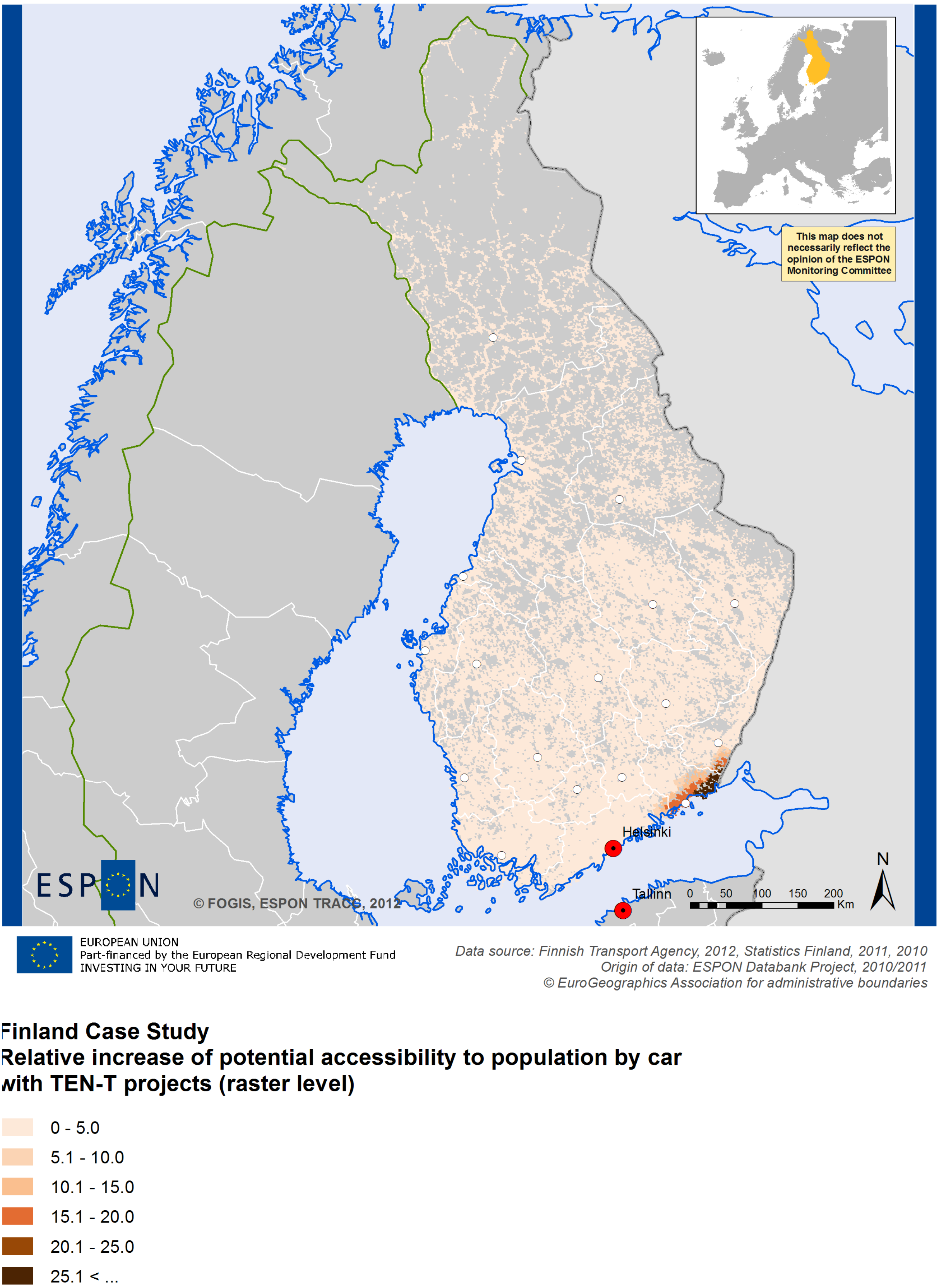
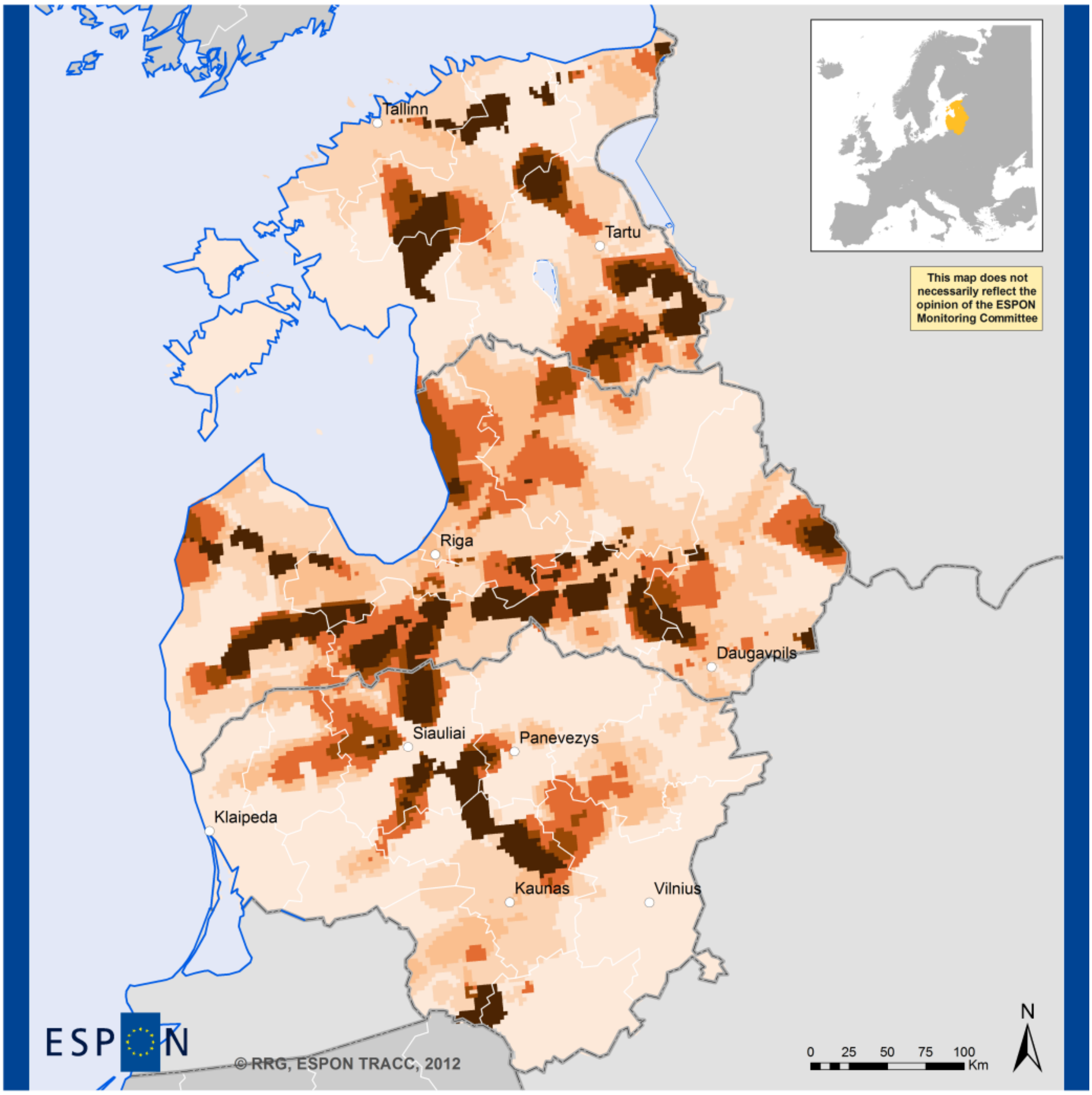


Figure 11.6. Finland case study, relative increase of potential accessibility to population by car with TEN-T projects



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Source: RRG GIS Database, 2012; OSM, 2012; European Commission, 2011
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Baltic States Case Study (2011)
Relative increase of pot. accessibility by public transport with TEN-T projects (raster)

0 - 5	○ Main city
6 - 10	
11 - 20	
21 - 50	
51 - 75	
76 < ...	

Notes:
Beta = 0.034657

Figure 11.7. Baltic States case study, relative increase of potential accessibility to population by public transport with TEN-T projects

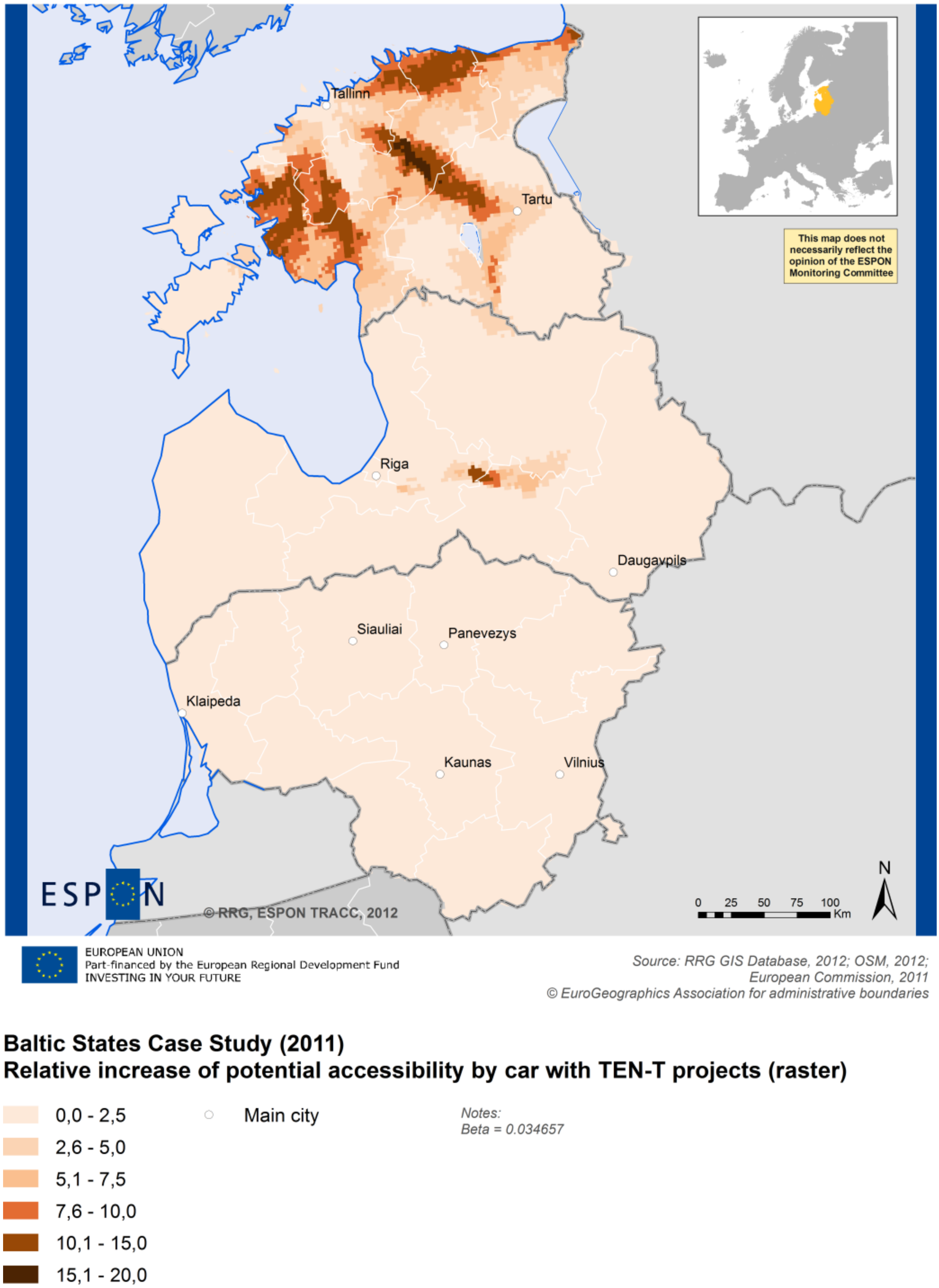
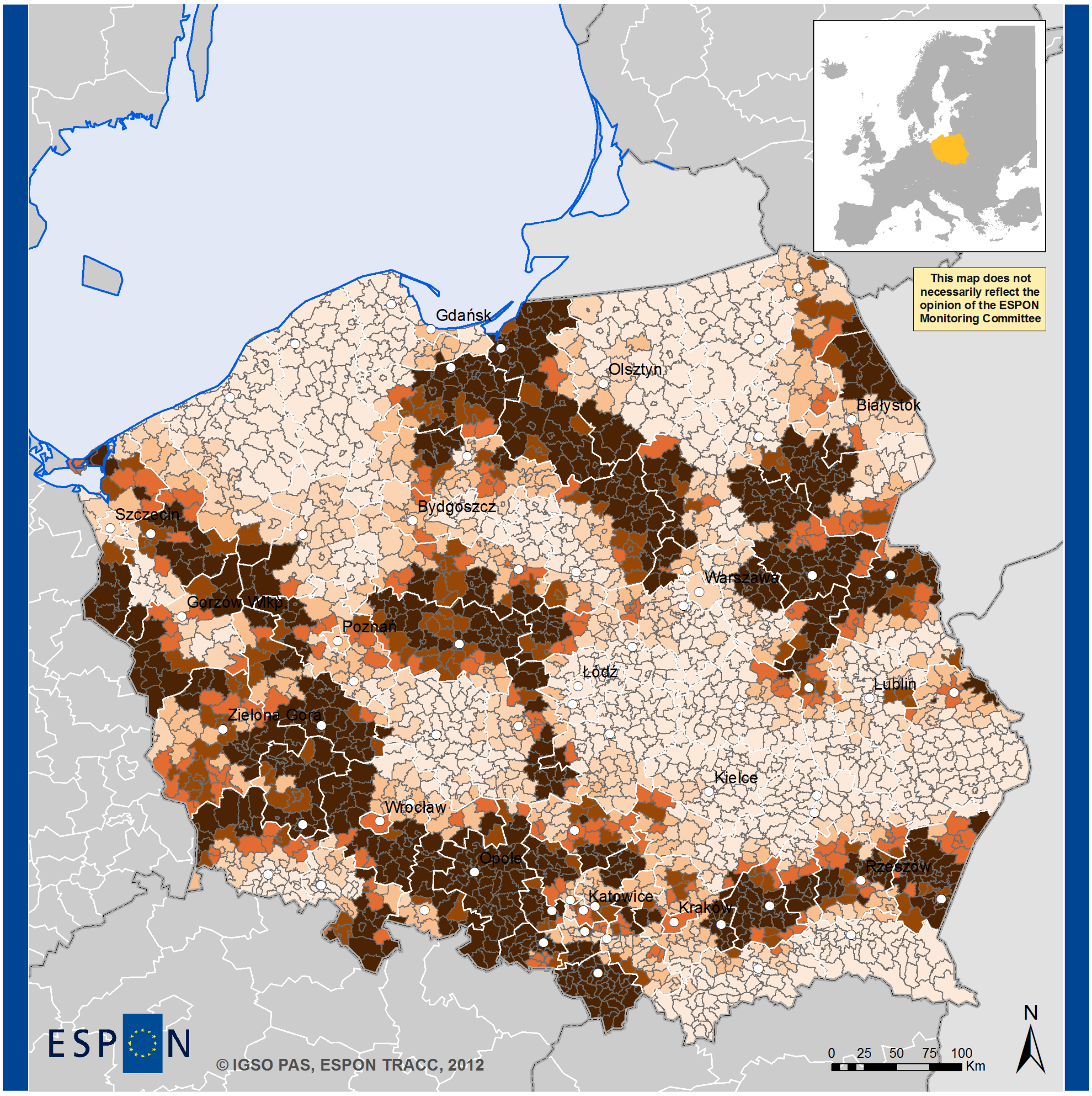


Figure 11.8. Baltic States case study, relative increase of potential accessibility to population by car with TEN-T projects



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Source: IGSO PAS, 2011
Origin of population data: Local Data Bank, GUS, 2011
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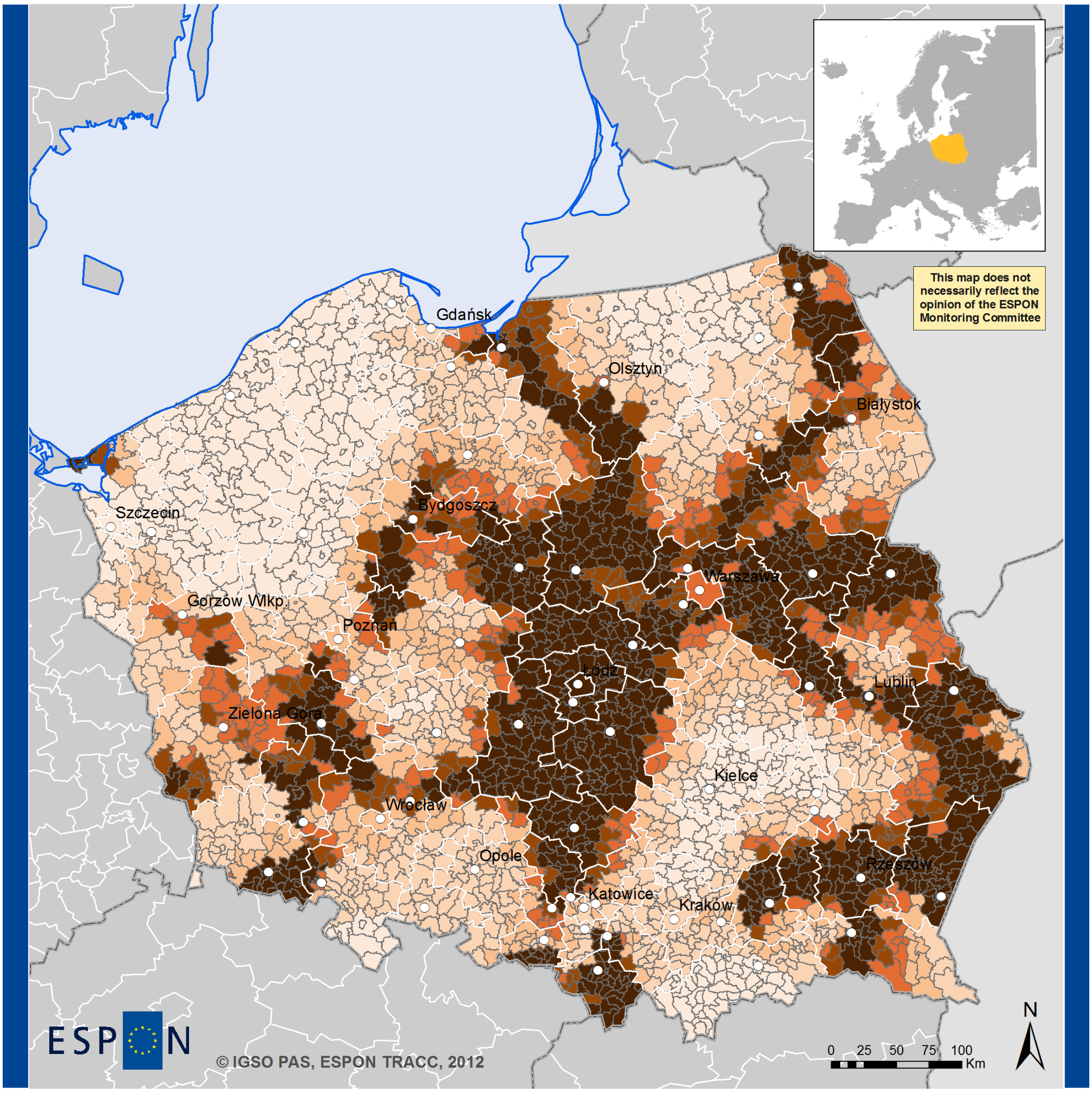
Poland Case Study
Relative increase of potential accessibility to population by public transport with TEN-T projects

