CONNECTING EASTERN EUROPE TO THE EUROPEAN HIGH-SPEED RAIL NETWORK

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ABOUT THIS PAPER: THE TRANSPORTNET FRAMEWORK

This research project has been developed in the frame of a six-week course on Infrastructure Development and Management, offered by TransportNET and held in April and May 2008 in Genova, Italy. TransportNET is a network composed of eight leading Universities involved in Transport research, funded by the European Union under the Sixth Framework Marie Curie Actions Program. Set up in 2003, the academic network launched in October 2006 a 2-year EST (Early Stage) program, in order to introduce a group of 16 fellows from 11 different countries in transport-related research. The fellows, originating from different professional backgrounds such as civil and environmental engineering, economics, urban planning and architecture as well as law, were able to achieve high-level education in the frame of a European doctoral school.

While in the first year several one-week courses dealing with research methodology, transport modelling and forecasting, transport economics and policy as well as transport systems were given in the different university locations all over Europe, in the second year the fellows attended four stream in-depth courses dealing with transport business and markets, trade transport and policy, urban mobility as well as infrastructure development and management. All courses did not lack of contact with the “real world” outside of the academic research environment, since they also incorporated technical visits to relevant institutions and companies involved in the planning, regulation and operation of transportation, in all transport modes (land-, water- and air-based) and types (passenger and freight transport). In the frame of these courses, the fellows were grouped in international and interdisciplinary working teams and asked to elaborate in a short time period a project dealing with a given topic in the particular course field.

In this context, the research presented below is an example of common work by four participants of this EST TransportNET program, who highly profited from the 2-year training described. It is needless to say that not only new knowledge and skills related to transport research were acquired, but also important lessons to the challenges and advantages of interdisciplinary and intercultural teamwork were learned. Due to the different national and professional backgrounds of the participants, the groups were able to gather individual knowledge, skills and experiences and to compile together missing information and facts.

1. INTRODUCTION

High-Speed Rail (hereafter HSR) is seen in Europe as a sustainable modal alternative for national and international trips over medium to long distances. Increased attractiveness of the rail due to high-speed services facilitates a positive modal shift from car and air-based modes. In light of this, it is important to investigate the viability of the extension of the European high-speed railway network to Central and Eastern Europe (CEE), and its potential configuration.

In this paper, the feasible corridors for the connection of Central European cities to the existing HSR network are established on the basis of the geographic and socioeconomic underlying conditions, demand estimation and infrastructure costs estimation. The geographic scope is derived from the geopolitical definition of the CEE region. It comprises ten new EU member states (in alphabetical order): Bulgaria (BG), Czech Republic (CZ), Estonia (EE), Hungary (HU), Latvia (LV), Lithuania (LT), Poland (PL), Romania (RO), Slovakia (SK) and Slovenia (SI), along with EU prospect Croatia (HR). Austria (AT), Germany and Italy are the passageways to CEE. Other countries of the region of the former Yugoslavian Federation and Soviet Union are considered just marginally.

In the next section the current context of HSR in Europe is briefly outlined. In section 3, an analysis of socio-economic and geographic conditions leads to the preliminary definition and ranking of corridors, according to feasibility. A rough estimation of their construction and operation costs in Section 4 precedes a demand analysis in Section 5, which is based on an ETIS matrix with origin-destination traffic volumes. The feasibility of selected corridors is evaluated through a comparison of the estimated demand with the required demand figures for operation of HSR lines in two scenarios. Finally, a simple comparison of main indicators of corridors' route alternatives is presented in section 6.

2. HSR DEVELOPMENT IN EUROPE

In the following first the development of HSR projects in Europe is presented (2.1), in order to then have a look to the estimation of their costs and benefits, as well as related financing schemes (2.2).

2.1 HSR context in Europe

With the aim of promoting a balanced and sustainable development through the improvement of transport connections and interoperability within and between EU countries, the Trans-European transport network (henceforth TEN-T) was defined in 1993. The TEN-T projects and axes comprise roads, inland waterways, airports, seaports, inland ports as well as traffic management systems. This network was planned to reinforce the economical and social cohesion along with the implementation and development of a competitive internal market. However, the TEN-T network policy focuses on the integration of the transport networks of all EU-27 Member States and it does not address to the extension of trans-national axes between the EU-27 and its neighbouring countries. Thus, in 1994 and 1997 the Pan European Transport Networks were created, for additional cooperation with the CEE countries and New Independent States (NIS). Thus, according to the Transport Infrastructure Needs Assessment (TINA), ten Pan-European transport corridors within accession countries and four pan-European maritime areas were defined. However, the EC has emphasized itself that the superposition of these two networks “leaves a policy gap in terms of improving transport links between the larger EU and the new neighbours” (EC, 2007).

Regarding the TEN-T rail network (henceforth TERN), half of the TEN-T priority projects are dedicated to the rail sector, incorporating 78 000 km of tracks. Under section 3, article 10, paragraph 1 of the Decision N° 1692/96/EC is explained that the TERN comprises both, high-speed and conventional rail network. The difference between them is related to the speed allowed both by the rail tracks and the rolling stock. According to the UIC (2008), high-speed signifies operations of at least at 250 km/h, but what is truly important is the performance perceived by the customers, in terms of travel time, frequency, comfort, safety, etc. Therefore, a HSR network includes not only new HSR lines and rolling stock equipped for speeds generally equal or greater than 250km/h, but also specially upgraded HSR lines and rolling stock equipped for speeds of the order of 200 km/h. Moreover, due to topographical or town planning constraints there might be some upgraded HSR lines where the maximum speed must be adapted case-wise (UIC, 2008). In fact, the first high-speed line in Western Europe was inaugurated in France, in September 1981, between Paris and Lyon. Its success gave rise to the extension of national systems and, later, to the ambitious concept of the interoperable European high-speed network. While in the last ten years service-km offered in HSR services all over Europe have grown by 70%, the growth rate of passenger traffic in the related services has been of 160%, due to a higher and more profitable occupation rate (UIC, 2008).

