Transrapid - Transportation System with High Potential

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ABSTRACT: The Transrapid Maglev System represents the most advanced track bound transportation system. Based on decades of Maglev technology development and the experience from commercial operation, Transrapid is able to solve current and future transportation problems in an economic and environmentally friendly way [1]. New results of further development offer big opportunities to reduce investment and operating cost in the near future. More and more units, currently designed and manufactured specifically for Transrapid, may be replaced by using low cost units from other industrial products. In addition, the Transrapid technology enables medium and/or high speed passenger transport as well as freight (all kind of containers) transport, using a standardized guideway design. Another issue to ease the introduction of Transrapid into the worldwide transportation market is the localization of the production of a significant volume of the equipment, as well as management and execution of the operation and maintenance by local staff. Despite these facts, the German Transrapid project "Munich airport link" was cancelled because of unexpected high costs for civil engineering. In the paper an analyses of the cost break down and the process of decision making is discussed.

1 STATUS OF TRANSRAPID DEPLOYMENT

1.1 China

While the Transrapid airport link between Pudong International Airport and Long Yang Metro Station operates with great success, planning variants are under investigation to extend the line to a big transportation hub at Hongqiao Airport. The alignment to transit the 16 million metropolis needs obviously more time than expected.

The further extension to Hangzhou has been published to be considered in an action plan of the neighbored Zhejiang Province and shall be built starting in 2010.

1.2 USA

The Technical Corrections Bill was signed by the President and therefore enacted in June 2008. A total of a 112.5 Mio US$ guaranteed contract authority funding, comprising 90 million US$ (80%) federal funding and additional 22.5 million US$ (20%) state matching funds, was allocated to the Maglev Deployment Program. This funding is designated for the California-Nevada (Las Vegas) Project and a yet-to-be-chosen east coast maglev project. By law 56.25 million US$ (50%) of the total funding will be allocated to the California-Nevada (Las Vegas) Project. The remaining 50% of funding is to be divided between the three east coast maglev projects of Pittsburgh, Baltimore-Washington and Atlanta.

The Federal Rail Administration (FRA) will allocate further funds for the safety rules of particular applicability for all maglev projects. In this context the FRA intends to reactivate the existing MoU of 2003-2007 with the German Federal Ministry of Transport, Building and Urban Affairs (BMVBS) with a view to an application of the Transrapid Technology in the USA in adherence with the technical approval procedure.

1.3 Germany

Despite the cancellation of the Munich airport link project (see comments below), the current Program for further Maglev Development (WEP) will be carried out as scheduled, and the operation of the Emsland Test Facility shall continue to test the WEP results [2].

Main objective is the safety assessment of the new systems with regard to application in other countries, based on German Maglev Construction and Operation Ordinance (MBbO), and based on German Maglev rules and regulations issued 23rd of October 2007 by Eisenbahn-Bundesamt (EBA), the German Federal Railway Authority.

EBA will hold its competence on Maglev technology and established an experts' Maglev Working Group. These experts might grant support to foreign authorities upon request in executing an official approval and acceptance process.

1.4 Other countries

The Brazilian government is going to establish a high-speed railway service linking Brazil's two mega-cities, São Paulo and Rio de Janeiro, with an extension to Campinas. The tendering for the realization of the 520 km route is expected in March 2009. Transrapid technology will be considered as a favorable alternative, due to the difficult topography. The government has allocated US $ 11 billion in its National Development Program (PAC). Integral parts of this project shall be the airport links in the State of São Paulo and the City of Rio de Janeiro.

Initiated by regional governments of the United Kingdom, feasibility studies for the maglev projects of Glasgow - Edinburgh and Liverpool - Manchester are currently in progress.

2 COMMENTS ON CANCELATION OF MUNICH PROJECT

2.1 Planning figures

The purpose of the project was the rapid connection between Main Station and Airport, distance about 40 km, by service every 10 min within 10 min. The current commuter railroad link needs about 45 min.

