

Maintenance criteria for renewal of operating licence

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ABSTRACT: Maintenance is at all times required to provide an available system in a safe operating condition for train running. The Maglev construction and operating regulations (MbBO) have been drawn up for DB, the company running the Maglev system, for this purpose and must be observed if the operating licence is to remain valid. Drawing on maintenance methods adopted on the Emsland Transrapid Testing Facility (TVE) and the scope of documentation involved, an indication is given of what is required of a high-speed maglev application system and in what manner the documents are to be evaluated. Light is then shed on the consequences for maintenance procedures and maintenance costs deriving from the analyses conducted.

1 INTRODUCTION

In addition to its other purposes, maintenance is designed to ensure that the magnetic levitation system is available in a correctly functioning, operation-ready and safe operating condition at all times. The actual maintenance procedures required are to be laid down at the latest before the system goes into full commercial operation.

To ensure that this is done, the Magnetic Levitation Train Construction and Operating Regulations (MbBO) specify the procedures the maglev company has to comply with when applying for and renewing the operating licence issued by the Federal Railway Authority.

The following paper presents the methods and criteria that the maglev company intends to use when determining the maintenance requirement for the high-speed maglev application system, the documents that are to be prepared, and how these documents are to be assessed.

2 BASIC PRINCIPLES

2.1 Structure of Responsibilities

The maglev company is required by law to guarantee the construction and operation of a magnetic levitation system that meets the relevant safety standards. The areas of responsibility this covers are shown schematically in Figure 1:

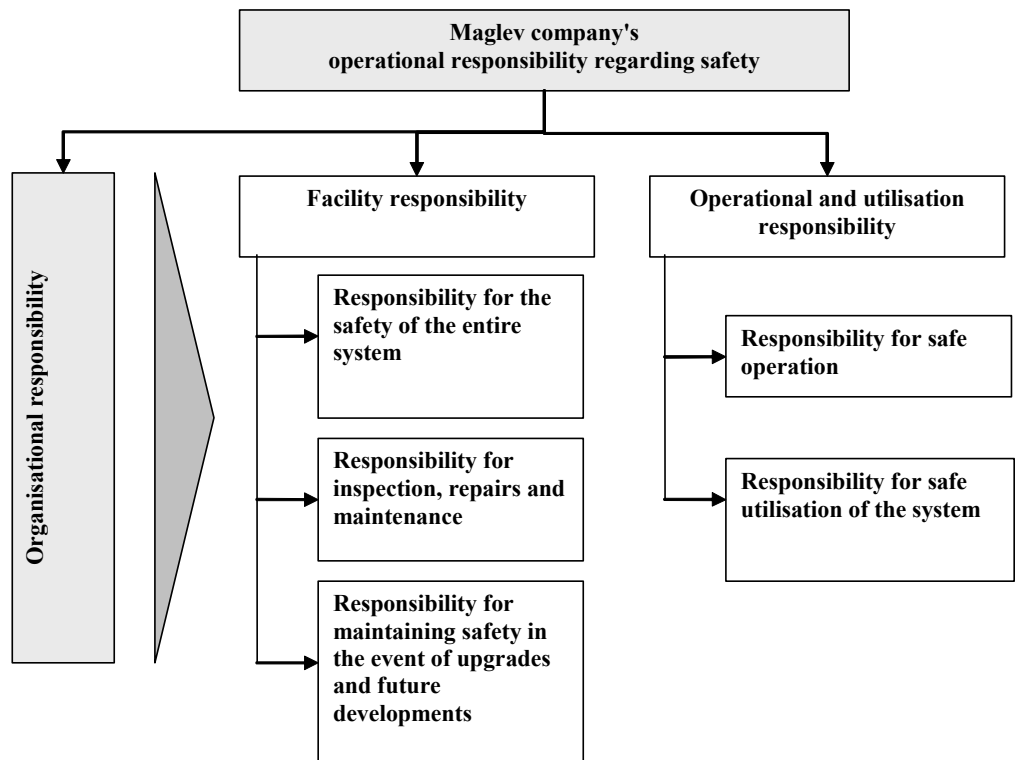


Figure 1: Maglev company's responsibility

In this part of the presentation we have limited our attention to facility responsibility, which also includes responsibility for the maglev vehicles. Facility responsibility is broken down into the company's responsibility for the safe condition of the operating facilities and vehicles, for inspection, maintenance and repairs, and its responsibility to ensure compliance with safety standards in the event of any modifications and improvements carried out during upgrades and future developments, i.e. for any action that may be taken to maintain the operational safety of the system. It should be mentioned at the same time that, when providing evidence of compliance to the Federal Railway Authority, it is of minor importance whether the maintenance is performed by the maglev company itself or by a third party.

As far as the supervisory and authorising body, the Federal Railway Authority, is concerned, it is the maglev company that is responsible for ensuring that the safety standards are complied with when any changes or modifications are made to the system.

The issuing of an operating licence by the authorising body is based on the Magnetic Levitation Train Construction and Operating Regulations (MbBO). In contrast to the Railway Construction and Operating Regulations, which contains specific criteria relating to the inspection and test intervals for vehicles, for example, the maintenance procedures are based on the condition and type of operating facilities and vehicles in use, and on the stress to which they are subjected.

With reference to facility responsibility, § 8 of the MbBO specifies the following:

*To provide the appropriate level of safety at all times, the company is required to carry out **scheduled maintenance** on the operating facilities and vehicles. The type, extent and frequency of the maintenance procedures is based on the condition on the condition and type of the operating facilities and vehicles in use, and on the stress to which they are subjected.*

The maglev company exercises its facility responsibility, particularly in accordance with § 8 of the MbBO, for example, by applying the following principles. They are partly dealt with in subsequent chapters:

- Specification of principles and procedures for setting up the maintenance programme and obtaining EBA approval
- Monitoring of compliance with the principles and procedures for setting up the maintenance programme by the manufacturer, incl. plausibility check of evidence submitted for the maintenance intervals

- Preparation and verification of the criteria with respect to the quality of the maintenance company
- Request for submission of the maintenance concept (maintenance organization and processes) and comparison with the state of the art
- Monitoring of the organisation, the processes and observance of the maintenance intervals
- Request for submission of evidence of the same level of safety in the event of modifications/improvements.

2.2 Maintenance Objectives and Criteria

To ensure that the requirements of MbBO and both the operational and economic requirements are taken into account, a considerable amount of conceptual work is required in advance during the planning phase with respect to the maintenance that will be performed on the magnetic levitation system (maglev system) during the operational phase. In addition to traditional maintenance procedures (such as inspection, routine maintenance, repairs and improvements), this also covers cleaning, vegetation control, supply of materials and waste disposal, winter services and other duties relating to traffic safety.

DB Magnetbahn has defined the following objectives:

Objectives relating to safety, availability and functionality:

- Not to exceed and ultimately to improve the failure rates on which the risk analysis for the safety concept are based for the entire lifetime of the maglev system. These include all the data obtained for both internal and external risks.
- Not to exceed and ultimately to improve the failure rates, in order to comply with the availability criteria defined in the tender specifications (Guideline 41601), Requirement 858, Annex 9, for the useful service life of the maglev system in accordance with Requirement 1049.

Objectives relating to operations:

- Maintenance, cleaning and other activities, such as vegetation control and winter services performed on the maglev system, plus the maintenance and cleaning of third-party facilities must be planned and performed so that regular scheduled services (4am– midnight at 10-min intervals) are not disrupted for a period of at least 20 years. Exceptions to this rule are to be included in a list of exemptions and approved in consultation with DB Magnetbahn.
- Operation on a single track, with the other track used during maintenance work must be possible.

- During maintenance, cleaning and train operations, and during any maintenance and cleaning of third-party facilities, the health and safety of staff or third-party staff members may not be jeopardised.

Objectives relating to economic issues:

Preventive maintenance performed on the operating facilities and vehicles of the maglev system is to be conceived so that

- the average annual costs for the maintenance of the operating facilities for a period of 30 years following the start of commercial operations do not exceed EUR xxx million.
- the average annual costs for the maintenance of the maglev vehicles for a period of 30 years following the start of commercial operations do not exceed EUR xxx million.

