Simulating the Proposed Munich Maglev System on the Transrapid Test Facility in Emsland

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Abstract

The maglev rail operator Deutsche Bahn AG has published its requirements for the high-speed Munich airport link as a set of so-called functional specifications. The recently overhauled maglev facility in Emsland in the north of Germany provides DB AG with the means to test whether these functional specifications have been met. System functionality is warranted by the industrial suppliers. The organisational constraints and the limitations of the verification process will be discussed.

1 Operational requirements

Deutsche Bahn AG (DB AG) will build, own and operate the maglev line linking Munich's main station and Munich International Airport.
DB's primary objective is to offer its customers an attractive and cost-efficient transport service. As the train operator, DB AG will also be responsible for ensuring the safety of the maglev train service.

To guarantee that these goals are reached and that the associated obligations are met, DB (as the operator of the service) has formulated a set of specifications that the magnetic-levitation regional transport system planned for Munich must meet. These specifications, which have been published in reference 1, take account of Deutsche Bahn's experience as a train operator in the area of wheel-rail transport and of the results obtained so far from the operation of the Transrapid Testing Facility in Emsland (TVE).

The operator's specifications are classified into the following areas:

- Operational and transport safety
- Performance
- Reliability
- Punctuality
- Customer satisfaction
- Environmental compatibility
- Cost effectiveness

The requirements stipulated by the operator in the published specifications document are what are known as functional specifications. That means that the specification document identifies those functional requirements that, from the operator's point of view, the maglev rail system must meet.

It is a principle of such functional specifications that they do not describe how the actual technical solutions should be designed. This approach ensures that sufficient room is maintained for improving and optimising the system. How solutions are engineered is the responsibility of the companies in the maglev systems industry.

The functional specifications compiled by DB AG take into account the relevant statutory provisions governing the use of magnetic levitation technology, such as the Maglev Railway Construction and Operating Regulations (MbBO).

The specifications stipulate the requirements of the builder, owner and operator of the system, DB AG, that the general contractor of the high-speed maglev system in Munich must meet. The requirements are concerned with the condition and functional status of the system on the acceptance date and during the system's lifetime, as well as with cooperative activities in the areas of system planning, development, production, construction and commissioning. These individual processes must be configured as components of a life-cycle process as defined in European standard EN 50126.

The requirements were compiled so as to be:

- testable,
- unambiguous,
- complete,
- comprehensible,
- legal and
- consistent.

The requirements should be tested as part of a functional acceptance procedure and should be covered by warranty.

The functional specifications published by DB AG will help system suppliers to develop and improve regional maglev transport solutions that are both market- and customer-focused.

2 Prerequisites

As part of its preparations for operating the high-speed maglev service in Munich, Deutsche Bahn wishes to test and assess the fitness and suitability of current magnetic levitation technology for its purposes. The basis of this assessment will be DB's functional specifications referred to above.

Most of the functional specifications laid down by DB require documentary verification that itself presupposes testing of the maglev railway as a complete system.

This also applies to those requirements that, in order increasing planning reliability, must be demonstrated before construction of the high-speed maglev route in Munich commences. Emphasis is given to the following aspects:

- Overall system functionality after integration of technological improvements generated by the maglev systems industry
- Testing of organisational structures in the areas of operation and maintenance that meet the needs of the Munich system

Figure 1: The TR08 maglev vehicle on the TVE test facility

Operational procedures can be tested and simulated at the Transrapid test facility in Emsland (TVE) and the results used to assess the high-speed magnetic levitation rail system.

Up until now, the TVE facility was used for testing long-distance maglev systems. The decision to use the high-speed maglev system in a regional transport setting has meant that the TVE has had to undergo a comprehensive improvement programme.

The TVE facility, which represents both test bed and test object in one, was overhauled and modernised between 2003 and 2004 with funding supplied by the federal government and industry.

Table 1 shows the timetable for the TVE improvement programme up until the time when DB AG takes over the operation of the facility.