- 0.0 – 5.0
- 5.1 – 10.0
- 10.1 – 15.0
- 15.1 – 20.0
- 20.1 – 25.0
- 25.1 - 375.6

○ NUTS 3 Capitals

Figure 11.9. Poland case study, relative increase of potential accessibility to population by public transport with TEN-T projects



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Source: IGSO PAS, 2011
Origin of population data: Local Data Bank, GUS, 2011
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Poland Case Study
Relative increase of potential accessibility to population by car with TEN-T projects

- 0.0 – 5.0
- 5.1 – 10.0
- 10.1 – 15.0
- 15.1 – 20.0
- 20.1 – 25.0
- 25.1 - 242.5

○ NUTS 3 Capitals

Figure 11.10. Poland case study, relative increase of potential accessibility to population by car with TEN-T projects

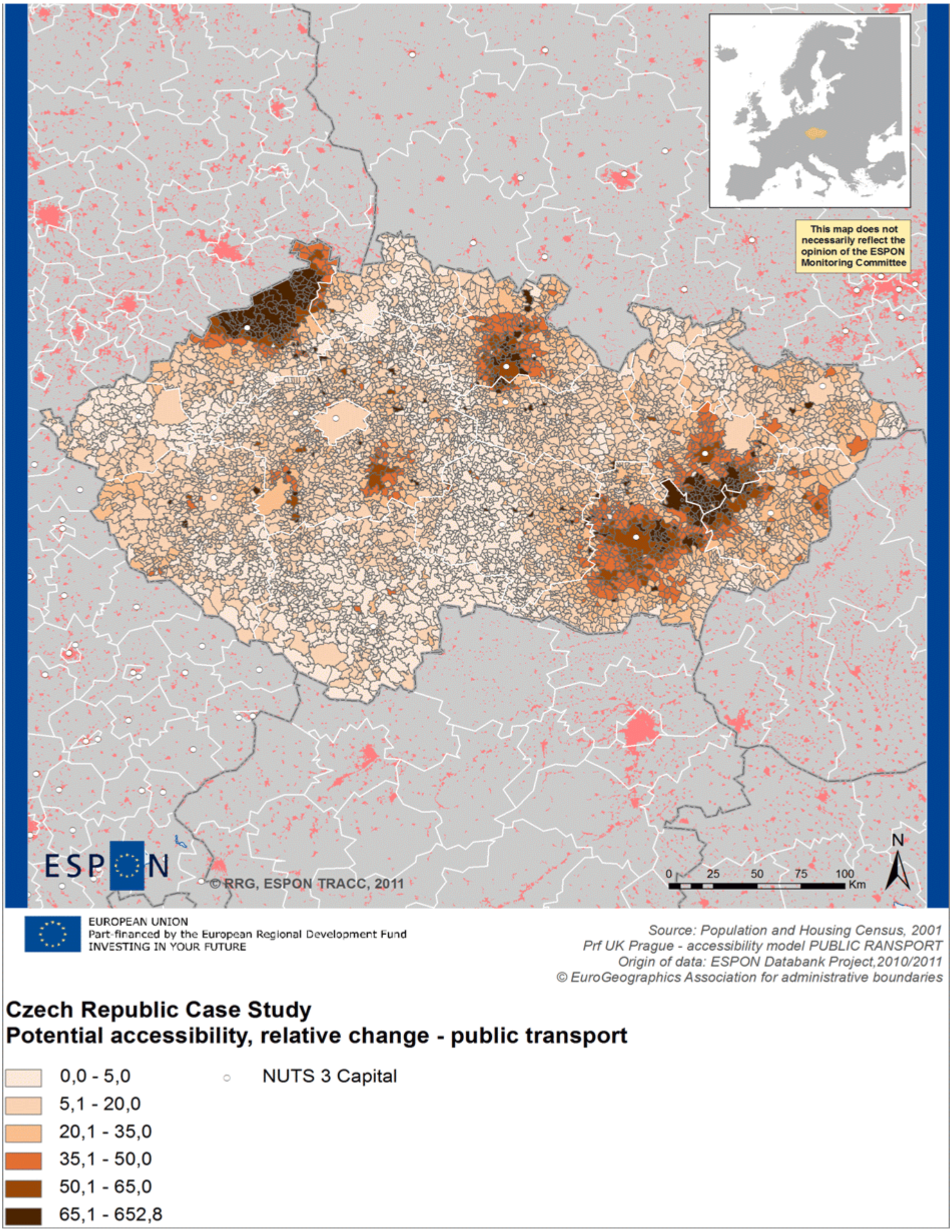


Figure 11.11. Czech Republic case study, relative increase of potential accessibility to population by public transport with TEN-T projects

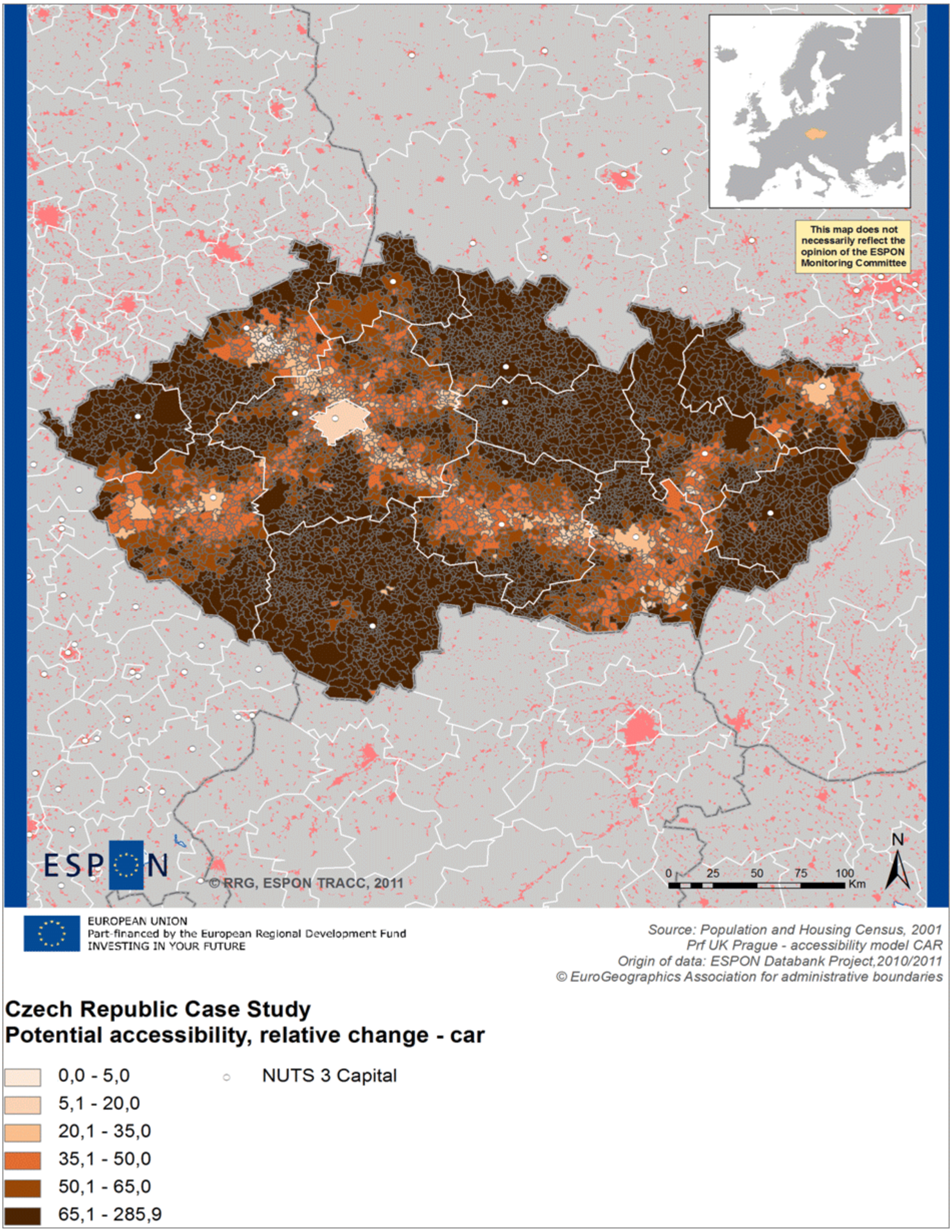
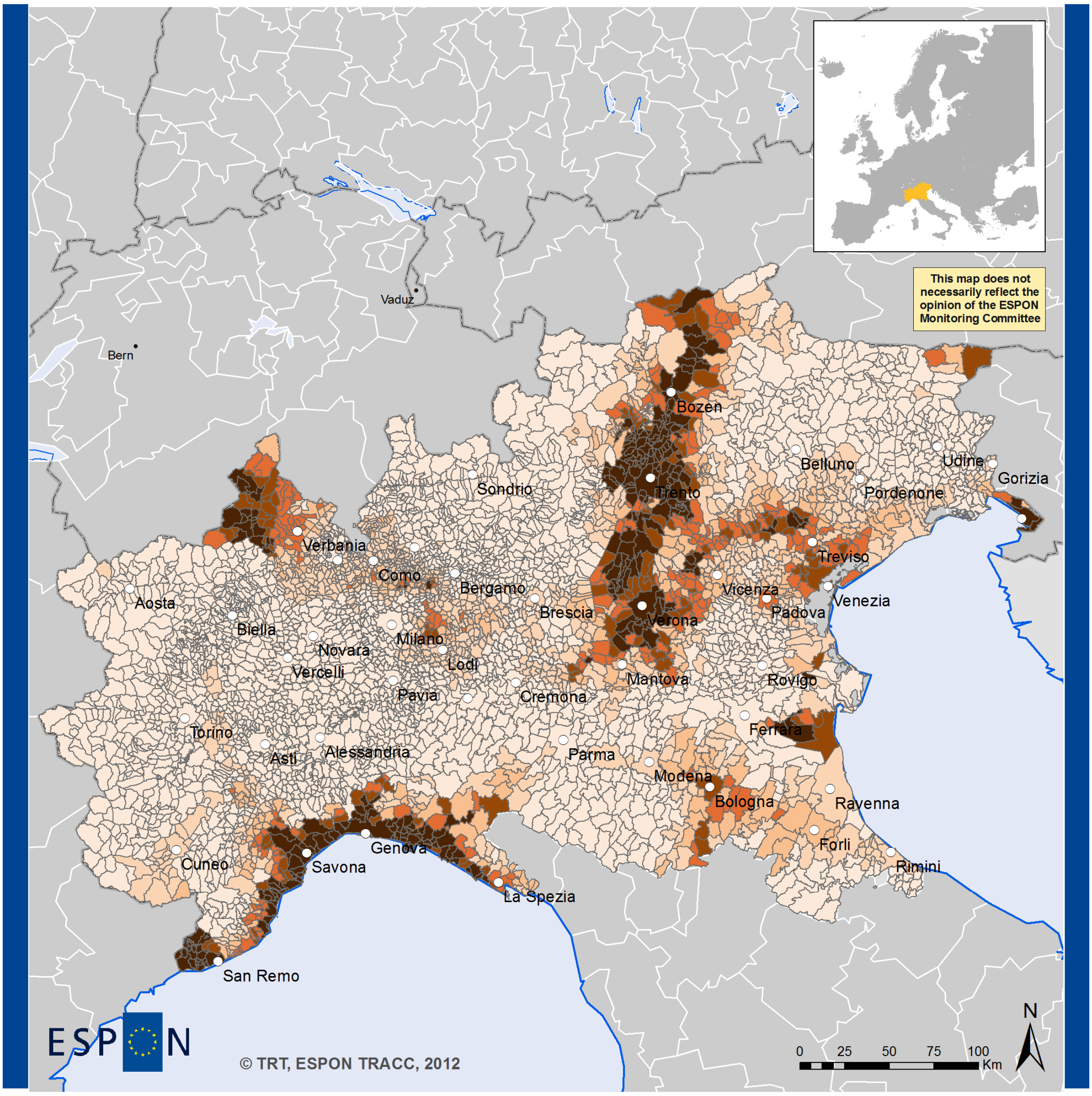


Figure 11.12. Czech Republic case study, relative increase of potential accessibility to population by car with TEN-T projects



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Source: TRT Accessibility model (2012), Rail Network: RRG GIS Database (2011), Road Network: OSM (2011), Italian Statistical Office (ISTAT)- Population (2006), TEN-T outline plans (October 2011)
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Northern Italy Case Study
Future situation after implementation of TEN-T outline plans (2020)
Regional potential accessibility to population by public transport (β=0.034657);
relative change (%) (standarised on public transport average)

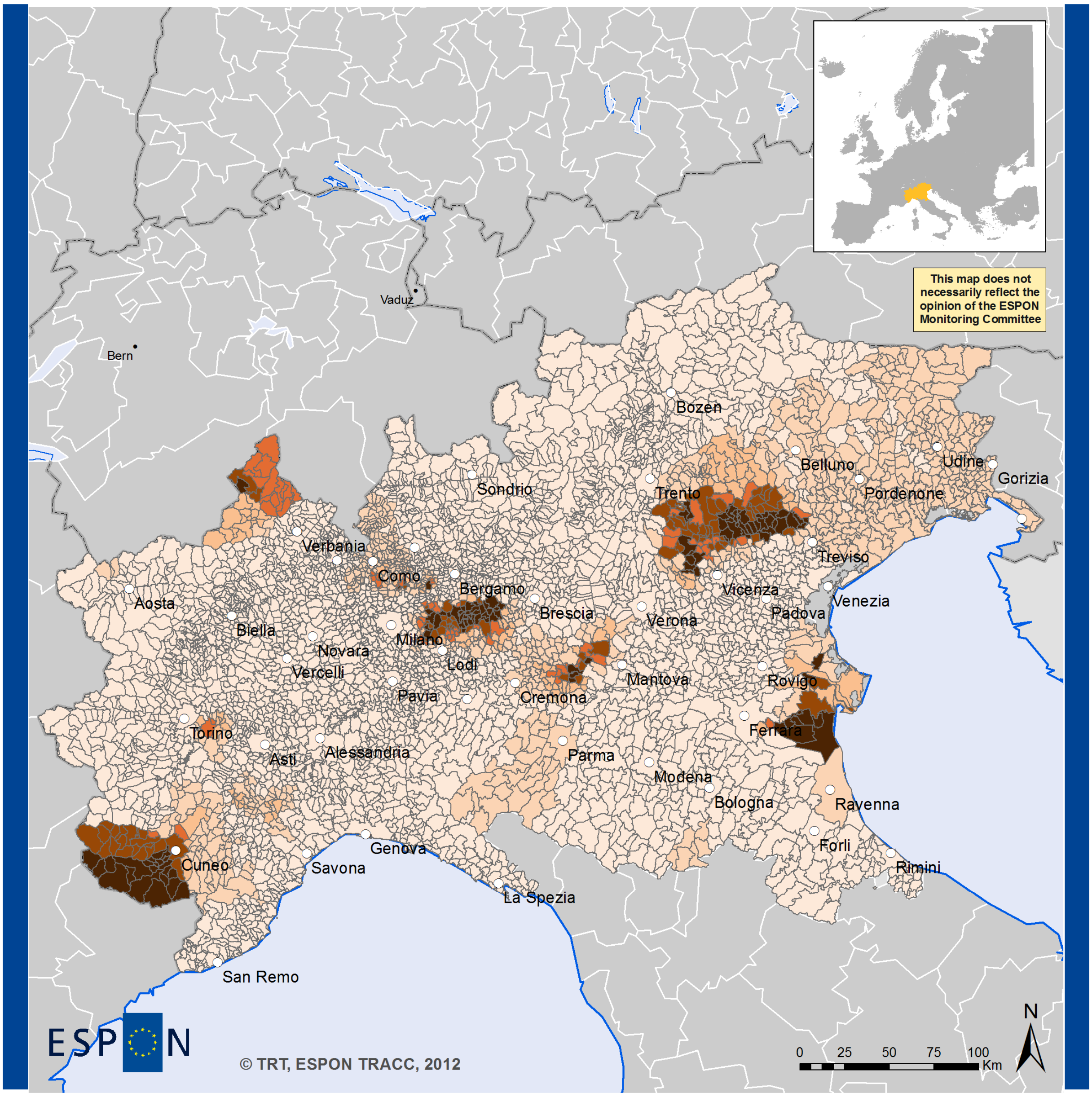
- 0.0 - 5.0
- 5.1 - 10.0
- 10.1 - 15.0
- 15.1 - 20.0
- 20.1 - 25.0
- 25.1 < ...

○ *NUTS3 Capital*

100 (population weighted average) =

Minimum:
Maximum:

Figure 11.13. Northern Italy case study, relative increase of potential accessibility to population by public transport with TEN-T projects



EUROPEAN UNION
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Source: TRT Accessibility model (2012), Rail Network: RRG GIS Database (2011), Road Network: OSM (2011), Italian Statistical Office (ISTAT)- Population (2006), TEN-T outline plans (October 2011)
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Northern Italy Case Study
Future situation after implementation of TEN-T outline plans (2020)
Regional potential accessibility to population by road (β=0.034657);
relative change (%) (standarised on road average)

0.0 - 5.0
5.1 - 10.0
10.1 - 15.0
15.1 - 20.0
20.1 - 25.0
25.1 < ...