Within the TEN-T priority projects until 2020, six rail corridors in the Central and Eastern new member countries have been identified. Among these corridors, only two are considered for high-speed development. In frame of priority project PP 6, Slovenia is planning to upgrade the existent railway lines for high-speed traffic, first between Jesenice and Ljubljana, second between Maribor and Zidanimost and third from Divaça to Koper close to Trieste. Additionally, in priority project PP 22, Bulgaria is planning to upgrade the existing rail to high-speed. The foreseen line would connect the city of Kalotina over the capital Sofia in the western part of the country with the city of Bourgas in the East, passing by the cities of Plovdiv and Stara Zagora.

2.2 Costs, Benefits and Financing of HSR lines

The development of a HSR network can be seen as difficult challenge, due to a set of risks related to very high initial capital costs, slowly rising revenues and an extensive amortization period (Roll et al., 1998). HSR projects may form a long-term compromise for the countries and transport industries involved. Nevertheless, regarding the TEN-T network, sources of financing are not only based on national funds and private investment, but also originate from several EU sources. The EU funds originate from a specific TEN-budget, and legitimate for the financing of feasibility studies, loan guarantees and interest rate subsidies. In addition, the European Regional Development Fund, the Cohesion Fund and the Instrument for Structural Policies for Pre-Accession could be also included. Additionally, loans from the European Investment bank (EIB) can be claimed. These EIB loans might pre-finance up to 50% of a project to very low interest rates. Such type of funding might be also available to extent the HSR network towards the Eastern Europe. Finally, for the Pan-European corridors loans by the European Bank for Reconstruction and Development and the World Bank may be available.

In general, Leveque (2005) identifies five costs components, which have to be taken into account by the (public and private) stakeholders of HSR projects:

1. Fixed costs, related to the overall initial investment, including previous studies and the project design as well as the construction phases of sub-and super-structures and the acquisition of the rolling stock

2. Variable usage costs, affecting necessary maintenance and repairing costs

3. External costs, related to negative externalities such as noise emissions (on the French High-speed lines for instance, they sum up to 10-20% of the overall user costs)

4. Costs in a long term run for the further network development and extension

5. Additional costs due to financial balancing among different infrastructure- and operation-related services

The construction costs per km depend essentially on the HSR route, whether if is on viaduct, in tunnel or on flat or hilly land. This is one of the reasons that explain why construction costs for HSR lines vary all over the world significantly. While the fixed, variable and external costs depend on a set of technical, geographical and organizational characteristics, financial costs ought to loan interests and further risks can estimated on the basis of an average percentage of the overall costs (e.g. 8% in France; Leveque, 2005).

Concerning the coordination and distribution of revenues and costs between the infrastructure manager and the transport service operators, the European-wide common model is based on slot-charges, similar to a toll on a highway. Having a look at the French example, the prices of the slots charged by the French Railway Infrastructure Manager are differentiated by line and train types, and nowadays also by schedules, i.e. indirectly reflecting de demand by different charges for peak and non-peak hours (Interview Emery, 2008).

However, among the already implemented HSR lines in Europe, few really successful examples of profitable exploitation can be found. The Paris-South-East connection with Lyon, with a design speed of 300 km/hour, enables a travel time of 2 hours between the two biggest economical centres of the country (Interview Emery, 2008 and website SNCF, 2008). Its investment volume was about 1.28 billion Euros (1989 prices), paid by the State and local communities in the form of a number of lump-sum-subsidies. The profit for the local communities was estimated in 1997 on 30% (Domergue et al., 1997). With 120-130 trains per day (related to average frequencies of 20 minutes) the connection enjoys today a profitability of almost 100%.

However, for a macro-economic cost-benefit analysis of a HSR line as TERN not only the profitability of the project itself, but also its broad sets of travel time and accessibility gains of the rather peripheral regions within the European market have to be considered. The latter is often also connected to the induction of social, environmental, and economic development and benefits for these regions. Considering time-space maps for rail-based passenger transport in Europe for different years, one sees easily the phenomenon of a “shrinking continent” (Spiekermann and Wegener, 1995). In the context of travel time gains, the HSR market shares are rather to compare to air-based transport than to interurban land transport (rail, bus and private cars). While for travel times of longer than four hours, the air-transport attractiveness normally prevails, for a travel time of three hours the two modes can be seen as equally attractive, and for a travel time of up to two hours, using e.g. the TGV in France between Paris and Lyon, the competition by air transport has resulted to be very low (Moulinier, 2003). Thus, concerning travel time, HSR is considered to be competitive especially for journeys from 300 to 500 km. Anyway, when speaking about Eastern Europe, bus companies form also an important source of competition for these long-distance journeys, because of their very low prices. Their attractiveness is probably related to the fact that the value of time is still lower in Eastern Europe, and the amount of hours spent on travelling might be compensated by low tariffs. Besides travel time gains, according to the Steer Davies Gleave (2004) report, the most important reason for countries to invest in HSR lines is related to the extra capacity, rather than the speed. Indeed, the construction of HSR lines additionally frees capacity on the conventional routes for (slower) freight and passengers' trains.

Of course, there are also critical opinions concerning HSR development, especially related to the expected socio-economic impacts. Related doubts refer mainly to the risks of an unbalanced growth of the connected cities, leaving the regions that are out of the network lagging behind in their development. For instance, Vickerman et al. (1997) put emphasis on possible goal conflicts since improved links between the national and regional centres of economical activity may tend to increase existing differences in accessibility levels between those major cities and the less accessible regions. Thus, HSR destinations might be reachable in a shorter time than much closer locations. Applying additional accessibility indicators, such as population potential and daily accessibility indicators for an analysis of discontinuous, very finely grained zones, one reveals the increasing gap between the central and peripheral areas. Vickerman et al. (1997) conclude that the TEN-Ts might lead regions to diverge, rather than reduce differences in accessibility between them (idem).

