

Update of Selected Potential Accessibility Indicators

Final Report

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Foreword

In the context of the ESPON 1.2.1 project, S&W developed as part of their contribution potential accessibility indicators reflecting the situation in the year 2001. These potential accessibility indicators were used in several ESPON projects and in European documents, among them the 3rd Cohesion Report.

In 2006, the ESPON 2006 Programme wished to have updated road and rail accessibility maps available in order to meet demand, also in relation to the 4th Cohesion Report. In 2006 ESPON commissioned a study to update potential accessibility indicators for road and rail for NUTS-3 regions.

The work was carried out in the second half of 2006 by Spiekermann & Wegener, Urban and Regional Research (S&W), Dortmund, Germany in cooperation with RRG Spatial Planning and Geoinformation, Oldenburg/H., Germany. Klaus Spiekermann (S&W) was responsible for the study and the accessibility modelling, Carsten Schürmann (RRG) was responsible for the update of the infrastructure network database. Marcus Brockmann (RRG) and Christoph Heidenreich (S&W) added actual rail travel times for all European countries to the network database.

This report is the Final Report of the study. It contains the methodology, the database and the results achieved including the new potential accessibility maps. A data set with the new accessibility indicators accompanies the report in electronic form.

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1 Introduction

Accessibility is the main "product" of a transport system. The task of transport infrastructure is to enable spatial interaction, i.e. the mobility of persons and goods for social, cultural or economic activities. In the context of spatial development, the quality of transport infrastructure in terms of capacity, connectivity, travel speeds etc. determines the locational advantage of an area (i.e. a region, a city or a corridor) relative to other locations, i.e. its competitive advantage. 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 (Wegener et al., 2002).

The important role of transport infrastructure 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 (see Linneker, 1997). Investments in transport infrastructure lead to changing locational qualities and may induce changing spatial development patterns.

This relationship of accessibility and spatial development was taken up in the European Spatial Development Perspective which gives improvements in accessibility a high priority as a policy target: "Good accessibility of European regions improves not only their competitive position but also the competitiveness of Europe as a whole" (European Commission 1999a, 69).

Consequently, the topic of accessibility played an important role also in ESPON 2006. In ESPON 1.2.1 (2005) a broad range of indicators describing the transport system and its spatial implications were developed, among them different accessibility indicators such as travel time, daily accessibility and potential accessibility. Variations of the potential accessibility indicators were generated in ESPON 1.1.1 (2005) for the European urban system (FUAs), in ESPON 1.1.3 (2006) for issues of enlargement and in ESPON 2.1.1 (2005) for forecasting regional impacts of European transport policies. The potential accessibility indicators of ESPON 1.2.1 were used in several ESPON projects and in European documents, among them the 3rd Cohesion Report.

The potential accessibility indicators of ESPON 1.2.1 reflect the situation in the year 2001. This gave rise for demand by the ESPON 2006 Programme for updating those indicators. The study reported here comprises the calculation and mapping of updated potential accessibility indicators for road and rail for NUTS-3 regions of the ESPON space. For this, an improved version of the accessibility model used in ESPON 1.2.1 was applied. The updated ac-

cessibility indicators are based on the most recent available regional socio-economic data and reflect the transport infrastructure situation in the year 2006. The indicators especially take account of

- the 2004 EU enlargement including reduction of waiting times at border crossings,
- the extension of the motorway networks particularly in the new member states,
- the improvements of the rail network, mainly in the old member states through the development of high-speed rail.

This report is the Final Report of the study. It describes the methodology applied (Chapter 2), the infrastructure network and socio-economic database and its improvement (Chapter 3) and the results achieved including the new potential accessibility maps (Chapter 4). A data set with the new accessibility indicators accompanies the report in electronic form.

2 Methodology

The task of this study is to provide updated indicators of potential accessibility by road and rail. Potential accessibility is one of the most common and most extensively tested accessibility indicators (for reviews see Schürmann et al., 1997; Wegener et al., 2002; Spiekermann and Neubauer, 2002; ESPON 1.2.1, 2005). Potential accessibility indicators by mode have been proposed by the Working Group "Geographical Position" of the Study Programme on European Spatial Planning (SPESP) as reference indicator concept (Wegener et al., 2002) and have been further developed and widely used in ESPON 2006.

Potential accessibility is based on the assumption that the attraction of a destination increases with size, and declines with distance, travel time or cost. Destination size is usually represented by population or economic indicators such as GDP or income. Accessibility to population is seen as an indicator for the size of market areas for suppliers of goods and services; accessibility to GDP as an indicator of the size of market areas for suppliers of high-level business services. Potential accessibility is founded on sound behavioural principles but contains parameters that need to be calibrated and their values cannot be expressed in familiar units.

Potential accessibility is a construct of two functions, the *activity function* representing the activities or opportunities to be reached and the *impedance function* representing the effort, time, distance or cost needed to reach them (Wegener et al., 2002). For potential accessibility the two functions are combined multiplicatively, i.e. are weights to each other and both are necessary elements of accessibility:

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

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 . A_i is the total of the activities reachable at j weighted by the ease of getting from i to j . The interpretation is that the greater the number of attractive destinations in areas j is and the more accessible areas j are from area i , the greater is the accessibility of area i .

Occasionally, but not in this study, the attraction term W_j is weighted by an exponent α greater than one to take account of agglomeration effects. The impedance function is nonlinear. Generally a negative exponential function is

used in which a large parameter β indicates that nearby destinations are given greater weight than remote ones.

The accessibility model used (based on Spiekermann and Wegener, 1996; ESPON 1.2.1, 2005) uses centroids of NUTS-3 regions as origins and destinations. The accessibility model calculates the minimum paths through the networks, i.e. minimum travel times between the centroids of the NUTS-3 regions. For each NUTS-3 region the value of the potential accessibility indicator is calculated by summing up the population in all other European regions, including those outside ESPON space, weighted by the travel time to go there. For this weighting, the parameter β has been set to 0.005. That means that assuming a travel time between two regions of zero minutes (which does not occur in reality), the population of the destination region would be included with its full value in the potential accessibility of the origin region, while for a travel time of little more than two hours the weight is 0.5, and for a travel time of little more than five hours the weight goes down to 0.2 only (see Figure 1).

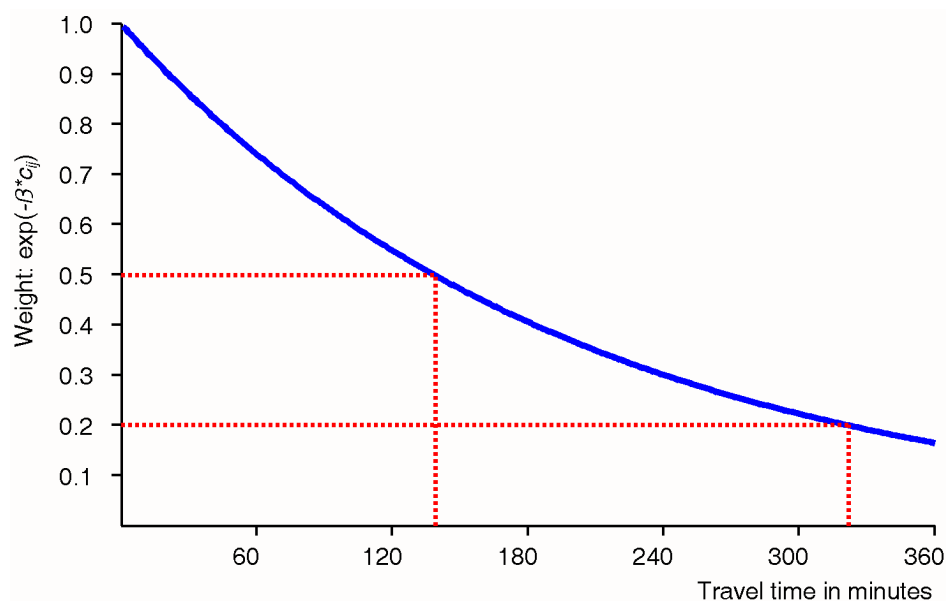


Figure 1 Weighting of destination population

Potential accessibility was calculated for road and rail for the year 2006. Because the interest is in changes of accessibility during the past five years, the indicator values for the year 2001 were recalculated in order to match the improved database (see Chapter 3). For the presentation of the accessibility indicators and the changes over time four map types were developed:

- *Absolute level of accessibility.* The first map type shows the absolute level of potential accessibility in the year 2006. Because the accessibility indicators are in non-familiar units they are standardised to the average accessibility of the European Union with 27 member states, i.e. the absolute values are transformed so that the European average is 100. By presenting the absolute values as such indices, it can be seen which regions are in a better or a worse position than the European average.
- *Relative change of accessibility.* The second map type shows the relative development of potential accessibility as change between 2001 and 2006 in percent of the (non-transformed) absolute value in 2001.
- *Absolute change of accessibility.* The third map type shows the absolute development of potential accessibility between 2001 and 2006. This map type gives additional information on the spatial distribution of accessibility growth, because high relative changes in the second map type might occur because the initial value is very low. In the maps, the differences between the absolute values of the two years are expressed as percentage of the European average in 2006; i.e. in the transformed index units of the year 2006.
- *Index change of accessibility.* The last map type shows the change of the index values of potential accessibility between 2001 and 2006. Whereas the previous change maps looked at the change of the absolute values expressed either in relative or in absolute terms, this map type ignores the absolute values and focuses on the change of the relative position of the regions. For this, the accessibility values of 2001 are standardised to the EU27 average of that year and those of 2006 to the average of that year, each EU27 average is set to 100 and the regional values are transformed accordingly. The map then shows the differences of the index values, i.e. the change of the position of the regions relative to other regions. Positive values express an improvement of the relative locational quality, while negative values express a loss in relative locational quality.

Chapter 4 presents the updated potential accessibility indicators for road and rail using the four map types described above. But before that, Chapter 3 discusses the database used and its improvements and updates.

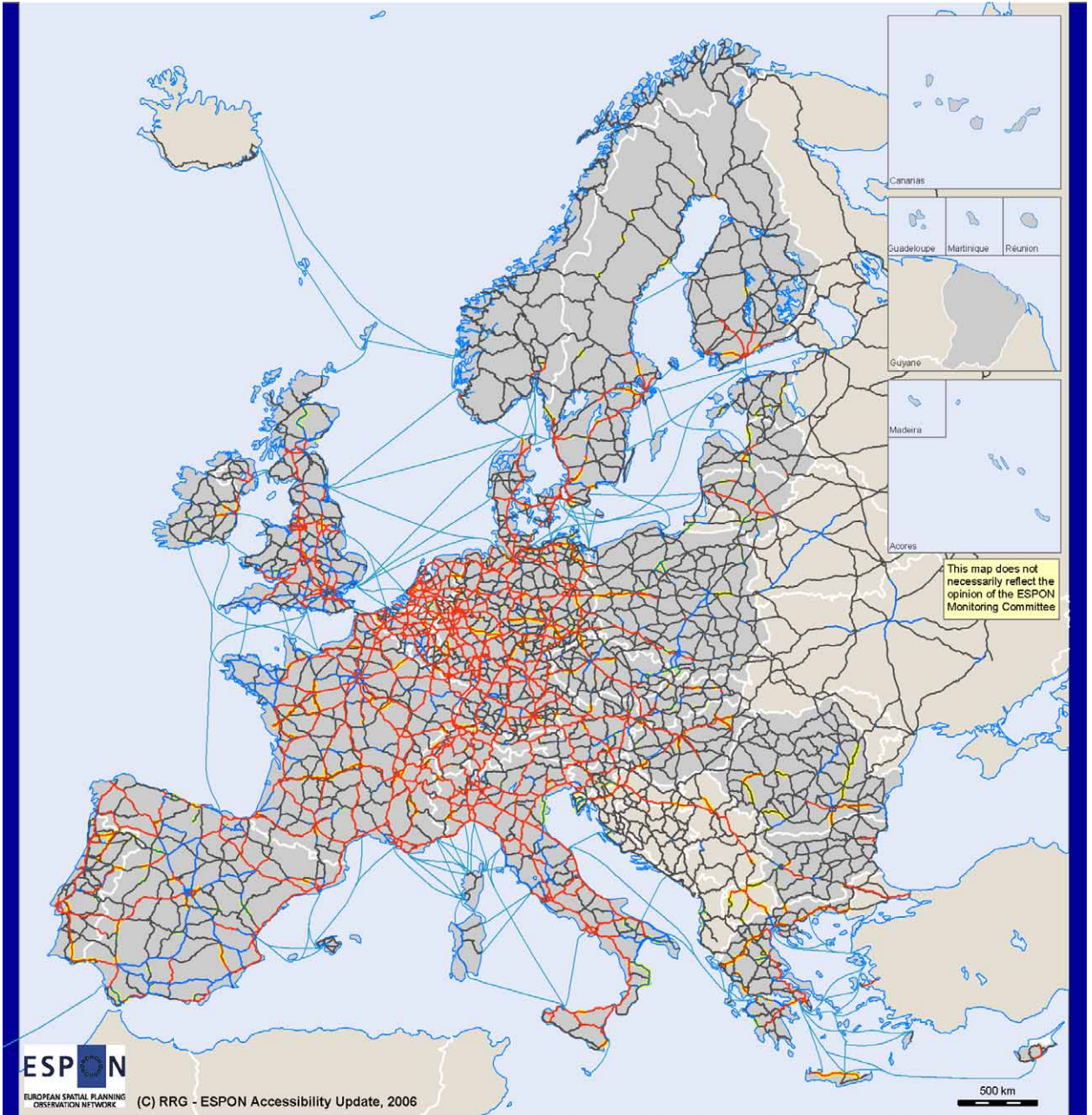
3 Database

The calculation of the updated road and rail potential accessibility indicators for 2006 in this study is based on a detailed GIS database of trans-European transport networks which covers all countries of the ESPON space and the remaining European countries and includes all modes of transport.

The RRG GIS Database (RRG, 2006) used for this study provides digital data for 38 countries in Europe (all countries of the European Union as well as Switzerland, Norway, Iceland, Albania, the European part of Turkey, the countries of former Yugoslavia and the countries of the European part of the former USSR) in standard GIS format. Inter alia, this database includes full information on the pan-European road and rail networks, including railway stations, car and rail ferry routes and ferry seaports. The different categories of the database are stored as individual layers in the GIS database. The road and rail network layers of this GIS database are used to calculate the accessibility potential of the NUTS-3 regions of the ESPON countries.

Road network layer

The road network layer includes all TEN and TINA roads, E-roads, motorways and highways, dual-carriageway roads, as well as other trunk roads and other important national roads and road ferries and other roads to guarantee connectivity of NUTS-3 regions, altogether forming the trunk road network of Europe (Figure 2). The TEN-T road outline plans are fully coded in this database, including the envisaged completion years of each project (section), along with additional outline plans from the national transport ministries, road authorities or road agencies. Information on the TEN and TINA links and outline plans are taken from different recent EC publications (European Communities 1996; European Commission 1995; 1998; 1999b; 2002a; 2002b; 2003; 2004a; 2004b; 2005; HLG 2003; TINA Secretariat 1999; 2002). Furthermore, one of the unique features of the road network layer of the RRG database is the coding of the historical development of the road networks in all countries, dating back as far as 1975. For the accessibility update study road networks representing the state of networks in the years 2001 and 2006 were extracted, thus reflecting the infrastructure development between those two years (see Figure 2). Travel times on each individual road link are generated as a function of link type and country-specific speed limits and regional population densities to reflect the risk of congestion. Border waiting times are estimated on a limited number of observations and are assumed to be reduced over time in the course of European integration.