These two cost values are derived from the general financial data and are to be reported by DB Magnetbahn as target costs.

To achieve these objectives, consistent design and development of all components based on low life cycle costs and a so-called "maintenance management system" is necessary. Such a maintenance management system will be used to control all the technical, administrative and organisational procedures necessary to identify the current condition of the system, to maintain a correctly functioning, operation-ready and safe operating condition of the system and, in the event of deviations, to return the system to the normal condition during the life cycle. The system will be based on an maintenance concept.

It has been agreed that maintenance for the high-speed maglev link in Munich is to be performed by a general contractor, who is required to prepare a maintenance concept in consultation with the maglev company, which will then be used to develop and implement a maintenance programme.

The general contractor is also responsible for achieving the maintenance objectives.

The maintenance instructions issued by the manufacturers, which contain details of the individual procedures, are one of the key elements of the maintenance concept. These instructions are to be prepared using the practical knowledge and experience gained by the manufacturers on the basis of components employed in the maglev system in Emsland and in Shanghai.

Before the start of the operational phase, the general contractor is to include this maintenance concept in the maintenance programme for the maglev system and the associated quality procedures and work instructions. Legal requirements and technical regulations in particular must be complied with.

The minimum requirements for the structure and content of the maintenance programme are specified in the "Principles and procedures for setting up the maintenance programme". The maglev company is required to submit this document to the Federal Railway Authority for approval in accordance with § 8(2) of the MbBO. This document, together with the acceptance of the operating facilities and vehicles, the safety concept, the operating manual and evidence of the safety of the system, is a prerequisite for the issuing of the operating licence by the Federal Railway Authority in accordance with § 4(2) of the MbBO.

3 PREVENTIVE MAINTENANCE PROGRAMME

The principles and procedures for setting up the maintenance programme, in addition to the corporate goals and the organisational structure, must be included in the maintenance programme.

Setting up and modifying the maintenance programme is a process that begins during the manufacturer's planning and design phase, is continued through the operating programme phase and subsequently develops into a continuous improvement process after the system has been put into operation. This is supplemented by the experience gained during regular scheduled services and maintenance. The updating of the maintenance programme as a result of the knowledge gained is to be carried out by the general contractor in consultation with DB Magnetbahn.

3.1 Manufacturers' Specifications

As mentioned earlier, the process for setting up the maintenance programme starts with the manufacturer. He begins by taking the design concept, the information obtained from his calculations and field trials, and the specified operational conditions or those he has himself planned, and subsequently prepares the maintenance instructions, taking into account the principles and procedures for setting up the maintenance programme and the operator's specifications. These are to include a description of the type, extent and frequency of all the procedures required to perform maintenance on the component in question. The maintenance instructions must also include the different types of procedures used, classified on the basis of preventive and corrective measures.

The maglev company will then examine the maintenance programme in terms of its "compliance with the maintenance principles and procedures". It can also assess the plausibility of the maintenance

programme as to whether it will achieve its maintenance objectives and, if necessary, propose changes.

The manufacturers' maintenance instructions are thus the basis for

- setting up a maintenance programme for the entire system that is modified to meet the specifications of the operating concept and the associated operating programmes
- planning/designing/equipping maintenance facilities and determining the test equipment required, the auxiliary systems and the initial provision of replacement parts
- determining the staff required for maintenance (qualifications, number, working hours and training) and the maintenance requirement
- preparing maintenance and operating manuals.

3.2 Maintenance Analysis

The extent of the maintenance procedures to be performed is determined systematically using maintenance analysis. The analysis is binding in particular for those maintenance procedures involving the maintenance of safety-related items that are incorporated in the vehicles and operating facilities of the magnetic levitation system, unless other regulations exist (e.g. applicable DB guidelines). The procedure can and should, if applicable, be used for items that are of major importance for the reliability and operational worthiness.

