1 INITIAL POSITION

This presentation reports on the results of a preliminary feasibility study on a ground-based high-speed connection in the Northern part of the pan-European corridor IV between Berlin and Budapest.

This preliminary feasibility study was awarded by the Saxonian Ministry of Interior and is associated with an Interreg IIIB project of the European Union which addresses the development of economics as well as the development of traffic and transport in the Eastern Central Europe.

The special quality of this preliminary feasibility study is given by a comparison of two techniques that should be worked out: firstly the realisation of this link in classic railway high-speed technique and secondly in magnetic levitation technique in terms of the Transrapid.

The objectives of this investigation were:
- to assess whether the installation of a ground-based high-speed link between Berlin and Budapest may be reasonable in terms of micro economic, macro economic and spatial aspects on the one hand and
- when the answer is positive, to give a statement which of both techniques should be preferred for realisation.

2 DESIGN OF THE FEASIBILITY STUDY

In order to achieve the objectives it was necessary to assess the expected costs of line construction, vehicles, operations and maintenance as well as the expected revenues by the sale of tickets. This was requiring a prognosis on the volume of traffic on the one hand and a complete planning of operations including vehicle circulation on the other hand. The appropriate study design results from the mentioned aspects and is outlined in figure 1. The work packages ‘feedback’ and ‘refining’ are reserved for further investigations.
3 SYSTEM DEFINITIONS, STOP STATIONS AND SYSTEM EDGES

The planning horizon of the study is the year 2020. The following vehicles were chosen according to their present development state:

- the ICE 3-M for the wheel/rail-system and
- the Transrapid Tr 08 for the maglev system.

The operational top speed is assigned to

- 300 kilometres per hour for the ICE 3 and
- 450 kilometres per hour for the Transrapid Tr08.

Both systems are assumed to run on an own double-tracked carriageway on the open line. The maximum longitudinal gradient amounts to

- 3.5 % for the railway and
- 10 % for the Transrapid.

The choice of this longitudinal gradient means to railway – and as well to Transrapid - that the line is addressed to passenger transport exclusively. In both techniques light freight transport is possible as an express service, e. g. during the night using the technique of passenger transport vehicles. This fact remained unconsidered in this study.

The capital cities of all countries in the course of the line Berlin, Prague, Bratislava and Budapest are chosen as stop stations to both systems. The cities Dresden, Pardubice and Brno are furthermore chosen as stop stations due to their importance as regional centres. The airports of Berlin and Vienna are connected to the lines as well. In Germany two other line variants have been investigated: The line course via Leipzig and the line course via Cottbus; the latter may connect to the line the pan-European corridor III to Southern Poland and Ukraine (see Fig. 2).

4 LINE ROUTING

The line routing of both systems is governed by the line layout parameters and by topography, settlement and existing infrastructure as well.

Relevant parameters of line routing of High Speed Rail in ground view are the minimum radius for a lateral acceleration of 1,0 m/s² (in case of \( v_{e,RS} = 300 \text{ km/h}; 3662 \text{ m} \)) and the standard radius for a lateral acceleration of 0,5 m/s² (in case of \( v_{e,RS} = 300 \text{ km/h}; 6247 \text{ m} \)). Whenever applicable without additional expenditures the standard radius should be used. In case of Transrapid this differentiation between standard and minimum radius has not to be applied due to its very precise monolithic carriageway and due to itscontactless levitation and guiding technique leading to a non-appearance of mechanical abrasion. Because of these reasons a higher lateral acceleration of 1,5 m/s² is permissible\(^1\). That leads to a radius of 5530 m for a line layout velocity of \( v_{e,MSB} = 500 \text{ km/h} \). Thus the required radii for High Speed Rail and Transrapid are in the same range despite the significantly higher velocity of the Transrapid. That’s why the trace variants of both techniques do not differ importantly in ground view, apart from the fact that the railway trace is slightly better combinable with parallel motorways when using the minimum radius.

The relevant line layout parameter of the vertical section is the maximum longitudinal gradient. The maximum longitudinal gradient of the Transrapid amounts to 10 % and the one of High Speed Rail is 3.5 %. But also the radius of the levelling curve of gradient changes has a significant influence on the longitudinal profile because of its quadratical dependency of speed. This leads to the fact that High

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\(^1\) The line layout of High Speed Rail may be designed with a higher lateral acceleration and accordant lower radii as well when a rigid slab track and tilting technology is applied. But not realized yet.
Speed Rail running 300 km/h may only take full advantage of its limiting gradient of 3.5% when a longitudinal height barrier of at least 28 m has to be surmounted. The Transrapid running 500 km/h may use its limiting gradient of 10% not even until a minimum height barrier of 278 m.

But the Transrapid being able to run steeper gradients than 3.5%, is nevertheless more advantageous in mountainous terrain as the figure of the ore mountain crossing between Dresden and Prague is showing clearly (see fig. 3).

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**Fig. 2: Stations and System Edges**

**Fig. 3: Longitudinal Profile of the Ore Mountain Crossing Between Dresden and Prague**
Despite its higher velocity of 100 km/h\(^2\) the Transrapid requires only half of the tunnel length being denoted to High Speed Rail. The descent of the Ore Mountains in the center of figure 3 should be pointed out particularly because there the Transrapid may take full advantage of its maximum longitudinal gradient of 10\%.

The total length of the direct traces between Berlin and Budapest amounts to 937 km for the High Speed Rail variant and 885 km for the Transrapid variant. The difference is related to the higher climbing ability of the Transrapid permitting a straight-lined and thus shorter line routing especially between Brno and Vienna (see fig. 4).