Trunk roads in Europe in 2006

-  Motorways
-  Dual carriageway roads
-  Major roads
-  Secondary roads
-  Ferry links
-  Eurotunnel
-  Road projects completed 2001-2006

(C) EuroGeographics Association for the administrative boundaries

Source: RRG 2006, RRG GIS Database

Figure 2 Illustration of the road network database

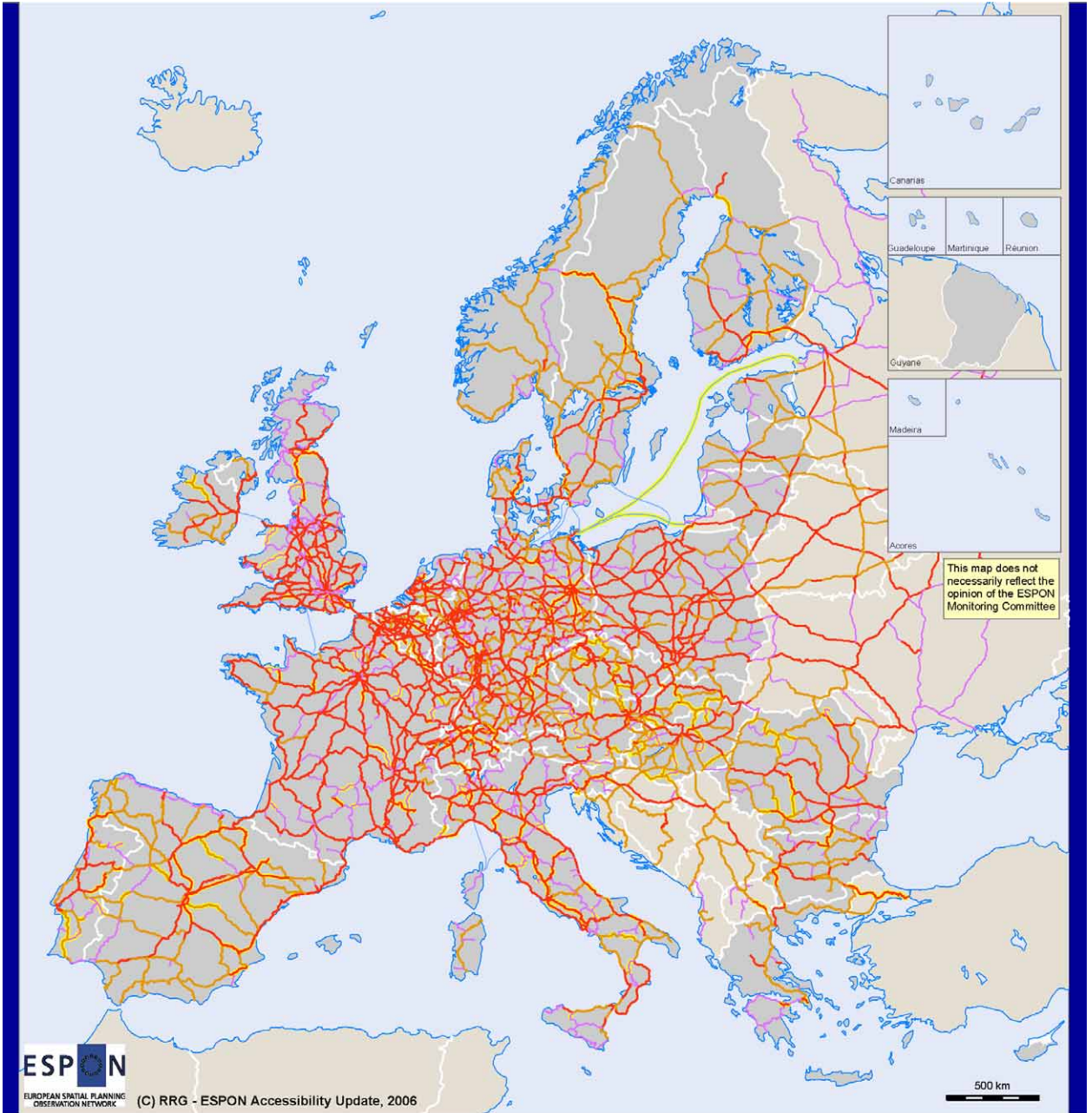
Railway network layer

The railway network layer of the RRG database includes all railway lines under operation today. For the accessibility modelling only a subset of the rail network is used. It includes all sections of the TEN and TINA rail networks and all sections of the *Dedicated Rail Freight Network*, as specified in recent EC documents (European Communities 1996; European Commission 1995; 1998; 1999b; 2002a; 2002b; 2003; 2004a; 2004b; 2005; HLG 2003; TINA Secretariat 1999; 2002). In addition, new planned railway lines based on the TEN and TINA outline plans and outline plans of national transport ministries and railway authorities, and selected railway links currently closed for operation are also included as well as rail ferries. Along with the rail links, also the railway stations are coded (Railfaneurope.net 2004). Furthermore, one of the unique features of the railway network layer of the database is the coding of the historical development of the railways in all countries, dating back as far as 1975. The railway links are shown in Figure 3. In addition to the rail links and stations, also travel times are available in the RRG database. Timetable based travel times between main stations for the years 2001 and 2006 were collected and incorporated into the database. From the rail database two model networks were extracted representing the infrastructure and travel time development between 2001 and 2006. (see Figure 3): one rail network representing the situation in 2001, and another representing the actual situation at the end of 2006.






Regional socio-economic data

The regional data used for the accessibility modelling cover latest available population data for the year 2003 for all NUTS-3 regions according to the NUTS 2003 system of regions (Eurostat, 2004) taken from the ESPON database and national sources for regions outside the ESPON space.

As potential accessibility indicators are combinations of two components, the destination activity of interest (here population) and the impedance term (here travel time) can change over time and thus alter the accessibility values. However, as population data for 2006 are not yet available, it was decided to work with population figures for the year 2003 for the accessibility indicators of both 2001 and 2006. This means that the changes in accessibility over time can be exclusively attributed to the changes in the transport system, i.e. the effects of changes in the distribution of population are excluded.



Rail network in Europe in 2006

-  Main lines, double track
-  Main lines, single track
-  Secondary lines
-  Ferries
-  Rail projects completed 2001-2006 or major improvements in travel times

(C) EuroGeographics Association for the administrative boundaries

Source: RRG 2006, RRG GIS Database

Figure 3 Illustration of the rail network database

Database updates

The ESPON Database already includes accessibility indicators of the potential type for the year 2001, calculated in EPSON 1.2.1 (2005) by S&W. At that time basically the same road and railway network database was used. Although that 2001 transport network database was already of high quality, the database has since been updated and upgraded in many respects:

- The latest EC documents on the future development of the TEN-T networks published since 2001 were incorporated.
- The network accuracy, resolution and density was improved.
- Railway network travel times for 2006 were collected from web-based timetable information systems of the national railway companies. In this process the information for the year 2001 was cross-checked, improved and amended where necessary.
- The present study utilises the NUTS 2003 system of regions instead of the old 1999 system of regions applied for the potential accessibility indicators in EPSON 1.2.1.
- NUTS-3 population figures taken from the ESPON database for the ESPON space and from national sources for other regions were updated to the year 2003.

Taken all the above mentioned network improvements into account, the potential accessibility indicators for 2001 cannot be directly compared to the potential accessibility indicators currently in the ESPON database (variable codes AcRoE01N3 and AcRaE01N3); while the overall spatial patterns remained the same, the exact numbers between the old 2001 indicators and the newly calculated 2001 indicators may differ to a small degree.