The concrete answer to the question of whether the implementation of the TEN-Ts contributes to spatial polarization or if it actually links peripheral regions to the economic core is certainly complex. Without being able to give a definite conclusion, it is obvious that a set of demographic, socioeconomic and technical aspects related to current and future transport supply have to be taken into account. Additionally, potential network effects should be considered, since they usually entail additional socio-economic benefits and are linked to the discussion on regional and intra-European equity. Hence, the trade-off between benefits and costs is yet uncertain and the final decision over the project implementation is not a technical but rather a political one.

3. SELECTION OF CORRIDORS

Being aware of the multiple evaluation criteria of HSR projects, in the following a very simple method for preliminary corridor definition is proposed, which consists of two basic steps. First, the geographic and socio-economic prerequisites of potential regions and cities are considered (3.1), and second, three first priority and some second and third priority corridors are defined on the basis of a basic gravity model and related traffic flow estimations between major metropolitan areas (3.2).

3.1 Geographic and socio-economic conditions

The CEE region comprises population of more than 100 millions (circa 1/4 of the population of the EU-15), living in area of more than 1.1 million km^2 (1/3 of Western Europe). There is no metropolitan area with more than 3 million inhabitants and only 13 cities have more than 1 million inhabitants, compared to over 50 cities in Western Europe. The rest of population is then mostly dispersed in rather small communities; urbanization rates vary from 50% (RO, SI) up to 75% (CZ) and are thus lower than in West Europe. The population density (approximately 100 people per km^2) continuously decreases in direction to the East and is significantly lower than in regions with HSR systems in operation (e.g. Germany 233 people per km^2).

The major part of the region is formed by flatlands (Great Panonian, Northern European and Walachian). Thus, geomorphologic conditions in the region are quite advantageous with respect to the potential costs of building HSR infrastructure. This is only disrupted with the arc of Carpathian Mountains spreading out from Slovakia and Southern Poland to Romania, creating a natural barrier in South-North-East directions. Also, the Czech Republic is bordered by the continuous range of hills (Bohemian Range). The Alpes separate Slovenia and Croatia from Northern and Western direction. Other mountains (Dinarian Alpes and Balkan) skirt the southern edge of the region, hindering access to parts of Bulgaria (with its capital Sofia) and Croatia (Dalmatia).

Despite remarkable economic growth in the last years (up to 10% in Slovakia), the GDP per capita and disposable income are still distinctly smaller in the CEE region than in neighbouring Germany or Austria. However, it is already comparable to EU-15 countries such as Spain, Portugal or Greece, where high-speed tracks are being built or planned. There are still big regional differences and therefore, adequate economic power (and thus potential generation and attraction of HSR trips) might be justified at least for the most important metropolitan areas in Central Europe (Warszawa, Budapest and Prague). Another advantage of these cities is their proximity to largest centres in Germany (Berlin, Munich), within the reasonable threshold distance of 500 km. Distance (and thus competition with air mode) could be seen as the most important obstacle for HST connection to other large cities in the Balkan and the Baltic states. Current GDP growth rates are not expected to maintain during the next 25 years. Forecasts of the European Commission expect growth rates to go down to 1-4% (EC, 2003). The population is expected to be relatively stable, with changes of -1% to +1%.On the basis of the forecasts for long-term GDP growth for the period of analysis.

3.2 Preliminary selection of corridors

For a preliminary selection of the connections for which HSR may be of interest, all metropolitan areas in the Eastern Europe with more than five hundred thousand inhabitants are considered. Eurostat's NUTS 3 or LUZ (larger urban zone) levels data are used in order to comprise a broad area that can better represent the catchment area for a connection point along a HSR line (website EUROSTAT, 2008).

Traffic demand flows between any two cities i and j can be calculated based on a gravity model that would need to be calibrated. However, in order to rank the connections in terms of a relative measure of demand, there is no need for further data or calibration. For simplification, the costs are assumed to be directly proportional to the distance, and the over-costs implied by geographical constrains are neglected. Then (Eq. 1) provides a straightforward way to rank the connections in terms of a Potential Demand (PD).

$$PD_{ij} = \frac{MetGDP_i \times MetGDP_j}{Distance_{ij}} \qquad \text{(Eq. 1)}$$

where MetGDP is the Metropolitan GDP in Euros, which refers to the population of the city or metropolitan multiplied by the respective GDP per capita in the area. Since the demand of HSR is known to present high income elasticity, a criteria solely based on population would be bound to give misleading results. Metropolitan GDP reflects the total wealth available in the city, and thus conditions the willingness to pay for HSR services. Figure 1 represents graphically population and GDP of the metropolis under analysis.