Table 1: Timetable up until the time when DB AG assumes responsibility for running the TVE test facility

	2003				2004				2005			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
Improvement programme												
Safety testing												
Testing phase												
Trial phase with functional acceptance												
Handover to DB AG												
Operation of the TVE facility by DB AG												

2.1 TVE improvement programme

The scope of the improvement programme was determined on the basis of the functional specifications published by Deutsche Bahn and referred to earlier. Also of relevance was the weak-point analysis of the TVE facility carried out by DB Magnetbahn. Deutsche Bahn consulted with the maglev industry to determine which of the requirements listed in the functional specifications referred to above should be demonstrated at the TVE test facility using scheduled operations tailored to accommodate the conditions at the Emsland test facility.

The main goal of the improvement programme is the need to update the facility so that it reflects the current standards in maglev technology, as realised in Shanghai. Reliability must be raised to a level that is high enough to ensure that the operational performance necessary for meaningful verification and evaluation can be maintained during the test phase. It was also expected that costs would be reduced, particularly the costs for maintenance work.

Costs also had to be maintained within an economically justifiable limit. For instance, although the guideway in Emsland did not correspond to the type of guideway to be used in Munich, improvements were limited to measures designed only to improve reliability. The replacement of the entire guideway was not feasible for cost reasons.

The core elements of the improvement programme are:

- Propulsion system
  - Update of the propulsion software
  - Conversion of transformer substation 2
    (i.e. metallic isolation of the two drive zones, which were previously only separated at the control level)
  - Installation of new protection and control equipment for the guideway switching stations
- Operation control system
  - Conversion of the operation control system and the radio transmission system (to achieve consistency with the product standard in Shanghai)
- Vehicle
  - Measures to increase the reliability of assemblies or modules used in the TR08 maglev vehicle
  - Installation of support skids with CFC liners
- Guideway
  - Coating the gliding strip on concrete guideway beams
  - Vibration dampers installed in the steel beams on the northern loop
  - Reduction of temperature-dependent beam deformation
  - Installation of a movable maintenance beam

Once the TVE improvement programme has been completed, experts from the regulatory authority will conduct safety tests.

If the safety trials are a success, DB AG will then proceed with the functional acceptance procedure.

2.2 Functional acceptance procedure

Functional acceptance is scheduled to take place at the end of 2004 as part of a three-month trial operating period on the TVE facility. This will involve DB AG verifying that every one of the functional requirements to be assessed complies with the contractually agreed acceptance criteria. An area of particular importance is the planned shuttle services in Munich.

The central objective of the functional acceptance procedures is to assess the levels of system availability and reliability once the TVE improvement programme has been completed. The test programmes focusing on kilometric performance, punctuality and stopping precision were defined for this purpose (see Table 2). Each of these long-term tests is carried out for a period of one or two weeks in accordance with a specific timetable.

Table 2: Test programmes

Test programme	B1	B2	B3	B4	B5
Subject of test	Kilometric performance	Punctuality & stopping precision	Shuttle service (Munich)	Shuttle service with intermediate stops	24 h continuous operation
Test duration	2 weeks	2 weeks	1 week	1 week	24 h
Kilometric performance	1549 km/day	1549 km/day	1549 km/day	1549 km/day	t.b.a.
Mode	Automatic	Automatic	Automatic	Automatic	Automatic
Timetable:					
No. of runs per day	20	20	40	20	t.b.a.
No. of laps per run	2	2	1	2	t.b.a.
No. of intermediate stops per run	0	0	0	3	t.b.a.
Service operating days	Mon–Fri	Mon–Fri	Mon–Fri	Mon–Fri	
Maintenance day	Sat	Sat	Sat	Sat	
Test parameters:					
Load capacity	100%	100%	100%	100%	
Visitor dates	2nd week only	none	none	none	t.b.a.
Stabling of maglev vehicle outdoors	yes	yes	no	no	no

Test programme B1 serves to test the requirements relating to kilometric performance. To pass test B1, a kilometric performance of at least 1549 km must be recorded on each of the ten service days during the two-week test.