4 Results

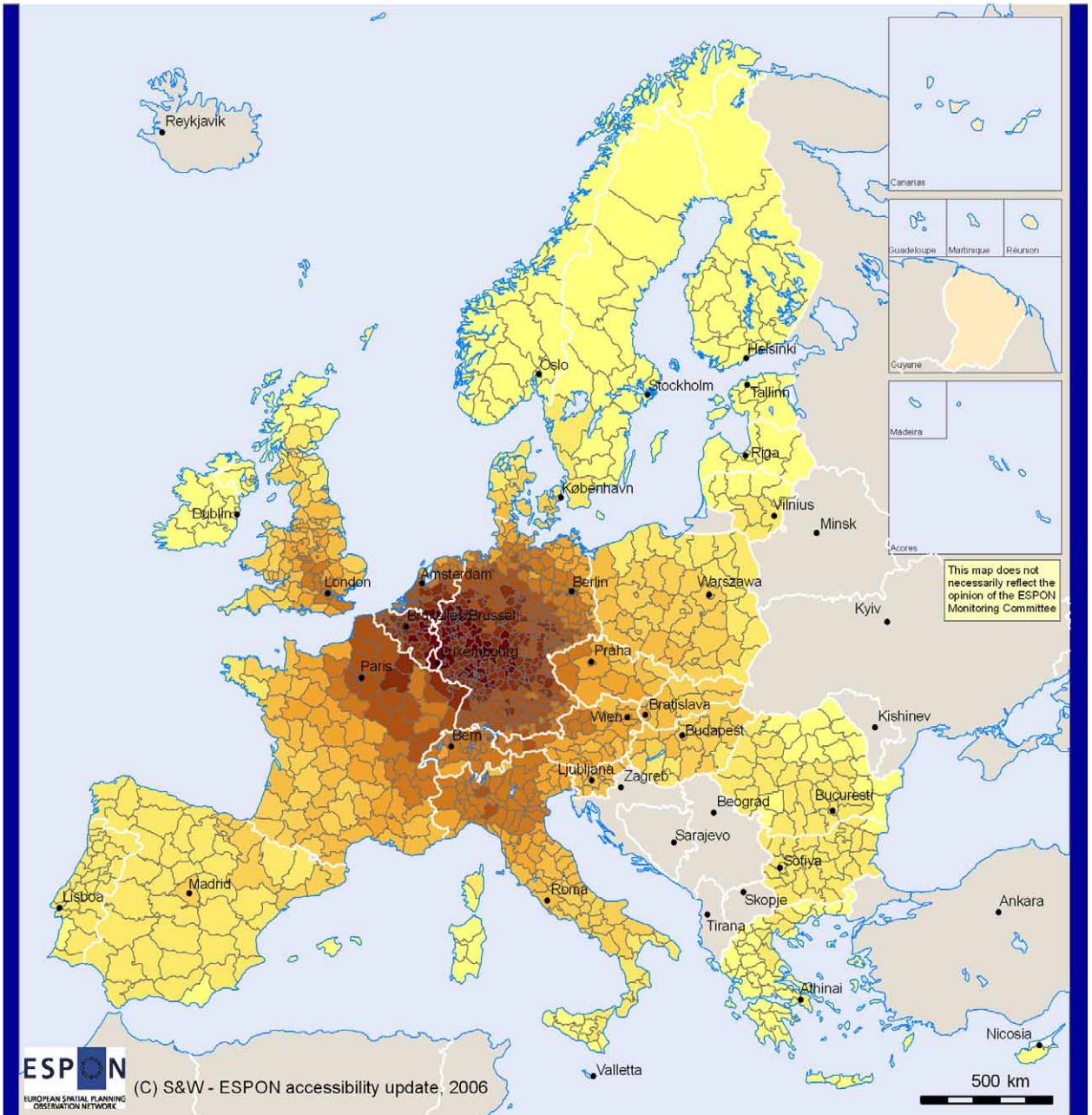
This chapter presents the updated accessibility maps for the year 2006 and the changes since 2001. The first section presents the results for potential accessibility by road, the second section the results for potential accessibility by rail. Both sections contain the series of map types described in Chapter 2.

4.1 Potential accessibility by road

The absolute value of potential accessibility by road for the year 2006 is shown in Figure 4 expressed as index value in which the EU27 average is set to 100. The regions in Belgium, the Netherlands and in the western parts of Germany have the highest accessibility values in Europe leading partly to a level more than twice the European average. But also regions in northern and eastern parts of France, in the south-east of England, in Switzerland, the western parts of Austria and the northern parts of Italy have very good accessibility by road. In all these regions the combination of good road infrastructure in form of dense motorways and high concentration of population leads to these favourite positions. Accessibility by road decreases towards regions located outside the core. Lowest accessibility by road is found in the northern regions of the Nordic countries. Also most regions of the Baltic States, Bulgaria, Romania and Greece have very low potential accessibility.

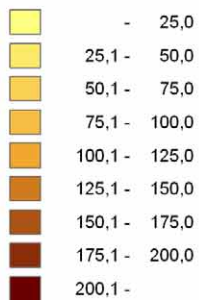
The relative development of potential accessibility by road since 2001 shown in Figure 5 gives a distinct spatial pattern. Regions with high absolute values did not have strong relative gains, because with the already existing high level the addition of some new motorways has only low relative impact. Highest relative growth can be seen in the western parts of Poland and the Czech Republic where the combination of some infrastructure projects and the reduction of border waiting times in the context of the EU enlargement has positive effects. Clear growth of potential accessibility by road due to completed road infrastructure projects can be seen in several regions all over the EU; most clearly in northern Greece as a consequence of the new motorway Via Egnatia.

Looking at absolute growth of potential accessibility by road in Figure 6, many of the regions with high relative growth show also high absolute growth, in particular those regions that have around average accessibility. But regions in Portugal, Spain, Greece, the Nordic countries and the Baltic States with low accessibility values and high relative growth do not show very high absolute growth. And on the other hand, several regions with high accessibility values do not show high relative growth but substantial absolute growth; in particular in the New Länder in Germany the road transport infrastructure projects show significant absolute effects on accessibility.



Potential accessibility

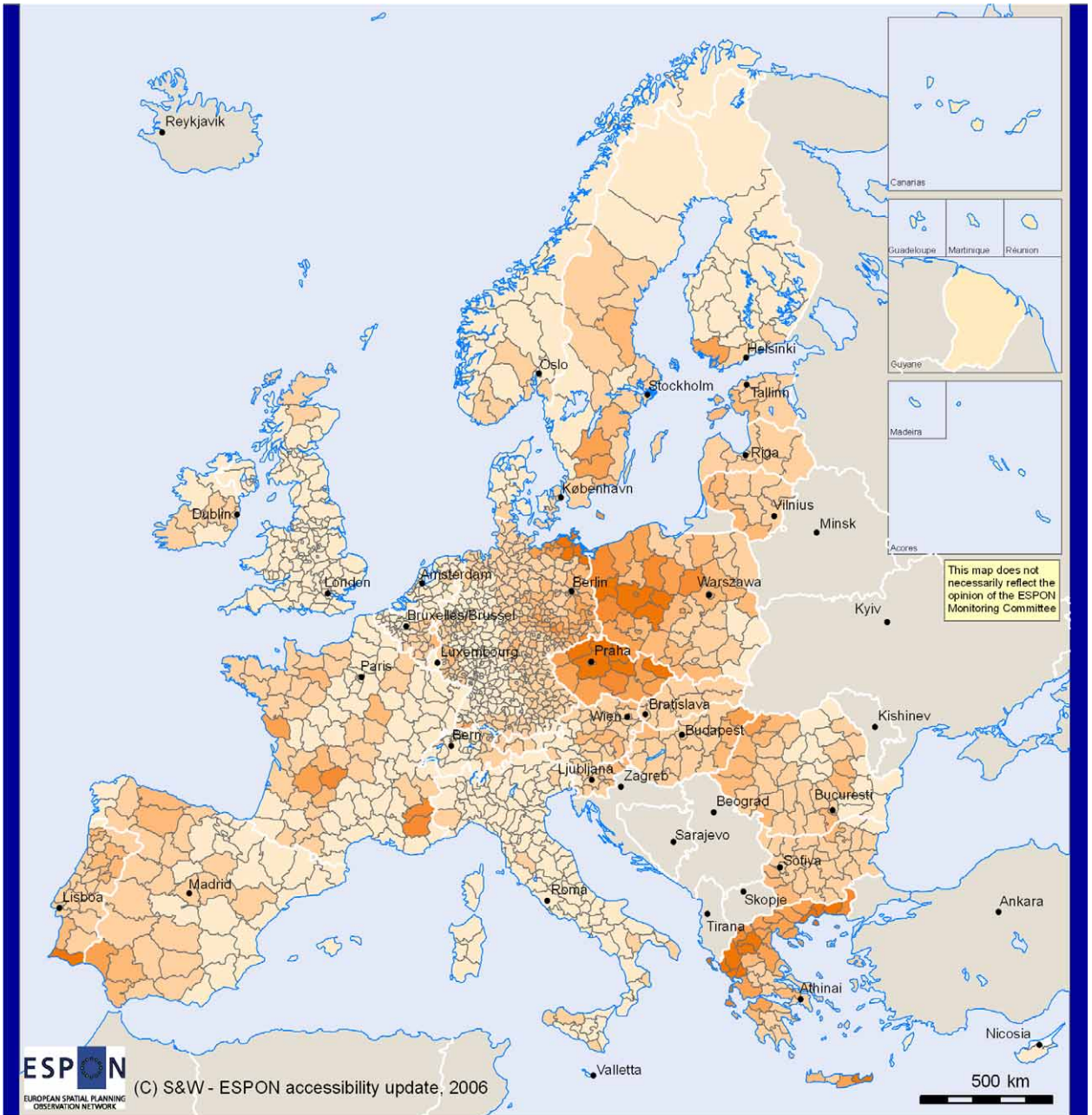
Road, 2006 (EU27 = 100)