NUTS3 Capital

100 (population weighted average) =

Minimum:
Maximum:

Figure 11.14. Northern Italy case study, relative increase of potential accessibility to population by car with TEN-T projects

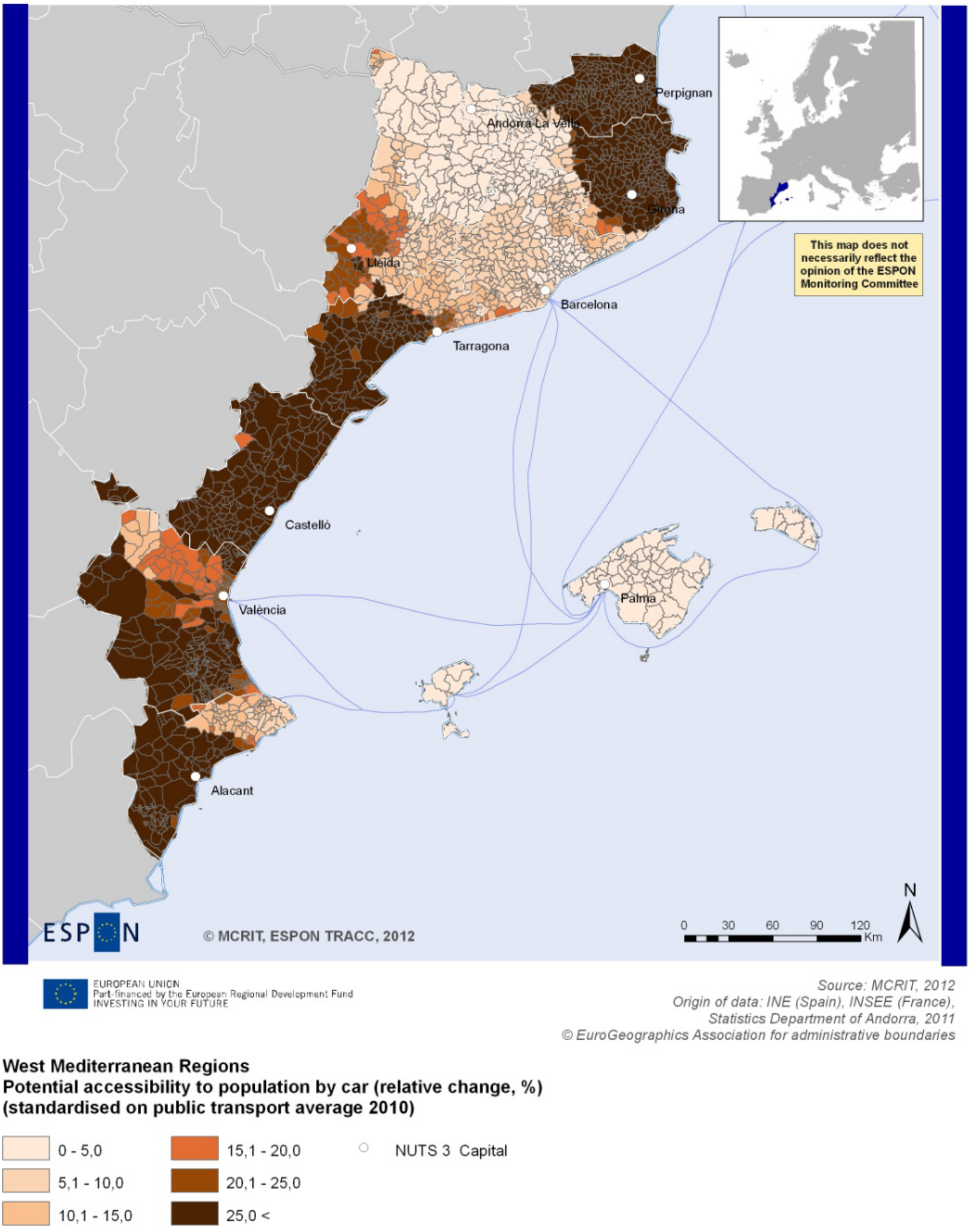


Figure 11.15. West Mediterranean Regions case study, relative increase of potential accessibility to population by public transport with TEN-T projects

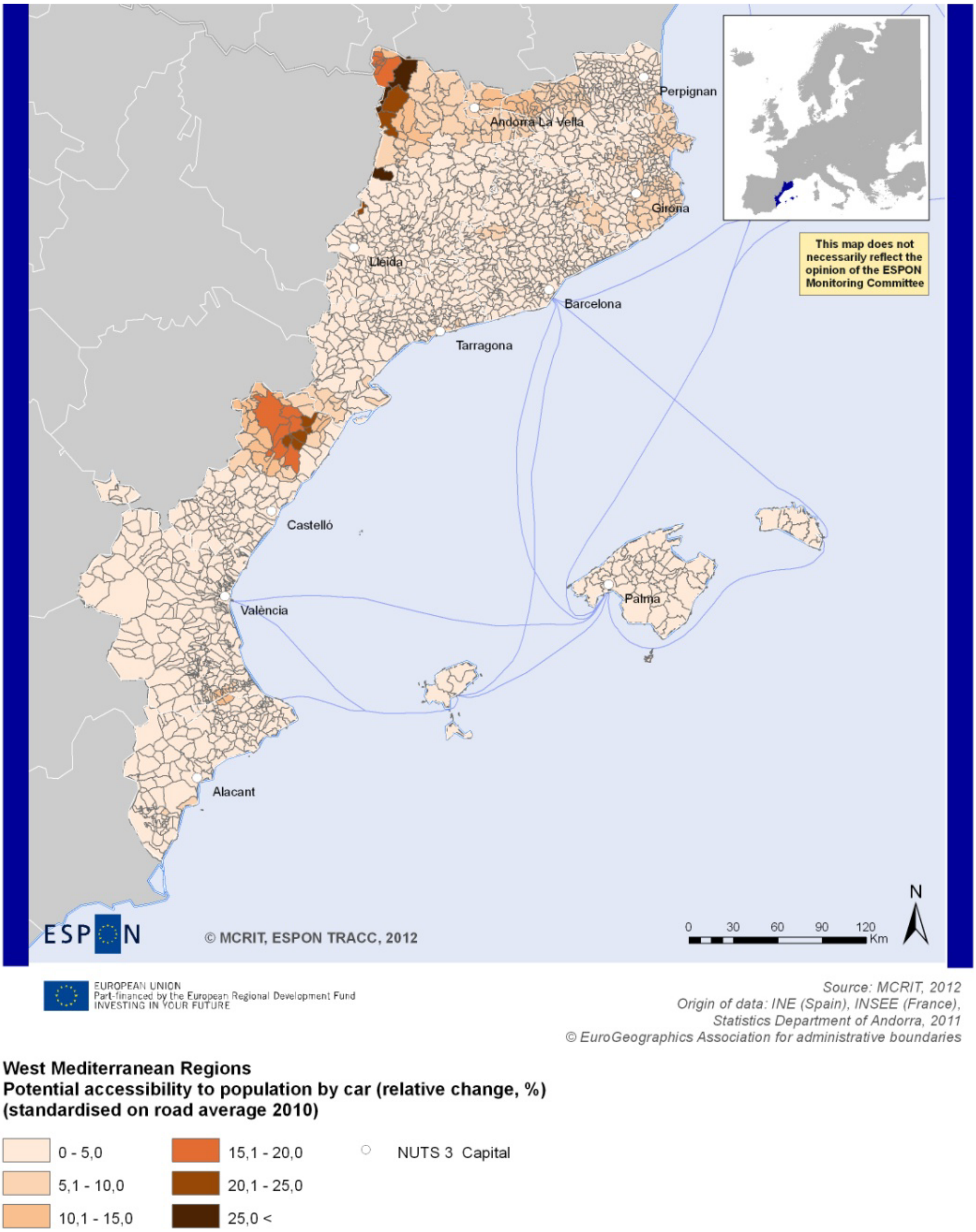


Figure 11.16. West Mediterranean Regions case study, relative increase of potential accessibility to population by car with TEN-T projects

12 Accessibility and regional development

As discussed in Chapter 4.4, the important role of transport infrastructure for regional development is one of the fundamental principles of regional economics. In its most simplified form this principle implies that regions with better access to the locations of input materials and markets will, ceteris paribus, be more productive, more competitive, and hence more successful than more remote regions.

Today the relationship between transport infrastructure and economic development has become more complex than ever. There are successful regions in the European core confirming the theoretical expectation that location matters, but there are also centrally located regions suffering from industrial decline and high unemployment. On the other side of the spectrum, the poorest regions, as theory would predict, are at the periphery, but there are also prosperous peripheral regions such as the Nordic countries. To make things even more difficult, some of the economically fastest-growing regions are among the most peripheral ones. Figure 12.1 (ESPON 1.2.1 2004, 22) illustrates this complexity by showing the regions that perform better or worse than their geographical position would suggest.

The EU hopes to contribute to reducing the socioeconomic disparities between its regions by developing the trans-European transport networks (TEN-T). However, although they are among the most ambitious initiatives of the European Community, the value of the TEN-T programme is not undisputed.

Critics argue that many of the new connections fail to link peripheral countries to the core and instead strengthen the ties between central regions, reinforcing their accessibility advantage. Some argue that regional development policies based on the creation of infrastructure in lagging regions have not succeeded in reducing regional disparities in Europe, whereas others point out that it has yet to be ascertained that the reduction of barriers between regions has disadvantaged peripheral regions. From a theoretical point of view, both equalising and polarising can occur. A new motorway or high-speed rail connection between a peripheral and a central region, for instance, makes it easier for producers in the peripheral region to market their products in large cities; however, it may also expose the region to the competition of more advanced products from the centre and so endanger formerly secure regional monopolies. These issues have received new attention through the enlargements of the European Union in 2004 and 2007 and the recent economic crisis.

There have already been several ESPON projects addressing the regional economic impacts of changes in accessibility through transport infrastructure investments. ESPON 2.1.1 (Territorial Impacts of EU Transport and TEN Policies) assessed the impacts of EU and national transport and telecommunications policies on regional economic development and cohesion in the enlarged European Union using three forecasting models (ESPON 2.1.1, 2003). The transport policy scenarios included different priorities of TEN-T infrastructure investments (e.g., all priority projects, all projects, only cross-border projects, or only projects in lagging regions), different options of transport pricing, and combinations of both.

The main general result from the scenario simulations was that the overall effects of transport infrastructure investments and other transport policies are small compared with those of socio-economic and technical macro trends such as globalisation, increasing competition between cities and regions, aging populations, and increasing labour force participation and labour productivity. The second main result was that even large increases in regional accessibility translate into only very small increases in regional economic activity. However, that statement needs to be qualified, as the magnitude of the effect depends on the already existing level of accessibility:

- For regions in the European core with all the benefits of a central geographical location *plus* an already highly developed transport and telecommunications infrastructure, additional gains in accessibility bring few additional incentives for economic growth.

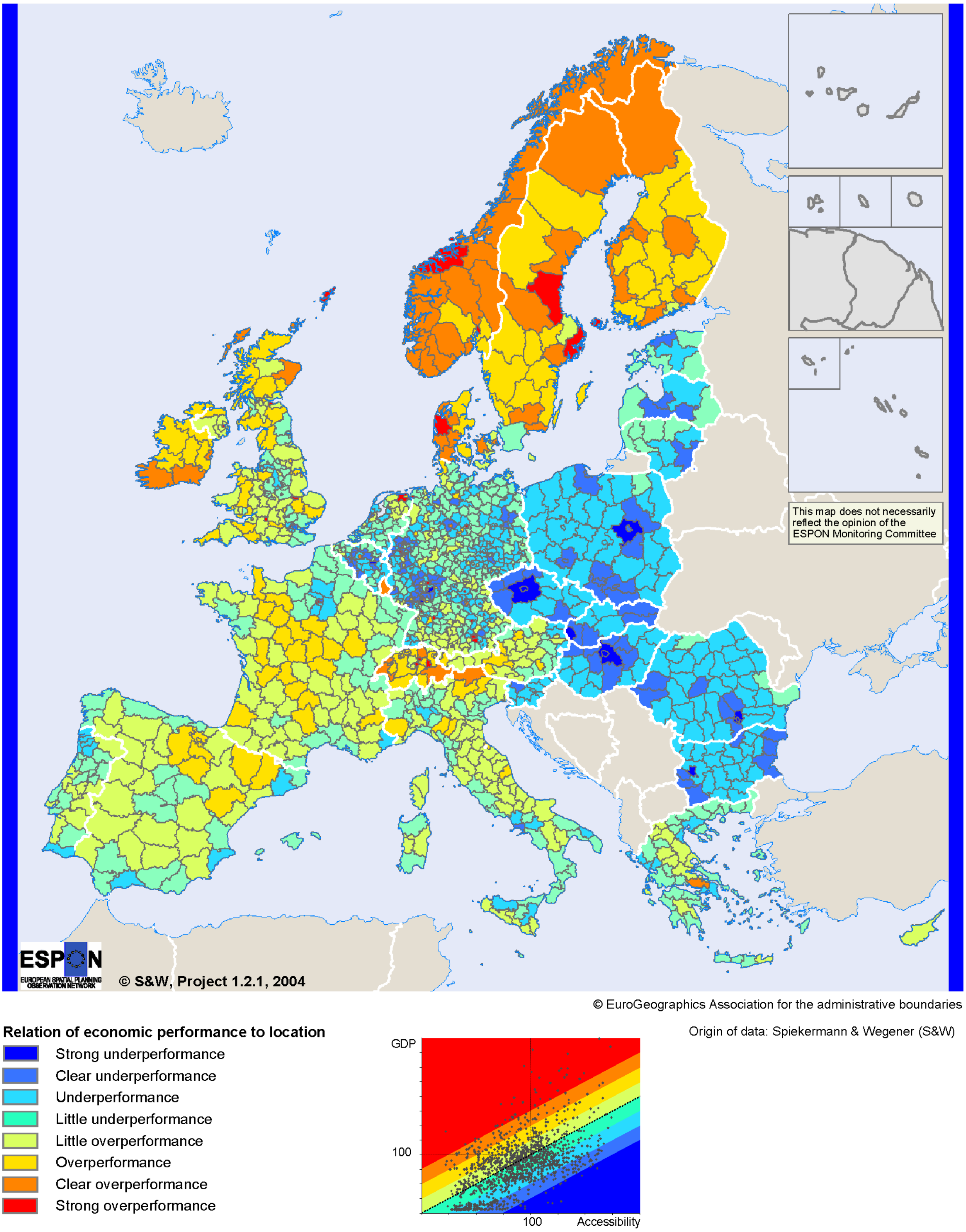


Figure 12.1. Accessibility v. economic performance, 2001 (ESPON 1.2.1, 2004, 22)

- For regions at the European periphery, however, which suffer from a remote geographical location *plus* an underdeveloped transport infrastructure, a gain in accessibility brings significant progress in economic development. But the opposite may happen if the new connection opens a formerly isolated region to external competition.
- The magnitude of the effects of infrastructure projects is related to the number and size of projects. The effect of pricing scenarios depends on their direction: Scenarios that make transport less expensive have a positive, scenarios that make transport more expensive, a negative economic effect. Negative effects of pricing policies can be mitigated by their combination with network scenarios with positive economic effects, although the net effect depends on the magnitude of the two components.

Similar scenarios were calculated in ESPON 1.1.3 (Enlargement of the European Union and the Wider European Perspective as Regards its Polycentric Spatial Structure) for the new EU member states. There the scenarios examined the effects of enlargement as such and the associated reductions in border waiting times and different strategies of transport infrastructure investments in the new member states (ESPON 1.1.3 2006). The results were in general agreement with those achieved in ESPON 2.1.1 indicating that transport infrastructure investments in the new member states could make a significant contribution to help those countries' economies catch up with those of the old member states. Figure 12.2 demonstrates this by showing the impact on GDP per capita in a scenario in which massive infrastructure improvements in the new member states are assumed in addition to the TEN and TINA implementation plans. However, the comparison between the two maps shows that, though in relative terms economic growth is faster in the new member states than in the old member states, the old member states gain much more in absolute terms.

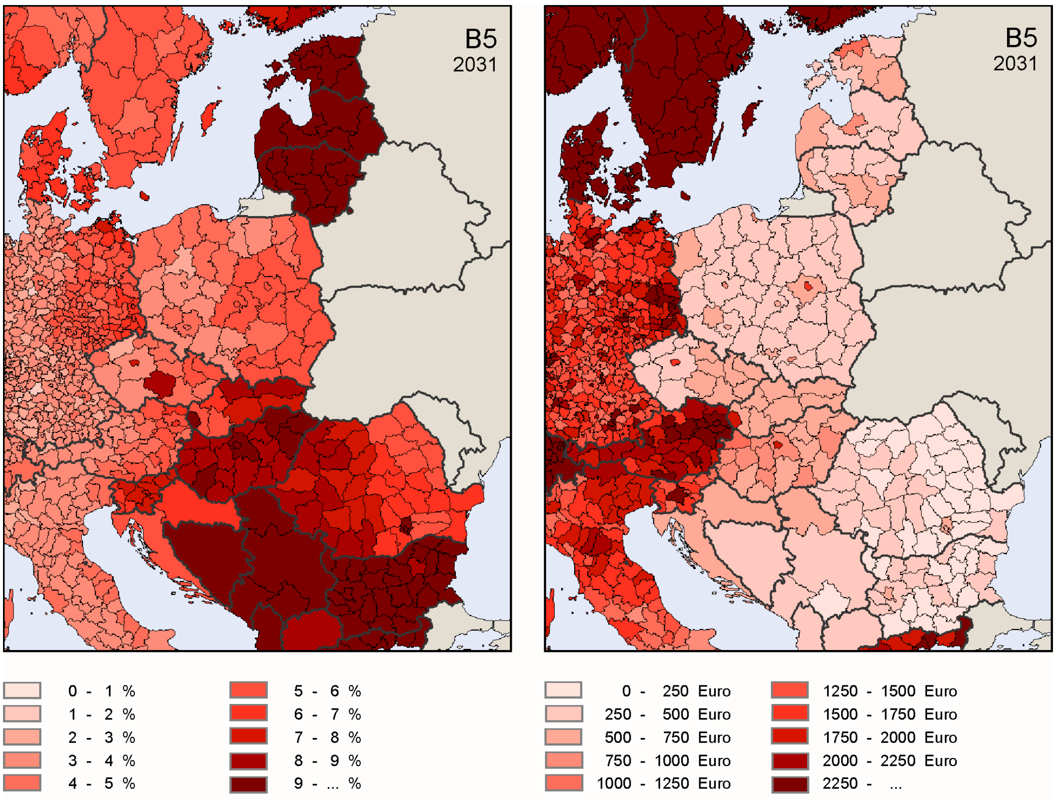


Figure 12.2. Relative (left) and absolute (right) GDP effects of changes in accessibility (ESPON 1.1.3, 2006, Part 2, 208–209)

ESPON 3.2 (Spatial Scenarios and Orientations in Relation to the ESDP and Cohesion Policy) examined the effects of different transport infrastructure programmes (ESPON 3.2, 2006). Although the contribution of accessibility to the changes in regional socioeconomic impacts could not be clearly identified as they were packaged with other policies, the evaluation confirmed the results of ESPON 2.1.1 showing that the strongest economic effects of accessibility changes can be expected in the western regions of the new member states and the Iberian peninsula.

Similar scenarios in which transport infrastructure changes are combined with other policies in complex policy packages are currently being examined in ESPON ET2050 (Territorial Scenarios and Visions for Europe 2050). The preliminary results confirm that the impacts of accessibility are small where accessibility is already high but are significant in peripheral regions where accessibility is low (ESPON ET2050, 2013).

12.1 The SASI model

In the ESPON TRACC project the SASI regional economic model was used to investigate the likely economic, social and environmental impacts of different EU and EU member states strategies to influence the spatial development of the European territory, i.e. to asses these impacts with respect to the major European Union goals competitiveness, cohesion and sustainability.

The SASI model is a recursive simulation model of socio-economic development of regions in Europe subject to exogenous assumptions about the economic and demographic development of the European Union as a whole and transport and other spatial policies. The SASI model differs from other approaches to model regional development by modelling not only production (the demand side of regional labour markets) but also population (the supply side of regional labour markets). The model was developed at the University of Dortmund in co-operation with the Technical University of Vienna (Wegener, Bökemann, 1998) and has since been applied in several EU projects, among them IASON (Integrated Appraisal of Spatial Economic and Network Effects of Transport Investments and Policies), ESPON 2.1.1 (Territorial Impacts of EU Transport and TEN Policy), ESPON 1.1.3 (Enlargement of the European Union and the Wider European Perspective as Regards its Polycentric Spatial Structure), the Interreg-IIIb project AlpenCors (Alpen Corridor South) and the 6th RTD Framework Programme project STEPs (Scenarios for the Transport System and Energy Supply and their Potential Effects).

