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

Applied Research 2013/1/10
Draft Final Report | Version 18/04/2014

Annex
Vol. 1 Chapters 10-13
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.

This report does not necessarily reflect the opinion of the members of the Monitoring Committee.

Information on the ESPON Programme and projects can be found on www.espon.eu

The web site provides the possibility to download and examine the most recent documents produced by finalised and ongoing ESPON projects.

This basic report exists only in an electronic version.

© ESPON & Spiekermann & Wegener, Urban and Regional Research (S&W), 2014.

Printing, reproduction or quotation is authorised provided the source is acknowledged and a copy is forwarded to the ESPON Coordination Unit in Luxembourg.
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. Then, the results of the accessibility indicators will be analysed in terms of territorial cohesion.

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.

The first comparison looks at the different generic indicator types. The correlation (as coefficient of determination, $r^2$) for the relationship between two indicators of different generic type was calculated, 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 ($r^2 = 0.68$).

Several indicators in TRACC were calculated for different transport modes. A second analysis gives 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 $r^2$ of between 0.7 and 0.9.
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 r² of 0.75 for the European potential accessibility freight indicator. Road freight accessibility and freight accessibility explain to a very high degree multimodal accessibility freight, however road is even higher than rail.

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 10.1 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 the same for different spatial context.

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 r² 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 r² 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 r² 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 r² 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.

How similar are the results of travel accessibility indicators compared to those for freight? From the 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 r² is for "European potential accessibility" by air (0.32). Highest correlations are for "Daily accessibility" by road (0.84) and "European potential accessibility" by rail (0.86), all other relationships are between these extremes.

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. Even more, for different analytical questions that arise in different circumstances request always the definition and implementation of appropriate accessibility indicators. Here, it is important to have indicators at different spatial contexts, ranging from the global down to the regional or even local, to have different types of generic indicators and their individual definition ranging from easy to understand travel cost indicators to more complex potential type indicators, and finally, it is important to differentiate between transport modes and between travel and freight indicators.
Table 10.1. Correlation between indicators for different spatial contexts

<table>
<thead>
<tr>
<th>Spatial context</th>
<th>Basic characteristic</th>
<th>Indicator 1</th>
<th>Indicator 2</th>
<th>Correlation ($r^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel</td>
<td></td>
<td>Access to global cities (Travel time to New York)</td>
<td>Access to top MEGAs (Average travel time to main MEGAs by fastest mode)</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Global travel connectivity (Number of intercontinental flights reachable in five hours)</td>
<td>European daily acc. travel (pop. in 5 h by fastest mode)</td>
<td>0.66</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Global pot. acc. travel (Intermodal acc. to seat capacity of intercontinental flights)</td>
<td>Europ. pot. acc. travel (to population multimodal)</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Global pot. acc. travel (Intermodal acc. to seat capacity of intercontinental flights)</td>
<td>Europ. pot. acc. travel (to population intermodal)</td>
<td>0.94</td>
</tr>
<tr>
<td>Freight</td>
<td></td>
<td>Global freight connectivity (Intercontinental container throughput reachable within 36 hours travel time by road)</td>
<td>Daily accessibility freight (GDP within allowed lorry driving time of 13 h)</td>
<td>0.69</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Global pot. acc. freight (to intercontinental container throughput by road)</td>
<td>Europ. potential acc. freight (to GDP by road)</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Global pot. acc. freight (to intercontinental container throughput by rail)</td>
<td>Europ. potential acc. freight (to GDP by rail unitised)</td>
<td>0.97</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Global pot. acc. freight (to intercontinental container throughput by water)</td>
<td>Europ. potential acc. freight (to GDP by water unitised)</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Global pot. acc. freight (to intercontinental container throughput multimodal)</td>
<td>Europ. potential acc. freight (to GDP by multimodal)</td>
<td>0.73</td>
</tr>
<tr>
<td>European v. regional Travel</td>
<td></td>
<td>European daily acc. travel (pop. in 5 h by road)</td>
<td>Avail. of urban functions (Cities in 60 minutes by road)</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>European daily acc. travel (pop. in 5 h by rail)</td>
<td>Avail. of urban functions (Cities in 60 minutes by rail)</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Europ. pot. acc. travel (to population by road)</td>
<td>National pot. acc. travel (to population by road)</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Europ. pot. acc. travel (to population by rail)</td>
<td>National pot. acc. travel (to population by rail)</td>
<td>0.21</td>
</tr>
<tr>
<td>Freight</td>
<td></td>
<td>Daily accessibility freight (GDP within allowed lorry driving time of 13 h)</td>
<td>Avail. of freight terminals (within 2 hours by lorry)</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Europ. potential acc. freight (to GDP by Road)</td>
<td>National potential acc. freight (to national GDP by lorry)</td>
<td>0.10</td>
</tr>
</tbody>
</table>
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 10.2). 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. To give a benchmark, the coefficient of variation for GDP per capita in the European Union is around 40 percent.