(C) EuroGeographics Association
for the administratives boundaries

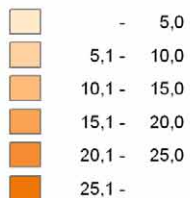
Data sources:
RRG GIS Database
S&W Accessibility Model

Figure 4 Potential accessibility by road in 2006



Potential accessibility

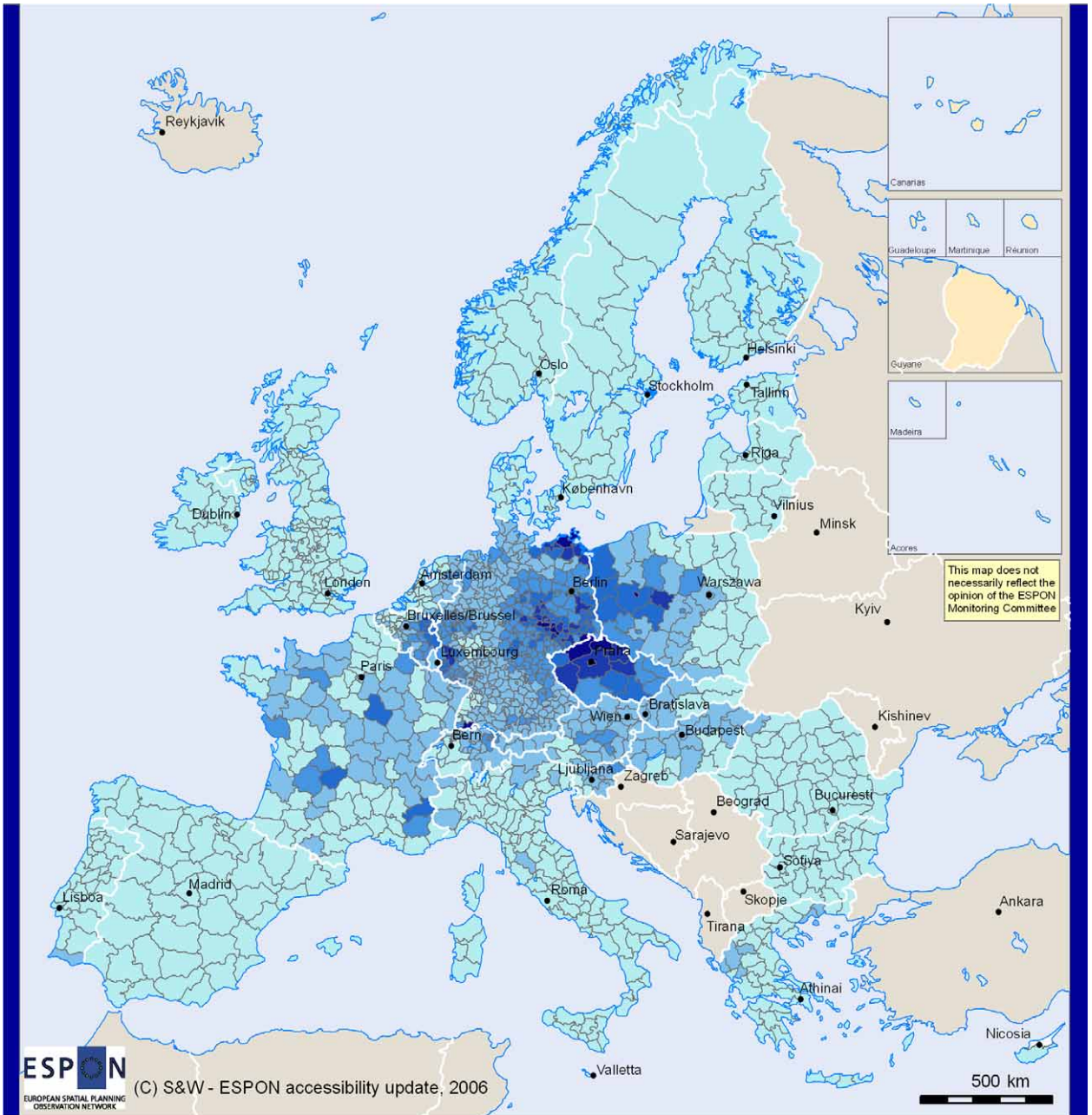
Road, relative change 2001-2006 (in %)



(C) EuroGeographics Association
for the administratives boundaries

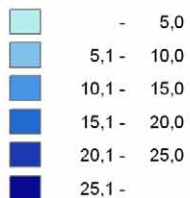
Data sources:
RRG GIS Database
S&W Accessibility Model

