ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 3 (2014) 319 – 328

Transportation Research Procedia

www.elsevier.com/locate/procedia

17th Meeting of the EURO Working Group on Transportation, EWGT2014, 2-4 July 2014, Sevilla, Spain

Potential impacts on accessibility and consumer surplus of improvements of the European railway system

Rotoli F.[a]* , Christidis P.[a], Vannacci L.[a], Lopez-Ruiz H. G.[a],

Navajas C. E.[a], Ibáñez R. N.[a]

[a] *European Commission, Joint Research Centre – Institute for Prospective Technological Studies (IPTS) , Economics of Climate Change, Energy & Transport Unit (ECCET), Edificio EXPO - C/ Inca Garcilaso 3 , E-41092 Seville, Spain*

Abstract

It is widely accepted that "transport infrastructure endowment influences competiveness of a Region; the provision of investment in transport infrastructure entails positive effects on productivity and growth, even if on the other side, heavy infrastructures (as railway lines) could affect negatively on the environment" (5th Cohesion Report, 2010). This article aims to explore the potential impact of improvements of the passenger rail network in order to evaluate how these could potentially increase accessibility and consumer surplus in EU regions; it summarizes the results of the model simulations carried out with a combination of the TRANSTOOLS rail network and the assignment module of Traffic Analyst.

Three different scenarios have been tested by changing speeds on the whole network. The post-processing analysis has been carried out with utilities developed in Matlab, while the results for each zone (at NUTS3 level) have also been reported in easy-to-read ArcGIS maps. The outcomes provide insight into how the demand for passenger rail transport would react and where the highest benefits and costs, in terms of accessibility and consumer surplus gains, can be expected. This information, in turn, can be useful for the prioritization of investment needs and the identification of parts of the rail passenger market where new demand may be generated.

Selection and peer-review under responsibility of the Scientific Committee of EWGT2014

Keywords: Accessibility; Welfare; European railway system; Transport simulation and policy;

Disclaimer: *The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.*

* Corresponding author. *E-mail address:* Francesco.Rotoli@ec.europa.eu

Selection and peer-review under responsibility of the Scientific Committee of EWGT2014
doi:10.1016/j.trpro.2014.10.012

1. Introduction

Transport infrastructure endowment influences competiveness of a Region enabling spatial interaction, i.e. the mobility of people and goods for social, cultural or economic activities; the features of a transport system in terms of capacity, connectivity, travel speeds etc. determine the locational advantage/disadvantage of an area (i.e. a region, a city, etc.) relative to other zones.

The crucial role of transport infrastructures and related investments is highlighted either in several EU projects or in the White Paper on Transport (2011): "Infrastructure shapes mobility. No major change in transport will be possible without the support of an adequate network and more intelligence in using it. Overall, transport infrastructure investments have a positive impact on economic growth, create wealth and jobs, and enhance trade, geographical accessibility and the mobility of people. It has to be planned in a way that maximises positive impact on economic growth and minimises negative impact on the environment".

In practice, "the provision of investment in transport infrastructure entails positive effects on productivity and growth, even if on the other side, heavy infrastructures (as railway lines) could affect negatively on the environment" (5th Cohesion Report, 2010); production and other economic activities can be carried out more efficiently as the quality and the capacity of a region's transportations networks increase (Forslund and Johansson, 1995).

This article aims to explore the potential impact of improvements of the European railway system in order to evaluate how these could increase accessibility and consumer surplus for rail passenger in the EU regions. It summarizes the results of the model simulations carried out with a combination of the TRANSTOOLS rail network and the assignment module of Traffic Analyst.

Three different scenarios have been tested: two scenarios simulating respectively increases of speed at least up to 90 km/h or up to 200 km/h and one scenario assuming decreases of speed down to 45 km/h on the whole network.

For each scenario first the effects on travel time between each couple of EU regions have been investigated in order to evaluate the accessibility indexes; then on the basis also of the new levels of demand, the consumer surplus analysis has been carried out.

The results provide insight into how the demand for passenger rail transport would react and where the highest benefits and costs in terms of accessibility and consumer surplus gains can be expected. This information, in turn, could be useful for the prioritization of investment needs and the identification of parts of the rail passenger market where new demand may be generated.

Regarding the structure of the paper, after this introduction, Paragraph 2 provides a brief review of the technical literature on accessibility and consumer surplus while in Paragraph 3 the proposed methodology is described; the outcomes of our analysis are reported in Paragraph 4 and finally Paragraph 5 sets out our conclusions.

2. Brief review of technical literature

2.1. Accessibility

The topics of accessibility and related indicators have been widely treated in the scientific literature of the last years (Schürmann et al., 1997, Linneker, 1997, Vickerman, 1995, Wegener et al., 2002, Van Wee et al., 2011, Spiekermann and Neubauer, 2002, Geurs et al., 2004, Salze et al., 2011, Gutiérrez, 2001,) and also in several European and international research projects or studies (e.g. ESPON 2007, TIPTAP ESPON project, NECTAR – Cluster 6, Cohesion reports, etc.).