For forecasting regional economic development the SASI model applies an extended production function with regional economic structure, productivity, accessibility, availability of labour, R&D investments, population density and availability of developable land as explanatory variables. In addition it uses a migration function in which net migration is forecast with regional wage level and quality of life as explanatory variables. To take account of the slow process of economic structural change, the economic variables are lagged by five years. A detailed documentation of the SASI model is contained in Wegener (2008) and S&W (2013).

The spatial dimension of the model is established by the subdivision of the European Union plus Norway, Switzerland, Liechtenstein, Iceland and the Western Balkan countries in 1,338 NUTS-3 regions and by connecting these by road, rail and air networks. For each region the model forecasts the development of accessibility and GDP per capita. In addition cohesion indicators expressing the impact of transport infrastructure investments and transport system improvements on the convergence (or divergence) of socio-economic development in the regions of the European Union are calculated. The temporal dimension of the model is established by dividing time into periods of one year duration. By modelling relatively short time periods both short- and long-term lagged impacts can be taken into account. In each simulation year the submodels of the SASI model are processed in a recursive way, i.e. sequentially one after another. This implies that within one simulation period no equilibrium between model variables is established; in other words, all endogenous effects in the model are lagged by one or more years.

All simulations with the SASI model start from the year 1981 to demonstrate that the model is able to reproduce the past development and how the future development continues or deviates from the past development. The forecasting horizon of the model has recently been extended to the year 2051.

The SASI model has six forecasting submodels: European Developments, Regional Accessibility, Regional GDP, Regional Employment, Regional Population and Regional Labour Force. A seventh submodel calculates Socio-Economic Indicators with respect to efficiency and equity (see Figure 12.3).

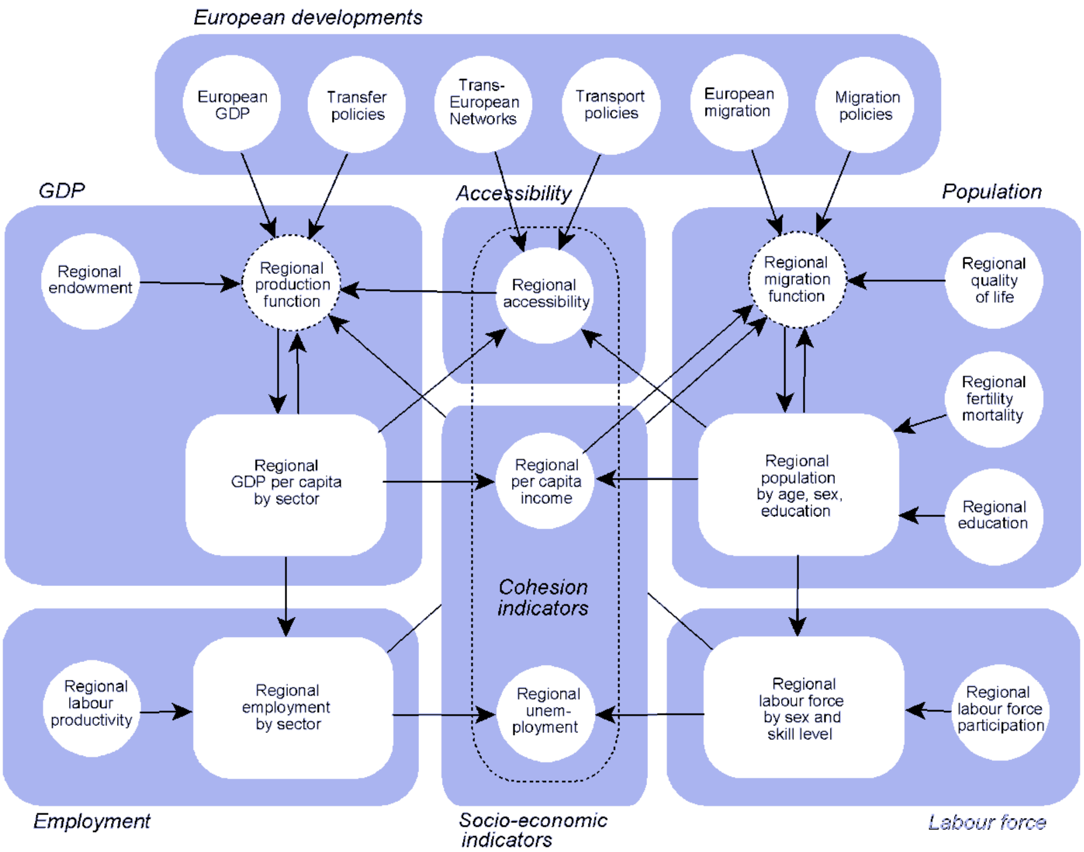


Figure 12.3. The SASI model

12.2 TRACC scenarios

To examine the impacts of accessibility changes on regional competitiveness, cohesion and sustainability one Baseline Scenario and three policy scenarios were defined (see Table 12.1):

- The *Baseline* scenario represents the most likely development of the transport infrastructure with implementation of the core TEN-T network until 2020 and no further network extensions thereafter, yet moderate reductions of travel times through upgrading of the existing network.
- The *Growth* scenario TA assumes concentration of TEN-T investments on the 15 old EU member states before 2004 (EU15) and no such investments in the new member states that joined the EU after 2004 (EU12) and similar focus of the upgrading of the existing network.
- The *Cohesion* scenario TB assumes concentration of TEN-T investments on the new member states (EU12) and no such investments in the old member states (EU15) and similar focus of the upgrading of the existing network.
- The *Sustainability* scenario assumes only rail investments after 2021 and an environmental tax on road and air travel.

Table 12.1. TRACC scenarios

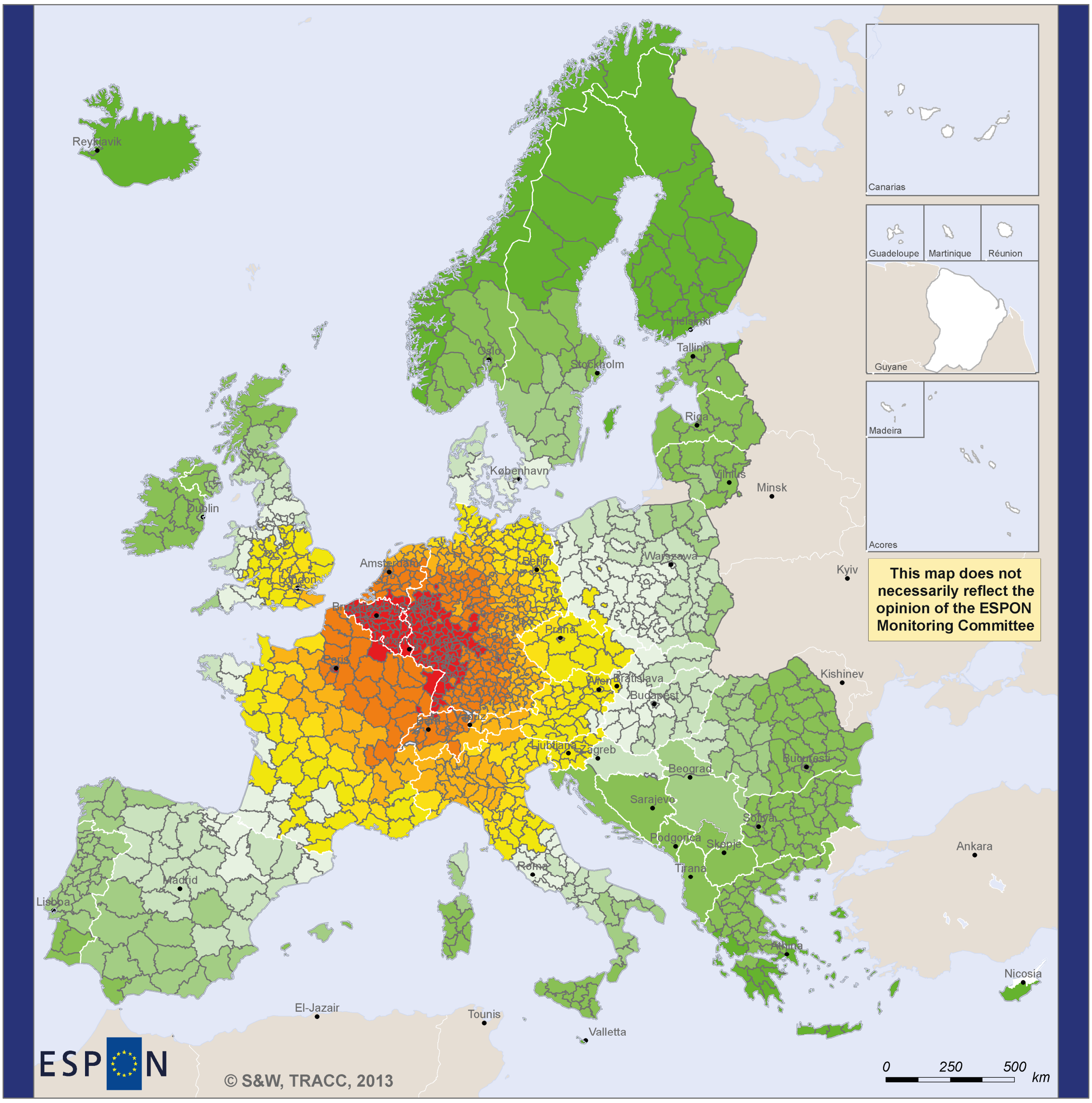
Scenario		Coun-tries	Network development	Infrastructure system improvement (travel time reduction by factor below)			
Code	Name			2026	2031	2041	2051
00	Baseline	All	Nothing after 2021	0.99	0.98	0.96	0.94
TA	Growth	EU15	TEN-T after 2021	0.90	0.85	0.75	0.65
		EU12	Nothing after 2021	0.99	0.98	0.96	0.94
TB	Cohesion	EU15	Nothing after 2021	0.99	0.98	0.96	0.94
		EU12	TEN-T after 2021	0.90	0.85	0.75	0.65
TC	Sustainability	All	TEN-T rail after 2021 Environmental tax on road and air	rail: 0.90 road: 0.99	rail: 0.85 road: 0.98	rail: 0.75 road: 0.96	rail: 0.65 road: 0.94

12.3 Scenario results

Figures 12.4 to 12.15 on the following pages show selected results of the scenario simulations with the SASI model.

Figures 12.4 to 12.8 present one of the four kinds of multimodal accessibility indicators calculated in SASI, accessibility by road and rail:

- Figure 12.4 shows the spatial distribution of accessibility for person travel by road and rail over the NUTS-3 regions in Europe at the end of the forecasting period in 2051 As in many accessibility maps in this report, it is clearly visible that accessibility is the product of two components, geographical position and transport infrastructure. Even after some forty years of continued transport infrastructure investment, the huge advantage in accessibility of the centrally located regions in western and southern Germany, the Benelux countries and northern France has remained almost the same as today.
- Figure 12.5 illustrates the changes in accessibility assumed in the Growth scenario TA as difference map showing the percent difference between accessibility in scenario TA and accessibility in the Baseline scenario in 2051. In difference maps red indicates positive and blue indicate negative differences. As to be expected in the Growth scenario TA, in which transport network improvements occur mainly in the old member states (EU15), the positive differences in accessibility between TA and the Baseline scenario are strongest there.
- Figure 12.6 shows the corresponding difference map for accessibility travel road/rail for the Cohesion scenario TB. As to be expected the positive difference in accessibility over the Baseline scenario are strongest in the new member states in EU12.
- Figure 12.7 shows the difference for accessibility travel road/rail for the Sustainability scenario TC. This is the only scenario in which accessibility is reduced by the environmental tax on road and air traffic, and these reductions are not compensated by new high-speed rail connections and the upgrading of existing rail lines. So consequently the difference map of this scenario is blue throughout, with the strongest reductions in accessibility in western and southern Europe and the northern counties. It should be noted that larger legend classes had to be used to show the large negative differences due to the environmental tax.
- Figure 12.8 compares the assumed accessibility changes in the four scenarios over time, separately for the old (EU15) and new (EU12) member states. Each trajectory indicates the development of accessibility travel road/rail in one scenario; the heavy black line represents the development in the Baseline scenario.



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Regional level: NUTS 3
Source: Spiekermann and Wegener
Urban and Regional Research (S&W), 2013
Origin of data: SASI Model, 2013
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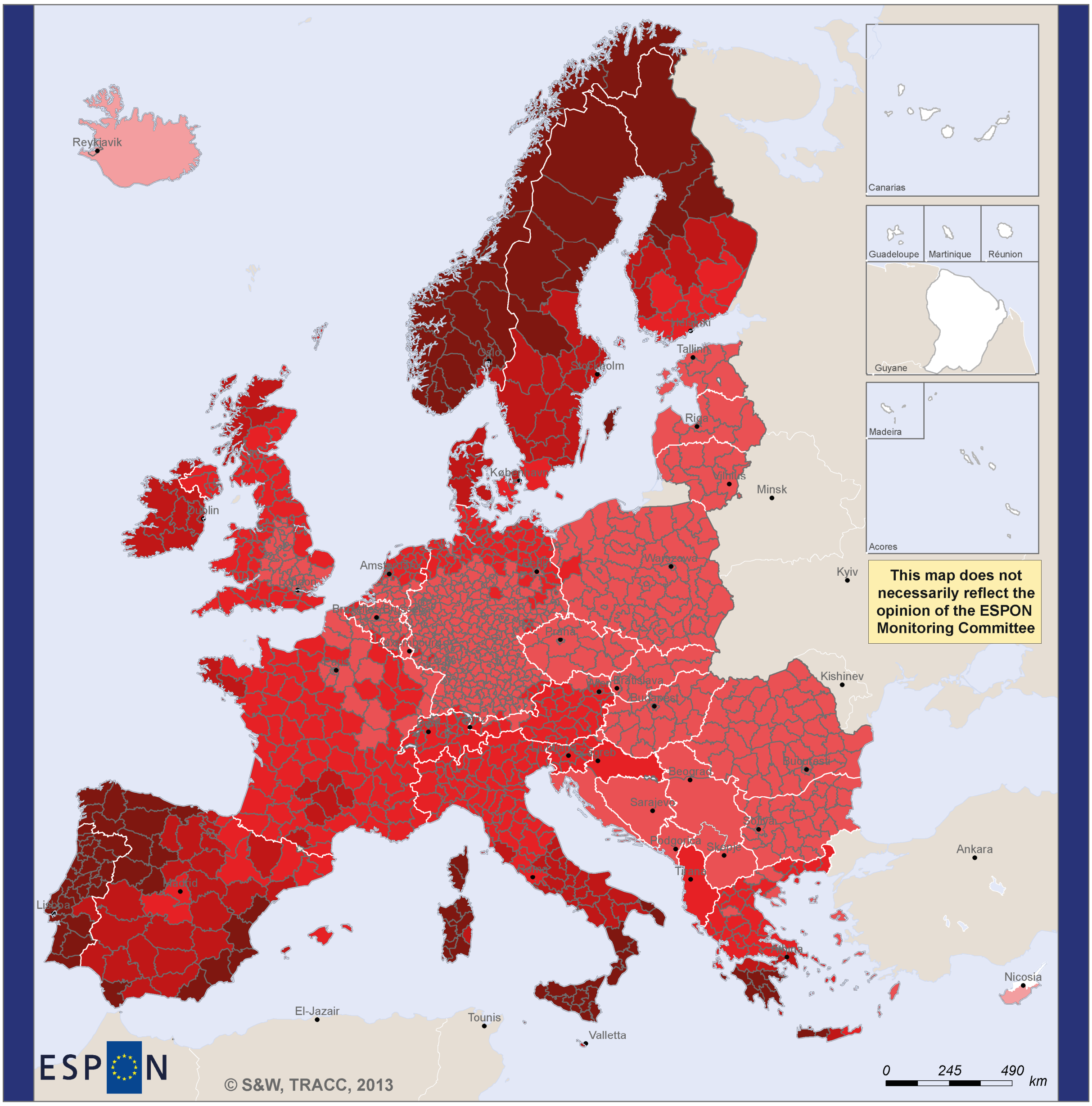
Accessibility travel road/rail
Baseline scenario
2051

0 - 5	25 - 30	no data
5 - 10	30 - 35	
10 - 15	35 - 40	
15 - 20	40 - 45	
20 - 25	45 - 50	

Figure 12.4. TRACC SASI scenarios: Baseline scenario: accessibility travel road/rail 2051



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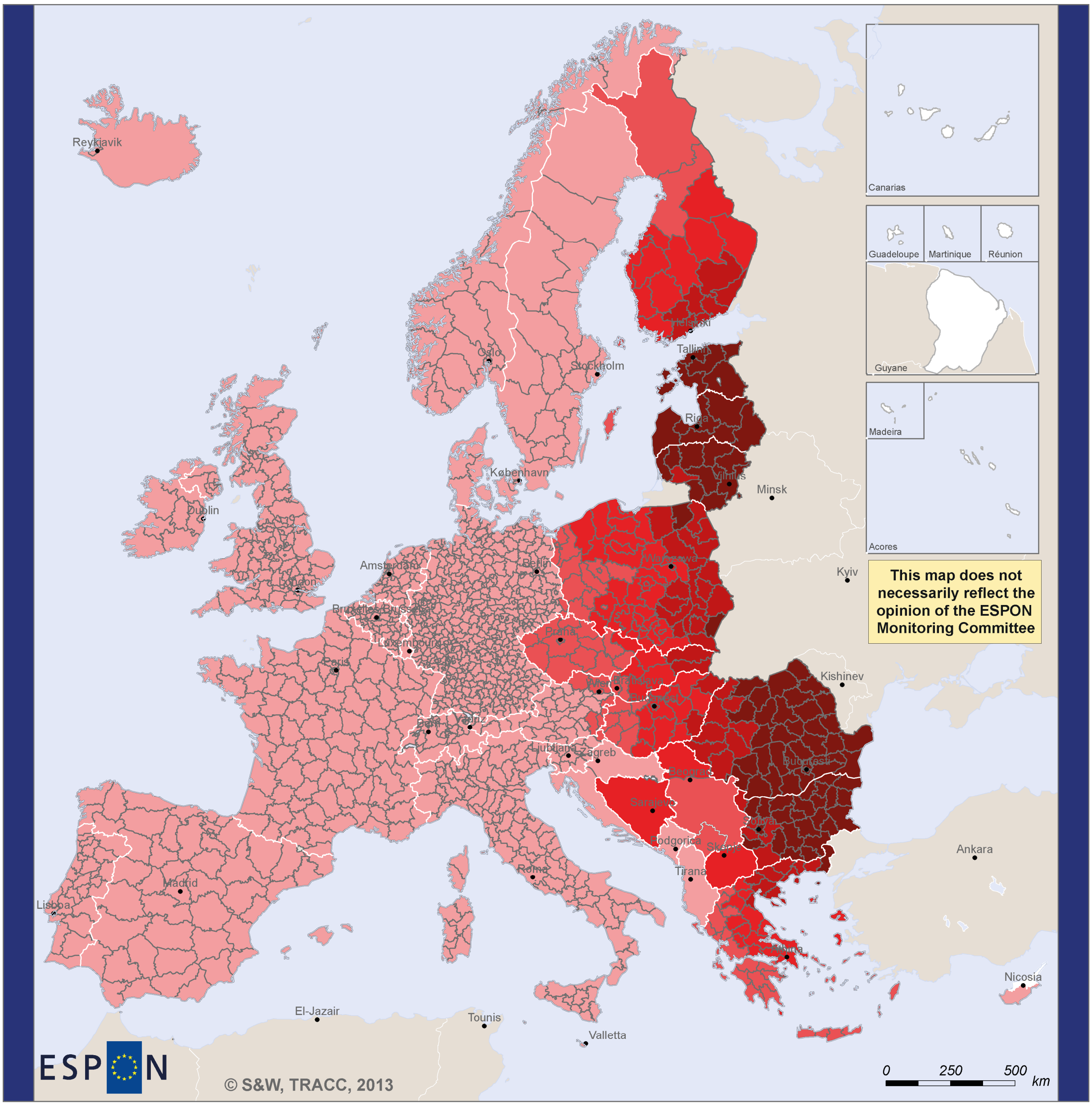
Accessibility travel road/rail
Growth scenario TA
Difference to Baseline Scenario (%) 2051