Figure 5 Potential accessibility by road, relative change 2001-2006



Potential accessibility

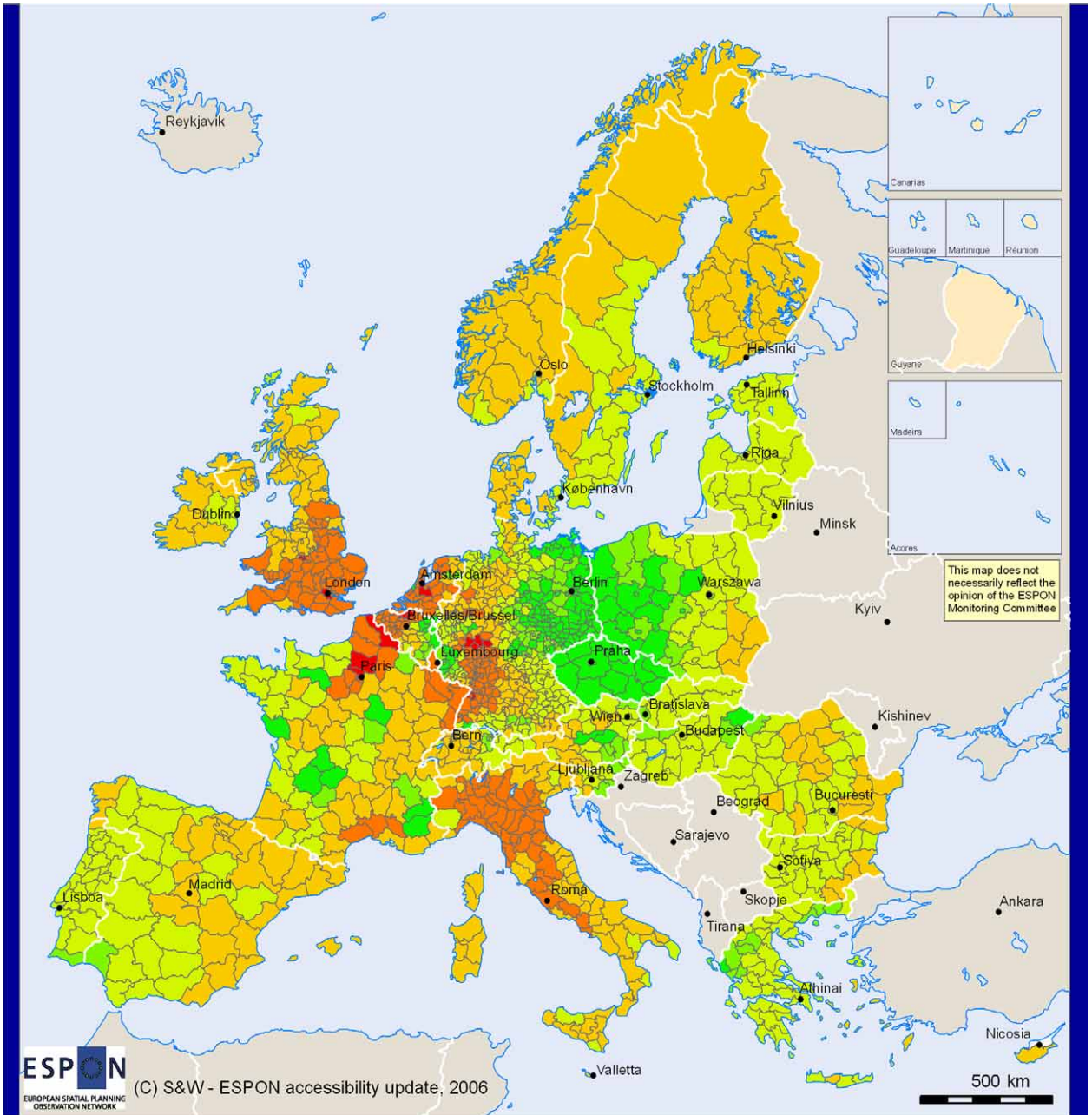
Road, absolute change 2001-2006 (EU27 absolute average in 2006 = 100)



(C) EuroGeographics Association for the administrative boundaries

Data sources:
RRG GIS Database
S&W Accessibility Model

Figure 6 Potential accessibility by road, absolute change 2001-2006



Potential accessibility

Road, change of standardised index 2001-2006



(C) EuroGeographics Association for the administrative boundaries

Data sources:
RRG GIS Database
S&W Accessibility Model

Figure 7 Potential accessibility by road, change of relative position of regions 2001-2006

These developments led also to changes in the relative position of individual regions compared to the European average (Figure 7). Regions coloured in green did improve their relative location in terms of potential accessibility by road, regions coloured in red lost relative position. The relative winners are regions in western Poland, the Czech Republic and the New German Länder. They improved their relative position by more than six index points. With the exception of few regions at the eastern border of the EU and Malta and Cyprus, all regions of the new member states progressed in relative terms as well as many regions in Greece, France, Spain and Portugal. Relative losses are found in the Nordic countries, the UK and Ireland and southern Italy as well as in many regions in the European core which have an overall good position but lose some relative comparative advantage in location as other regions are catching up.

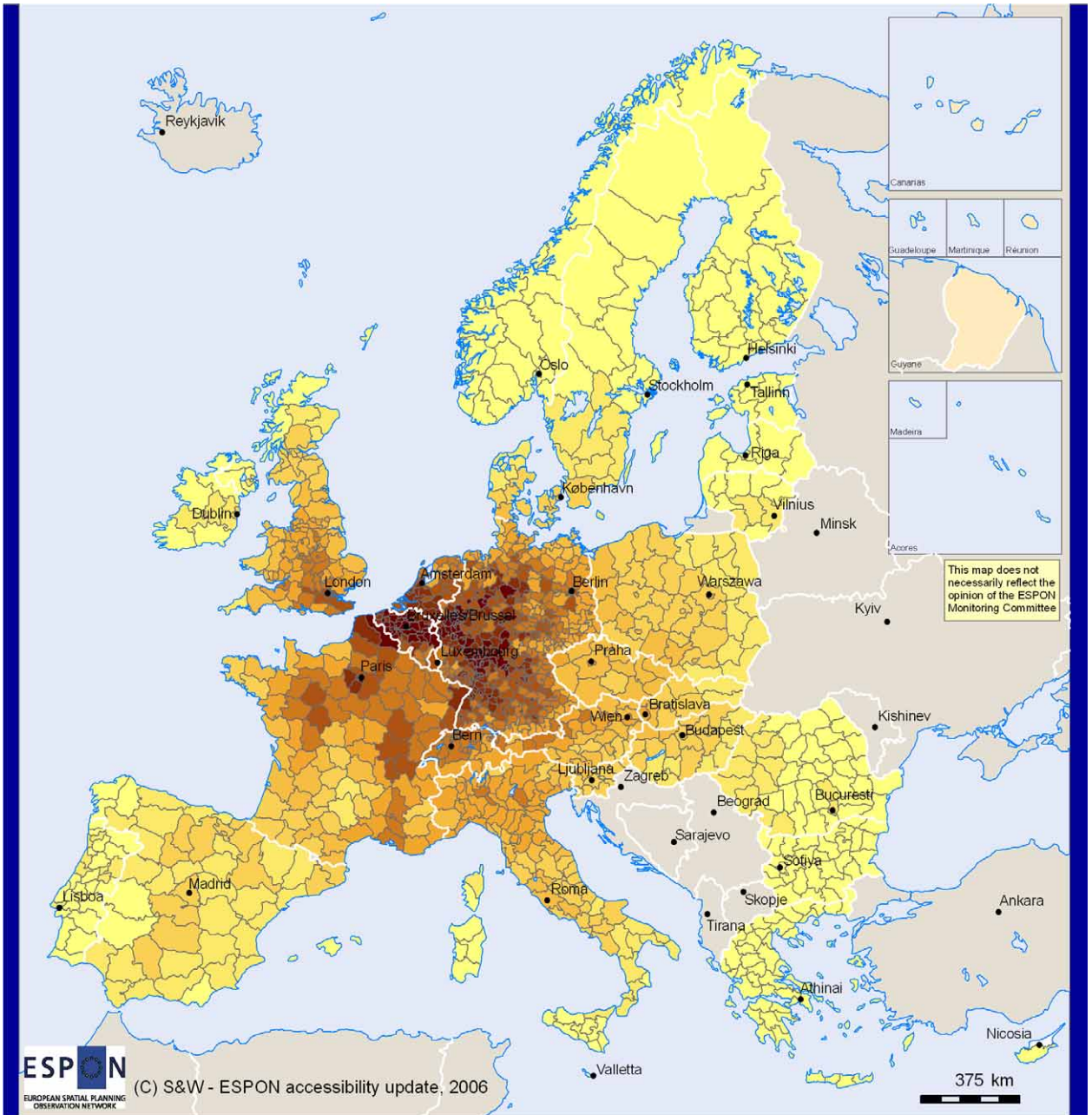
4.2 Potential accessibility by rail

Figure 8 shows the absolute value of potential accessibility by rail for the year 2006. Again, regions in the European core have the highest values. However, instead of forming a plateau of high accessibility, regions with top accessibility are forming corridors along high-speed rail links. High-speed rail also brings very high accessibility to regions outside the European core, for instance in France to Tours and Lyon and Marseille or in Germany to Berlin. Below average accessibility by rail can be found in Ireland, Spain, Portugal, southern Italy and most regions of the new member states. Lowest accessibility by rail is located in the northern parts of the Nordic countries, the Baltic States and most regions of Romania, Bulgaria and Greece.