The definition of accessibility slightly differs among of various authors, anyway it can be defined as 'the amount of effort for a person to reach a destination' or 'the number of activities which can be reached from a certain location' (Geurs et al., 2001); 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).

As highlighted in Wegener et al., 2002, accessibility indicators could vary in complexity and they may be sensitive to several dimensions; they might be calculated, inter alia, in function of: origin, destination, spatial impedance, type and mode of transport. In our analysis we focused on EU regions at NUTS3 level (origin and destination) and on rail passenger services; moreover the spatial impedance between two zones is assumed equal to the travel time along the minimum path linking the regions over the rail network (network impedance approach).

In past studies the accessibility has been analyzed using various indicators; Geurs et al. (2004) for example identify four basic perspectives on measuring accessibility:

- Infrastructure-based indicators analyze the (observed or simulated) performance or service level of transport infrastructure (i.e. level of congestion, travel times by train, density of networks, etc.).
- Location-based indicators describe the accessibility of a location to spatially distributed activities (i.e. the number of jobs within 30 minutes travel time from the origin zone).
- Person-based measures analyze accessibility at the individual level, incorporating spatial and temporal constraints (i.e. the activities in which an individual can participate at a given time).
- Utility-based indicators describe the economic benefits that people derive from access to the spatially distributed activities, interpreting accessibility as the outcome of a set of transport choices.

This paper tries to evaluate the effects of improvements of the European railway system by means of potential and daily accessibility measures, as better described in paragraph 3.

2.2. Consumer surplus

Consumer surplus, the consumer's willingness to pay above the market price, is the most common way of evaluating economic benefits of (transport) projects. This measure is often called Marshallian consumer surplus and it has been widely treated in the technical literature (Geurs et al., 2001, Cascetta, 2009, Eijgenraam et al., 2000, UK TAG Unit 3.5.3); the impacts (of transport investments) perceived by users can be calculated as a change in net perceived utility (or surplus) associated with the travel choices made in the project and non-project situations (Cascetta, 2009).

The most common category of direct benefits associated with any given transport project is represented by travel time savings; travel time savings can be expressed in monetary terms by means of values of time, differing for example by purpose of journey, mode, etc. (Geurs et al., 2001, UK TAG Unit 3.5.6, US DOT Guidance).

In our analysis for each scenario the total change in consumer surplus has been calculated using the rule-of-half formula (assuming implicitly that there is a linear relationship between the cost of travel and the demand); the demand has been expressed as number of trips by rail and the price as travel time (generalized cost). Moreover we have assumed a monetary evaluation of time savings for each trip purpose according to the values of time suggested in the TAG Unit 3.5.6 (UK Department of Transport).

3. Methodology

As briefly described above, this article summarizes the results of the model simulations carried out in order to estimate the potential impacts of changes in speed for the whole European railway system.

The model simulations were carried out with a combination of the TRANSTOOLS rail network and Traffic Analyst; the TRANSTOOLS model (http://energy.jrc.ec.europa.eu/transtools/) provides a detailed network for passenger rail and its assignment module (Traffic Analyst, <www.rapidis.com/products/traffic-analyst/>) allows the model to capture changes in route choice as result of the hypothesized changes in speed.

The demand levels between origins and destinations at NUTS 3 level (i.e. provinces) for the baseline (2005) have been assumed according to the ETISPlus data (the EU NUTS regional classification is described in http://epp.eurostat.ec. europa.eu/portal/page/portal/nuts_nomenclature/introduction). The impacts on total transport demand and modal shift have been forecasted for each alternative scenario using the demand module.

Finally the post-processing analysis has been carried out with utilities developed in Matlab and the results for each zone have been also reported in easy-to-read ArcGIS maps.

Three different scenarios have been implemented by changing speeds as follows:

- *Scenario 200 km/h:* speed increased up to 200 km/h for all links that currently have a speed lower than 200 km/h. For links with current speed higher than 200 km/h (high speed trains), no changes were introduced.

- *Scenario 90 km/h:* speed increased up to 90 km/h for all links that currently have a speed lower than 90 km/h. For links with current speed higher than 90 km/h, no changes were introduced.
- *Scenario 45 km/h:* speed decreased down to 45 km/h for all links that currently have a speed higher than 45 km/h. For links with current speed lower than 45 km/h, no changes were introduced.