The following are key objectives:

- Collection of the data relating to all those items that are installed and are to be maintained, incl. the identification of safety-related components
- Collection of the data relating to the procedures to be performed on each item
- Specification of the procedures on the basis of standardized, comprehensible criteria in line with the objectives (see Chapter 2)
- Cost-effectiveness of the maintenance

Depending on the kind of item, the maintenance analysis uses findings taken from the following sources:

- Failure modes and effects analyses (FMEA) and fault tree analyses (FTA)
- Stress analysis and evidence of environmental strength
- MTBF values or service life of the items obtained either on the basis of theoretical calculations and/or tests or from experience
- Operational experience
- Operational experience with identical or similar items used in other transport systems, power supply systems or industrial applications
- Requirements specified in the technical approval

The processing of the results is to be documented in a comprehensible manner so that each step of the analysis and the results can be verified at any time. The results of the maintenance analysis are to be documented and preserved for three years after the item has been taken out of service.

Figure 2 shows the steps in the analysis of the maintenance procedures.

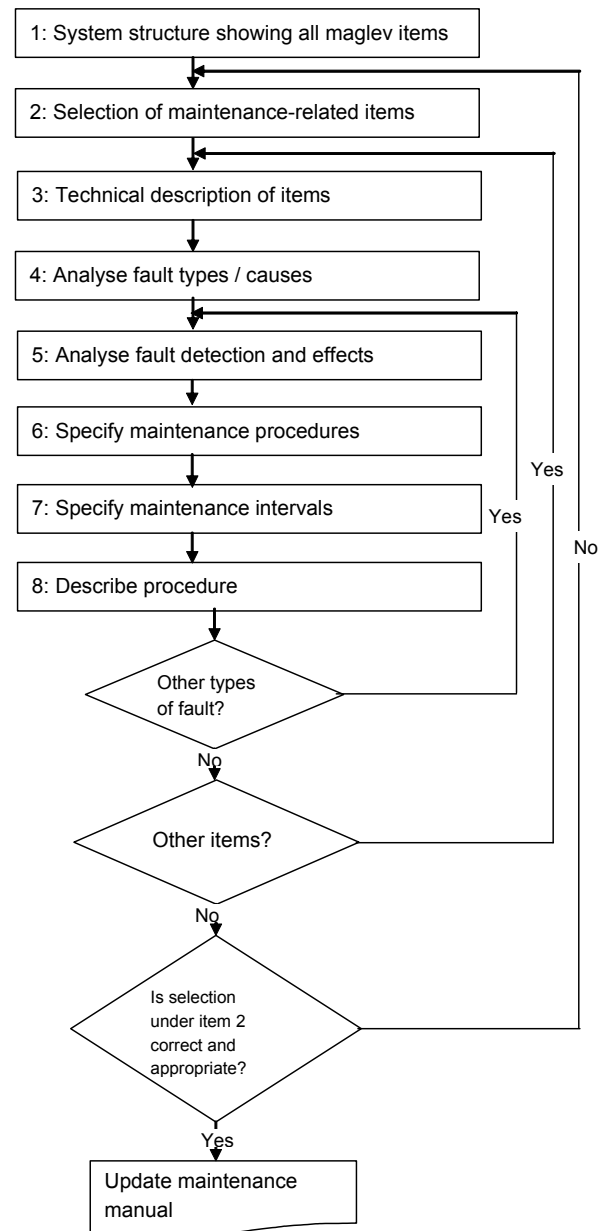


Figure 2: Flow chart for maintenance analysis

3.3 Setting Up and Updating the Maintenance Programme

Based on the manufacturers' maintenance instructions that were prepared with the aid of the analysis, the general contractor develops a programme for the maintenance of the maglev system that is modified to meet the actual operational conditions. This programme is to be approved in consultation with the maglev company.

During the service life, the general contractor will continue to develop the maintenance programme on his own responsibility on the basis of experience gained during regular scheduled services and maintenance. To this end, he will constantly determine whether the parameters used as the basis for setting up the maintenance programme are still valid, and will update the maintenance programme if necessary to comply with the latest information in consultation with the manufacturer and obtains approval for the changes from the maglev company. The process that is used in this case is shown in Figure 3.