Highest relative gains in accessibility by rail occurred in many regions that have below average absolute values, e.g. in Spain and Portugal, the southern regions of Italy or in the Nordic countries (Figure 9). In regions with good accessibility, only the high-speed projects in southern Germany led to significant relative gains, other regions have rather low relative growth.

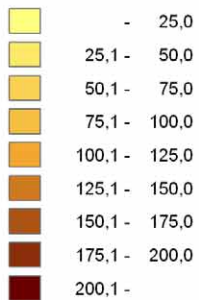
The spatial pattern is somewhat different when looking at absolute changes (Figure 10). Highest gains are located in southern Germany and in Belgium. But many other regions in western Europe experienced substantial gains in rail accessibility. On the other hand, absolute growth in most of the regions of the new member states and in the Nordic countries was rather low.

Consequently, in relative comparative terms most regions in the new member states lost index points (Figure 11). Also, as other regions caught up, regions with high accessibility by rail lost some of their dominance, in particular French regions. Relative winners are mainly located in southern Germany, Italy and Spain in which high-speed rail projects led to an improvement of their locational position compared to other European regions.



Potential accessibility

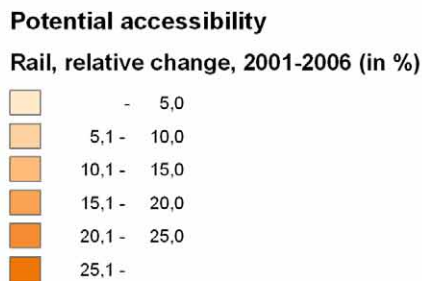
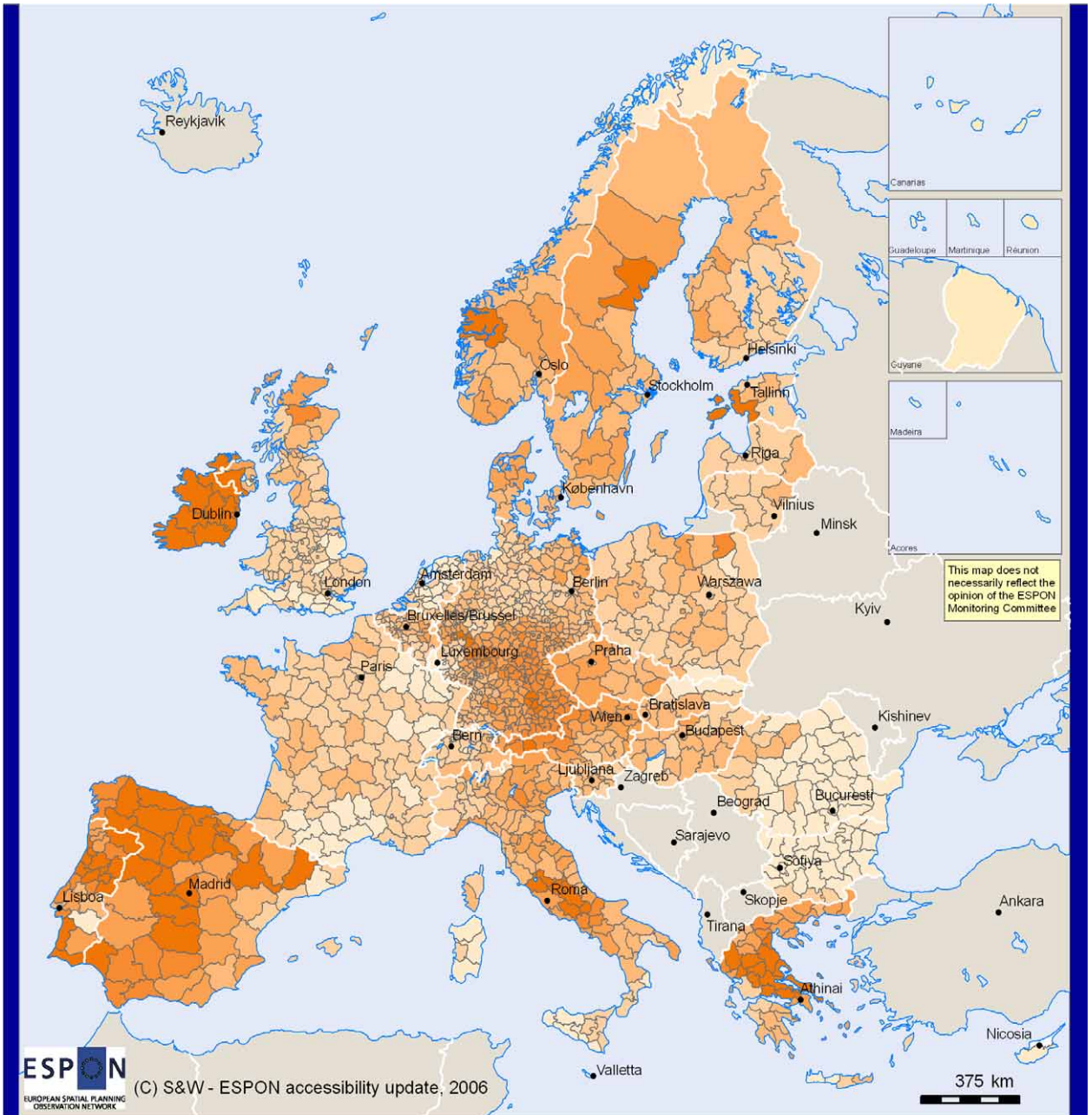
Rail, 2006 (EU27 = 100)



(C) EuroGeographics Association for the administrative boundaries

Data sources:
RRG GIS Database
S&W Accessibility Model

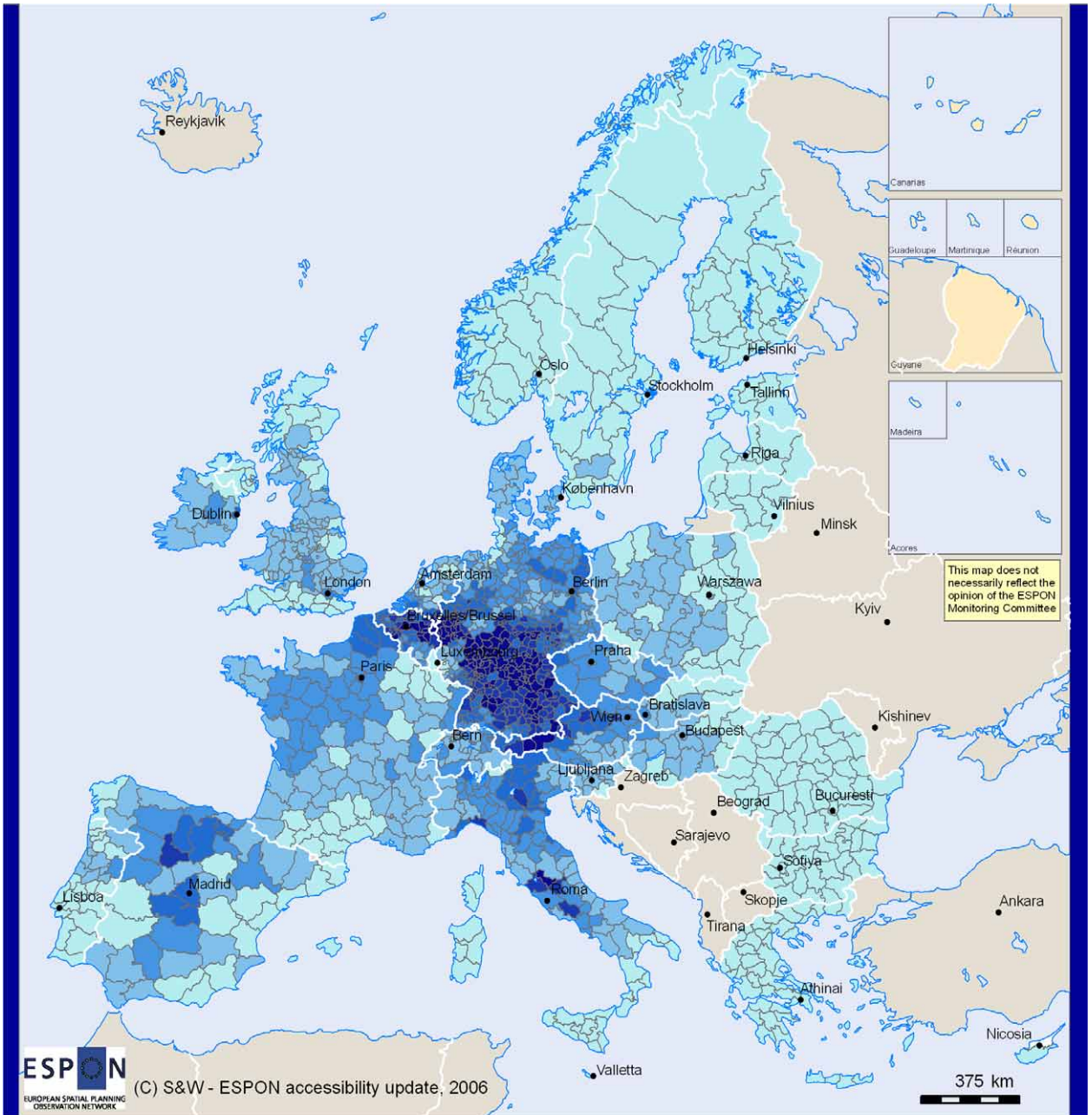
Figure 8 Potential accessibility by rail in 2006