24 - 30	no data
18 - 24	
12 - 18	
6 - 12	
0 - 6	

Figure 12.5. TRACC SASI scenarios: Growth scenario TA: accessibility travel road/rail, difference to Baseline Scenario (%) 2051



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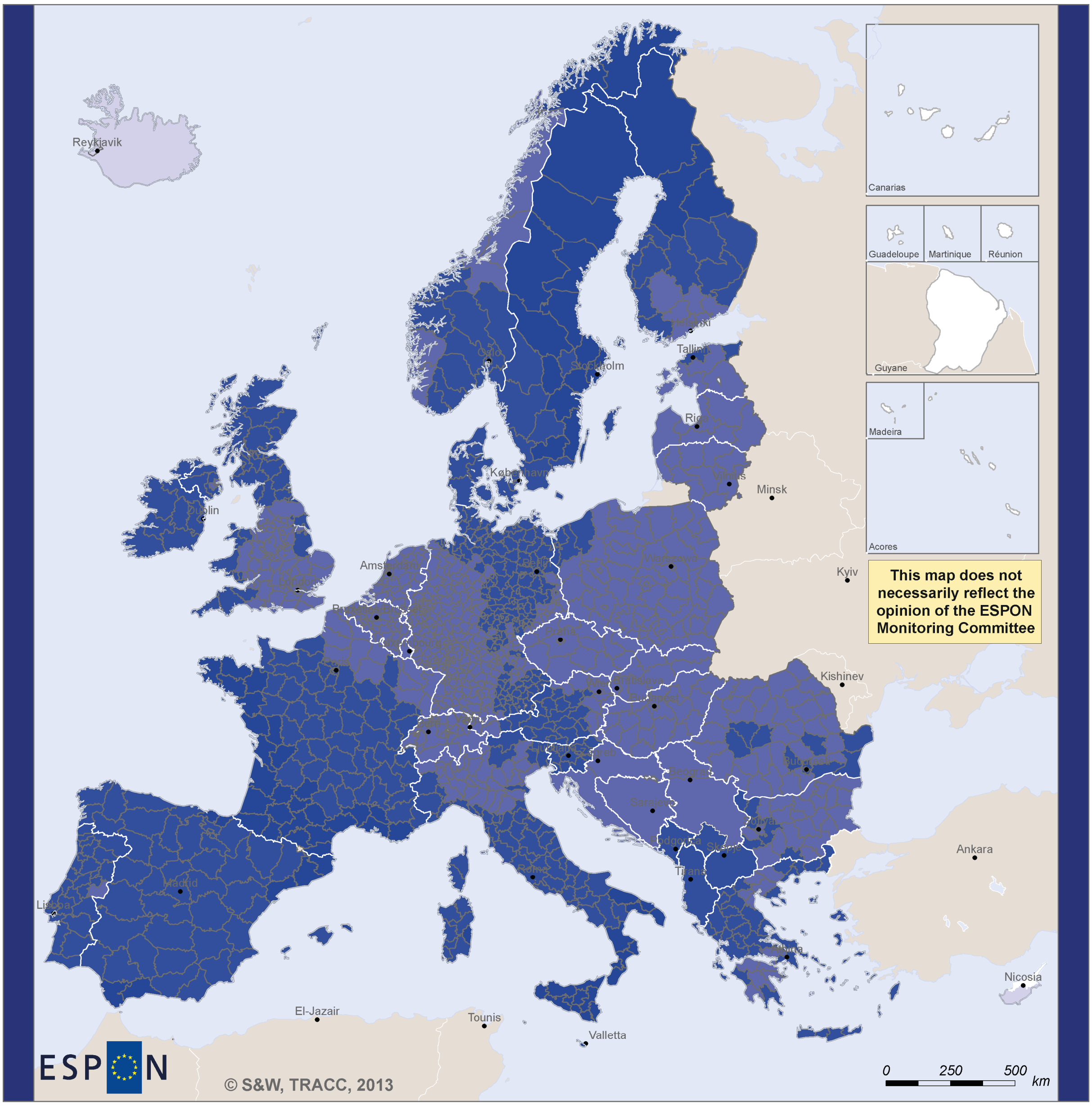
Accessibility travel road/rail
Cohesion scenario TB
Difference to Baseline Scenario (%) 2051

- 24 - 30
- 18 - 24
- 12 - 18
- 6 - 12
- 0 - 6
- no data

Figure 12.6. TRACC SASI scenarios: Cohesion scenario TB: accessibility travel road/rail, difference to Baseline Scenario (%) 2051



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Accessibility travel road/rail
Sustainability scenario TC
Difference to Baseline Scenario (%) 2051

- -10 - 0
- -20 - -10
- -30 - -20
- -40 - -30
- -50 - -40
- no data

Figure 12.7. TRACC SASI scenarios: Sustainability scenario TC: accessibility travel road/rail, difference to Baseline Scenario (%) 2051

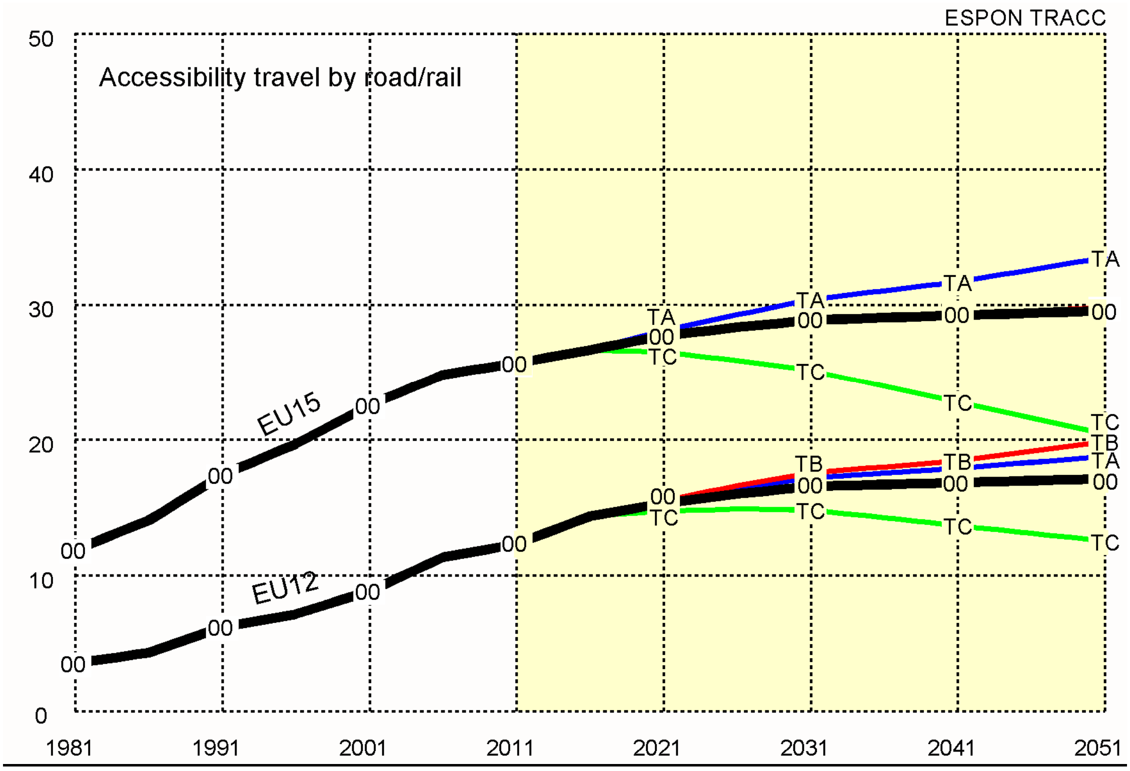


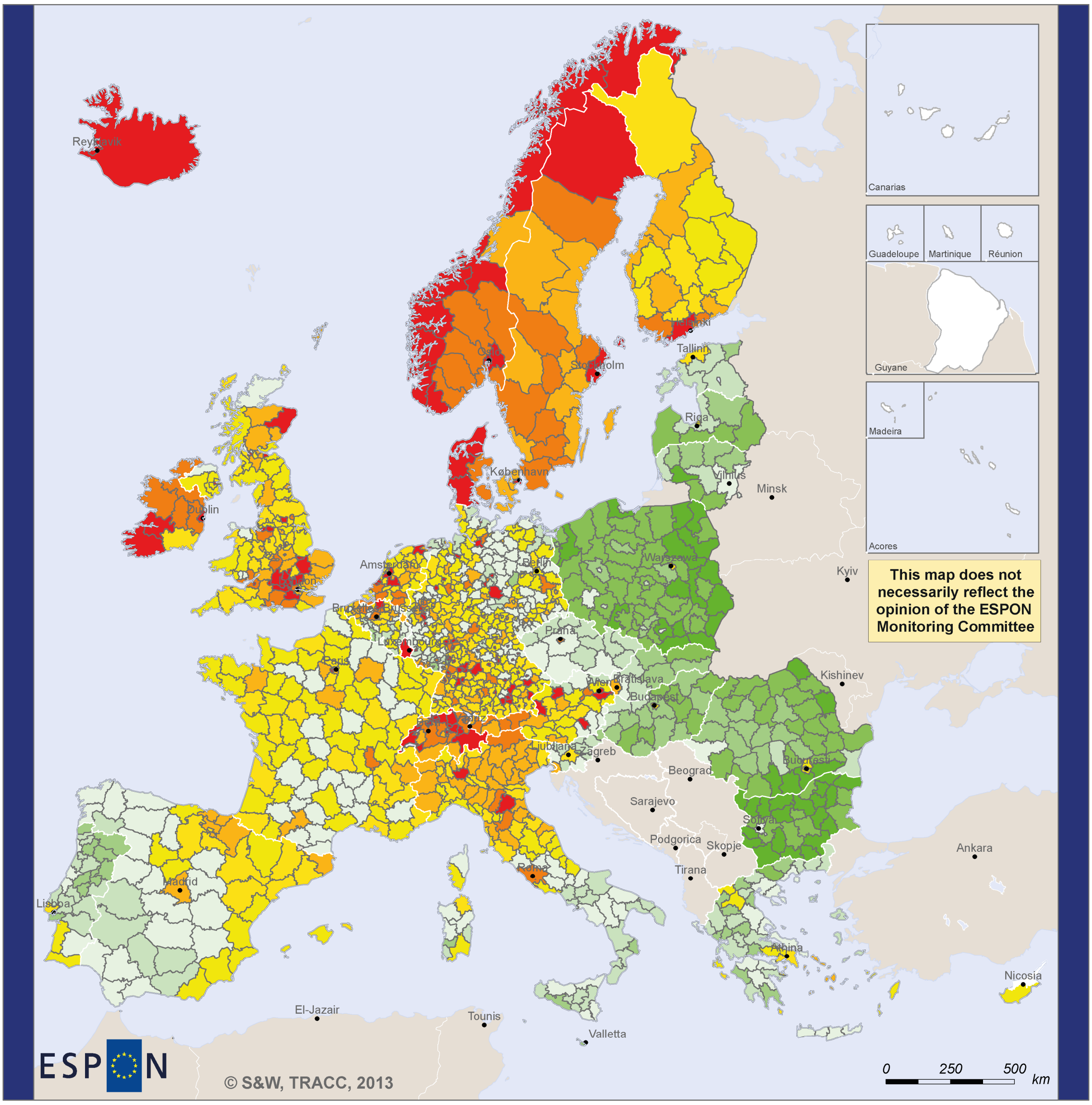
Figure 12.8. TRACC SASI scenarios: Scenario comparison: accessibility travel road/rail in EU15 and EU12, 1981-2051

In summary, it can be seen that accessibility travel road/rail has increased continuously since the 1980s due to infrastructure investment and technological advance and is assumed to continue to increase, though with decreasing speed, until 2051. It is also apparent that the new and upgraded infrastructure in scenarios TA and TB affect accessibility positively only moderately, whereas cost increases, such as in scenario TC, have a strong negative effect. Moreover, the effects are in general larger in absolute terms in EU15 than in EU12.

Similar maps and diagrams could be shown for the other three kinds of multimodal accessibility calculated in the SASI model.

Figures 12.9 to 12.13 on the following pages show in the same format the impacts of the changes in accessibility on regional gross domestic product (GDP) per capita:

- Figure 12.9 shows the distribution of GDP per capita of NUTS-3 regions in Europe at the end of the forecasting period in 2051.It may surprise and disappoint many that over the next forty years the existing gap in affluence between the old member states in western Europe and the new member states in central and eastern Europe, and some countries in southern Europe, is forecast to continue to exist in 2051. However, even this result is based on rather optimistic assumptions about continuing convergence of labour productivity,
- Figure 12.10 shows the percent differences in regional GDP per capita between the Growth scenario TA and the Baseline scenario. A comparison with the corresponding difference map of accessibility travel road/rail in Figure 12.5 shows that relatively large differences in accessibility result in only very small differences in GDP per capita, approximately in the order of only one tenth – a result already found in earlier ESPON projects (see above).
- Figure 12.11 shows the same phenomenon for the Cohesion scenario TB. Again the similarity of the pattern of change with that of accessibility in Figure 12.6, except for the magnitude of change, is striking.



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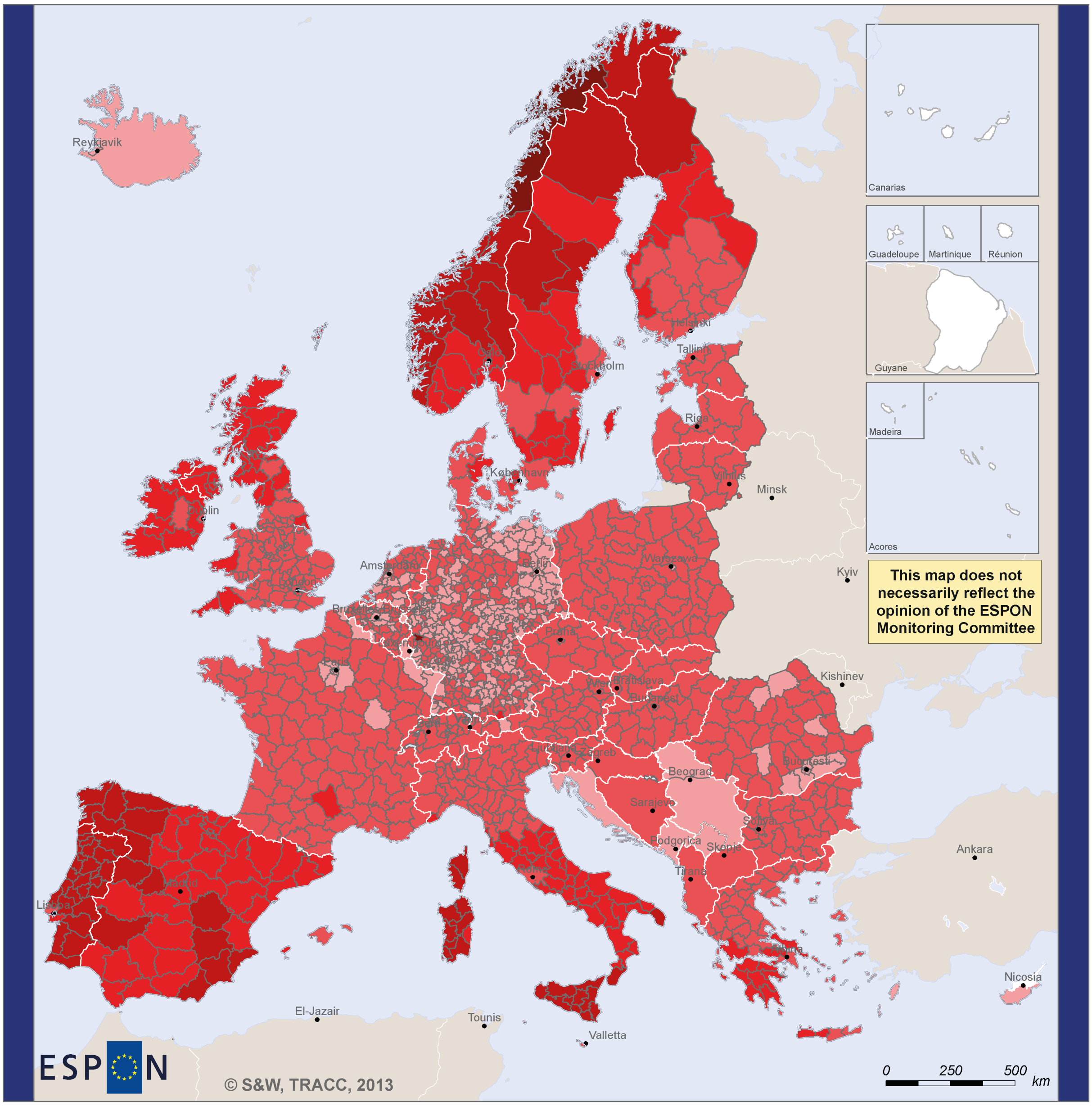
GDP per capita (in 1,000 Euro of 2010)
Baseline scenario
2051

10 - 15	35 - 40	no data
15 - 20	40 - 45	
20 - 25	45 - 50	
25 - 30	50 - 55	
30 - 35	55 - 50	