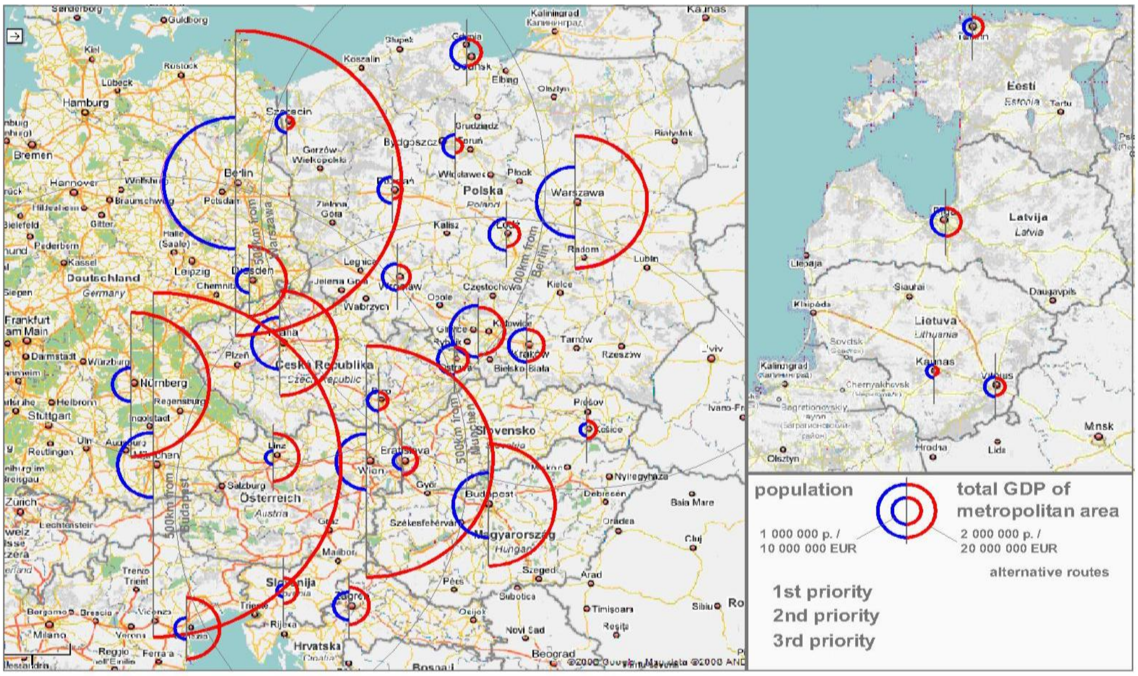

Figure 1 – Population and GDP of CEE metropolitan regions Figure legend (WEBSITE EUROSTAT, 2008)

The time dimension is introduced at this point, because fast economic growth of the CEE countries may lead to significant changes in the relative values for Metropolitan GDP. Thus, the Metropolitan GDP is computed for every city, for the years 2010, 2020 and 2030. The population is assumed to be (more or less) stable over the whole period of time; estimates for long-term GDP growth are taken from the EUROSTAT (2008).

Nevertheless, the actual demand for trips between two cities depends on other factors beyond these; for instance, cultural and economic links between two areas may prevail over these factors. The consideration of these factors would possibly tend to relative increment of the attractiveness of domestic connections compared to international ones and are taken into account in the detailed demand analysis for the one case study corridor.

The ETIS matrix for the traffic volumes distribution shows clearly that, for comparable distances, national connections bear on average ten times higher volumes of traffic than international relations. Moreover, it can be assumed that the attractiveness of a connection is an inverse function of the distance, (decreasing with long distance). So, although this may be a fair approximation for trip generation in general, when it comes to assignment to HSR corridors in particular, a function of another form would be more appropriate, considering the core value of a travel time between two and three hours.

Coming out the geographic, demographic, economic and network analysis, prelusive synthesis leads to definition of 13 corridors for further considerations in this study. Based on presumed feasibility, these HSR infrastructure projects are divided into three priority groups (Figure 2).

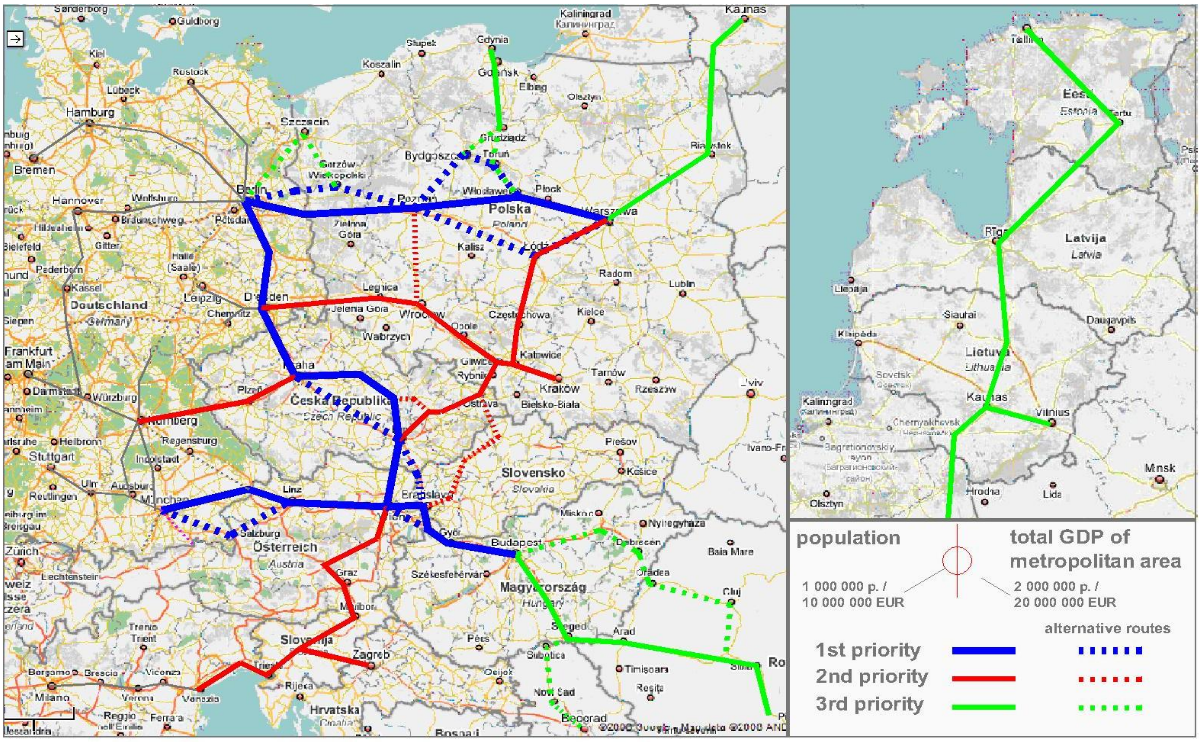

Figure 2 – First, second and third priority corridors (OWN ELABORATION, 2008)

Three corridors, connecting the largest metropolis of Central Europe, were selected for the first group, and analysed in more detail:

- **Corridor 1: Warszawa – Berlin** connects capitals of two largest countries in the region and two of the largest economical centers as well. It is considered in three alternatives: through Poznan directly (1.1) or through Lodz (1.2) and Bydgoszcz (1.3). First one provides the shortest (<500km), fastest (least stops) and cheapest (construction costs) connection. Second one embraces another large Polish metropolitan area (potentially larger utilization) with only a slight increase in distance (<5%). The latter one detours by more than 10% but increases accessibility for North-Central part of Poland. None of alternatives fully copies the existing corridor. Building a new track (exclusively dedicated for passenger transport?) would improve the situation on the old corridor (mainly freight), which is at the capacity already today (ERIM) and rather bad condition (not suitable for HST upgrade). Alternatives 1.1 and 1.3 would complement the Polish network with a missing direct link from Warszawa to Plock and Wloclawek (both >100 thousand inhabitants). Whole corridor is lead in flatlands, crossing few major rivers, such as Oder or Varta.