(C) EuroGeographics Association for the administrative boundaries

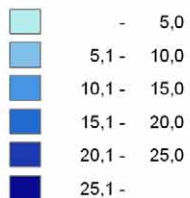
Data sources:
 RRG GIS Database
 S&W Accessibility Model

Figure 9 Potential accessibility by rail, relative change 2001-2006



Potential accessibility

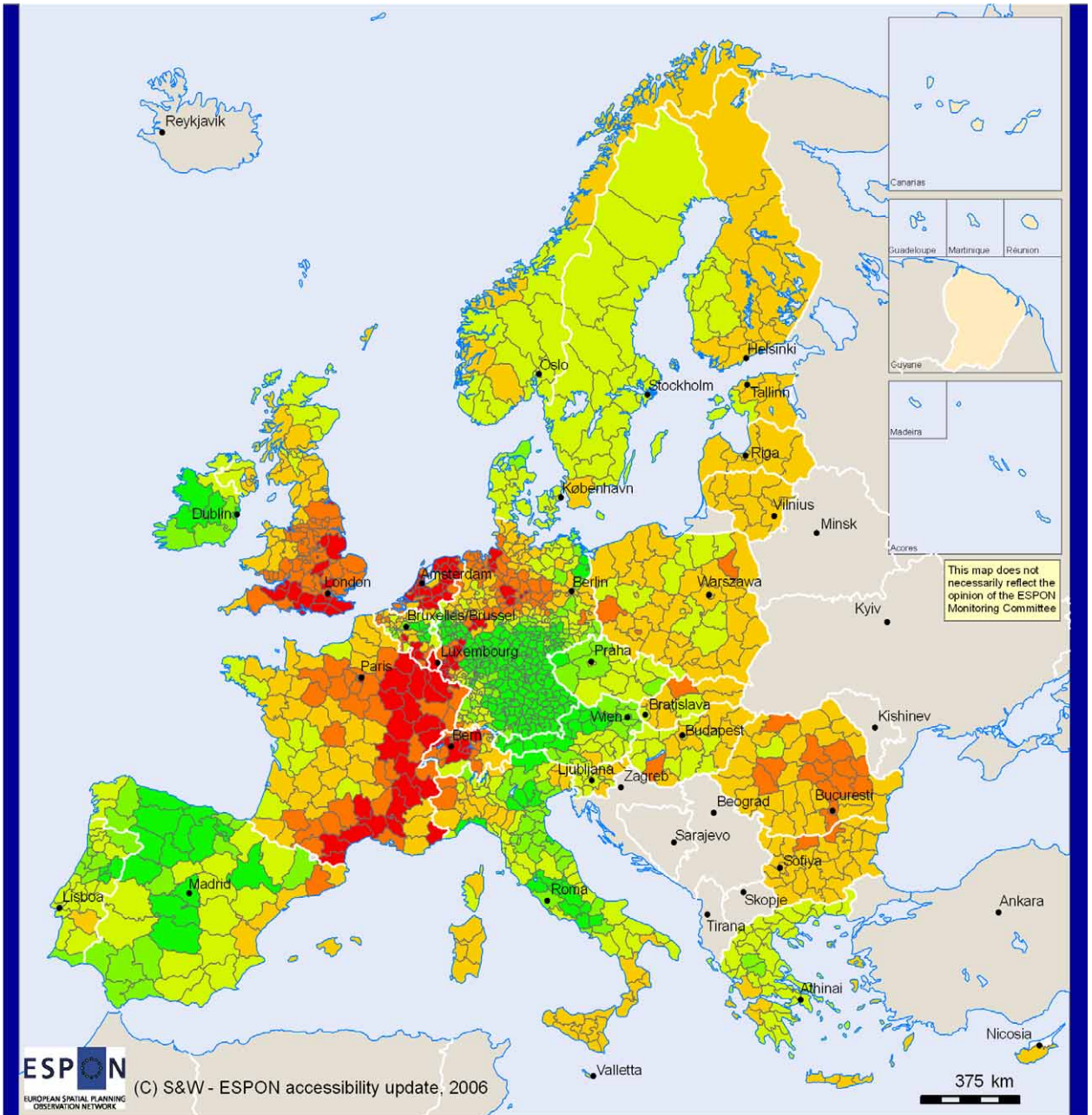
Rail, absolute change 2001-2006 (EU27 absolute average in 2006 = 100)



(C) EuroGeographics Association for the administrative boundaries

Data sources:
RRG GIS Database
S&W Accessibility Model

Figure 10 Potential accessibility by rail, absolute change 2001-2006



Potential accessibility

Rail, change of standardised index 2001-2006



(C) EuroGeographics Association for the administrative boundaries

Data sources:
RRG GIS Database
S&W Accessibility Model

Figure 11 Potential accessibility by rail, change of relative position of regions 2001-2006

5 Conclusions

The potential accessibility indicators updated in this study express the opportunities regions in Europe might gain from current transport infrastructure connecting them to the activities or facilities of interest. A number of observations can be made based on the spatial distribution of potential accessibility by road and rail and its recent development:

- Large disparities of accessibility by both, road and rail continue to exist in the European Union. Regional deficits in competitiveness based on poor location remain.
- The transport infrastructure development of the past years was not able to change the overall European spatial pattern of regions with good, moderate and low accessibility. And this cannot be expected in the future because central regions will remain central and peripheral regions peripheral.
- However, transport infrastructure projects can have substantial impacts on potential accessibility of individual regions. In particular, high-speed rail is able to reshape the European continent in terms of accessibility by bringing high accessibility to regions outside the European core.
- Due to the specific characteristics of road and rail networks, the resulting spatial patterns of regions with highest accessibility differ. Whereas road leads to a plateau of high accessibility, high accessibility by rail is much more concentrated around nodes and along corridors of high-speed rail lines.
- The process of EU enlargement had its impact on potential accessibility. In particular for road transport, the combined working of reduced border waiting times and infrastructure development has improved the situation in several regions of the new member states.
- The development of the accessibility indicators between 2001 and 2006 shows also the focus of the new member states on prioritising road infrastructure development at the expense of rail infrastructure and services. Whereas for potential accessibility by road, most regions in the new member states improved their relative position within the European Union, the opposite is true for accessibility by rail. Here, most regions that already belong to the group of peripheral regions even increase their distance to the European average of potential accessibility by rail.

- From a methodological point, attention has to be paid when looking at changes over time. Absolute change, relative change or change of the standardised index value might yield very different results for individual regions. Only by considering these three types of changes together, a full interpretation of the development can be given.

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