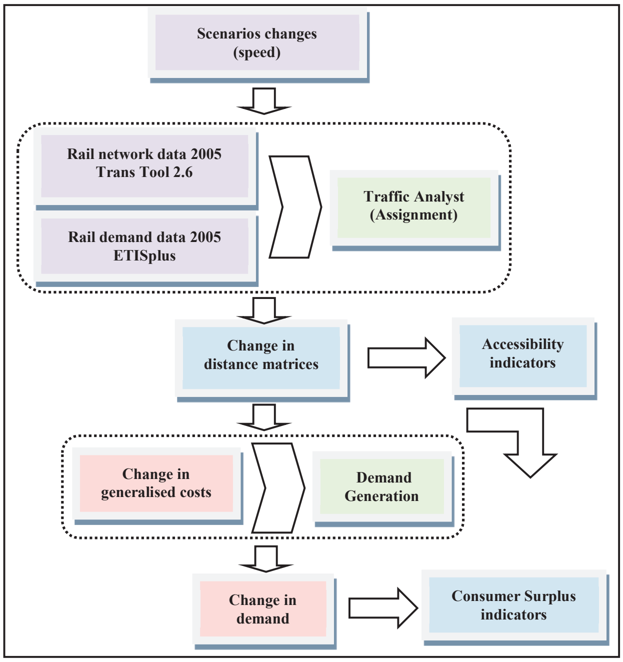

Fig. 1 Flowchart of methodological steps

In practice the article has considered the best and worst (hypothetic) network settings by simulating respectively the Scenario 200 km/h and Scenario 45 km/h; this last one hypothesizes a degradation of the current network (or better an imaginary configuration previous to the baseline), to evaluate the benefits of the existing infrastructure endowment compared to this lower bound.

Subsequently the analysis has estimated the effects of more feasible and less ambitious interventions such as increases of speed on some links (i.e. Scenario 90 km/h).

3.1. Accessibility

Regarding the accessibility analysis, for each alternative scenario the characteristics of the network have been changed and the ALL-OR-NOTHING assignment module (with generalized cost depending only on travel time) has been run. According to the new travel times between each couple OD, for each scenario, various potential accessibility indicators have been evaluated.

As well know, 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):

$$A_{i\,m}(t) = \sum_j W_j(t) * F(c_{ij}(t)) \tag{1}$$

where $A_{im}(t)$ is the accessibility of zone i by mode m (rail in our analysis) in year t, $W_j(t)$ is the activity to be reached at zone j (in our case the population of the destination j) and $F(c_{ij}(t))$ is the impedance function depending on the generalized cost (c_{ij}) of reaching area j from area i. The attraction term sometimes (not in this study) is weighted by an exponent α greater than one (W_j^{α}) to take account of agglomeration effects.

Summarizing, A_i represents the total of the activities reachable in j weighted by the ease of getting from i to j.

As described by the impedance function, the interaction between locations declines with any increase in disutility (distance, time, and costs) between them. In general the perception and the valuation of the distance between an origin and a destination differ according to transport modes, purpose of trips, characteristics of the household and of the destination (Geurs et al., 2001); in the present paper we have focused on rail mode, on the population of destination and on three different travel purposes (business, work/commute, non-work) even if the reported results are not referred to each purpose but only to the total trips.

As also proposed in other studies (Spiekermann and Wegener, 1996; ESPON 2007) our analysis has used centroids of NUTS3 regions as origins and destinations. The ALL-OR-NOTHING assignment module has evaluated the minimum paths through the networks, i.e. the path with minimum travel times between the centroids of the NUTS3 regions. For each zone the value of the potential accessibility indicator has been calculated by summing up the population in all other regions weighted by the travel time to go there (by means of the impedance functions);

Several forms of distance decay function have been already used and described in past accessibility studies; this analysis has considered five different shapes depending on travel time (disutility):

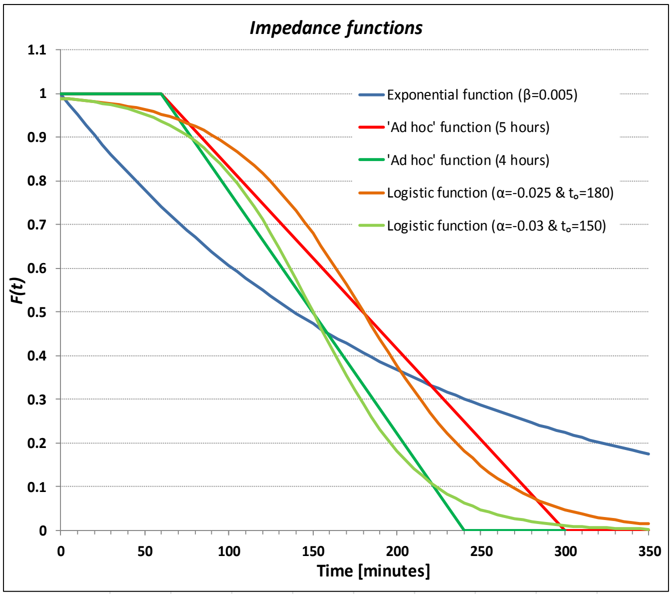

Fig. 2 Considered impedance functions

- a negative exponential function with β=0.005:

$$F(t_{ij}) = e^{-\beta t} \tag{2}$$

- two generalized logistic functions dropping almost to zero after four or five hours (to represent the total population that can be reached from region i within a certain time or cost limit, in this case 4 or 5 hours) and with equation (α=-0.03, t_0 =150 minutes or α =-0.025, t_0=180 minutes respectively):

$$F(t_{ij}) = \frac{1}{\left(1 + e^{-\alpha(t-t_0)}\right)} \tag{3}$$

- two *'ad hoc'* functions dropping to zero after four or five hours (see figure 2);

The previous figure reports the above described impedance functions to better analyze and compare the shapes and the differences among of them; each function entails a different accessibility measure:

- for the exponential function β has been set to 0.005, so considering a null travel time between two regions, the population of the destination zone would be totally included (100%) in the accessibility measure of the origin, but any increase in travel time implies a decrease in *F(t)*; it reaches a value of 0.5 after about 2 hours, and goes down to about 0.2 after 5 hours;
- the logistic functions entail daily accessibility measures which consider almost completely (> 95%) the population of destinations with distance in travel time lower than 60 minutes, while *F(t)* falls almost to zero after four or five hours;
- finally this study proposes also two *'ad hoc'* impedance functions dropping linearly from 1 to zero with travel times within 1 and 4 (or 5) hours; since the calculations of accessibility have been implemented in Matlab with a post-processing application, it has not been difficult to reproduce the proposed shapes.

