An Entire Comparison of Maglev and High-Speed Railway Systems

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KEYWORDS: Comparison, Decision making, Realization, Benefit, Costs, Analysis

ABSTRACT: The decision making and realization of maglev and traditional high-speed railway projects may be based on a multi-level and multi-criteria decision. Several criterions from different areas are playing a decisive role and have to get involved into the decision making. Economical, ecological, political, technical and technological aspects coexist. They may be evaluated from the views of users, operators, society and politics. In traditional decision making of railway projects traffic, economic and ecological aspects are standing in the front. But this general practice is to question for new transportation systems like the maglev system Transrapid. The evaluation should also take aspects from the fields of the national economy and the industry into adequate account. Against this background, an entire approach for comparing maglev and high-speed railway systems is recommended, which bases on a multi-dimensional and multi-criteria model. In conclusion, the entire approach is exemplified for the Transrapid and the German high-speed railway ICE.

1 INTRODUCTION

The European Union attaches importance to the development of transportation systems. Beside the expansion of the railways, the EU has recognised the potentials of Magnetically Levitated Systems, especially the Transrapid. The realization for a high-speed transportation system leads to a deciding situation, which should be solved by wide accepted approaches. Following the importance (section 1.1) and the infrastructure of high-speed transportation (section 1.2) are explained before the traditional used comparisons (chapter 2) and an entire approach (chapter 3) are discussed.

1.1 Importance of high-speed transportation

Mobility and transportation infrastructure are essential pre-conditions for the industry, the national economies and the growing together of Europe and the development of its regions. They are providing the basis for trade, goods traffic and consumption. Furthermore mobility and transportation infrastructure are a primary need for the population. They guarantee a high grade of freedom and quality for the citizens, for their work and leisure time. Both, industry and society rely on a well constructed infrastructure. Infrastructure is an important location factor in the regional and global sense and influences strongly the competitiveness. In spite of these facts, infrastructure is hold responsible for many negative impacts. Especially environmental pollution, disturbing noise and land use are complained. The development of the society, the growth of the national economies and the mobility of individuals and goods are impossible without an equivalent volume of traffic and transportation infrastructure.

The enlargement of the European Union with the ten new Member States is increasing the volume of traffic enormously. It may be expected, that the developments of traffic will lead to an overload of the capacity of the European road traffic network. Therefore new sustainable traffic infrastructures and systems are needed. They may strengthen the existing economic areas. Beside of the so called ‘Blue Banana’ there may be developed a second economic core area, the ‘New Banana’ (see figure 1).

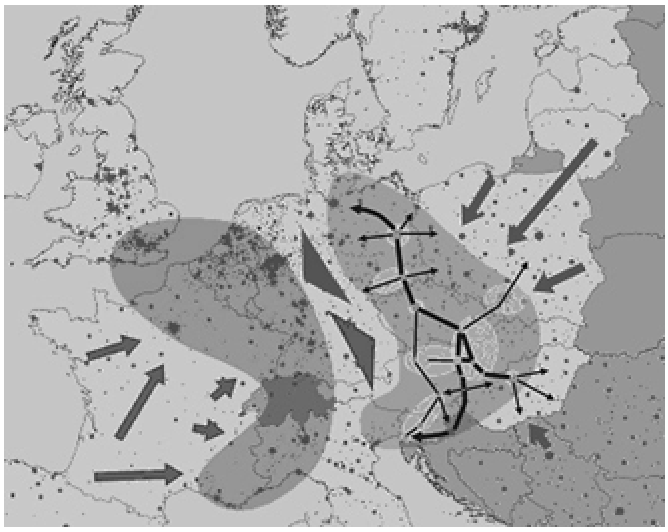

Figure 1: Development of a second economic core area in Central-East-Europe (left: “Blue Banana”, right: “New Banana”) (source IPE GmbH, Vienna)

This idea is a main focus of the research project ‘Sustrain Implement Corridor – SIC!’. An important part is the module high-speed transportation [1]. In this module a high-speed transportation line between Berlin – Dresden – Prague – Brno – Vienna – Bratislava – Budapest in the Pan-European Corridor IV is analysed and developed.

Against the background of increasing energy requirement, limited fossil resources – especially oil deposits – and ever-growing CO_2-loads, the road traffic may not be the adequate answer for the challenges of the future developments of the EU. The road traffic may be preferable from the point of efficiency indeed. But there are some more perspectives like the national economy, the traffic, the politics or the industry, that must also be considered. It is necessary to establish integrated and sustainable traffic systems for the effectively and environmentally acceptable handling of traffic.