Figure 1. Vehicle TR09, prototype for Munich project

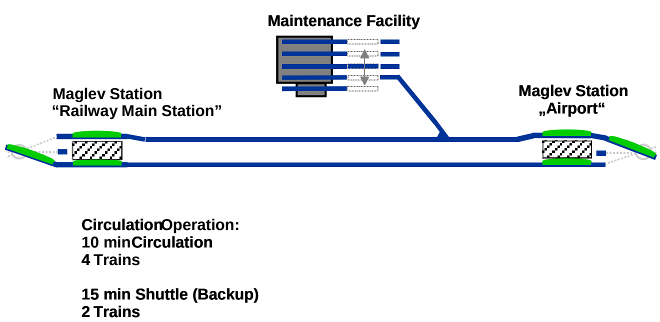

Figure 2. Track scheme of Munich airport link project

5 vehicles type TR09 [2] with 3 vehicle sections were foreseen, hereof 4 vehicles in circulation, 1 vehicle as maintenance reserve.

Item	**Data**
Length of main track	37,7 km
Length of tunnel, hereof - *track tunnel* - *underground stations*	9,0 km *8,4 km* *0,6 km*
Portion of main track in tunnel	24 %
Type of track tunnel	Single track tubes
Planned cross section of tube	52 m²
Portion of at-grade guideway Portion of elevated guideway	84 % 16 %
Type of at-grade guideway Type of elevated guideway	9,3 / 12,4 m concrete beams 25 m concrete beams
Type of foundation	Pillars (at-grade and elevated)

Table 1. Munich airport link, civil system infrastructure

2.2 Conditions of finance and contract

The project was cancelled 8 years after project definition (pre-feasibility study started in 2000), on March 27, 2008. This was few months before the expected legal Building Permission to be issued by Eisenbahn-Bundesamt (EBA).

Deutsche Bahn (German Railway) executed the project planning and was designated to become building owner and operator. In this role, Deutsche Bahn organized the call for tender and defined the contract conditions as investor.

The call for tender demanded an “Overall System Responsible” consortium consisting of companies from system and construction industry to build and maintain the system during 30 years at an overall lump-sum fixed price. The consortium should realize the Maglev specific systems and the civil system infrastructure (see table 2 for definition).

During the year before cancellation, the project became increasingly subject of political disputes and was abused to an disreputable campaign driven by local politicians. As a result, the project became more and more controversial. Many people and groups demanded, the public money foreseen to finance the Munich Maglev project should better be spent for improvement of the existing railway network or for social purpose, not willing to realize the significant advantages of the Transrapid airport connector, the strategic importance of the project and its highly positive effect for local employment.

Germany's federal government and the Bavarian government strictly limited the financing support to a fixed amount referring to a three years old cost estimate.

For the Munich Transrapid project, the contractual fixed price including all risks of cost escalation, even resulting from changes in the scope of work, should be the same as the some years old cost estimate of 2004.

The gap resulting from price escalation and uncertainties in the 2004 estimate should be compensated by a design-to-cost process.

2.3 Development of investment cost

The following table enables to compare the cost estimated in 2004, and the cost calculated in 2008 on the basis of the conditions of call for tender of November 2007.

	Cost estimation 2004		Cost calculation 2008		Δ
Scope	[Mio.€]	Source	[Mio.€]	Source	[%]
General civil infrastructure - planning - buildings - land acquisition	405	Estimate by Deutsche Bahn and contracted planning bureaus	690	Estimate by Deutsche Bahn and contracted planning bureaus	70
Civil system infrastructure - guideway without long stator, incl. foundations and bridges - tunnels - underground stations	610	Estimate by Deutsche Bahn and contracted planning bureaus	1.650 1)	Calculation by Civil Consortium 2)	270
Maglev specific systems: - vehicles - propulsion - -operations control - long stator, guideway switches	875	Estimate by System Industry	1.060	Calculation by System Industry 2)	21
Total system	1.890 3)		3.400		84

Comments:
1) Scope in 2006 not exactly the same as 2004
2) Mainly according to call for tender, without recognized design-to-cost potential
3) This figure was promulgated to as 1,85 billion €

Table 2. Munich Airport link, cost development 2004 vs. 2008

2.4 Evaluation of cost escalation

The prices for the Transrapid specific equipment remained basically on the level of 2004. The moderate increase of 21 % represents the general cost increase of work and materials and the extension of the installation time.