Punctuality is assessed on the basis of the results from test programmes B2 to B4.

In the B2 test programme, for example, only two trains during the two-week test period may arrive at their destination with a delay of more than 10 minutes.

The B2 programme also allows the stopping precision of the trains to be assessed. No more than two trains are permitted to miss their target stopping point.

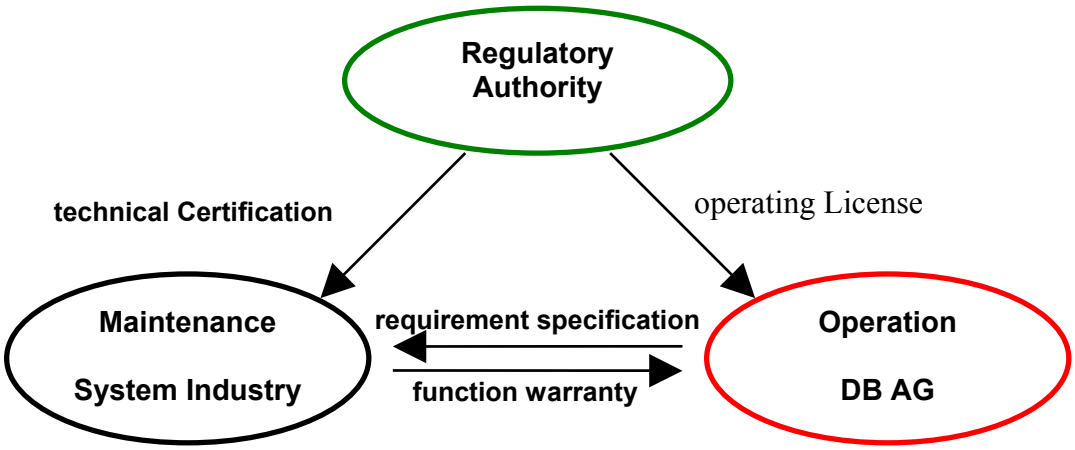
In the test programme B3, a shuttle service analogous to the one that will run in Munich is tested. The functional acceptance procedure therefore represents the first phase of the simulation of the high-speed maglev link planned for Munich.

3 Organisation

Besides enabling the technical, economic and functional characteristics of the maglev system to be tested, the TVE test facility will, from 2005 on, also allow the organisational interaction between the various institutions involved in the operation of a real maglev service:

- the train operator,
- the manufacturer and
- the regulatory authority.

Figure 2: Organisational structure at the TVE facility from 2005



The maglev test facility in Emsland will be run by DB AG. As part of the licensing arrangements, the operator (DB) must demonstrate to the regulatory authority that the facility is safe. The functionality of the technology used at the facility must be covered by the manufacturer's maintenance warranty. As is planned for Munich, maintenance work on the TVE test facility will be farmed out to a general contractor.

In future, there will be a strict division in terms of organisation and personnel between operation and maintenance at the TVE facility. This will help to achieve the cost transparency needed to determine actual operating and maintenance costs.

The customer-supplier principle is complemented (from a legal perspective) by a warranty arrangement that penalises suppliers who fail to deliver agreed functionality to the improved TVE. However, malfunctions that arise from TVE elements that did not undergo improvement are excluded from this warranty arrangement.

4 Operations plan 2005

After the functional acceptance procedure has been completed successfully, Deutsche Bahn AG will assume responsibility for the operation of the TVE test facility from 2005. This will enable not only engineering and technical issues, but also organisational and management processes to be designed, tested and, where necessary, optimised. The objective is to test and simulate as far as possible the structures, operational plans and operational sequences required for the Munich system.

The TVE test facility will be available for testing and simulating a number of operational plans in 2005. DB itself will focus on implementing scheduled operational plans as this type of operation is best suited to testing the operational structures planned for Munich. Services that run according to a fixed timetable are also required if standardised determinations and assessments of reliability and availability are to be made. A range of test variants will be defined that include a number of different shuttle scenarios both with and without passengers.