1.2 High-speed transportation infrastructure for the EU

The transport policy has faced up the challenges of the future developments of the EU and has formed the major vision of the development and implementation of the high-speed railway transportation in particular through a Trans-European Transport Network (TEN-T). There is another important fact concerning the realization of high-speed transportation systems in Europe. The enlargement of the European Union has led to rethink the TEN-T and to develop the Pan-European Corridors and Areas (see figure 2). The Pan-European Corridors include ten road and rail corridors between West, Central and Eastern Europe. About 20.000 kilometers line sections of high-speed railway are to connect the important economical areas in Europe.

Corridor	Stations
I	Helsinki – Tallinn – Riga – Kaunas and Klaipeda – Warsaw and Gdańsk • Branch A (Via/Rail Hanseatica) – Riga to Kaliningrad to Gdańsk • via Baltica (E 67) – Helsinki to Warsaw
II	Berlin – Poznań – Warsaw – Brest – Minsk – Smolensk – Moscow – Nizhny Novgorod
III	Brussels – Aachen – Köln – Dresden – Wrocław – Katowice – Kraków – L'viv – Kyiv
IV	Dresden/Nuremberg – Prague – Vienna – Bratislava – Győr – Budapest – Arad – Constanța / Craiova – Sofia – Thessaloniki / Plovdiv – Istanbul

Figure 2: Some Pan-European Corridors and Areas

The promotion of high-speed transportation is a manifested aim of the European transport politics, in order to relocate road and air traffic to rail and to reduce environmental pollutions. High-speed transportation systems, like the German Magnetically Levitated System Transrapid, offer high potentials and may play an important contribution to handle the future volumes of traffic in the EU. It may be true, that other traffic systems are also be able to enhance the growth of the European urban areas and the coalescence of the European economic area. But only the development and implementation of high-speed maglev and railway systems are able to relocate certain parts of road and air traffic to more ecological transportation systems. The target of traffic relocation must not only be pushed from an ecological perspective. It has to face up the question of generated economical benefits. Traditional high-speed railways show some disadvantages like moderate traffic speeds and considerable costs for construction and operating. So the question is, if the railways may be the right answer for high-speed transportation in comparison to the maglev system.

2 TRADITIONAL COMPARISON OF HIGH-SPEED TRANSPORTATION SYSTEMS

2.1 A short technical comparison

For high-speed transportation, two systems are differentiated. These are the conventional high-speed railways, like the German InterCityExpress (ICE) (see figure 3 right), the Spanish AVE or the French Train à Grande Vitesse (TGV), and the Magnetically Levitated Systems, like the German Transrapid (see figure 3 left). But the question is, which system is better ?

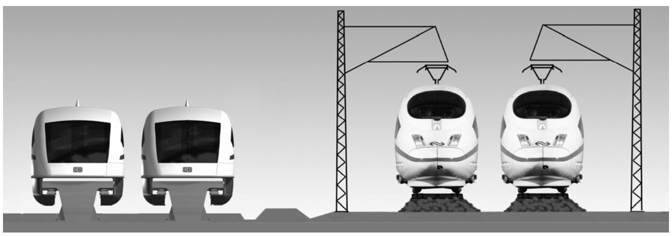

Figure 3: Transrapid and InterCityExpress (ICE)

Following, a comparison of some important technical data between ICE and Transrapid is given (see figure 4).

Parameters	InterCityExpress (ICE) 3*	Transrapid**
Active Priciple	load transmission and guidance by wheel and rail	load transmission and guidance by electromechanical fields
Wear	high	none
Operation Control	by engine driver	without a engine driver
Traffic Safety	high	very high
Operational Maximum Speed	300 km/h	450 km/h
Sections per Vehicle	8	5 (from 2 to 10 possible)
Seats (on average)	415	438
Maximum Engine Performance	8.000 kW	approx. 25.000 kW
Net Weight Vehicle	409 t	247,3 t
Width	2,95 m	3,70 m
Length (total)	200 m	128,3 m
Load	axle load 16 t	load per unit length 2,2 t/m
Sound Emissions		
- at 200 km/h	82 ... 84 dB	79 dB
- at 300 km/h	87 ... 91 dB	86 dB
- at 400 km/h	-	94 dB
Route Planning		
- Maximum Longitudinal Gradient	3,5 %	10 %
- Maximum Transverse Gradient	6,5 %	12 %
Acceleration	maximum 1,0 m/s²	constant 1,5 m/s²

* The shown parameters refer to the type series 403.
** The shown parameters refer to the type series TR 08.