The obtained results have been exported and represented in tabular form and also in easy-to-read ArcGis Maps (see Paragraph 4)

3.2. Consumer surplus

As already highlighted in the previous paragraph, the accessibility analysis has focused on the new travel times (due to the proposed interventions) between each couple OD. To carry out the consumer's surplus analysis, instead, it has been necessary to forecast also the new demand level for each scenario by means of the demand generation module.

Of course a rise in speed on the railway links entails a reduction in travel time and an increase in level of demand; vice-versa decreases of the current speeds on the network (baseline 2005) down to 45 km/h (degraded scenario) imply rises in travel time and reductions in demand.

The total consumer's surplus can be calculated using the rule-of-half formula, expressing the demand as number of trips by rail and the price as generalized cost (in our case travel time):

$$CS = \frac{1}{2}\sum\left(T_{ij}^{m^0} + T_{ij}^{m^1}\right)\left(c_{ij}^{m^0} - c_{ij}^{m^1}\right) \quad (4)$$

To evaluate and to represent the consumer's surplus for each NUTS3 Region, the summation in the previous formula has been extended to all the couples OD with fixed origin i and variable destination j.

Moreover, also a monetary evaluation of the new scenario benefits has been implemented by multiplying in (4) the time saving for each trip purpose by the following monetary values of time, as suggested in the TAG Unit 3.5.6 of the UK Department of transport:

- Business (working time): 47.12 pound/h = 47.12 *1.2 euro/h
- Commuting (non-working time): 6.46 pound/h = 6.46*1.2 euro/h
- Non work (non-working time): 5.71 pound/h = 5.71*1.2 euro/h

The exchange rate from pound to euro has been assumed equal to 1.2.
Also the results of this analysis (variation in demand, consumer surplus and its monetary evaluation) have been reported both in tables and in ArcGis maps.

4. Results

As reported below, the results of this study show as the current railway infrastructure endowment already benefits many regions mainly in Italy, Spain, Germany, Netherlands, UK, Austria, France, Belgium, etc. but improvements in speed could still increase significantly the accessibility and the consumer's surplus of the countries outside the European core, as Poland, Bulgaria, Romania, Slovakia, etc..

Moreover, in the author’s opinion, the monetary evaluation of the consumer's surplus can represent an economic measure of what the travelers are willing to pay but do not pay and it might be considered a slightly indication of theoretically available room in the market (depending also on the actual feasibility of the interventions).

To allow a more detailed analysis of the outcomes, table 1 shows the estimated percentage variation of all the considered accessibility indicators (at country level and between each alternative scenario and the baseline 2005); it reports also the average speed on the network weighted on the length of the links.

All the proposed scenarios show a positive impact on the accessibility level for each country; also the current infrastructure endowment presents a significant variation in accessibility compared to a hypothetical degraded scenario with maximum speed of 45 km/h on the whole network.

Table 1 Percentage of variation in accessibility of all the alternative scenarios vs baseline and average speed on the network