Figure 12.9. TRACC SASI scenarios: Baseline scenario: GDP per capita 2051



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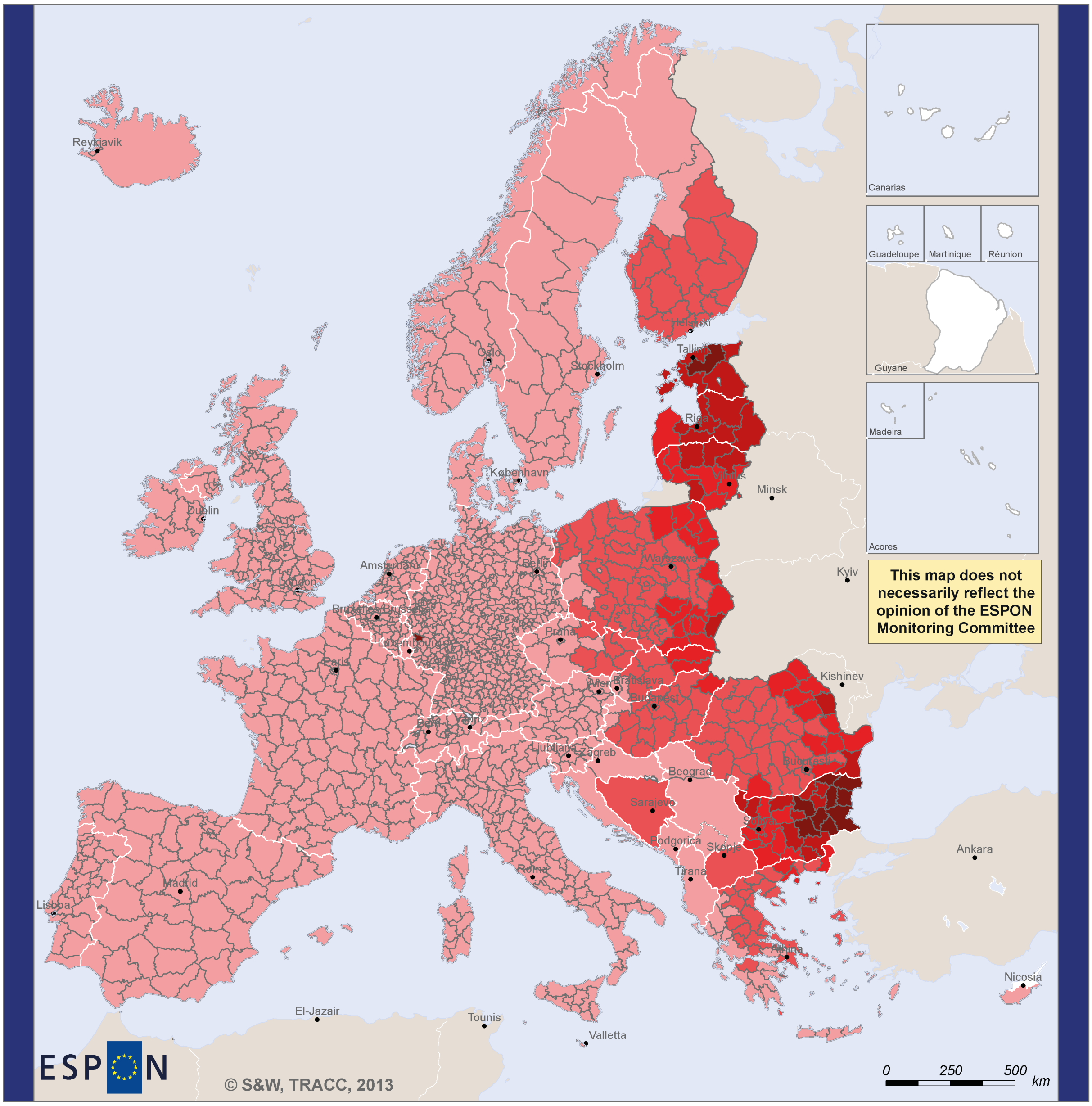
GDP per capita (in 1,000 Euro of 2010)
Growth scenario TA
Difference to Baseline Scenario (%) 2051

- 24 - 30
- 18 - 24
- 12 - 18
- 6 - 12
- 0 - 6
- no data

Figure 12.10. TRACC SASI scenarios: Growth scenario TA: GDP per capita, difference to Baseline Scenario (%) 2051



EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

Regional level: NUTS 3
Source: Spiekermann and Wegener Urban and Regional Research (S&W), 2013
Origin of data: SASI Model, 2013
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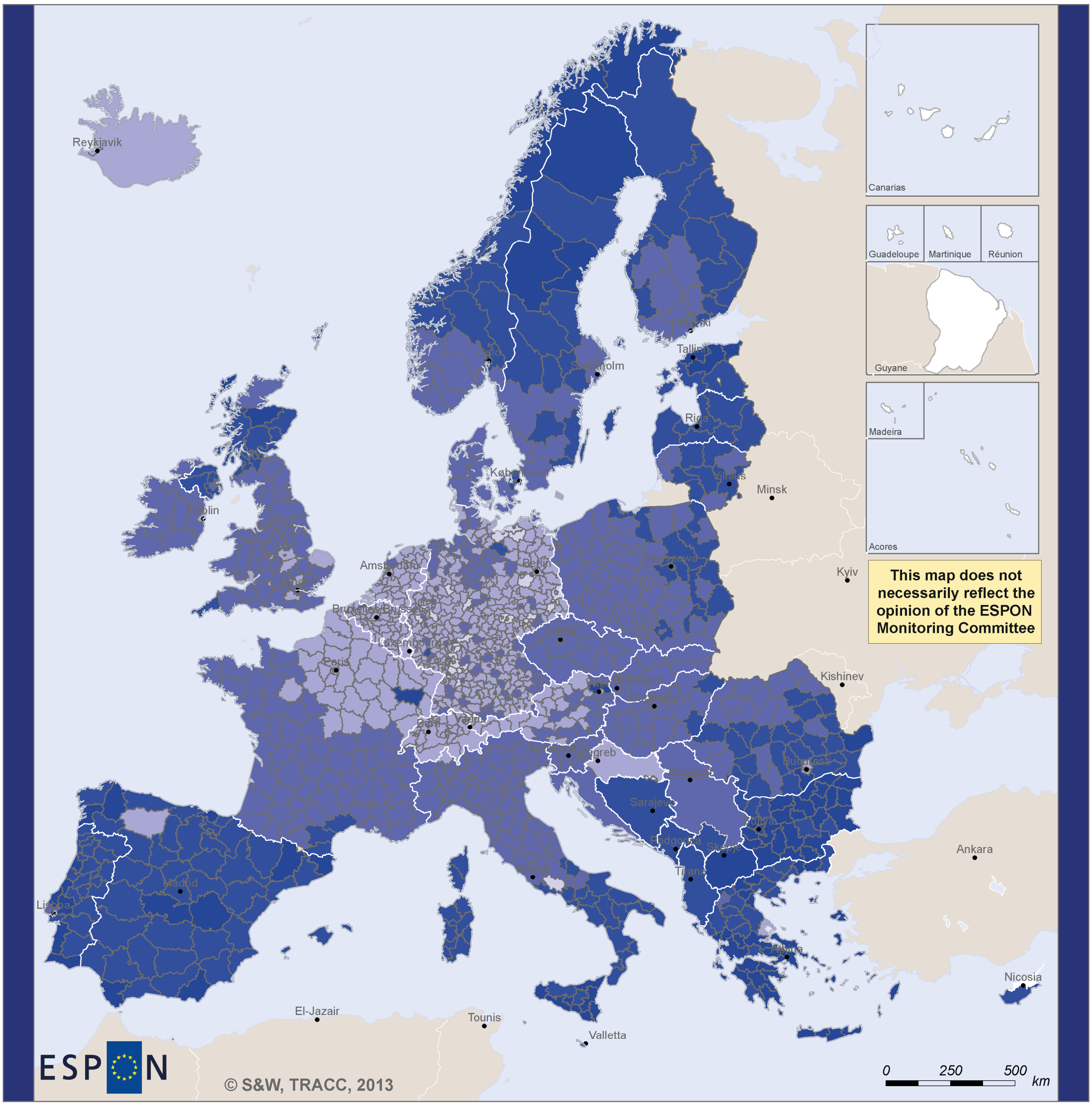
GDP per capita (in 1,000 Euro of 2010)
Cohesion scenario TB
Difference to Baseline Scenario (%) 2051

24 - 30	no data
18 - 24	
12 - 18	
6 - 12	
0 - 6	

Figure 12.11. TRACC SASI scenarios: Cohesion scenario TB: GDP per capita, difference to Baseline Scenario (%) 2051



EUROPEAN UNION
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INVESTING IN YOUR FUTURE

Regional level: NUTS 3
Source: Spiekermann and Wegener
Urban and Regional Research (S&W), 2013
Origin of data: SASI Model, 2013
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GDP per capita (in 1,000 Euro of 2010)
Sustainability scenario TC
Difference to Baseline Scenario (%) 2051

- -10 - 0
- -20 - -10
- -30 - -20
- -40 - -30
- -50 - -40
- no data

Figure 12.12. TRACC SASI scenarios: Sustainability scenario TC: GDP per capita, difference to Baseline Scenario (%) 2051

- Figure 12.12 shows that the direction of impact is reversed in the case of a reduction in accessibility. A comparison with the pattern of accessibility changes in Figure 12.7 reveals that, while the changes in accessibility appear larger in EU15, the negative impacts on GDP per capita are clearly stronger in EU12.
- Figure 12.13 compares the development of GDP per capita averaged over NUTS-3 regions in EU15 and EU12 over time. It becomes understandable that while GDP per capita in EU12 grows much faster in relative terms than GDP per capita in EU15, in absolute terms the regions in EU15 gain more. It is also confirmed again that the negative economic impacts of reductions in accessibility tend to be much stronger than the positive impacts of improvements of accessibility (the trajectories of the TA and TB scenarios are hidden behind the trajectory of the Baseline scenario).

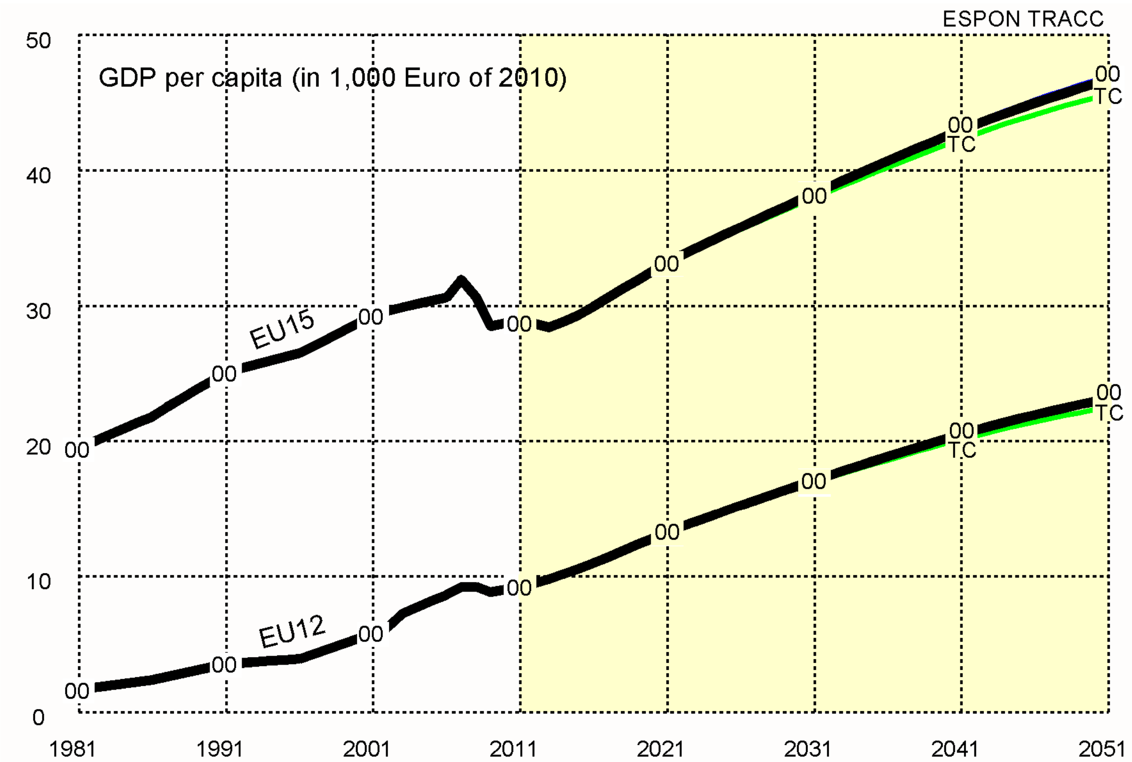

Figure 12.13. TRACC SASI scenarios: Scenario comparison: GDP per capita in EU15 and EU12, 1981-2051

Figures 12.14 and 12.15 shed some light on the cohesion and sustainability impacts of changes in accessibility:

- Figure 12.14 compares the trajectories of the cohesion indicator most frequently used by the European Commission to assess the effectiveness of its Cohesion policy in reducing economic disparities between regions, the coefficient of variation, a measure of deviation of regional indicators from their European average. The higher the measure, the greater the disparities. In the figure the development of the coefficient of variation of GDP per capita and accessibility travel road/rail are compared. It can be seen that both indicators have since the 1980s become significantly lower indicating a massive trend towards convergence, and that this trend, according to the SASI model, is likely to continue in the future, though at a slower speed. It can also be seen that accessibility is more evenly distributed across regions than GDP per capita, and that the extra costs of mobility in scenario TC turn convergence into divergence.

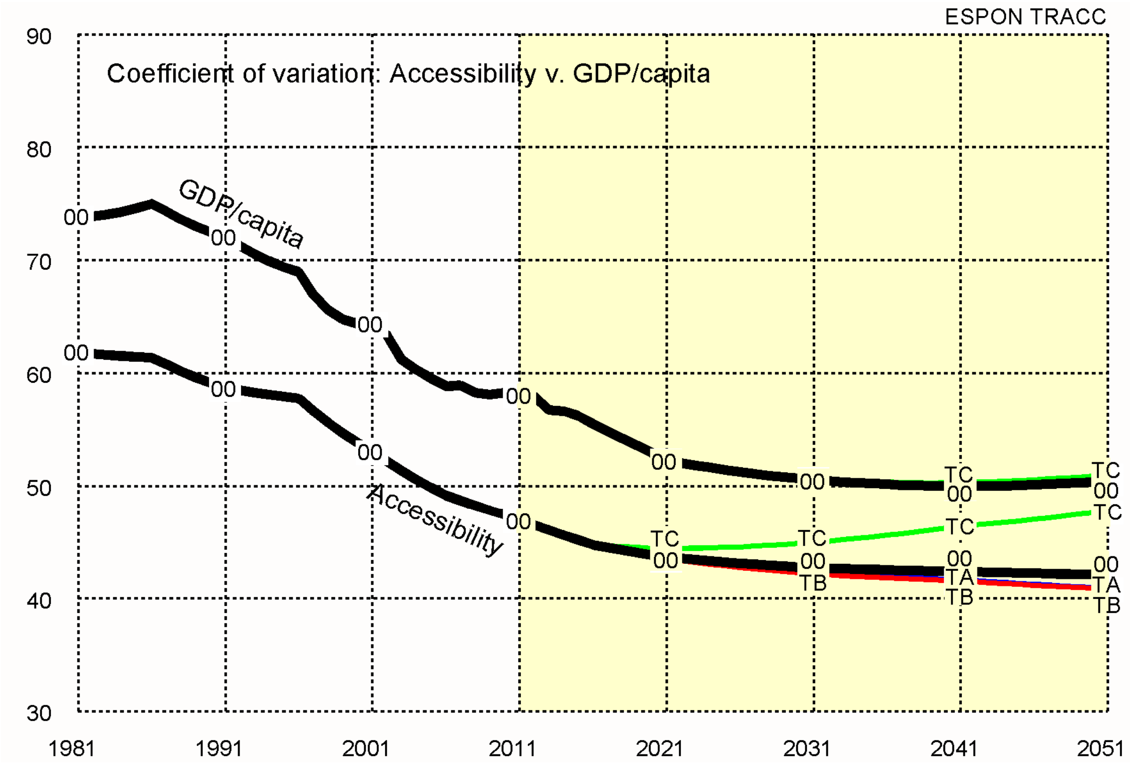

Figure 12.14. TRACC SASI scenarios: Scenario comparison: coefficient of variation, accessibility travel road/rail v. GDP per capita, 1981-2051

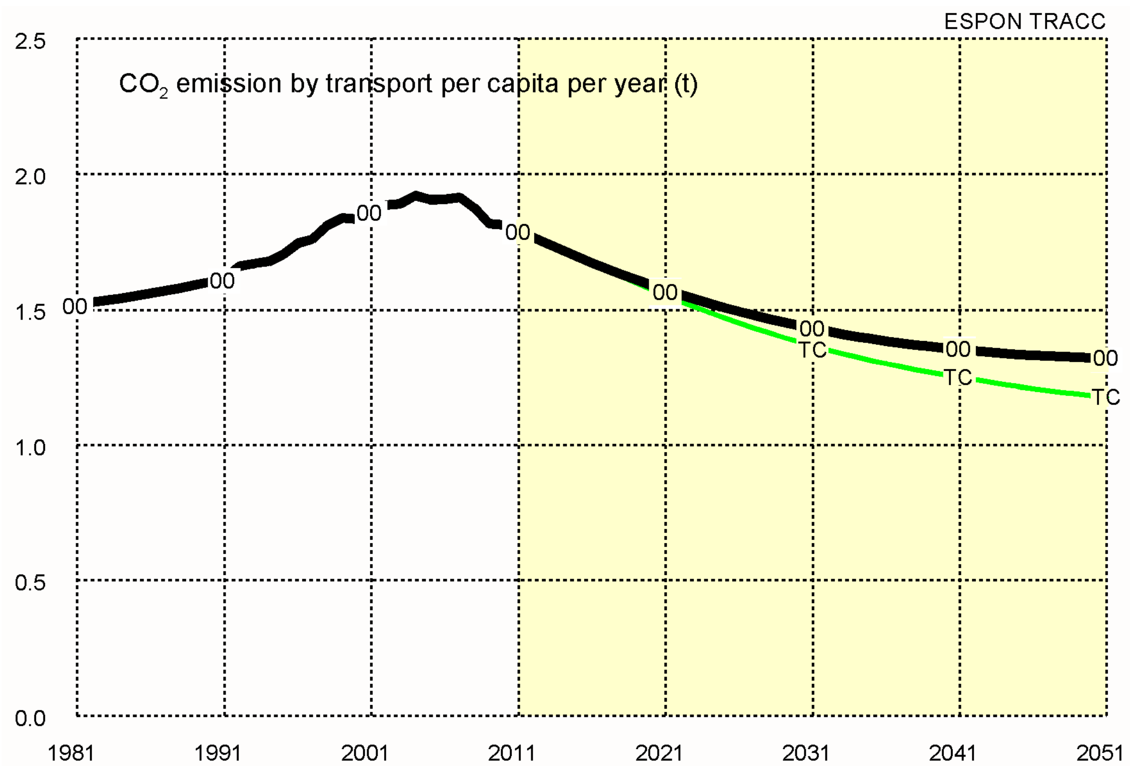

Figure 12.15. TRACC SASI scenarios: Scenario comparison: CO_2 emission of transport, 1981-2051

Figure 12.15 finally allows a view on the sustainability of the scenarios with respect to energy consumption and greenhouse gas emissions of transport. The diagram reproduces the well-known growth of CO_2 emission of transport since the 1980s and the modest trend change since the economic crisis The diagram also suggests that under the assumptions made in the transport part of the SASI model about drivers of travel and freight transport demand and the diffusion of renewable energy in transport the ambitious targets of the European Union for the reduction of greenhouse gas emission by transport of 60 percent compared to 1990 are not likely to be achieved, The diagram also informs about the possible contribution of accessibility to achieving this target. Whereas infrastructure improvements and efficiency increases have no discernible effect, transport pricing measures as in Sustainability scenario TC can deliver a sizable contribution.