Figure 4: Comparison of technical parameters of the ICE and the Transrapid

The comparison clarifies the technical advantages of the Transrapid. The average travel speed of the high-speed railways ranges between approx. 130 km/h and 220 km/h, strongly depending on the distance between the stations. The Transrapid achieves an average travel speed of approx. 300 km/h. this represents approx. 67 % of the operational maximum speed, because of the high continuous acceleration. The Transrapid is obviously the more attractive and powerful transportation system, especially with a maximum operating speed of 450 km/h. On the one hand, the advantages qualify it for premium peer-to-peer-transportation-links with a high traffic volume like the planned project in Munich. On the other hand, it is particularly suitable for long-distance transportation of passengers like the researched line from Berlin to Budapest [1]. The Transrapid is very competitive with air transportation at distances between 400 and 700 kilometers and against passenger cars at distances starting of 100 kilometers. In contrast to the Transrapid, the high-speed railways are only conditionally able to compete with passenger road and air traffic at distances between approx. 150 and 350 kilometers.

The realization of high-speed transportation systems must fulfil the major elements of the transport politics. The main aims consist in the increase of speed in the transportation corridors, flexibility, networking and environmental acceptance. These aims result in a series of requirements:

– high speed,
– high railway frequency,
– high safety and reliability,
– high flexibility,
– high ride comfort,
– low costs,
– low stresses (noise, pollutions, vibrancies) and
– low energy consumption.

The two existing high-speed transportation systems in railway and maglev technology must be evaluated and compared against the background of these requirements and the traffic demands. But it must happen in a focus of economical and ecological effects, the aims of politics and promotion of the industry as well. Both systems have obvious advantages in some fields. The question are how to evaluate these aspects in an entire view and which methodology should be used for this comparison. [2].

2.2 The traditional comparison in traffic planning

The realization of major traffic infrastructure influences the society, the economy, the industry and the ecology in various manners. In order to keep the stresses of an infrastructure project in an acceptable range, a high-speed railway or maglev system must prove its advantages. These advantages are traditionally proven by a benefit-cost-ratio. Therefore extensive and detailed studies must be carried out.

The realization of traffic infrastructure is typically faced by high costs. The investment and operating costs play a key role for the transportation infrastructure, because of their amounts. They must be examined in an intense planning process, with feasibility studies, economic estimations and arrangements for financing. Often this process takes many years, because it is a multi-level procedure with many feedbacks.

Traditionally, a comparison of high-speed transportation systems is carried out in an evaluation process for infrastructure projects. The contributing criterions for the decision of realization of a specific project must be evaluated in a multi-criteria procedure. Therefore different models have been developed. In Germany, decisions for traffic infrastructure are made in the national general planning for the transportation network, called "Bundesver-kehrswegeplanung". The method in the evaluation process is a standardised, multi-level and multi-criteria evaluation. It is based on a combination of the cost-benefit analysis and the value-benefit-analysis, which compares the advantages and the disadvantages of an infrastructure system or project by costs and benefits [3]. The aim is to determine a specific cost-value ratio of each project with the present value of the benefits as numerator and the present value of the investment costs in the denominator.

The multi-level process delivers a master plan for new construction, upgrading and maintenance of the transportation infrastructure network. The master plan reflects the political aims, e.g. the implementation of the TEN-T. The bases for the planning are prognoses of traffic volumes and financing provisions. Under these conditions, the considered projects are evaluated and prioritized. The main criterions for the decision making process are:

- the cost-value ratio from the cost-benefit analysis based on different benefits (NB to NH) and cost (K) (see figure 5),
- the results of an additional analysis of spatial effects and
- the results of an additional analysis of environmental risks and effects on flora, fauna and habitat.

Abbreviation	Description
NB	Costs of transportation
NW	Maintenance of traffic routes
NS	Transportation safety
NE	Availability
NR	Spatial effects
NU	Environmental effects
NI	Induced Traffic
NH	Transport connexions of seaports and airports
K	Investment costs

Figure 5: Components for evaluation in the cost-benefit-analysis in the German general transportation planning

The cost-benefit-analysis uses only a monetary dimension. All effects are transformed in cash values, the positive effects represent the benefits, the negative the costs. The spatial and ecological effects are evaluated in a non-monetary dimension. The evaluation method uses a similar procedure to the value-benefit-analysis. Therefore the original values of units have not to be converted in cash values. The final decision is based on a consolidated value, which consists of elements of the cost-benefit-ratio, the additional analyses of spatial effects, environmental risks and effects on flora, fauna and habitat. Although the method seems to be quite objective, there are several subjective possibilities of influences.