	Baseline 2005 Vs Scenario 45 km/h*					**Scenario 90 km/h Vs Baseline 2005**					**Scenario 200km/h Vs Baseline 2005**					**Average Speed on the network weighted on the length of links**			
Country	PA-E	PA-4A	PA-4	PA-5A	PA-5	PA-E	PA-4A	PA-4	PA-5A	PA-5	PA-E	PA-4A	PA-4	PA-5A	PA-5	Scenario 45	Baseline 2005	Scenario 90	Scenario 200
Austria	76%	48%	52%	58%	61%	27%	28%	30%	37%	35%	390%	584%	600%	762%	695%	44.6	86.0	94.4	200.0
Belgium	81%	69%	74%	77%	78%	7%	19%	18%	21%	18%	113%	439%	376%	376%	328%	44.8	92.1	101.1	201.1
Bulgaria	45%	15%	16%	24%	25%	53%	28%	29%	39%	41%	506%	291%	294%	387%	395%	44.9	67.3	90.1	200.0
Czech Republic	65%	10%	15%	28%	31%	42%	29%	34%	68%	56%	449%	543%	551%	797%	758%	45.0	70.8	91.2	200.0
Germany	80%	67%	69%	73%	73%	14%	29%	28%	29%	27%	193%	425%	399%	407%	386%	44.7	94.0	105.6	200.2
Denmark	67%	28%	29%	43%	41%	22%	8%	8%	10%	10%	285%	103%	108%	123%	134%	44.6	83.0	98.7	200.0
Estonia	28%	6%	7%	16%	13%	39%	12%	7%	6%	12%	631%	57%	52%	82%	90%	43.8	62.0	90.0	200.0
Spain	77%	20%	29%	40%	45%	1%	0%	0%	0%	1%	65%	45%	42%	77%	63%	45.0	147.1	147.9	201.9
Finland	39%	3%	6%	9%	12%	7%	1%	1%	1%	1%	228%	20%	29%	66%	59%	45.0	92.0	96.9	200.0
France	86%	47%	52%	64%	66%	2%	1%	1%	1%	1%	94%	102%	97%	113%	111%	44.4	140.9	142.2	204.9
Greece	47%	21%	23%	30%	32%	32%	18%	18%	25%	24%	418%	206%	189%	236%	241%	45.0	77.8	94.8	200.0
Croatia	63%	13%	19%	29%	30%	47%	18%	20%	24%	25%	656%	258%	252%	290%	324%	44.7	83.3	98.7	200.0
Hungary	56%	26%	30%	41%	41%	48%	34%	38%	63%	55%	535%	483%	479%	582%	569%	44.6	67.4	90.2	200.0
Ireland	40%	10%	13%	22%	23%	17%	2%	3%	7%	6%	73%	123%	114%	167%	157%	45.0	80.3	93.8	200.0
Italy	71%	45%	49%	57%	59%	9%	15%	14%	22%	18%	176%	249%	224%	256%	248%	44.9	101.6	107.7	200.1
Lithuania	43%	7%	8%	15%	14%	61%	17%	16%	23%	24%	674%	129%	140%	196%	215%	44.4	77.4	90.7	200.0
Luxembourg	87%	64%	70%	81%	83%	8%	17%	16%	19%	18%	151%	798%	668%	730%	599%	45.0	78.2	91.4	200.0
Latvia	41%	0%	3%	8%	8%	26%	1%	2%	3%	4%	489%	54%	55%	112%	108%	45.0	80.1	97.1	200.0
Netherlands	73%	61%	63%	65%	67%	8%	16%	16%	13%	14%	159%	395%	367%	366%	347%	44.8	87.3	94.1	200.0
Poland	53%	13%	15%	26%	26%	49%	26%	26%	37%	39%	454%	322%	326%	464%	460%	44.7	69.4	92.3	200.4
Portugal	77%	54%	59%	69%	69%	0%	0%	0%	0%	0%	56%	57%	53%	66%	57%	45.0	138.3	139.1	200.0
Romania	48%	8%	11%	20%	21%	33%	8%	9%	18%	16%	425%	132%	145%	232%	236%	45.0	75.2	90.9	200.0
Sweden	51%	0%	3%	4%	9%	16%	0%	0%	1%	1%	174%	4%	18%	67%	54%	43.8	91.6	104.4	200.0
Slovenia	71%	44%	46%	48%	50%	48%	93%	82%	72%	78%	548%	707%	675%	678%	715%	44.0	68.7	90.7	200.0
Slovak Republic	56%	22%	26%	35%	34%	50%	23%	22%	26%	31%	518%	365%	374%	530%	533%	44.5	68.7	90.4	200.0
United Kingdom	71%	56%	59%	63%	64%	7%	9%	9%	10%	9%	125%	246%	218%	241%	215%	44.7	96.6	103.5	200.0

*The reported values are calculated as percentage of variation referred to the Baseline, so with the formula (Accessibility_2005 – Accessibility_45km/h)/Accessibility_2005

PA-E: Potential accessibility with exponential decay function

PA-4A: Potential accessibility with 'ad hoc' decay function dropping to zero after 4 hours

PA-4: Potential accessibility with logistic decay function dropping almost to zero after 4 hours

PA-5A: Potential accessibility with 'ad hoc' decay function dropping to zero after 5 hours

PA-5: Potential accessibility with logistic decay function dropping almost to zero after 5 hours

In particular, considering the scenario 45 km/h versus the baseline, the variation in potential accessibility (utilizing an exponential decay function) is always higher than the variation in potential daily accessibility (travel time within 4 or 5 hours); however the difference among of the five indicators varies according to the specific country.

For the peripheral and border regions (Finland, Sweden, Denmark, Estonia, Latvia, Lithuania, Greece, Croatia, Bulgaria, Romania, Ireland, Poland), there is a significant difference between the values of percentage variation for the potential or the daily accessibility; this effect could be explained also by the geographical position of these regions (lower mass of activity to be reached within short time) in addition to their infrastructure characteristics.

Even comparing, for example, the results for Netherlands, Germany, Belgium and the data obtained for France or Spain, they could in part be influenced by their location and likely also by the different size of the NUTS3 regions in the core of Europe; a denser grid could imply higher daily accessibility value than a sparse one.

Considering, for instance, two large neighboring areas with travel time of a bit more than 5 hours, by splitting the destination region in several smaller zones, part of the population could be included in the accessibility measure of the origin region, even if with a low weight due to the travel time likely still close to five hours.