The dominating cost increase of 270 % results from civil system infrastructure.

The guideway only represents about one third of the cost for civil system infrastructure. Two thirds refer to tunnels and underground stations. The following reasons mainly contribute to the cost increase:

- False estimation of actual cost for underground station during the planning period.
- Request to increase the tunnel cross section from 42 m² to 52 m² (+ 24 %) to outnumber the standard of ride comfort with respect to change of air pressure, and increased length of tunnel to avoid public debates about noise protection.
- Increased installation time 81 months. In 2004, an installation time of 48 months had been estimated.

The main reason for increase of installation time is as follows: The call for tender stipulated extreme restrictions to build the underground station with regard to accessibility in the railway station area:

- “Cut and Cover” was not allowed,
- only temporary installation of small lifting holes was permitted,
- temporary de-installation of railway tracks was not admitted.

The evaluation can be summarized as follows: There are two general reasons for the cost increase of 70 % respectively 270 % of all civil works:

The first reason results from a common practice to plan civil works without any participation of construction companies, thus underestimating the actual cost. The consortium of construction companies called for fixed price tender received the plans and contract conditions the first time 4 months before cancellation, despite more than 7 years of planning period. Competition regulations are said to be the cause of such practice.

The second reason results from the contract conditions definitively defined by Deutsche Bahn. The contract stipulated a fixed price including all potential cost escalation in future, a catalog of a roughly five hundred functional requirements and partly unverifiable acceptance conditions, and hardly acceptable commercial conditions such as pre-funding of main portions of the contracted work and deliveries by the consortium over a long period of time, even after final acceptance.

These inappropriate conditions lead to the promulgated price of 3.4 billion €, which is 1.5 billion € higher than the target of 1.85 billion € - the easy argument to a political decision to cancel because of financial reasons, because no one believed that any design-to-cost process could reduce the 3.4 billion € to the fixed price of 1,85 billion €.

The increase of calculated cost was not caused by the Maglev technology, but by the civil works (tunnels, stations) and the contract conditions. Under such conditions a conventional railway project would have experienced the same cost increase.

3 COST FRAME FOR A REPRESENTIVE AIRPORT CONNECTOR

With regard to future applications of Transrapid, the investigations for the Munich project revealed significant design-to-cost effects, which shall be used in similar projects. The respective effect on investment is shown hereafter by an example of a representative Transrapid airport connector. The data may be used as a basis for a first estimate in feasibility studies of future projects..

3.1 Typical project data

The key data may be as follows: track length about 40 km, service every 10 to 15 min, 100 rides per day each direction (in total 200 trips per day),

Peak capacity per train is 450 passengers seating and standing [2], the assumed average is 150 passengers per train run.

This means a daily capacity of 90.000 passengers (both directions), and an assumed daily average volume of 30.000 passenger rides (both directions), or about 10 million passengers per year.

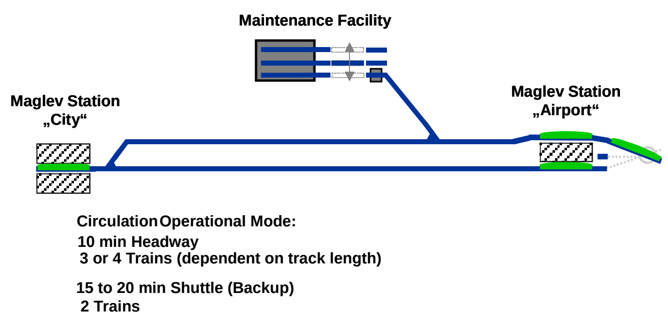

Figure 3. Track scheme of representative airport connector

Compared with the track scheme of the Munich airport link (Figure 2), Transrapid enables a highly space efficient solution of the city station, shown in Figure 3. In general, nobody wants to waste space in premium real estate areas for idle railway tracks. At Transrapid however, the ratio of “station space demand” to “transportation capacity” is much lower compared with other track-bound transportation systems. Therefore, a link using Transrapid technology enables to realize a city station at zero-level, being much more attractive to riders at much lower investments compared with an underground station.