The collection of all the data relating to the completed maintenance procedures is the fundamental basis for the provision of evidence of compliance to the Federal Railway Authority as the authorising body in accordance with the MbBO on the one hand, and for the detailed analysis of component failures, disruptions and the examination of the manufacturer-related maintainability data (e.g. MTBF values) by the general contractor on the other.

When maintenance procedures are specified, the standards and regulations to be used are to be included. It is particularly important to verify that the specified maintenance procedures can be performed in compliance with the rules and regulations of the employees' health, safety and accident prevention associations. The provisions are to be implemented when the maintenance tools are designed and the sequence of operations is specified in the maintenance manual.

A selection of requirements relating to the maintenance programme content is presented below:

- Definition of types of procedure, coding of procedures (standardized throughout the system)
- Definition of maintenance object (incl. standardised item designation based on the system structure)
- Reference list of operating and maintenance instructions in use
- Definition of inspection zones and operating conditions

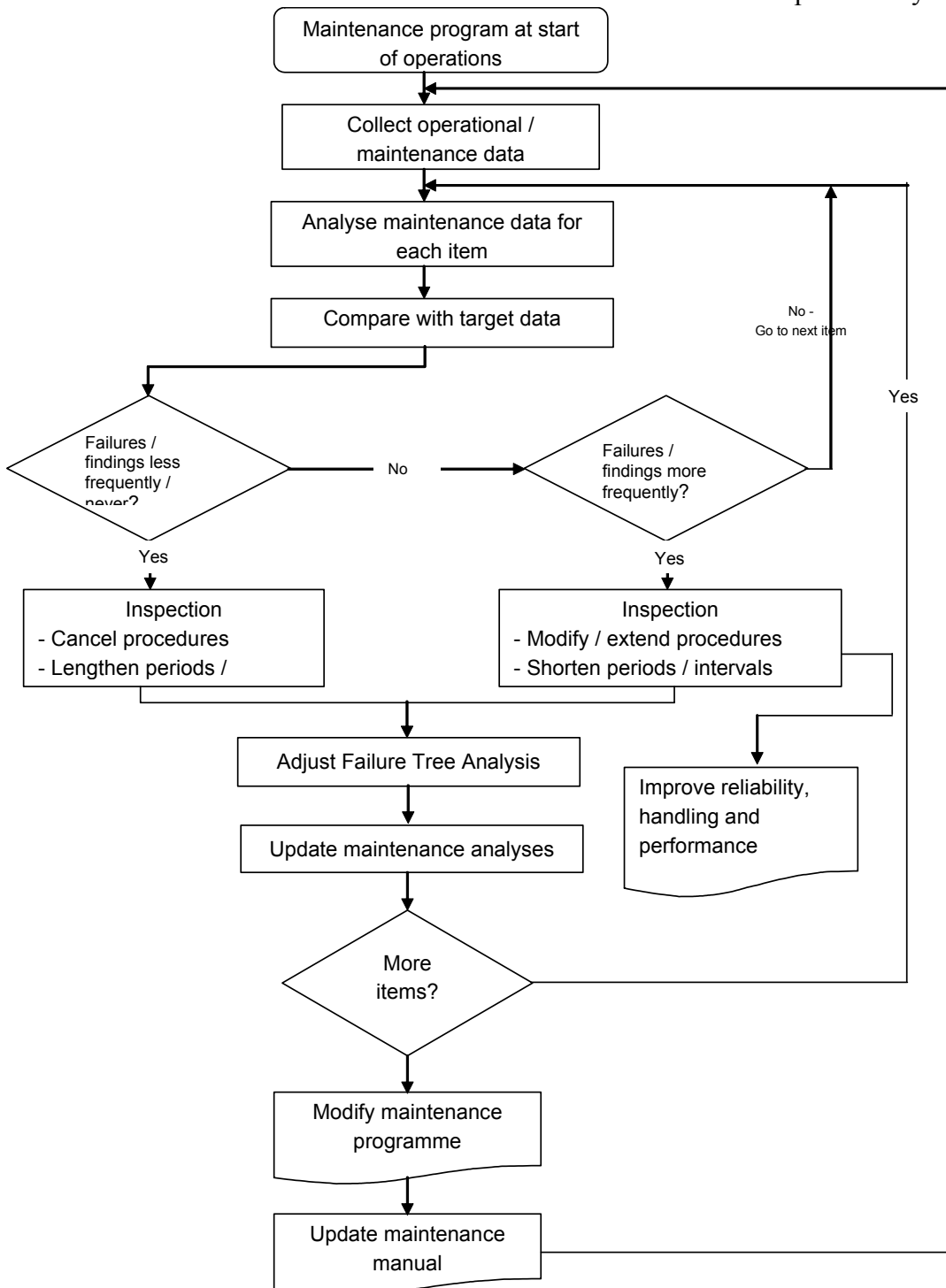


Figure 3: Flow chart for updating the maintenance programme

- Failure effect category
- Brief description of required infrastructure
- List / brief description of test equipment and assembly tools
- Staff qualifications
- Brief description of how procedures are performed
- Approximate length of time required for the procedure (MTTI or MTTR) and setup/dismantling times
- Brief description of how procedures are coordinated with regular scheduled services
- Guidelines for collecting and preparing operational and maintenance data, and calculating life cycle data
- Catalogue section with list of procedures prepared for processing with a commercially available software program, e.g. EXCEL.

Furthermore, any documentation relating to the maintenance work shall provide the maglev company with statements on the cost-effectiveness and planning of the resources required.

4 DATA COLLECTION SYSTEM

The use of a facility management system is planned to archive the documentation relating to the maintenance procedures. A preliminary version was developed at the end of the nineties for the Transrapid test facility in Emsland and upgraded as a result of the practical application of the system. This information system was used as the basis for the maintenance of the line in Shanghai.