These effects are even more evident comparing the scenario with increases in speed up to 200 km/h and the baseline; the core regions (Germany, Belgium, Luxembourg, Netherlands, Austria, etc.), central and characterized by a smaller region definition, present a relative variation in daily accessibility (within 4 or 5 hours) bigger than the variation in potential accessibility (with exponential impedance function); conversely the peripheral countries

(Finland, Sweden, Denmark, Estonia, Latvia, Lithuania, Greece, Croatia, Bulgaria, Romania) show an opposite tendency.

Table 2 Percentage variation in time, demand, accessibility, consumer surplus and its monetary evaluation (alternative scenarios vs baseline)

	Baseline 2005 Vs Scenario 45 km/h*					Scenario 90 km/h Vs Baseline 2005					Scenario 200km/h Vs Baseline 2005				
Country	% Time	% Demand	% Potential accessibility	% Consumer's surplus	% Monetary evaluation	% Time	% Demand	% Potential accessibility	% Consumer's surplus	% Monetary evaluation	% Time	% Demand	% Potential accessibility	% Consumer's surplus	% Monetary evaluation
Austria	68%	-27%	-76%	-64%	-64%	-4%	2%	27%	6%	6%	-35%	19%	390%	48%	48%
Belgium	82%	-44%	-81%	-81%	-81%	-2%	2%	7%	3%	3%	-33%	33%	113%	40%	40%
Bulgaria	34%	-10%	-45%	-36%	-36%	-13%	5%	53%	14%	14%	-39%	15%	506%	51%	51%
Czech Republic	49%	-17%	-65%	-49%	-49%	-12%	5%	42%	14%	14%	-44%	21%	449%	53%	53%
Germany	69%	-20%	-80%	-91%	-91%	-4%	2%	14%	5%	5%	-28%	11%	193%	39%	39%
Denmark	37%	-24%	-67%	-57%	-57%	-18%	15%	22%	5%	5%	-30%	27%	285%	32%	32%
Estonia	20%	-7%	-28%	-23%	-23%	-11%	6%	39%	14%	14%	-27%	18%	631%	38%	38%
Spain	133%	-30%	-77%	-147%	-147%	-0.07%	0.00%	1%	0%	0%	-13%	4%	65%	14%	14%
Finland	55%	-31%	-39%	-47%	-47%	-1%	1%	7%	1%	1%	-23%	21%	228%	29%	29%
France	104%	-22%	-86%	-132%	-132%	-0.24%	0.06%	2%	0%	0%	-14%	4%	94%	15%	15%
Greece	45%	-20%	-47%	-47%	-47%	-9%	4%	32%	11%	11%	-34%	16%	418%	46%	46%
Croatia	25%	-12%	-63%	-43%	-43%	-4%	2%	47%	12%	12%	-17%	9%	656%	42%	42%
Hungary	45%	-14%	-56%	-43%	-43%	-15%	5%	48%	17%	17%	-48%	14%	535%	56%	56%
Ireland	57%	-46%	-40%	-51%	-51%	-5%	6%	17%	6%	6%	-33%	54%	73%	54%	54%
Italy	79%	-28%	-71%	-80%	-80%	-2%	1%	9%	3%	3%	-25%	16%	176%	33%	33%
Lithuania	20%	-6%	-43%	-29%	-29%	-14%	4%	61%	17%	17%	-32%	11%	674%	45%	45%
Luxembourg	91%	-100%	-87%	-71%	-71%	-5%	3%	8%	6%	6%	-38%	175%	151%	85%	85%
Latvia	19%	-12%	-41%	-49%	-49%	-1%	1%	26%	4%	4%	-11%	7%	489%	31%	31%
Netherlands	56%	-33%	-73%	-51%	-51%	-2%	2%	8%	2%	2%	-28%	24%	159%	41%	41%
Poland	38%	-13%	-53%	-43%	-43%	-14%	6%	49%	17%	17%	-42%	18%	454%	55%	55%
Portugal	108%	-44%	-77%	-123%	-123%	-0.004%	0.000%	0%	0%	0%	-7%	4%	56%	14%	14%
Romania	37%	-11%	-48%	-40%	-40%	-8%	3%	33%	11%	11%	-32%	12%	425%	43%	43%
Sweden	63%	-25%	-51%	-64%	-64%	-2%	1%	16%	4%	4%	-22%	11%	174%	27%	27%
Slovenia	42%	-39%	-71%	-35%	-35%	-19%	32%	48%	23%	23%	-51%	120%	548%	91%	91%
Slovak Republic	43%	-14%	-56%	-46%	-46%	-15%	5%	50%	18%	18%	-47%	24%	518%	62%	62%
United Kingdom	57%	-24%	-71%	-68%	-68%	-3%	2%	7%	4%	4%	-26%	15%	125%	36%	36%

*The reported values are negative since calculated as variation between the Baseline and the Scenario 45 km/h (so considering to downgrade the current infrastructure endowment)

Here we would point out that, although technically not feasible (or hardly achievable), the scenario 200 km/h tries to represent an extreme 'optimum' situation, an upper limit for the rail network, as well as the scenario 45 km/h represents a lower bound, with which comparing more plausible and less ambitious interventions (i.e. scenario 90 km/h).