The maglev industry will be able to use the TVE facility to test developments of individual components and subsystems. In addition to integration procedures and commissioning tests carried out by industry, the TVE facility will also be used to conduct industry-defined qualification and approval trials.

The TVE is also open to companies that have not up until now been a part of the maglev systems industry. Such companies can sign licence agreements that permit them to test and qualify their own maglev technology developments at the Emsland test site.

As no trains will run during the installation of the new guideway support system, this period will be used to conduct a routine structural assessment of the guideway.

5 Limits on the simulations

As with any other simulation tool, TVE cannot reproduce all the conditions and parameters that apply to the particular configuration studied –a 100% simulation is therefore not achievable. Even after the TVE improvement programme has been completed, 100% simulation will remain economically unfeasible.

Figure 3: Plan of the TVE route

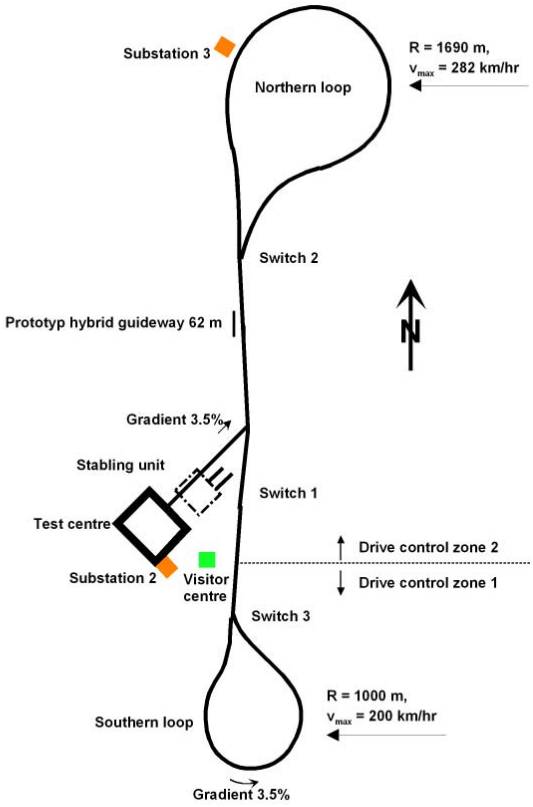


Figure 3 shows the route of the TVE guideway.

The guideway and guideway equipment at the TVE facility are not equivalent to the technology planned for use in Munich. In Emsland, the various guideway beams in use are all prototypes and reflect the developments in maglev guideway systems. For this reason, verifying the requirements concerning the reliability and maintainability of guideway components is either not possible at the TVE facility or the sampling levels are too low.

The propulsion system does not contain all the redundancies that have been specified for the Munich system. For instance, the drive block in substation 3 has only one rather than two converter units. The mechanics and the contactors used in the switching stations at the TVE facility are not equivalent to the technology to be used in Munich. Any failure of these components or assemblies during testing must therefore be excluded from the assessment.