- **Corridor 2 Budapest – München** connects, similarly to previous, major economic centers along the Danube river (including Wien and Bratislava). Capacity is more or less sufficient also in prospects with infrastructure occupation up to 85% (ERIM). It is thus possible just to upgrade the existing infrastructure in many sections. From the construction point of view, fairly dense population in rather narrow corridor could increase the costs of new development.

- **Corridor 3 Budapest – Berlin** is the longest, thus the largest investments demanding one of the 1st priority group. Almost one third of its length traverses hilly areas and rivers Danube and Elbe are crossed repeatedly. However, economical power, importance and proximity of the interconnected areas along the corridor suggest still very highest utilization of all. The distance between Berlin and Wien would be shortened by 40% and the corridor copies natural and historically important axis Praha – Bratislava/Wien – Budapest. Although the sections Praha – Pardubice – Brno – Bratislava is already being upgraded to higher speeds (Pendolino), a new track Praha – H. Brod – Brno could be also considered to built for HSR, what would enable to abandon the current alignment (through Pardubice).

3.2.2 Second Priority (conditionally feasible corridors in the future)

Second priority projects would complete the First priority (East-West) network in the Central Europe with cross-links (north-south). In contrast to 1st priority corridors, the HSR demand is expected to be lower and construction infrastructure costs significantly higher, due to mountain crossings. Shorter-distance corridors in Balkan were added to this group. Economic strength and mobility of this part of Europe is yet lower even compared to Central European countries. However, population potential of the largest metropolitan areas (Istanbul, Athens, Bucuresti, Thessaloniki and Sofia) is high and the demand should rise with increasing economy and cross-border cooperation, also supported by HSR.

The corridors selected for the 2nd priority group are following:

- Corridor 4 Wien – Ljuljana/Zagreb – Venezia

- Corridor 5 Praha – Nurnberg – Frankfurt(Main)

- Corridor 6 Warszawa – Ostrava – Praha/Wien/Budapest

- Corridor 7 Krakow – Wroclaw – Dresden/Berlin

- Corridor 8 Bucuresti – Sofia – Thessaloniki – Athens

- Corridor 9 Bucuresti – Varna – Burgas – Istanbul

3.2.3 Third Priority (least feasible for implementation HSR)

The Third priority group encompasses corridors that are connecting either rather smaller peripheral cities in Poland (Gdansk, Szczecin), or quite distant eastern metropoles (Riga, Bucuresti). In the first case, only a high increase of economy could balance lack of potential demand. The cities of the second subgroup are simply too distant between each others and from the other metropolitan areas, Only a purely political decision may lead to construction of these HSR lines, because the travel time savings by air transport will always prevail.

The corridors sorted in the 3rd priority group are following:

- Corridor 10 Gdansk – Poznan/Warszawa
- Corridor 11 Szczecin – Berlin/Warszawa
- Corridor 12 Bucuresti – (Beograd) – Budapest
- Corridor 13 Tallinn – Riga – Kaunas/Vilnius – Warszawa

4. INFRASTRUCTURE DEVELOPMENT COSTS

Infrastructure development costs for each corridor are roughly estimated based on a general assumption on the cost per km of HSR line built, and an over cost for several specific types of geographic conditions constraints. The respective costs per km were adapted from the CENIT (2004) study that offers a range of costs based on the European experience for HSR line development. Since they had to be adjusted to prices for the base year 2008, the methodology introduced in the Heatco (2005) study was used; on the basis of the HIPC-Index for the different European countries via a price adjuster that converts the market prices to factor prices under the application of the Power-Purchase Parity (PPP) and one common currency on EU-27 level (Heatco, 2005). In Table 1 are presented the costs per km according to CENIT (2004), updated to 2008 prices:

Table1- Estimated costs per km of a HSR line in Europe (OWN ELABORATION, BASED ON CENIT, 2004)

Constrution difficulty (Topography)	**Costs per km (Million EUR)**
Upgraded (not distinguished)	13,5
Easy (flatlands)	13,5
Average (hills)	18,9
Difficult (mountains)	24,3
New (urban)	27,0
Operation costs	**649**
Maintainance costs	**98,9**

Infrastructure costs vary with geographic conditions, i.e., for flatlands where 0 to maximum 12% of tunnels and viaducts are required, no over cost is included. On the other hand, hills with 12 to 25% of tunnels and viaducts are taken into account by including 40% over costs and mountains with more than 25% of tunnels and urban areas are burdened with 100% over costs. For each corridor, a rough estimation of the percentage length built in each geographical condition was carried out. The difference in costs between upgrading existing rail lines and construction of brand new infrastructure in flatlands is not really significant. Whilst upgrading affects savings in land acquisition, it requires the removal and scrapping of the existent tracks. Both, upgrading and new construction, require hence comprehensive construction works and affect external costs which are estimated as being similar.

5. DEMAND ANALYSIS

For the main corridors a deeper demand assessment based on two basic development scenarios is proposed. Thus, in the following fist the basic assumptions under support of a transport model are presented (5.1), and then the scenarios for demand expectations are exposed (5.2). In 5.3 these potential demand figures are compared with the theoretically required demand for cost balanced exploitation. Finally, for one corridor the own demand analysis is put side by side with the estimations of another existent study (5.4).

5.1 Assumptions

A more thorough analysis of demand and infrastructure development costs is carried out for the first priority and number 5 corridors. It is based on the VACLAV model for passenger transport provides a trustworthy source of spatially detailed traffic estimation for Europe (Schoch, 2003). The VACLAV passenger transport model is a classical four-stage (trip generation, distribution, modal split and assignment) transport model developed at IWW (INFRAS/IWW, 2004) Trip generation is determined on NUTS 3 level; trip distribution is estimated through a gravity model; the modal split is calculated by an enhanced logit model that assigns traffic volumes to three generic modes – rail, road and air. The ETIS matrix contains estimated traffic volumes per Origin-Destination (O-D) pair per mode, derived from the VACLAV model.