The table 2 shows for each scenario and at country level the variation (with respect to the baseline) in travel time, demand, potential accessibility (only exponential decay function), consumer surplus and its monetary evaluation, while figure 3 reports graphically the percentage variation in potential accessibility and in consumer surplus for each scenario and for each region.

The countries with higher average speed on the network (Spain, France, Italy, Germany, Portugal, Belgium) present the most benefits in terms of travel time, demand and consumer surplus comparing the do-nothing scenario with the degraded hypothesis (45 km/h), but they can expect very small gains by increasing the speed at least up to 90 km/h on the whole network. On the contrary, areas such as Slovenia, Slovak Republic, Poland, Lithuania, Hungary, Estonia, Bulgaria or Czech Republic, presenting lower average speed and taking less advantage of their actual infrastructure endowment, can still benefit of improvements in speed.

Of course these benefits increase significantly if the speed on the whole European railway network is upgraded at least to 200 km/h; the most gains in terms of both accessibility and consumer surplus can still be expected in the areas outsides the core of Europe, even if profits could be spread out around the whole continent, as evident also from the maps in figure 3.

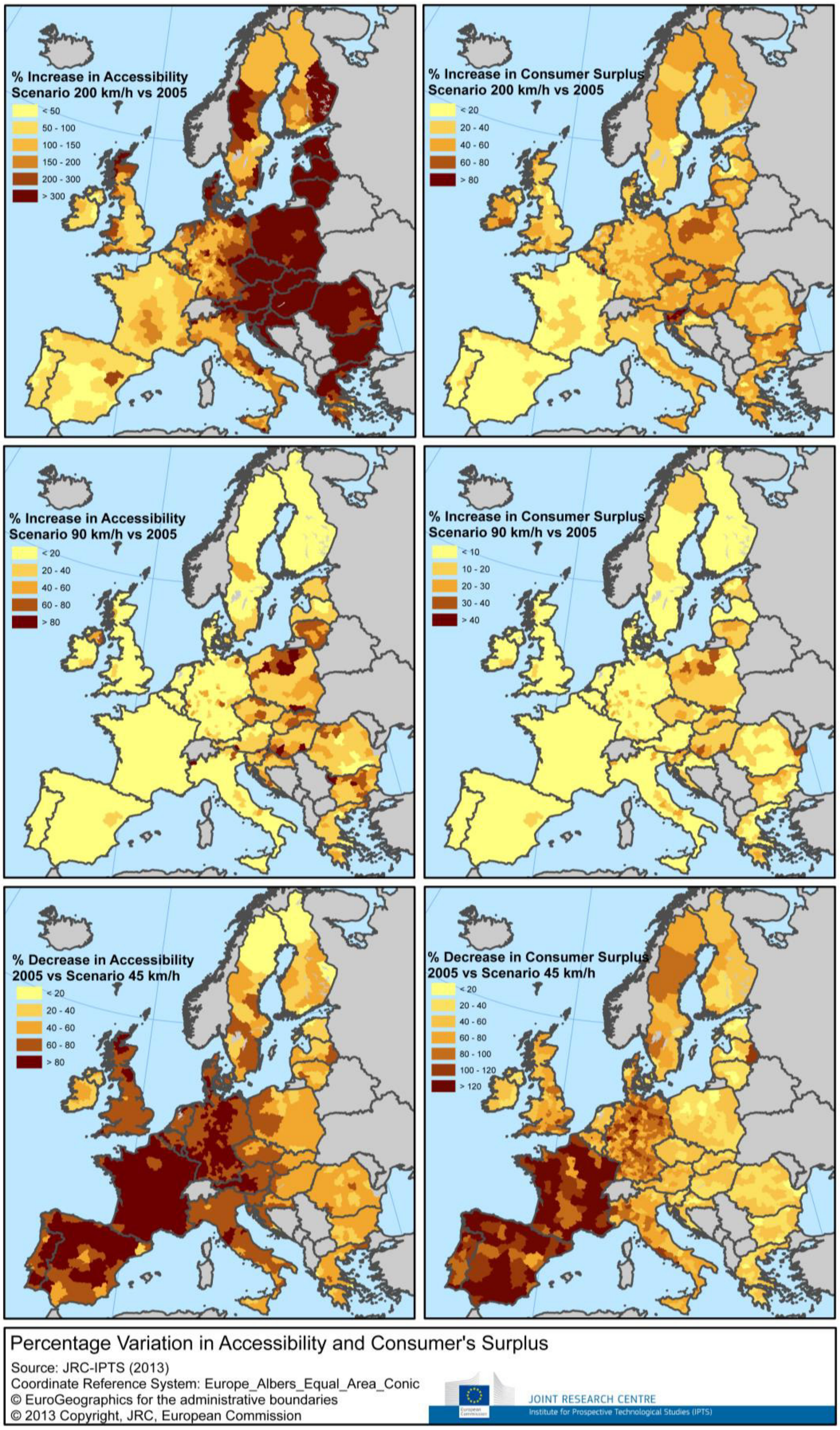

Fig. 3 Percentage variation in potential accessibility and in consumer surplus for each scenario

Conclusions

As already highlighted above, this article has tried to explore the impacts of improvements of the European railway system in order to evaluate how these could potentially increase accessibility and consumer surplus for passengers in EU regions; it summarizes the results of the model simulations carried out with a combination of the TRANSTOOLS rail network and the assignment module of Traffic Analyst.