12.4 Conclusions

Based on the empirical and modelling analyses in ESPON TRACC and previous ESPON projects the impacts of changes in accessibility on competitiveness, cohesion and sustainability can be summarised as follows:

- Good accessibility is a precondition for economic development. Regions with good access to suppliers and markets are ceteris paribus more economically successful than remote and isolated regions.
- Even large changes in accessibility lead to only small changes in economic development. The magnitude of the effect depends on the existing level of accessibility: Further improvements of the already high accessibility of central regions will have only little effect, improvements of the accessibility of remote regions can have significant effects on their economic development.
- A reduction of accessibility through higher fuel prices or environmental taxes will reduce the accessibility of central regions more than that of remote regions, but will negatively affect economic development of remote regions more than that of central regions.
- Transport infrastructure improvements, even if focused on rail, have very little impact on energy consumption and greenhouse gas emissions by transport unless they are accompanied by pricing policies making road and air transport more expensive.

13 Policy implications

What are the main lessons learned from the TRACC project on accessibility for policy making at different territorial levels? This final chapter of the TRACC Scientific Report summarises first some policy relevant findings and conclusions and gives eventually some hints on research implications.

13.1 Policy relevant findings and conclusions

In the following bullet points main findings of the project are summarised and some tentative conclusions are drawn.

- ***Accessibility is a 2 dimensions driven variable:*** Accessibility consists of two components, available activities of interest and transport infrastructure leading to them**.** Low accessibility values reflect in some cases sparsely populated areas and/or low service endowment, often in the European peripheries; but in others cases low accessibility values are driven by poor transport infrastructure, more often in Eastern Europe than in Western Europe. Accessibility related policy should not only concentrate on the transport infrastructure side as investments in the points of interest might be more efficient. That means that transport and spatial development policies should be more integrated at all territorial levels.
- ***Global travel accessibility.*** Seen from an accessibility perspective, the integration of European regions in the global economy is very heterogeneous. In particular for passenger travel, huge differences exist between European regions in terms of linkages to global destinations and global accessibility.
- ***Global freight accessibility changing.*** The progressive rise of Far East as trade partner opens to Mediterranean regions the perspective of exploiting a position advantage. In this respect, efficient multimodal infrastructures (ports, transhipment facilities, intermodal centres, roads, railways) might increase the global accessibility of Southern European regions thus reducing the current differences with respect to the North Sea area.
- ***European travel accessibility patterns***. The dominating accessibility pattern in Europe for passenger transport is as follows: highest values in the Core of Europe, in capital city regions in other countries, and in other selected industrial or touristy regions such as Southwestern Scandinavia (Oslo-Gothenburg-Copenhagen), the Western Mediterranean coastal corridor (from southern Spain to northern Italy), the Rhone valley, Southern Italy, Saxony and Upper Silesia. Citizens in core regions are more likely to seamlessly travel in Europe or access global transport gateways (more transport services and point to point connections, shorter local trip legs) as they have denser motorway and rail networks and concentrate a higher number of European and global air hubs.
- ***European freight accessibility patterns.*** Geographical position, availability of infrastructures and strength of the economy are the three key elements which describe the pattern of European accessibility in relation to freight. Logistic activities tend to follow population and economic concentrations. Best connectivity to freight transport networks is recorded in the North Sea due to the presence of largest container ports in Europe, in addition to denser motorway and freight village networks. The Mediterranean rim has large container ports but less dense motorway and freight village networks in their hinterlands limit to a large extent high performance to coastal fringes. Main inland waterway axes (Rhine, Danube, Elbe) and canal systems in Germany back up good freight accessibility performance.
- ***The cost of low EU Integration***. The comparison of potential accessibility patterns restricting origins and destinations within EU Member States or allowing for European wide mobility shows that an important number of European regions are likely to lose out when they are restricted to access only national activities, or in other words under lower EU integration

conditions. This is especially obvious in border regions like western Poland, north-eastern and southern Germany, eastern and southern France. Low European integration can be due to political issues like border permeability to economic flows but more importantly due to cultural issues like barriers that languages represent to seek jobs or study abroad. Seen it the other way round, border regions are largely benefitting in terms of accessibility of the diminishing importance of those borders and the gain in opportunities available to their citizens.

- ***Local and regional peripheries do not match EU peripheries.*** No significant differences can be observed for performance in regional and local accessibility between regions located at the European Periphery and regions located at the European Core. Regional case studies have revealed relatively homogeneous patterns within regions. Regional and local accessibility in case studies is much more dependent on the local conditions of population and economic activity than to their overall European localisation.
- ***The East-West divide still persists at regional level.*** From most locations in Europe, at least one regional centre can be reached in less than 60 minutes travel time, but only people in Western Europe have options to visit more than five different cities in that time. Infrastructure endowment is still much lower in Eastern Europe, so despite having relatively similar levels of service provision, accessibility to services remains lower than in Western Europe. Accessibility to transport infrastructure is also lower in Easter Europe.
- ***The Urban-Rural divide still persists at regional level***. Accessibilities for capitals regions or for main agglomerations differ significantly from those for rural, peripheral and landlocked regions, as well as for intermediate areas. Minimum services are available with reasonable cost in most areas of Europe, even remote rural or sparsely populated, but the possibility to choose amongst different alternatives is concentrated in highly populated urban areas. Indicators focussing on availability of activities and services (travel cost) provide more balanced patterns on the territory than indicators focussing on the diversity of offer (cumulated opportunities, potential accessibility) which tend to provide more polarised patterns around largest metropolises and well deserved transport corridors.
- ***Inner peripheries in all regions.*** Inner peripheries with low accessibility values are not only located in the far North or in the Alpine space, as expected, but also in most European countries. The extent of these inner peripheries is substantially larger for rail than for car.
- ***Balanced access to services of general interest***. The analysis of case studies show a balanced geographical distribution of public services in Europe, allowing for minimum service availability despite of population figures or economic activity of regions. Many case studies have identified the threat of diminishing accessibility to services of general interest caused by withdrawal of the public sector in the framework of the current financial crisis.
- ***Public transport accessibility below car accessibility***. Accessibility patterns for cars and public transport differ to a large degree, both with respect to the level and also with the spatial patterns. Accessibility levels by car are in general higher at regional and local level than those for public transport, but public transport is still able to provide high levels of accessibility within metropolitan areas and in city centres, and along well deserved axes is. Accessibility indicators for cars tend to form different types of plateaus, while for public transport the same indicators form ‘stretches’ and ‘bands’ of high accessibilities along transport axis, interrupted by areas of low accessibilities where public transport is missing. Most of the case studies and most of the indicators applied demonstrate that accessibility by car is superior to accessibility by public transport. Only in a few metropolitan areas public transport is providing comparable accessibility to the population.
- ***Impact of financial crisis***. Accessibility is a matter of transport infrastructures and of availability of functions. As for transport infrastructures, the impact of the financial crisis is

likely to be detrimental in the light of the pro-cyclic approach in public investments dominating the EU architecture. Shortage of financial resources can easily lead to postpone or even cancel planned public investments, whilst private investments are also likely to slow down significantly. The picture could be different if the role of public expenditure as engine of aggregate demand to tackle economic crisis is re-discovered. As for availability of functions, two main linkages with the crisis can be mentioned. First, for some of the TRACC indicators public services (schools, hospitals) are involved. The concentration of services with the closure of minor local sites has been announced often in the last years. The financial crisis could provide the rationale for put this into practice. In that case, especially accessibility based on travel costs could significantly worsen for many (mostly peripheral) areas. Second, the crisis has been deepening (further than being fuelled by) disparities between European countries. So, current unbalances in accessibility to economic activity are likely to increase.

- ***No clear significant overall patterns observed in relation to impacts of TEN-T projects in case studies***. Impacts observed varied largely from one case to another. The diversity of typologies of projects in each case, and the use of particular hypothesis for final performance of envisaged infrastructures (e.g. speeds in new rail links) may be in part responsible for these differences. In a number of case studies, largest metropolitan areas and urban regions tended to win less in relation to intermediate and rural regions (e.g. in the Czech Republic, in the Baltic States, and to some extent in the Western Mediterranean and in Finland). In Poland, road projects benefit to a higher extent the Warsaw – Katowice region, but also important gains can be observed in the far less populated eastern regions bordering with Belarus and Ukraine.
- ***Specialised accessibility indicators***. Individual accessibility indicators are to depict different facets and different spatial structures. Accessibility cannot be assessed by just one indicator. Travel cost indicators to next “function” indicate the possibility of regions to have access to certain functions, while cumulated opportunities and potential accessibility indicators also include the variety of functions and therefore reflect the magnitude of alternative choices available. Potential indicators tend to show more laminar patterns (progressive), while availability of functions are more affected by singularities in the territory.
- ***Accessibility and regional development***. Based on the empirical and modelling analyses in ESPON TRACC and previous ESPON projects the impacts of changes in accessibility on competitiveness, cohesion and sustainability can be summarised as follows: Good accessibility is a precondition for economic development. Regions with good access to suppliers and markets are ceteris paribus more economically successful than remote and isolated regions. Even large changes in accessibility lead to only small changes in economic development. The magnitude of the effect depends on the existing level of accessibility: Further improvements of the already high accessibility of central regions will have only little effect, improvements of the accessibility of remote regions can have significant effects on their economic development. A reduction of accessibility through higher fuel prices or environmental taxes will reduce the accessibility of central regions more than that of remote regions, but will negatively affect economic development of remote regions more than that of central regions. Transport infrastructure improvements, even if focused on rail, have very little impact on energy consumption and greenhouse gas emissions by transport unless they are accompanied by pricing policies making road and air transport more expensive.

13.2 Research implications

The TRACC project has further developed and implemented different methodologies to measure accessibility and to evaluate regional impacts of changing accessibility. The following bullet points summarise some implications for further research into accessibility:

- ***Accessibility indicator set.*** The accessibility indicator set in TRACC and its implementation is a first attempt to assess accessibility from very different viewpoints and for different purposes. More research should be devoted to develop commonly accepted standard indicators like the European potential accessibility also for other spatial contexts and purposes.
- ***Raster approach to increase resolution of accessibility analysis.*** A good part of the findings in TRACC is based on grid cell maps, free of administrative divisions. Several particular areas and spatial patterns can be noticed only on the grid cell basis. TRACC has proven that even at the level of zoom-in regions significant intra-regional disparities exist, which cannot be detected by the traditional, aggregated models. Such intra-regional disparities are often greater than those between regions, thus accessibility studies should acknowledge these disparities and should find ways how to capture them. Raster analysis allows for a more accurate identification of territorial patterns generated by high level and public transport corridors.
- ***Public transport modelling approach*.** The quantification of public transport accessibility could be improved by modelling different services (road public transport, regional trains, intercity trains etc.) as independent modes, allowing for multimodal trip chains. On the one hand this would allow to better identify the role of each mode (e.g. road public transport for short distances, often when train is not available, regional trains mostly for commuters, etc.), thus providing more precise estimations of times and costs for different demand segments/travel purposes (e.g. accessibility to schools would probably use different input than accessibility to hospitals or potential accessibility to population. On the other hand, modelling multimodal chains (even if in a simplified way) would allow to explore the role of interconnectivity and co-modality, which are increasingly relevant concepts in public transport planning to provide efficient accessibility.
- ***Freight transport modelling approach****.* Some freight services are based on lines with fixed paths and stops (likewise public transport). Modelling these lines more explicitly would improve the representativeness of the accessibility indicators as the information on the regions pairs actually connected would be more precise. A pre-condition for implementing this approach on an European scale would be however the availability of a reliable and frequently refreshed database of the lines, which are continuously evolving. For rail-road combined transport some information exists, but for maritime container data is much more scattered and difficult to access. Still about freight, road freight accessibility is significantly influenced by assumptions on driving times and costs (e.g. respect or not of the maximum driving limits per day, use of two drivers, accompanied and unaccompanied trucks on ferries). Improvements on modelling of these aspects could be useful.
- ***Transport scenario modelling***. The modelling of transport infrastructure and policy scenarios was based on very global assumptions on the scenarios and the development of transport infrastructure. Further research in this direction might concentrate on the impacts of individual projects, of basic infrastructure alternatives and on the integration of transport policies and territorial and regional policies.
- ***Case study approach.*** The accessibility modelling for the seven case studies in TRACC was done with a rather strict definition of the accessibility indicators and a subsequent research programme. Together with a very identical structure of the case study reports, including the

same type of maps, diagrams, even the colour ramps were harmonised, the results are highly comparable across the different regions. However, because the indicators were calculated with seven different accessibility models, some with a detailed representation of public transport networks, some with a more abstract representation, some with raster based approaches, some with centroids of LAU-2 regions, differences in accessibility might also be traced back to differences in spatial resolution, parameters or country-specific definitions of destinations. But notwithstanding this small reservation, the strict case study approach might be used as a model for other territorially oriented case study projects.

- ***Transport network data.*** The different accessibility models, even at the European level, worked with partly different transport network data which are not easily to obtain and to maintain. In consequence, harmonised databases should be developed based on user needs assessment for accessibility modelling in Europe. In this framework, it has to be assessed how public transport networks can be more easily integrated based on up-to-date sources.

Annexes

A1 Literature

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A2 Data sources

The calculation of global, European and regional accessibility indicators and accessibility indicators for the case studies requires a comprehensive set of input data. Network data and socio-economic data for describing origin and destination features are needed at different spatial scales. Following is an overview about the utilised input data in tabular format, divided into

- Global accessibility indicators
- European accessibility indicators
- Regional accessibility indicators

The tables are organised by indicator. For each indicator, the utilised network data, origin-destination data and, as far as required, the utilised other data sources are listed. The information provided for each data source is the data set name, the data source (i.e. author, organization, etc.), the data format, and any additional comments. The tables indicate only those data sources that are actually used; additional data that have been compiled but has not been used is, thus, not listed.

Data sources for global accessibility indicators

Table A2.1 summarises the data sources for the calculation of the global accessibility indicators, indicator by indicator.

Table A2.1. Data sources for global accessibility indicators.

Indicator	**Network data**	**oigin-destination data**	**Other data**
Travel			
Access to global cities	*Data sets(s):* - Trans-European road network 2011 - Trans-European rail network for 2011 - European/global flight network *Data source(s):* Road and rail networks: RRG GIS Database. Flight network: S&W flight network database *Data format(s):* Excel, ASCII *Comments:*	*Data sets(s):* *Data source(s):* *Data format(s):* *Comments:*	*Data sets(s):* *Data source(s):* *Data format(s):* *Comments:*
Global travel connectivity	*Data sets(s):* - Trans-European road network 2011 - Trans-European rail network for 2011 - European/global flight network *Data source(s):* Road and rail networks: RRG GIS Database. Flight network: S&W flight network database	*Data sets(s):* *Data source(s):* *Data format(s):* *Comments:*	*Data sets(s):* *Data source(s):* *Data format(s):* *Comments:*

	Data format(s): Excel, ASCII *Comments:*		
Global potential accessi-bility travel	*Data sets(s):* - Trans-European road network 2011 - Trans-European rail network for 2011 - European/global flight network *Data source(s):* Road and rail networks: RRG GIS Database. Flight network: S&W flight network database *Data format(s):* Excel, ASCII *Comments:*	*Data sets(s):* *Data source(s):* *Data format(s):* *Comments:*	*Data sets(s):* *Data source(s):* *Data format(s):* *Comments:*
Freight			
Access to global freight hubs	*Data sets(s):* - Trans-European maritime network - Trans-European air freight network 2011 - Trans-European road network 2005 - Trans-European rail network for 2005 - Trans-European inland waterways (iww) network - Intermodal Centres layer *Data source(s):* Road and rail freight net-works come from the TRANS-TOOLS model. The iww and air freight networks are taken from the RRG GIS Database. Maritime network comes from the TRUST model. *Data format(s):* ESRI Personal Geodata-base, ArcView Shapefile *Comments:* The road, rail and iww networks are used be-cause these modes can be used as feeder of maritime and air, but the	*Data sets(s):* European container ports working as hubs for deep sea container traffic European airports work-ing as hubs for interconti-nental air freight traffic New York and Shanghai port New York and Shanghai airports *Data source(s):* RRG GIS Database *Data format(s):* ESRI Personal Geodata-base, ArcView Shapefile *Comments:* ---	*Data sets(s):* European container ports throughput European airports freight traffic and intercontinental destinations Container / bulk / general cargo ports turnover (Eu-rostat 2008-2010) *Data source(s):* European container ports throughput is taken from EUROSTAT database (years 2007-2009), the freight traffic and the in-tercontinental destina-tions of European airports are taken from the ETIS-plus database *Data format(s):* Excel Table, ESRI Per-sonal Geodatabase *Comments:* The air traffic data of the ETISplus database has not been officially publicly issued and has been used by courtesy of the ETISplus consortium. European container ports throughput figures as-signed to seaports as standard point attributes.

	indicator is only related to those two modes. The maritime network consist of fictitious links providing a full connectivity between all ports.		European airports freight traffic and intercontinental destinations figures assigned to airports as standard point attributes.
Global freight connectivity	*Data sets(s):* - Trans-European road network 2005 - Trans-European rail network for 2005 - Trans-European inland waterways (iww) network - Trans-European maritime network - Intermodal Centres layer *Data source(s):* Road and rail freight networks come from the TRANS-TOOLS model. The iww network is taken from the RRG GIS Database. Maritime network comes from the TRUST model. Intermodal Centres are taken from RRG GIS Database (source: organisations: DUSS, DGG, Italian Interporti, European Association of Freight Villages). *Data format(s):* ESRI Personal Geodatabase, ArcView Shapefile *Comments:* The maritime network consist of fictitious links providing a full connectivity between all ports.	*Data sets(s):* European container ports working as hubs for deep sea container traffic *Data source(s):* RRG GIS Database *Data format(s):* ESRI Personal Geodatabase, ArcView Shapefile *Comments:* ---	*Data sets(s):* European container ports throughput Container / bulk / general cargo ports turnover (Eurostat 2008-2010) *Data source(s):* European container ports throughput is taken from EUROSTAT database (years 2007-2009) *Data format(s):* Excel table, ESRI Personal Geodatabase *Comments:* European container ports throughput figures assigned to seaports as standard point attributes.
Global potential accessibility freight	*Data sets(s):* - Trans-European road network 2005 - Trans-European rail network for 2005 - Trans-European inland waterways (iww) network - Trans-European maritime network - Intermodal Centres layer *Data source(s):* Road and rail networks come from the TRANS-TOOLS model. The iww network is taken from the	*Data sets(s):* European container ports working as hubs for deep sea container traffic *Data source(s):* RRG GIS Database *Data format(s):* ESRI Personal Geodatabase, ArcView Shapefile *Comments:* ---	*Data sets(s):* European container ports throughput Container / bulk / general cargo ports turnover (Eurostat 2008-2010) *Data source(s):* European container ports throughput is taken from EUROSTAT database (years 2007-2009) *Data format(s):* Excel table, ESRI Personal Geodatabase

	RRG GIS Database. Maritime network comes from the TRUST model. Intermodal Centres are taken from RRG GIS Database (source: organisations: DUSS, DGG, Italian Interporti, European Association of Freight Villages). *Data format(s):* ESRI Personal Geodatabase, ArcView Shapefile *Comments:* The maritime network consist of fictitious links providing a full connectivity between all ports.		*Comments:* European container ports throughput figures assigned to seaports as standard point attributes

Data sources for European accessibility indicators

Table A2.2 summarises the data sources for the calculation of the European accessibility indicators, indicator by indicator.

Table A2.2. Data sources for European accessibility indicators.