The total demand for each of the 1st priority corridors is determined taking into account the traffic volume estimates from the ETIS matrix. Over 7000 O-D relations of the ETIS matrix between (NUTS3) regions in CEE countries and Germany, Switzerland and Benelux were considered. If the distance between the regions is lower than 1000km they are then assigned to particular sections of the corridors individually. Partial distribution are considered over equipotential alternatives and in case when only part of the section is to be used for given O-D relation; in the cases where only a part of the section is relevant, traffic volumes are attributed to that section proportionally to the length or when demand could be assigned to competing routes.

It must be stressed that such calculated figures are related to total demand (summed up from multiple O-D pairs) along respective corridors and their sections. Therefore, they comprise also demand for short-distance (national and regional inter-city) services that may use the developed infrastructure and thus should not be with demand for HSR services in particular. To calculate the factual HSR demand, many complicated assumptions would need to be incorporated, especially related with modal competitiveness.

5.2 Scenarios

There are two scenarios considered, the reference Scenario 0 and a mode-shift Scenario 1. The reference scenario is characterized by the assumption that no traffic is shifted from other modes and no new trips are generated. Thus, only the corresponding rail traffic volumes are assigned to the respective HSR sections. The second scenario is characterized by the assumption that traffic can be diverted from other modes, in the presence of favourable travel time ratios (HSR vs. Road and HSR vs. Air).

For simplification and due to lack of data available at the current moment, the potential for competitive shift of passengers from other modes in favour of HSR is assumed to be "flat" 10%. The figure thus represents low-edge average of rail modal shares in countries where HSR is already in operation. It is used just to roughly estimate potential demand for defined corridors, without asserting its precision. The proper calculation should be used later on. Air passengers suffer no diversion, because air shares result to be already low in the reference scenario; actually the ETIS matrix figures are from year 2000, so before the boom of low-cost airlines.

The overall results of the demand analysis for the first priority corridors for both scenarios are shown in the Table 2. Very interesting is the comparison of the relative increment of the demand in order of several hundreds of per cents, when 10% shift from roads is assumed. This reflects the fact that current rail shares in vast majority of CEE O-D relations are very low (couple of percent), compared to moderate (10-30%) shares in countries like Germany, France or the Netherlands. This is apparently caused mainly by insufficient and inconvenient supply – with rather low quality for high price, connectivity and average travel speeds.

Table 2 - Comparison of traffic volumes for every corridor in both scenarios (OWN ELABORATION, 2008)

Corridor / alternative	**Potential demand**		**Relative increase**
	Scenario 0	**Scenario 1**	
	10^6 pass/year	10^6 pass/year	**%**
Berlin – Warszawa			
Berlin – Frankfurt(O) – Poznan – Warszawa	1,8	7,6	425%
Berlin – Frankfurt(O) – Poznan – Lodz – Warszawa	5,1	32,2	638%
Berlin – Gorzow W. – Poznan – Bydgoszcz – Warszawa	4,66	29,5	633%
Munchen – Budapest			
Munchen – Linz – Wien – Budapest	4,24	29,98	707%
Munchen – Salzburg – Linz – Wien – Bratislava – Budapest	6,96	88,16	1267%
Berlin – Budapest			
Berlin – Dresden – Praha – Pardubice – Brno – Wien – Bratislava – Budapest	4,61	10,08	219%
Berlin – Dresden – Praha – H.Brod – Brno – Bratislava – Wien/Budapest	4,03	8,01	199%

5.3 Feasibility: Potential versus required demand

According to De Rus and Nash (2007) at least nine millions of passengers are required to assure cost balance of the HSR line. If the shadow pricing (i.e. public support for the operator) is implemented, required demand could drop to approximately six million passengers along the full length of a HSR line.

When multiplied with length of the corridors, resulting figures of required demand with or without shadow financing in passengers-kilometers (Pkm) are directly comparable with potential demand figures that come out of the demand analysis. The detailed data for both scenarios and for each section and route alternative, along with cost calculations are presented in Table 3.

Table 3 - Comparison of construction costs and demand estimations of the selected corridors (OWN ELABORATION, 2008)