2.3 Weaknesses of the traditional procedure

As shown above, microeconomic and environmental aspects dominate the evaluation of transportation systems, for railways as well. Projects, planned to be realised, are evaluated by different aspects from these both fields with this standardized procedure. But the question rises, if this traditional procedure is suitable for the decision of a realization of a maglev system.

The discussions in Germany on the implementation of a first commercial Transrapid line clarify, that this question is justified. Although the advantages, the benefits and the basic necessity are undisputed, the first Transrapid line is not in construction or even in operation up to now (September 2006). Several lines have been investigated, like the line Berlin – Hamburg. For the evaluation of those lines, the same standards were applied as for the evaluation of traditional railways. It has been shown, that the evaluation method has methodical difficulties. The development has been tailored to the existing traffic systems. In conclusion, the evaluation method discriminates new transportation systems like the Transrapid.

The methodical problems of the evaluation method come from different aspects. First, it is problematic, that the various criterions, which have to be considered, may not be measured in their original units, because of their various dimensions. For example, the cost-value ratio is based on a monetary dimension, the other criterions are qualitative and their effects are of non-monetary dimensions. In addition, the transformation of the original units of criterions, which are of a non-monetary dimension, may not be less problematic or nearly not feasible, e.g. for emissions of noise or CO_2, land use, time savings or impacts of accidents.

Another problem in the evaluation and decision process are the uncertainties for the necessary assumptions, e.g. for the volumes of traffic or the effects on employment. The effects may be forecasted only inexactly in its entirety [4]. There is no possibility in the present to verify the prospects for the decision maker.

As shown in section 2.2 the decision making itself is not out of difficulties, e.g. the consolidation with the results of the cost-benefit-analyses. On the one hand, many different aspects have to be considered; some of them are conflicting. And on the other hand, the evaluation models can only provide a support for the decision maker. All models give only specific views under the considered assumptions and may come to different results. The ultimate decision between the alternatives for a high-speed transportation system is specially affected by political influences and is a subjective decision taken by the decision maker or group [5].

The main problem for the evaluation of a new high-speed transportation system is the fact, that benefits for the economy and the industry are paid no attention. The Transrapid may generate significant positive impacts not only for the transportation network. It may also lead to positive economical effects [6].

Against the background of these shown problems, the evaluation and decision for realization of new transportation systems like the maglev system Transrapid should be carried out more distinguished.

It is necessary to include economic and industry political aspects in an adequate manner. Following a substantial method for an entire comparison of high-speed transportation systems is presented.

3 A MULTIDIMENSIONAL AND MULTI-CRITERIA COMPARISON

3.1 An alternative comparison

For a comparison of infrastructure projects of the high-speed railway and maglev systems all criterions of the evaluation method of the German general transportation planning have to be included. So, all criterions from the fields of traffic, microeconomic and ecology are taken into account. In addition, aspects from the fields of national economy and politics of industry have to be adequately included.

The authors have developed an entire approach for the comparison of maglev and high-speed railway systems [2]. The provided method is based on the fact that an ultimate decision, whether a traffic project will be realised or not, should not be taken only by the results of the cost-value ratio and its monetary dimension. Other quantifiable aspects (e.g. noise) qualitative facts (e.g. comfort) have to be considered adequately by the decision maker. Therefore the provided approach will not create a decision, but focuses on all important influencing factors.

3.2 An entire approach

The proposed multi-dimensional and multi-criteria comparison for maglev and high-speed railways systems is based on the principle of the value-benefit-analysis. The method is multi-dimensional because of four different simultaneously interested groups. And it is as well multi-criterial, because of technical, microeconomic and economic evaluation criterions and the involvement of effects for traffic, ecology and industry. For the evaluation process, the basic structure of the value benefit analysis has been adapted, because of their dimensionless and modifiable character. But the approach is executed without a weighting of the aim criterions and the aggregation of part benefits. This partial step would be critical, because of its subjectivity. The formalisation and automation in the decision making through possible weightings and aggregations has not been intended. The results of the four perspectives in the decision making process are maintained and the ultimate decision making is left to the observer.