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, disparities in accessibility are about 50 percent higher than for the economic performance.
Table 10.2. Coefficient of variation for accessibility indicators

<table>
<thead>
<tr>
<th>Spatial context</th>
<th>Basic characteristics</th>
<th>Generic type of accessibility indicator</th>
<th>Travel cost</th>
<th>Cumulated opportunities</th>
<th>Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Global</strong></td>
<td><strong>Travel</strong></td>
<td>Access to global cities</td>
<td>Global travel connectivity</td>
<td>Flights to intercontinental destinations reachable in five h</td>
<td>76.7 intermodal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Travel time to New York</td>
<td>Global potential accessibility travel</td>
<td>To seat capacity of intercontinental flights departing in Europe</td>
<td>40.8 intermodal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13.8 intermodal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Freight</strong></td>
<td></td>
<td>Access to global freight hubs</td>
<td>Global freight connectivity</td>
<td>Intercontinental container throughput reachable within 36/48/72 hours</td>
<td>57.9 road 46.9 rail 285.7 water</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Generalised travel cost to intercontinental hubs</td>
<td>To container throughput of European sea ports</td>
<td>27.1 road 25.7 rail 31.2 water 25.5 multimodal</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>9.5 maritime New York</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>25.6 air New York</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>17.3 maritime Shanghai</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>22.8 air Shanghai</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Europe</strong></td>
<td><strong>Travel</strong></td>
<td>Access to top MEGAs</td>
<td>European daily accessibility travel</td>
<td>To population</td>
<td>72.2 road 87.1 rail 84.6 fastest mode</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Average travel time to top MEGAs</td>
<td>European potential accessibility travel</td>
<td>To population</td>
<td>59.5 road 61.6 rail 38.6 air 39.0 multimodal 35.5 intermodal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22.8 fastest mode</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Freight</strong></td>
<td></td>
<td>Access to nearest maritime port</td>
<td>European daily accessibility freight</td>
<td>GDP accessible within allowed lorry driving time</td>
<td>72.9 road</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Average generalised cost to nearest maritime port</td>
<td>To GDP</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>106.4 all modes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Regional</strong></td>
<td><strong>Travel (Europe-wide)</strong></td>
<td>Access to high-level transport infrastructure</td>
<td>Availability of urban functions</td>
<td>Cities &gt; 50.000 within 60 minutes travel time</td>
<td>135.9 road 155.3 rail</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ICON based access time to motorway exits, rail stations, airports</td>
<td>National potential accessibility travel</td>
<td>To national population</td>
<td>30.9 road 31.5 rail</td>
</tr>
<tr>
<td><strong>Freight</strong></td>
<td></td>
<td>Access to freight terminals</td>
<td>Availability of freight terminals</td>
<td>Freight terminals within 2 h travel time</td>
<td>111.4 road</td>
</tr>
<tr>
<td><strong>(Europe-wide)</strong></td>
<td></td>
<td>ICON based access time to freight terminals</td>
<td>National potential accessibility freight</td>
<td>To national GDP</td>
<td>23.7 road</td>
</tr>
<tr>
<td></td>
<td></td>
<td>49.1 all modes</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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 the corresponding chapter of the Scientific Report, 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 are 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. Here, only the Europe-wide accessibility changes are briefly presented.

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. 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 11.1). 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. 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 11.2. 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.
Accessibility potential, rail
Change 2001 - 2011 (%)

- < 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- > 50

Figure 11.1. Potential accessibility to population by rail, relative change 2001 – 2011
Accessibility potential, multimodal
Change 2001 - 2011 (%)

- < 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- > 50

Figure 11.2. Potential accessibility to population multimodal, relative change 2001 – 2011
12 Accessibility and regional development

As discussed in Chapter 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 socioeconomic 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 11.1. 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.

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).

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 assess 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-IIb 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.

**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 11.1):

- 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

<table>
<thead>
<tr>
<th>Code</th>
<th>Name</th>
<th>Countries</th>
<th>Network development</th>
<th>Infrastructure system improvement (travel time reduction by factor below)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2026</td>
</tr>
<tr>
<td>00</td>
<td>Baseline</td>
<td>All</td>
<td>Nothing after 2021</td>
<td>0.99</td>
</tr>
<tr>
<td>TA</td>
<td>Growth</td>
<td>EU15</td>
<td>TEN-T after 2021</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EU12</td>
<td>Nothing after 2021</td>
<td>0.99</td>
</tr>
<tr>
<td>TB</td>
<td>Cohesion</td>
<td>EU15</td>
<td>Nothing after 2021</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EU12</td>
<td>TEN-T after 2021</td>
<td>0.90</td>
</tr>
<tr>
<td>TC</td>
<td>Sustainability</td>
<td>All</td>
<td>TEN-T rail after 2021</td>
<td>rail:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Environmental tax on road and air</td>
<td>road:</td>
</tr>
</tbody>
</table>

Scenario results

Figure 12.2 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.

Figure 12.2. 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.

Figure 12.3 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).

Figures 12.4 and 12.5 shed some light on the cohesion and sustainability impacts of changes in accessibility:

Figure 12.4 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 12.4. TRACC SASI scenarios: Scenario comparison: coefficient of variation, accessibility travel road/rail v. GDP per capita, 1981-2051

Figure 12.5. TRACC SASI scenarios: Scenario comparison: CO₂ emission of transport, 1981-2051
Figure 12.5 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 CO₂ 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.

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? 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 touristic 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 getaways (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 loose 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.
- **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.

**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.
The ESPON 2013 Programme is part-financed by the European Regional Development Fund, the EU Member States and the Partner States Iceland, Liechtenstein, Norway and Switzerland. It shall support policy development in relation to the aim of territorial cohesion and a harmonious development of the European territory.