Indicator	**Network data**	**origin-destination data**	**Other data**
Travel (traditional)			
Access to top ten MEGAs	*Data sets(s):* - Trans-European road network 2011 - Trans-European rail network for 2011 - European/global flight network *Data source(s):* Road and rail networks: RRG GIS Database. Flight network: S&W flight network database *Data format(s):* Excel, ASCII *Comments:*	*Data sets(s):* *Data source(s):* *Data format(s):* *Comments:*	*Data sets(s):* *Data source(s):* *Data format(s):* *Comments:*
European daily accessibility travel	*Data sets(s):* - Trans-European road network 2011 - Trans-European rail network for 2011 - European/global flight network *Data source(s):*	*Data sets(s):* *Data source(s):* *Data format(s):* *Comments:*	*Data sets(s):* *Data source(s):* *Data format(s):* *Comments:*

	Road and rail networks: RRG GIS Database. Flight network: S&W flight network database *Data format(s):* Excel, ASCII *Comments:*		
European potential accessibility travel	*Data sets(s):* - Trans-European road network 2011 - Trans-European rail network for 2011 - European/global flight network *Data source(s):* Road and rail networks: RRG GIS Database. Flight network: S&W flight network database *Data format(s):* Excel, ASCII *Comments:*	*Data sets(s):* *Data source(s):* *Data format(s):* *Comments:*	*Data sets(s):* *Data source(s):* *Data format(s):* *Comments:*
Travel (new)			
Travel speed	*Data sets(s):* - Trans-European road network 2011 - Trans-European rail network for 2011 - European/global flight network *Data source(s):* Road and rail networks: RRG GIS Database. Flight network: S&W flight network database *Data format(s):* Excel, ASCII *Comments:*	*Data sets(s):* *Data source(s):* *Data format(s):* *Comments:*	*Data sets(s):* *Data source(s):* *Data format(s):* *Comments:*
Urban connectivity	*Data sets(s):* - Trans-European road network 2011 - Trans-European rail network for 2011 - Trans-European passenger flight network for 2011 *Data source(s):* Road and rail networks for 2011 are taken from the RRG GIS Database.	*Data sets(s):* Cities in Europe with more than 50,000 inhabitants *Data source(s):* RRG GIS Database *Data format(s):* ESRI Personal Geodatabase *Comments:*	*Data sets(s):* City population *Data source(s):* Rand McNally International Atlas *Data format(s):* Table *Comments:* Population figures assigned to RRG GIS Data-

	Flight network generated based upon information about flight schedules. *Data format(s):* ESRI Personal Geodata-base, ArcView Shapefile *Comments:* Road network contains all motorways, dual-carriageway roads, E-roads, national roads and trunk roads. Rail network includes all railway links for passenger train ser-vices under operation. Flight network contains all schedules passenger flights; charter flights or non-scheduled flight ex-cluded.	---	base as standard point attribute
European potential ac-cessibility intermodal travel	*Data sets(s):* - Trans-European road network 2011 - Trans-European rail network for 2011 - European/global flight network *Data source(s):* Road and rail networks: RRG GIS Database. Flight network: S&W flight network database *Data format(s):* Excel, ASCII *Comments:*	*Data sets(s):* *Data source(s):* *Data format(s):* *Comments:*	*Data sets(s):* *Data source(s):* *Data format(s):* *Comments:*
Freight			
Access to nearest mari-time ports	*Data sets(s):* - Trans-European road network 2011 - Trans-European rail network for 2011 - Trans-European inland waterway network for 2011 *Data source(s):* Road, rail and IWW net-works for 2011 are based on Trans-Tools *Data format(s):* ArcGIS shapefile, Bridges *Comments:* Road network contains all motorways, dual-carriageway roads, E-roads, national roads and	*Data sets(s):* European port network for 2011 *Data source(s):* UN Locode database *Data format(s):* ArcGIS shapefile, Bridges *Comments:* A shapefile was gener-ated from the coordinates available in the Locode database	*Data sets(s):* Port handling in tones 2010 *Data source(s):* Eurostat *Data format(s):* MSAccess *Comments:* 2010 is latest dataset available by Eurostat, reporting yearly port han-dling by port in tonnes

	trunk roads. Rail network includes all railway links for freight services under operation.		
European daily accessibility freight	*Data sets(s):* Trans-European road network 2005 *Data source(s):* Road network comes from the TRANS-TOOLS model. *Data format(s):* ESRI Personal Geodatabase, ArcView Shapefile *Comments:* ---	*Data sets(s):* European NUTS3 zones *Data source(s):* ESPON Database project *Data format(s):* ArcView Shapefile *Comments:* The NUTS-3 region layer obtained from ESPON Database Project was updated in various directions.	*Data sets(s):* GDP of NUTS3 zones *Data source(s):* ESPON database (years 2006/2005) integrated with TRANS-TOOLS model (2005) database and national sources *Data format(s):* Access Table, ESRI Personal Geodatabase *Comments:* GDP figures assigned to NUTS-3 region as standard polygon attributes
European potential accessibility freight	*Data sets(s):* - Trans-European road network 2005 - Trans-European rail network for 2005 - Trans-European inland waterways (iww) network - Trans-European maritime network - Trans-European air freight network 2011 - Intermodal Centres *Data source(s):* Road and rail networks come from the TRANS-TOOLS model. Iww and and air freight networks are taken from the RRG GIS Database. Maritime network comes from the TRUST model. Intermodal Centres are taken from RRG GIS Database (source: organisations: DUSS, DGG, Italian Interporti, European Association of Freight Villages). *Data format(s):* ESRI Personal Geodatabase, ArcView Shapefile *Comments:* The maritime network consist of fictitious links providing a full connectivity between all ports.	*Data sets(s):* European NUTS3 zones *Data source(s):* ESPON Database project *Data format(s):* ArcView Shapefile *Comments:* The NUTS-3 region layer obtained from ESPON Database Project was updated in various directions.	*Data sets(s):* GDP of NUTS3 zones *Data source(s):* ESPON database (years 2006/2005) integrated with TRANS-TOOLS model (2005) database and national sources *Data format(s):* Access Table, ESRI Personal Geodatabase *Comments:* GDP figures assigned to NUTS-3 region as standard polygon attributes.

Data sources for regional accessibility indicators

As there are Europe-wide as well as case-study wide regional accessibility indicators, following are two different tables (Tables 3 and 4).

Tables A2.3 summarises the data sources used to calculate the European-wide regional accessibility indicators, while Table 4 summarises the data sources used to calculate the accessibility indicators for the regional case studies.

Table A2.3. Data sources for European-wide regional accessibility indicators.

Indicator	**Network data**	**origin-destination data**	**Other data**
Travel (European-wide)			
Access to high-level transport infrastructures	*Data sets(s):* - Trans-European road network 2011 - Trans-European rail network for 2011 *Data source(s):* Road and rail networks for 2011 are based on Trans-Tools *Data format(s):* ArcGIS shapefile, Bridges *Comments:* Road network contains all motorways, dual-carriageway roads, E-roads, national roads and trunk roads. Rail network includes all railway links for passenger services under operation	*Data sets(s):* - European airport network for 2011 - European rail stations for 2011 - European grid, 5x5 km - NUTS-3 regions for ESPON space *Data source(s):* Airport network based on Trans-Tools. Network of rail stations based on IGIS inventory (EIB) NUTS-3 layer: ESPON Database project *Data format(s):* ArcGIS shapefile, Bridges *Comments:* Raster grid generated by MCRIT	*Data sets(s):* - Airport traffic in 2010 based on *anna.aero* database and Trans-Tools - Grid population *Data source(s):* EEA (grid population) *Data format(s):* MSAccess Grid *Comments:* Population figures transferred from EEA grid to 5x5km TRACC grid based on Corine land-cover base
Availability of urban functions	*Data sets(s):* - Trans-European road network 2011 - Trans-European rail network for 2011 *Data source(s):* Road and rail networks for 2011 are taken from the RRG GIS Database. *Data format(s):* ESRI Personal Geodatabase *Comments:* Road network contains all motorways, dual-carriageway roads, E-roads, national roads and trunk roads. Rail network includes all railway links for passenger train services under operation.	*Data sets(s):* - Cities in Europe with more than 50,000 inhabitants - European grid, 2.5x2.5 km - NUTS-3 regions for ESPON space *Data source(s):* RRG GIS Database for cities and grid; NUTS-3 layer: ESPON Database project *Data format(s):* ESRI Personal Geodatabase *Comments:* NUTS-3 region layer obtained from ESPON Database Project was updated in various directions.	*Data sets(s):* - City population - Grid population *Data source(s):* Rand McNally International Atlas (city population), EEA (grid population) *Data format(s):* Table, grid *Comments:* Population figures assigned to RRG GIS Database as standard point attributes

National potential accessibility travel	*Data sets(s):* - Trans-European road network 2011 - Trans-European rail network for 2011 - European/global flight network *Data source(s):* Road and rail networks: RRG GIS Database. Flight network: S&W flight network database *Data format(s):* Excel, ASCII *Comments:*	*Data sets(s):* *Data source(s):* *Data format(s):* *Comments:*	*Data sets(s):* *Data source(s):* *Data format(s):* *Comments:*
Freight (Europe-wide)			
Access to freight terminals	*Data sets(s):* - Trans-European road network 2011 - Trans-European rail network for 2011 *Data source(s):* Road and rail networks for 2011 are based on Trans-Tools *Data format(s):* ArcGIS shapefile, Bridges *Comments:* Road network contains all motorways, dual-carriageway roads, E-roads, national roads and trunk roads. Rail network includes all railway links for freight services under operation.	*Data sets(s):* - European port network for 2011 - European freight villages network - European grid, 5x5 km - NUTS-3 regions for ESPON space *Data source(s):* UN Locode database. RRG GIS Database for freight terminals NUTS-3 layer: ESPON Database project *Data format(s):* ArcGIS shapefile, Bridges *Comments:* A shapefile was generated from the coordinates available in the Locode database. Raster grid generated by MCRIT	*Data sets(s):* - Port handling in tones 2010 - Freight traffic in railways - Grid population *Data source(s):* Eurostat (ports); Transtools (rail); EEA grid population. *Data format(s):* MSAccess Grid *Comments:* 2010 is latest dataset available by Eurostat, reporting yearly port handling by port in tonnes. Population figures transferred from EEA grid to 5x5km TRACC grid based on Corine land-cover base
Availability of freight terminals	*Data sets(s):* Trans-European road network 2011 *Data source(s):* Road network for 2011 taken from the RRG GIS Database. *Data format(s):* ESRI Personal Geodatabase *Comments:* Road network contains all motorways, dual-carriageway roads, E-roads, national roads and trunk roads. Information on lorry speed limits al-	*Data sets(s):* - Freight terminals in Europe - European grid, 2.5x2.5 km - NUTS-3 regions for ESPON space *Data source(s):* RRG GIS Database for freight terminals and grid; NUTS-3 layer: ESPON Database project *Data format(s):* ESRI Personal Geodatabase *Comments:* The NUTS-3 region layer	*Data sets(s):* Grid population *Data source(s):* EEA (grid population) *Data format(s):* Grid *Comments:* Population figures assigned to RRG GIS Database as standard point attributes

	ready assigned to the layer.	obtained from ESPON Database Project was updated in various directions.	
National potential accessibility freight	*Data sets(s):* Trans-European road network 2005 *Data source(s):* Road network comes from the TRANS-TOOLS model. *Data format(s):* ESRI Personal Geodatabase, ArcView Shapefile *Comments:* ---	*Data sets(s):* European NUTS3 zones *Data source(s):* ESPON Database project *Data format(s):* ArcView Shapefile *Comments:* The NUTS-3 region layer obtained from ESPON Database Project was updated in various directions.	*Data sets(s):* GDP of NUTS3 zones *Data source(s):* ESPON database (years 2006/2005) integrated with TRANS-TOOLS model (2005) database and national sources *Data format(s):* Access Table, ESRI Personal Geodatabase *Comments:* GDP figures assigned to NUTS-3 region as standard polygon attributes.

Table A2.4. Data sources for regional case study indicators.

Macro region	Network data	Statistical data
EURAM trans-border region (Spain, France, Andorra)	*Contents:* Networks for 2011 for road, rail, ferries, airports and seaports. Foreseen infrastructure networks with 2030 time horizon according to TEN-T. *Source:* TRANS-TOOLS database, updated with interconnecting links between transport networks. *Data format:* ArcGIS shapefile, Bridges	*Contents:* - Population by LAU2, 2011 - Number of jobs by LAU2, 2011 - Number of hospitals by LAU2, 2011 - Number of secondary schools by LAU2, 2011 - Number of medicine practitioners by LAU2, 2011 *Sources:* - Population: INE (Spain), INSEE (France), Statistics Department of Andorra - Labour market: INSS (Spain), INSEE (France), Statistics Department of Andorra - Hospitals database: Ministerio de Sanidad (Spain), Agence Régionale de Santé du Languedoc-Roussillon (France), Govern d'Andorra - Schools: Generalitat de Catalunya, Generalitat Valenciana and Govern de les Illes Balears (Spain), Conseil Géneral Pyrinees Orientales (France), Govern d'Andorra - Physicians database: estimated based on INE, INSEE and Eurostat ratios per 1000 inh. *Data format:* MSAccess, Excel

Northern Italy	*Contents:* Road and rail network data consistent with LAU-2 zoning system. *Sources:* RRG GIS Database (rail), OpenStreetMap (road) *Data format:* ArcGIS shapefile, geodatabase *Remarks:* Original networks are translated in format usable by the MEPLAN model. Times in the rail network are based on actual schedules and not on track maximum allowable speed.	*Contents:* - Population by age and sex, LAU-2, 2010 - Population, LAU-2, 2006 - Workplaces, LAU-2 (2001). - Health care facilities, LAU-2, 2010 - Secondary school, LAU-2, 2010/2011 Doctors, NUTS2, 2008. *Source:* Italian Statistical Office (ISTAT), ISTAT Census 2001, ESPON Database Project, Italian Ministry of State for Health, Italian Ministry of Education *Data format:* Access, Excel *Remarks:* Additional available data concern major transport infrastructure projects in the macro-region (Ten-T outline plans, October 2011).
Bavaria (Germany)	*Contents:* Full road, rail and public transport networks (busses, trams, subway) for Bavaria for 2009. *Sources:* StMWVT, Public transport timetables with additions through S&W. *Data format:* ArcGIS shapefile, ASCII *Remarks:* Network data comprise a complete representation of road and public transport networks for Bavaria, i.e. all roads that can be used by cars are included and the public transport network is based on a complete public transport timetable.	*Contents:* - Population, LAU-2, 2008, also disaggregated to 100x100 m raster cells - Population, LAU-2, 2006 - Services of general interest (education, health care, public administration), exact locations, 2008 *Source:* Miscellaneous *Data format:* Excel, ASCII, ArcGIS shapefile
Czech Republic	*Contents:* Two network datasets available (1:500 000 and 1:150 000) for road and rail and inland waterways for 2006 for the whole area of the Czech Republic (incl. transport nodes, i.e. railway stations, airports etc.). Road and rail attributes include, inter alias road number, length and category. Road network and attributes have been updated by the maps of Road and Motorway Directorate of the Czech Republic. No public bus network available. *Sources:* ArcČR500 (1:500,000), CEDA 150 (1:150,000), Road and Motorway Direc-	*Contents:* - Population, LAU-2, 2001 - Population, LAU-2, 2006 - Health care services (location of hospitals, 2012, general surgeries 2010) - Secondary grammar schools location (2010) - Public administration (location 2012) *Source:* Czech Statistical Office (Population and Housing Census 2001), ArcČR500, Ministry of Health of the Czech Republic, Ministry of Education, Youth and Sports, Ministry of Transportation, ESPON Database Project, PrF UK internal database *Data format:*

	torate of the Czech Republic (www.rsd.cz); ESPON Databank Project,2010/2011 *Data format:* ArcGIS shapefile, ESRI Geodatabase, ESRI Network Dataset *Remarks:* Sources combined, data 2006 updated in substantial features (mainly new motorways), several errors in network topology.	Excel, ArcGIS shapefiles, web database
Poland	*Contents:* Network data for 2010 available for the whole of Poland for roads, railways, inland waterways incl. ports and seaports, and air; network density optimised for voivodships. Road attributes include road number, length, category, number of lanes, width, condition and congestion. Rail attributes include technical speeds and lengths, and also train timetable for 2010 as NUTS-3 matrix. *Sources:* IGSO PAS, General Directorate for National Roads and Motorways of Poland, Voivodship Road Administrations, PKP Polish Railway Lines JSC *Data format:* MapInfo *Remarks:* Rail speeds not precise and for 2008 only.	*Contents:* - GDP/GVA, NUTS-2/3, 1999-2008 - Population (total, by age and sex), LAU-2, 1995-2009 - Population, LAU-2, 2006 - Employment, NUTS-2, 2000-2009 - Employment persons in main workplace, LAU-2, 1995-2009 - Land use data, NUTS-3, 2000-2006 - Other data, LAU-2 *Sources:* IGSO PAS, Central Statistical Office of Poland, ESPON Database Project *Data format:* Excel, dbase
Baltic States (Estonia, Latvia, Lithuania)	*Contents:* Entire road and railway network incl. all stations (2010/2011). Tram networks for Tallinn, Riga, Daugavpils and Vilnius (2010/2011/2012). Ferry networks, seaports (2010/2011), hospital locations (2012), higher secondary schools (2012) *Sources:* RRG, OpenStreetMap, Websites *Data format:* ArcGIS shapefile, geodatabase, html, kml	*Contents:* - Population, 2.5x2.5 km grid, 2000/2010 - Population, LAU-2, 2006/2008 - Built-up areas, 2.5x2.5 km grid, 2000/2010 - Employment (total, by sector), NUTS-3, 2000-2010 - Employment (total), LAU-2 *Sources:* RRG, European Environmental Agency (EEA), ESPON Database Project, ESPON Geospecs Project, Eurostat *Data format:* Dbase, Excel, ArcGIS Geodatabase
Finland	*Contents:* Network data for entire Finland for roads including domestic road ferry and cable connections (2012), bus stops (2012),	*Contents:* - *Population, 1x1 km grid, 2010* - *Population, LAU-2 (municipalities) 2010* - *Number of employees, 1x1 km grid, 2005* - *Number of employees, LAU-2 (municipalities)*

	railways and stations (2012). *Sources:* Finnish Transport Agency (Digiroad), Oy Matkahuolto Ab (bus stops), Finnish Transport Agency (rail geometry and stations locations), VR-Yhtymä Oy (rail time tables). *Data format:* ArcGIS geodatabase, ArcGIS shapefile. *Remarks:* Bus stops are applied in simulating bus network of Oy Matkahuolto Ab. All bus companies are not included and simulated travel times may differ from actual travel times. Travel times in the rail network are based on actual schedules and not on track speeds. Fastest intercity and local train travel times are applied. The travel times are gathered from time tables of R-Yhtymä Oy company.	*2005* - *University, central and regional hospitals, 2011, street address based locations* - *Health centres, 2011, street address based locations* - *Secondary schools, 2011, street address based locations* *Sources:* Statistics Finland, ESPON Database Project, National Institute for Health and Welfare/HILMO database, Finnish National Board of Education. Europe Geocode services (ArcGIS online). *Data format:* ArcGIS Geodatabase, ArcGIS shapefile, Dbase, Excel.

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