The basis for the comparison of maglev and high-speed railways is a hierarchical structured system of aim criterions (see figure 6). It starts from the view of four different interested groups – users, operating company, society and politics. Aim criterions represent the different expectations of each group. They have partly common aims, but also different and contrary expectations. For an evaluation, the focus may be aligned with the particular interested groups. Therefore aim criterions for each group were selected. They have to be evaluated on a quite simple structure:

- ++ aim criteria completely fulfilled
- \+ aim criteria almost fulfilled
- ± aim criteria partially fulfilled
- \- aim criteria scarcely fulfilled
- -- aim criteria not fulfilled
- p fulfilment only definable for a project

Nr.	Interested group/Aim criteria
1	Users
1.1	Overall travel time (travel speed/travel time, stations, transportation rate)
1.2	Costs (fare, additional costs)
1.3	Comfort (punctuality/availability, seats, entrance/egress, air conditioning, noise inside, baggage, passenger compartment, attractiveness/image, safety sensation, classes of comfort, interior)
2	Operating company
2.1	Maximisation of the incomes (fare incomes, parking places, useful areas in stations)
2.2	Minimisation of the investment costs (track system, vehicles, operational constructions, indirect costs, land acquisitions)
2.3	Minimisation of the operational costs (track system, vehicles, staff, energy)
2.4	Maximisation of the safety (level of automation, braking, fire protection, evacuation, construction of the track system, collision risk)
2.5	Maximisation of the availability, the image and the reliability (failure risk, technical availability, attractiveness, image)
3	Society
3.1	Reduction of negative environmental effects (pollution, noise emissions, vibrancies, land use, water supply, regional scenery, townscape, division effects/separation)
3.2	Increase of safety (reduction of deaths, seriously injured persons, slightly injured persons and material damages)
3.3	Improvement of the settlement and spatial structure (connexions metropolis/ congested areas, coverage of rural areas, networking national and European)
4	Politics
4.1	Transport Politics (mobility, business locations, volume of traffic, transportation safety, resources consumption, emissions, European coalescence, transportation systems)
4.2	Economy (productiveness/division of labour, regional economic structure, settlement and spatial structure, economic cycle/economic growth, external costs)
4.3	Politics for the industry (job market/employment, innovations, export chances, development potential, structural change)

Figure 6. System of aim criterions for the multi-dimensional and multi-criteria comparison

The comparison of the maglev system Transrapid and the high-speed railway ICE shows that the Transrapid outplays the ICE at many criterions and in some criterions even pronounced [2]. The technical preferences, the profitability and the environmental preferences make the Transrapid to an exceeding transportation system.

4 SUMMARY AND OUTLOOK

This abstract describes an approach for an entire comparison of maglev and high-speed railway systems. Starting from the expected developments for Europe and its volumes of traffic, the importance of high-speed transportation systems is emphasized. The question rises which transportation system is more meaningful to achieve the high aims of politics for the high-speed transportation. Some principle technical characteristics of maglev systems and high-speed railways are compared. For a comprehensive comparison more criterions have to be included. Therefore criterions from the fields of economics, ecology, politics of industry and society are drawn on a multi-criteria comparison.

So the main problems and weaknesses of the existing German evaluation method of the national general transportation planning are avoided. An entire approach for a comparison of maglev and high-speed railway systems is proposed. It includes and considers different views and aim criterions from users, operators, society and politics. The results of an application [2] show, that the Transrapid surpasses the high-speed railway in almost all fields.

REFERENCES

[1] SIC! Modul HGV – Sustrain Implement Corridor ! Modul Hochgeschwindigkeitsverkehr www.sustrain-ic.net

[2] Schach R, Jehle P, Naumann R (2006) Transrapid und Rad-Schiene-Hochgeschwindigkeitsbahn – Ein gesamtheitlicher Systemvergleich. Springer-Verlag Berlin Heidelberg.

[3] BMVBW – Bundesministerium für Verkehr, Bau und Wohnungswesen (2003) Grundzüge der gesamtwirtschaftlichen Bewertungsmethodik. Berlin Bonn

[4] Schach, R. (2005) Stochastische Investitionskostenberechnung für Verkehrsinfrastrukturprojekte. In: Proceedings of 5. Dresdner Fachtagung Transrapid. Dresden, Germany, September. p. 109.

[5] Rath A (1993) Möglichkeiten und Grenzen der Durchsetzung neuer Verkehrstechnologien dargestellt am Beispiel des Magnetbahnsystems Transrapid. Duncker & Humblot, Berlin. pp. 228.

[6] Baum H. (2005) Der industriepolitische Nutzen des Transrapid – Methoden der Quantifizierung. Presentation on the 5. Dresdner Fachtagung Transrapid.