3.2 Investment and maintenance cost estimate

The following table summarizes a construction cost estimate of such project, reasonable contract conditions assumed.

Transrapid Airport Connector (international project)	Cost estimate price base 2008 [Mio.€]
Maglev specific systems and components: - vehicles - propulsion and energy supply - operations and infrastructure control system - guideway equipment (long stator) and guideway switches	ca. 900
Guideway girders, foundations, bridges, short tunnels, peripheral works	ca. 600
Budget for planning, buildings and land acquisition	ca. 500
Total	2.000

Table 3. Cost estimate for a representative Airport Connector

In the above figure particular special expenses for long tunnels and/or spacious underground stations are not considered. The respective investment expenses may vary in a wide range dependent on local conditions and have to be taken into account individually for each project.

The above figures are based on the assumption of a lean and efficient turn-key project management organization, and that the executing consortia hold responsibility for the overall function of the system.

The amount of average maintenance expense per year (price level 2008) may range at about 0,5 % of the investment cost, i.e. 10 million € per year. This figure is valid for fully automatic operation and includes the execution of scheduled and unscheduled maintenance measures, supply of spare parts, the management of maintenance service, and a certain amount for product support by the manufacturers. For the project data assumed, the maintenance cost would be roughly 1 € per passenger trip.

3.3 Building Period

A building period of 48 months until final acceptance is expected to realize the representative airport connector. Local conditions may influence the duration and have to be evaluated individually.

4 EXTENDED FIELD OF APPLICATION

Based on the existing , in daily revenue service proven Transrapid passenger train technology, a cargo version and a freight version have been designed.

For the cargo version, the same undercarriage and technology as for the passenger vehicle TR09 are applied. The cargo version differs from TR09 only with regard to the carriage body, which is specialized to transport parceled goods and aircraft containers. The operational parameters such as max. speed and acceleration are similar.

The freight version is a new vehicle concept, based on the proven electromagnetic levitation and guidance technology, adapted to handle the different requirements as increased payload, extended vehicle height, lower operational speed of 180 km/h / 112 mph. Transrapid freight vehicles may transport up to 61 metric tons per section and could carry standard 40 ft. sea containers, tractor trailer containers, and/or customer-specific containers or pallets. Two 40 ft. containers can be carried on a middle section, one 40 ft. plus one 20ft. container on an end section. Transrapid freight trains could consist of maximal 20 sections capable of a payload of about 1200 metric tons / 2,500,000 lb.

There are no modifications required in the layout of the route (guideway, propulsion system , operation control system). The requirements of super speed passenger and cargo operation also cover those of freight operation, because the higher static loads are compensated by the lower dynamics at a speed of 180 km/h (112 mph). Therefore fully automated mixed traffic (passenger-, cargo-, and freight-transport) can be applied without a specific impact on investments and maintenance cost, if respective demand on a route or on some of its segments does exist.

5 POTENTIAL OF TRANSRAPID TECHNOLOGY

5.1 General benefits

Transrapid technology holds a large potential to further increase its economic attractiveness.

Until very recently, most of the components of Transrapid subsystems had to be developed and manufactured to meet specific requirements covered by no other marketable product. This caused very small series and single part production at a low level of automation. The ongoing progress of many technologies is giving great opportunities for Transrapid to apply automatic production means and components offered on the market for reasonable low prices.. The application in Transrapid subsystems is simplified by the fact, that Transrapid makes use of autonomous modular subsystems, and the advantage of long stator propulsion with all traction power devices located in substations and therefore without restriction to volume and/or weight.

Some significant examples are presented in the following chapters.

5.2 Vehicle on board equipment

Transrapid vehicles benefit from two strong trends of automotive technologies:

The first is the increasing application of electronic control functions, some of them safety related (“by-wire-technology”). New standards for micro-controller hardware and software platform (AUTOSAR) and safety related bus systems (FLEXRAY) give the opportunity, to apply approved products from mass series production for control systems in Transrapid vehicles.