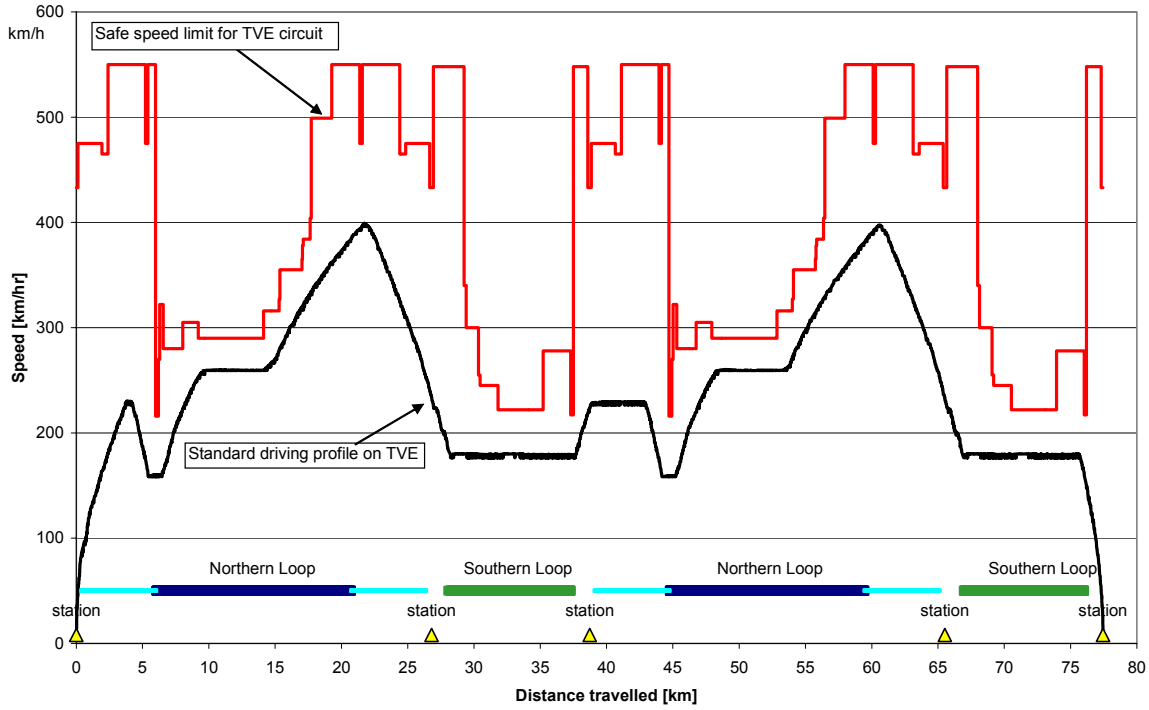
The limits of the driving profile on the TVE test facility are determined by the layout of the guideway and the power capacity of the propulsion systems used.

Figure 4 shows a standard driving profile for a run over two laps of the TVE facility. The total distance covered was 77.5 km. The maximum speed achieved on each lap was 400 km/h. The limit

profile shown represents the route's limiting speed [2] that is determined by the guideway layout and the maximum permissible loads and acceleration rates.

The operation control system ensures that the limit profile is never violated under any circumstances. As a result, the layout of the TVE guideway means that a constant run for five minutes at a speed of 300 km/h is not possible. The driving profile planned for the Munich system must therefore be adjusted on the basis of these constraints.

Figure 4: The standard driving profile and safe speed limit for the TVE route



Furthermore, multi-vehicle operations cannot be carried out on the TVE test facility. The passage of oncoming trains cannot therefore be examined at the TVE site. However, measurement equipment is available with which the pressure loads created by the passage of a train can be recorded.

As the station's platform is of reduced length, it is not possible to position all the doors of the maglev train along the platform. The station is not equipped with an automatic platform door system. The simulation and assessment of vehicle boarding and alighting procedures, which are planned for Munich, can therefore only be carried out to a limited extent.

It is important that these limitations are known when defining the test programmes and analysing the results. Any faults or malfunctions that result from these limitations or from components other than those used in the Munich set-up must therefore be either excluded from the assessment or included only in a restricted sense.

We will need to make use of the experience gained in Shanghai and, where that is not possible, appropriate procedures will be needed with which to make theoretical estimates of the operational risks involved.

6 Outlook

Taken together, the TVE test facility and the experience of the operating company in Shanghai will make a major contribution to assessing the maglev transport system. The assessment criteria that underlie any investment decision can therefore be placed on a firm foundation.

In addition, the TVE will continue to offer a platform to developers to test the functionality of their technology in a full-system environment.

By 2005, the work described above will have created a basis for decisions concerning the implementation and management of the maglev airport link in Munich in time for the project approval procedure.

References

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