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\(^2\) In tunnels only 400 km/h are acceptable because of aerodynamic reasons.
5  RUNNING TIME CALCULATIONS

The next planning step following line layout is the calculation of running times. In this field the Transrapid is showing its predominance against High Speed Rail most explicitly. The Transrapid accelerates very well and almost constantly with 0.9 m/s². Its top speed of 450 km/h is reached within 3 min (see fig. 5). The ICE requires nearly 5 min until it reaches its top speed of 300 km/h. Moreover the Transrapid may run approaches to stop stations in urban surrounding with a speed of 250 km/h due to its low noise emissions and low vibrations.

Fig. 5: Speed Profiles (Direct Variants)

Compared to ICE the running time benefit of Transrapid is significant: It needs 2:13 h from Berlin to Vienna and 3:20 h from Berlin to Budapest including 6.5 % of operational extra time³ and 10 % planning reserve. Its commercial speed amounts to 265 km/h including all extra times and to 295 km/h without planning reserve.

With this running performance the operating range of a one-day business trip (4 hour running time per direction) extends to a distance of 1000 km and more with Transrapid, in contrast with High Speed Rail not more than 700 km at maximum.

³ The lower operational extra time of Transrapid is justified by its completely own carriageway whereas the High Speed Rail has to share its carriageway on city access tracks with other train types. In addition, the traction system and the regular breaking devices of Transrapid are independent of friction.

⁴ Regular running time: technical running time + operational extra time, scheduled running time: regular running time + planning reserve.
6 TRAFFIC PROGNOSIS, OPERATIONAL CONCEPT, COSTS AND REVENUES, ECONOMIC EFFICIENCY

More detailed information on the results of traffic prognosis, operational concepts and cost of construction, of vehicles, of operations and of maintenance will be given in the lecture of Mr. Prof. Arnd Stephan titled "Operating Concept and System Design of a Transrapid MAGLEV Line compared with a High Speed Railway in the pan-European Corridor IV". In this respect only those aspects of these topics will be focussed in this article that are relevant to the assessment of profitability of both regarded high-speed links.

Based on three different scenarios annual transportation revenues are expected to be between 640 and 910 million € to High Speed Rail as result of the traffic prognosis. In contrast the annual transportation revenues of the Transrapid variant are estimated between 848 and 1096 million € (see Fig. 7).

The further analysis was based on the macro-economically “optimistic” scenario ("Optimistic Sz.") that assumes an 80 % real increase in petrol prices (price basis 2000) and a distance dependent highway toll of 7 €-Cent / km.

5 “Micro-economically optimistic” would be the medium scenario. This scenario delivers absolutely higher revenues because of higher ticket prices leading to lower traffic performance.
Fig. 8: Investment Costs and Annual Costs (Direct Variant)

Fig. 9: Cash Flow for 3 % Calculatory Interest Rate (Direct Variant)
left side: without an increase in non-petrol energy costs, right side: with a 40 % increase in non-petrol energy costs
Start of railway operations in the 11th year
For the two direct variants the investment costs of infrastructure and rolling stock are estimated to be 20.0 billion € for Transrapid and 13.7 billion € for High Speed Rail respectively (see Fig. 8).

Annual operational costs and costs of maintenance are expected to amount to

- 237 million € for Transrapid and 308 million € for High Speed Rail, without assuming an increase in non-petrol energy prices, and to
- 262 million € for Transrapid and 323 million € for High Speed Rail with an assumption of 40% increase in non-petrol energy prices.

In a period under review of 50 years the displayed revenues and costs are generating a financial internal rate of return (FIRR) of

- 2.2% (Transrapid) and 2.0% (High Speed Rail) without an increase in non-petrol energy prices and
- 2.0% (Transrapid) and 1.8% (High Speed Rail) assuming a 40% increase in non-petrol energy prices.

These figures and the cashflows displayed in figure 9 are showing that the investigated high-speed links are feasible during the operating period also in respect to micro economic aspects. With a calculatory interest rate of 3%\(^6\) (being assessed to governmental investments in traffic infrastructure) the break-even point of both technique variants will however not yet be reached in the 50 years period under review.

Characteristically to both technical variants being discussed is the lower deficit of High Speed Rail in the early part of the period under review because of its lower initial investments in infrastructure, whereas the Transrapid is more favourable in operations and might thus compensate for the early cost disadvantage of infrastructure in approximately 40 to 50 years of operation.

7 SUMMARY AND RECOMMENDATION

Besides the micro economical view investments in traffic infrastructure have to be considered under macro economical aspects including environment protection as well.

Positive in terms of Transrapid in macroeconomic view are the perpetuation of leadership in the field of a future technology and moreover an enhanced competitive position against short and medium distance flights. Regarding environmental protection low vibrations also on top speed level and lower noise emissions at a comparable speed level militate in favor of Transrapid, the latter being of special interest in cases of city access.

Negative in terms of Transrapid is the existence of a highly developed railway network in Europe with a compatible wheel-/rail high-speed technique allowing high-speed trains also to run on the conventional railway network, thereby serving the benefit of a high-speed connection to larger regions without additional train changes. But the following aspects have to be considered however:

- The resulting transfer resistances to the Transrapid trains are already included in the prognosis of its traffic volume. In other words: If there was an existing networked Transrapid system a new link Berlin – Budapest would have been forecasted on a higher traffic volume.
- assuming a further spreading of the Transrapid technique this disadvantage of migration would disappear in the long-term.

As aforementioned the planning horizon of this study is the year 2020. Thinking beyond this point in time and bearing in mind the long-term development of land-bound high-speed technique and high-speed networks in Europe, and taking also into account that the Transrapid is not economically benchmarked worse compared to High Speed Rail on the investigated link, the system recommendation for the line of interest for the present is: TRANSRAPID. But further, more detailed investigations are still necessary.

\(^6\) note: without inflation