Corridor Section		Length Total	Construction Costs (estimated)	Operation Costs (estimated)	Required demand no shadow	Required demand w/shadow	Potential demand 2000 net rail	Potential demand rail+10% road
		km	Mio EUR	Mio EUR/year	10^6 Pkm per year	10^6 Pkm per year	10^6 Pkm per year	10^6 Pkm per year
1	**Berlin – Warszawa**							
1a	Berlin – Frankfurt(O) – Poznan	253	3243,1	395,9	2277,0	1518,0	259,9	872,5
1b	Berlin – Gorzow W. – Poznan	253	3243,1	395,9	2277,0	1518,0	320,9	958,4
1c	Poznan – Warszawa	306	3986,3	478,9	2754,0	1836,0	1339,8	2233,3
1d	Poznan – Lodz	209	2702,6	327,1	1881,0	1254,0	1174,7	1990,3
1e	Poznan – Bydgoszcz	128	1635,1	200,3	1152,0	768,0	1234,4	2201,9
1f	Lodz – Warszawa	136	1689,1	212,8	1224,0	816,0	1737,0	2802,0
1g	Bydgoszcz – Warszawa	260	3378,3	406,9	2340,0	1560,0	1571,4	2433,3
1.1	**1a + 1c**	**559**	**7229,5**	**874,8**	**5031,0**	**3354,0**	**1599,7**	**3105,8**
1.2	**1a + 1d + 1f**	**598**	**7634,8**	**935,9**	**5382,0**	**3588,0**	**3171,6**	**5664,8**
1.3	**1b + 1e + 1g**	**641**	**8256,4**	**1003,2**	**5769,0**	**3846,0**	**3126,7**	**5593,6**
2	**Munchen – Budapest**							
2a	Munchen – Linz	233	3199,9	364,6	2097,0	1398,0	847,4	1980,6
2b	Munchen – Salzburg	133	1902,6	208,1	1197,0	798,0	1161,5	2589,4
2c	Salzburg – Linz	124	1926,9	194,1	1116,0	744,0	900,2	2050,1
2d	Linz – Wien	181	2483,7	283,3	1629,0	1086,0	1329,7	2858,6
2e	Wien – Bratislava	57	662,1	89,2	513,0	342,0	658,7	1623,6
2f	Wien – Budapest	241	3162,0	377,2	2169,0	1446,0	597,2	1369,7
2g	Bratislava – Budapest	180	2429,6	281,7	1620,0	1080,0	644,7	1419,3
2.1	**2a + 2d + 2f**	**655**	**8845,6**	**1025,1**	**5895,0**	**3930,0**	**2774,3**	**6208,9**
2.2	**2b + 2c + 2d + 2e + 2g**	**675**	**9405,0**	**1056,4**	**6075,0**	**4050,0**	**4694,8**	**10541,0**
3	**Berlin – Budapest**							
3a	Berlin – Dresden	183	2297,2	286,4	1647,0	1098,0	539,0	1111,1
3b	Dresden – Praha	131	2021,5	205,0	1179,0	786,0	526,9	1256,9
3c	Praha – H.Brod – Brno	203	3053,9	317,7	1827,0	1218,0	909,4	1841,4
3d	Praha – Pardubice – Brno	239	3480,9	374,0	2151,0	1434,0	1487,7	3036,5
3e	Brno – Wien	147	1824,3	230,1	1323,0	882,0	458,1	992,9
3f	Brno – Bratislava	128	1594,5	200,3	1152,0	768,0	708,4	982,9
3g	Wien – Bratislava	57	662,1	89,2	513,0	342,0	658,7	1623,6
3h	Wien – Budapest	241	3162,0	377,2	2169,0	1446,0	597,2	1369,7
3i	Bratislava – Budapest	180	2429,6	281,7	1620,0	1080,0	644,7	1419,3
3.1	**3a + 3b + 3d + 3e + 3g + 3i**	**937**	**12715,7**	**1466,4**	**8433,0**	**5622,0**	**4315,1**	**9440,28**
3.2	**3a + 3b + 3c + 3f + 3i**	**825**	**11396,8**	**1291,1**	**7425,0**	**4950,0**	**3328,4**	**6611,58**
5	**Nurnberg – Praha**							
5a	Nurnberg – Plzen	194	2929,6	303,6	1746,0	1164,0	126,6	645,6
5b	Plzen – Praha	91	1351,3	142,4	819,0	546,0	384,0	1147,6
5.1	**Praha – Nurnberg**	**285**	**4280,9**	**446,0**	**2565,0**	**1710,0**	**510,6**	**1793,2**

5.4 Verification of the demand analysis figures

The figures from the demand analysis are in line with outcomes from other studies. The most elaborated one is the study carried out by ITP Consult in 2002 on behalf of the Saxon Interior Ministry (2007). Figure 3 presents the comparison of the own and the ITP estimations for the different sections of the Berlin-Budapest corridor. The own figures are related to the *current* demand with potential growth in the future, while the ITP figures refer to 2020. The only significant difference in results of own study concerns the section between Wien and Bratislava, which is double compared to ITP outcomes. Obviously, 10% modal shift to rail from private car transport is not realistic for this section, due to proximity two metropolitan regions.

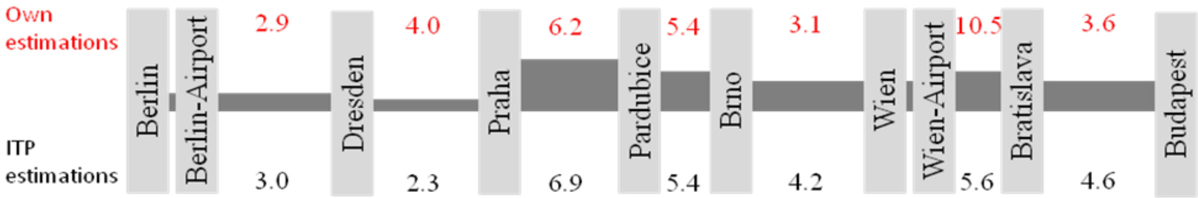

Figure 3 - Comparison of own and ITP demand estimations for the Berlin-Budapest rail corridor; (OWN ELABORATION, BASED ON SAXON INTERIOR MINISTRY, 2007)

6. COMPARISION OF ALTERNATIVE ROUTES

The 1st priority corridors are further analysed in more detail. Construction and operation costs and potential demand volumes are determined for two scenarios (scenario 0 and scenario 1) as well as for several alternative paths for each corridor. Further, travel times are estimated for the alternative paths. Net travel time is calculated from the distance and average speed of HSR, which is assumed to be 200 km/hour. Additional 0,5 hour of delay is added for each intermediate stop to reflect additional “loss” of time due to stopping, braking and acceleration. To incorporate time required to get to/from the station access/egress penalty 1,5 hour is added, finally.

The three aspects: (i) total costs (including construction, operation and maintenance), (ii) total travel time, and (iii) inverse value of potential demand are considered for comparative analysis of alternatives. Inverse value of potential demand is used to hold the sense of other two parameters – the lower the value is, it is better. The objective of this analysis is to find the best routing of each corridor to maximise the effects that come out of three indicators just described above, and to eliminate the redundant alternatives. Of course, direct comparison of the alternatives according to the three criteria is not recommendable. It would require the attribution of weights for each criterion, which is in general a very sensitive and complex process. However, there are already some facts obvious from the graphical visualisations presented in the Figure 4.