The second trend refers to electric drive or hybrid drive units for automobiles. While classical onboard networks operate at 12 V, new hybrid cars have networks ranging 300 V to 450 V. This is just the level of Transrapid onboard networks. New battery systems for automotive applications, based on NiMH- and Lithium-Ion-Technology are available on the market, and can replace NiCd aviation battery cells, which are currently still used in Transrapid vehicles in large amount (about 1.500 cells per vehicle section). In the future, batteries from automotive mass production featuring high quality and low price level will be used. The advanced battery technology also cuts a considerable part of vehicle’s maintenance expense. While current NiCd cells need a 3 month maintenance interval and reveal poor quality and life span, the new batteries developed for automotive applications need no maintenance and a life span of 10 to 15 years is prognosticated.

5.3 Propulsion equipment

The latest development of the Long Stator Propulsion system was presented in [3]. Meanwhile, the advanced units are being tested on the Emsland Test Facility (TVE), verifying their favorable features.

The objective was to apply only state-of-the-art components and software platforms which are widely used for industrial application, energy supply and transportation.

The main innovations refer to:

Standardized converter units using advanced Integrated Gate Commutated Thyristors (IGCT) and featuring feed-back of braking energy into the grid,

Innovative control system based on widely spread Sicomp IMC platform using commercial PC operating system,

Standardized low size switching units, mountable to guideway pillars, which will not need own buildings along the track.

Besides the positive effects on life cycle cost, these innovations contribute to realize an efficient and quick system integration and commissioning process.

5.4 Guideway girders

Big advantages result from recent developments with regard to a high degree of automation for industrial production of guideway girders [4]. The progress was supported by significant simplifications with regard to the equipment of girders and the interface between vehicle and guideway.

An additional important benefit from automated production of the girders is the fact, that quality data can be monitored and recorded by highly reliable means. Based on this feature, an extreme simplification of guideway maintenance will be effected.

Up to now, the Transrapid guideway was acknowledged to be without wear and tear, but an open dispute had been existing how to execute the inspection and supervision of the girders in compliance with current standards. Some opinions of experts went so far that each single girder should be regarded as an individual bridge, thus resulting an unreasonable high expenditure for inspection.

Future Transrapid projects get rid of such actions, because only few representative girders need to be inspected in detail. The inspection results are representative for all other girders, because all girders will be produced automatically in accordance with the verified quality standard. This maintenance strategy is completed by the fully automated supervision by sensor systems in the Maglev vehicles, which reliably detect changes of the geometry in the functional planes of the guideway.

6 LOCALIZATION

The amount of local content is a decision making issue for implementation of a new transportation system anywhere in the world. Transrapid can comply with respective requirements because only a small part of the overall investment refers to specific Maglev deliveries.

In each Transrapid project, the general civil infrastructure and the specific civil system infrastructure (see Table 2 and 3 for definition), representing the major portion of the investment, will be realized on site. In particular, the modern and advanced guideway girders shall be produced and equipped in a local factory [4]. Local production also refers to the long stator equipment. New approaches of design of stator packs refrain from the need of special manufacturing technologies and facilitate the production, applying techniques of electric motor production and protective coating of automotive parts..

With regard to the Maglev vehicles, a localization of the vehicle body and even the assembly of the entire vehicles may be considered. In such case, only the Maglev levitation and guidance system would be imported and supplied as a subsystem to the vehicle production line.

The Maglev subsystems for propulsion and power supply and for operations and infrastructure control system could be configured to a large amount using power and communication components from local production.

With regard to operation and maintenance, the Shanghai Maglev Transrapid project has impressively verified, that these jobs can be perfectly executed by local staff without long-term need of support from foreign experts.

Thus, the decision to apply Transrapid technology for transportation tasks worldwide includes attractive opportunities for local employment.

7 CONCLUSION

A strong progress of Transrapid system development is ongoing. The field of application has been extended by cargo and freight transport systems ,without the need of a redesign of the guideway. Therefore, fully automated mixed transportation can be applied, if respective demand on a specific route or on some of its segments exists. Design-to-cost features are consequently under verification, driven by the engagement of the German system and construction industry (see References). New approaches are overcoming former cost driving requirements.

The competitiveness of Transrapid and its attractiveness to operators and riders is still increasing and will accomplish transportation solutions which are highly efficient and environmentally friendly.

8 ACKNOWLEDGEMENT

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