Three different scenarios have been tested: two scenarios simulating increases of all speeds at least up to 90 km/h or 200 km/h and one scenario assuming a decrease down to 45 km/h on the whole network; the outcomes provide insight into how the demand for passenger rail transport would react and where the highest benefits and costs, in terms of accessibility and consumer surplus, can be expected. This information, in turn, could also be useful for the prioritization of investment needs and the identification of parts of the rail passenger market where new demand may be generated.

In particular, the results of the study show as the current European railway system already benefits many regions (mainly in Italy, Spain, Germany, Netherlands, UK, Austria, France, Belgium, etc.) but improvements in speed could still increase significantly the accessibility and the consumer's surplus of various areas (mainly outside the core) of Europe (as in Poland, Bulgaria, Romania, Slovakia, etc.).

Moreover the results suggest that the geographical location and the different size of the NUTS3 regions in the core of Europe could in part influence the measures of the potential and daily accessibilities; a further research development could attempt to better describe/analyze these effects in order to avoid or at least reduce their influence.

References

Cascetta, E., (2009) Transportation Systems Analisys - Models and Applications. Second Edition. *Springer*

Eijgenraam, C.J.J., Koopmans, C.C., Tang, P.J.G., Verster, A.C.P., (2000). Evaluation of Infrastructural Projects, Guidelines for a Cost-Benefit-Analysis. Research Program on the economic Effects of Infrastructure, *CPB Netherlands Bureau for Economic Policy Analysis*, Netherlands Economic Institute, Den Haag.

ESPON (2007): Update of Selected Potential Accessibility Indicators. Final Report. Spiekermann & Wegener Urban and Regional Research (S&W), RRG Spatial Planning and Geoinformation http://www.espon.eu.

EUROPEAN COMMISSION (2010), DG Regional Policy, Fifth Report on Economic, Social and Territorial Cohesion.

EUROPEAN COMMISSION (2013), TIPTAP ESPON Project: Territorial Impact Package for Transport and Agricultural Policies.

EUROPEAN COMMISSION (2011) WHITE PAPER. Roadmap to a Single European Transport Area –Towards a competitive and resource efficient transport system. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0144:FIN:EN:PDF

Geurs, K.T., Ritsema van Eck, J.R., (2001). Accessibility measures: review and applications. *RIVM report 408505 006*, National Institute of Public Health and the Environment, Bilthoven.

Geurs, K.T. Van Wee, B. (2004). Accessibility evaluation of land-use and transport strategies: review and research directions. *Journal of Transport Geography, Vol. 12*, pp. 127-140.

Gutiérrez; J. (2001), "Location, economic potential and daily accessibility: an analysis of the accessibility impact of the high-speed line Madrid-Barcelona-French border", *Journal of Transport Geography 9*, 229-242.

Linneker, B. (1997): Transport Infrastructure and Regional Economic Development in Europe: A Review of Theoretical and Methodological Approaches, *TRP 133*. Sheffield, Department of Town and Regional Planning

NECTAR-Network on European Communications and Transport Activity Research. http://www.nectar-eu.org/Clusters/Cluster6/Cluster6.htm

Salze, P,, Banos, A., Oppert, J.-M., Charreire, H., Casey, R., Simon, C., Chaix, B., Badariotti, D., Weber, C., (2011). Estimating spatial accessibility to facilities on the regional scale: an extended commuting-based interaction potential model. *International Journal of Health Geographics*.

Schürmann, C., Spiekermann, K., Wegener, M. (1997): Accessibility Indicators. *Berichte aus dem Institut für Raumplanung 39*. Dortmund: IRPUD.

Spiekermann, K., Neubauer, J. (2002): European Accessibility and Peripherality: Concepts, Models and Indicators. *Nordregio Working Paper 2002:9*. Stockholm: Nordregio.

UK Department of Transport 2011. Transport User Benefit Calculation. *TAG Unit 3.5.3*.

UK Department of Transport 2013. Values of Time and Vehicle Operating Costs. *TAG Unit 3.5.6*.

US-DOT (Department of Transportation) 2012, Revised Departmental Guidance on Valuation of Travel Time.

Van Wee, B., and Geurs, K. (2011). Discussing Equity and Social Exclusion in Accessibility Evaluations. *European Journal of Transport and Infrastructure Research, Vol. 11*, No. 4, pp. 350-367.

Vickerman, R.W. (1995). The regional impacts of Trans-European networks. *The Annals of Regional Science, Vol. 29*

Wegener, M., Eskelinnen, H., Fürst, F., Schürmann, C., Spiekermann, K. (2002) Criteria for the Spatial Differentiation of the EU Territory: Geographical Position. *Forschungen 102.2*, Bonn: Bundesamt für Bauwesen und Raumordnung.