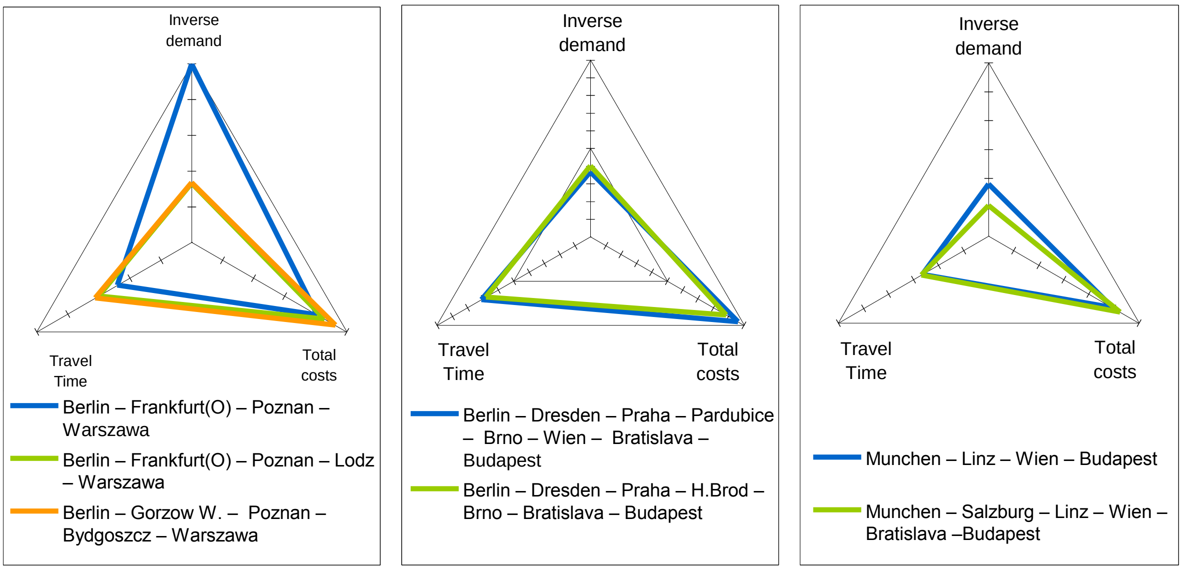

Figure 4 - Visual comparison of alternatives for the Berlin-Budapest corridor (OWN ELABORATION, 2008)

In case of corridor 1 Berlin – Warszawa it is clear that alternatives 1.2 through city of Lodz respectively would only require a little more (roughly 10%) investment on construction and operation. However, the potential demand would increase significantly (more than double pass.km) compared to "direct" alternative 1.1, since it would attract a lot of traffic from densely populated South-Central Poland. The same holds for alternative 1.3 (through Bydgoszcz), although this one is even more expensive and longer, so the benefits from the time reduction and gains in demand are thus slightly lower.

In case of the corridor 2 München – Budapest is the situation more ambiguous. The increased costs and travel times of the "detour" alternative 2.2 (through Salzburg and Bratislava) should be compensated with increased potential demand1. Very similar is the situation in case of corridor 3 Berlin – Budapest.

7. CONCLUSION

In the presented study the extension of the HSR network towards the East was analysed. Thirteen corridors of possible or desirable HSR lines were identified in the CEE region, based on both geographical and socio-economic circumstances. Within the corridors, three levels of priority were defined, regarding the importance and feasibility of each corridor. Giving the fact that the levels of demand for a HSR line are considered as a key element to compensate the high investment costs involved, the number of passengers and the investment costs for each of the first priority corridor were roughly estimated for each corridor. The construction and operation costs are naturally dependent on length and

[1] However, the factual increment as outlined in the Fig 4b is not so distinct. Remember that the difference is partially caused by overestimation of Wien – Bratislava section. The same may hold for other sections as well.

topography along the corridors. Demand volumes were determined for a set of alternative paths for each corridor, and for two scenarios (Scenario 0 and Scenario 1). The reference scenario (Scenario 0) is characterized by the assumption that no traffic is shifted from other modes and no new trips are generated by the construction of a new HSR line. The Scenario 1 suggests 10% modal shift from the road transport when HSR infrastructure is built and lines are in operation.

Despite fairly rough estimation, the results of the potential demand analysis show that none of the corridors provide enough demand for construction and operation of a HSR line, currently in the current conditions. It is observed that there is still higher demand at national level (intercity connections), rather than at international level. Since a major part of calculated demand is in fact for short distances only, current demand levels do not seem to justify the construction of HSR lines for speeds above more than 250km/h is not necessary now. However, the figures in ETIS matrices respect just current quite low quality of rail supply and thus, the rail mode shares are underestimated. An increase of the demand could be expected if a HSR link is put into service. Furthermore, considering the GDP growth and the increase of mobility, it would be probably feasible to extend the HSR network towards the East in the future. Indeed, the GDP of the CEE capital cities' metropolitan areas are already comparable to metropolitan areas in countries such as Spain, Portugal or Greece, where high-speed tracks are being built or planned already.

Nevertheless, it must be pointed out that it is not the demand alone that makes a HSR line investment worthwhile, but also the passengers' willingness-to-pay. Such an analysis was not in the scope of this paper. And ultimately, not every benefit emerging from the construction of a HSR line can be measured and assigned a monetary value, consequently.
On the one hand, the extension of the HSR towards the East could be seen as an instrument of "cohesion", facilitating the European exchange of labour and services. Additionally, it could bring many other social (including potential network effects), environmental and economic benefits. On the other hand, if HSR lines are constructed between core regions, where the demand is higher, periphery regions might not gain much value from it. Moreover, if the connection is between cities that do not have the same level of development, might be a tendency for the stronger to become even stronger and the weaker to become relatively weaker.

In the end, whatever the motivation for extending the HSR network towards the East is, trade-offs between benefits and costs, as well as the final decision to construct HSR lines are rather political decisions than economical choices. The ultimate decision to build or not to build the HSR belongs to the government, given the massive public funds involved. And ultimately, not all the strategic political motives can be assigned a monetary value. Whatever the motivation for implementing a HSR line, the criteria used for this decision are likely to be wider than the appraisal, but are difficult to assess. And at the end of the day, the overall choice falls between profit and social welfare.

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