All the data that describe the current operating condition and the results of inspections and maintenance work from both a technical and economic viewpoint are stored in the facility management system. Details of all the maintenance work, improvements and modifications are also documented. The purpose of the management system is to provide the operator, among other things, with the following data:

- Operating times, environmental and performance data in sufficient detail to assess the stress exerted on system components
- Master data of the items contained in the maintenance programme
- Planning data for the maintenance of the entire system
- Order and fulfilment data for commenced or completed maintenance procedures
- Status data based on diagnostics reports and inspection results
- Life cycle data
- Spare parts situation

More detailed specifications relating to data collection are found in the specifications for the maintenance concept.

At the appropriate time, the maintenance procedures, plus the inspection and maintenance intervals, will be examined on the basis of this data, as described earlier. In addition, faults affecting the correctly functioning, operation-ready and safe operating condition will be analysed using predetermined criteria and/or fault classes, e.g. with the aid of the following chart (as with DIN EN 50126).

Fault class	1	2	3	4
Description	Faults* with severe effects	Faults* with medium-severe effects	Faults* with noticeable effects	Faults* with minor effects
Grouping of faults in acc. with DIN 50126	Catastrophic	Critical	Marginal	Insignificant
Criteria for the rating				
Effects on persons [DIN 50126]	Fatal casualties and/or numerous severely injured	One fatal casualty and/or severely injured	No injuries	Possible minor injuries and/or inconvenience to customers
Effects on the environment [DIN 50126]	Severe environmental impact	Noticeable environmental impact	Noticeable environmental threat	
Effects on assets and components	Severe damage, total loss	System standstill, stranded vehicle, failure of key subsystems and components	Continued use only if no replacement during operation is possible	Faults and failure of subsystems and components with minor restrictions on performance

Using the ranking of the collected data based on the fault classification, decisions can be taken at short notice that will result in both immediate action being taken in the management of the operations to ensure safe operation and in initiating the long-term planning of procedures to eliminate any shortcomings.

5 OUTLOOK

The maglev company exercises its legal responsibility by preparing maintenance specifications and obtains approval from the Federal Railway Authority in particular for the principles and procedures for setting up the maintenance programme. In addition, it either performs the maintenance itself or can provide evidence that it has subcontracted the work to an appropriately qualified maintenance company. It ensures that the maintenance procedures are state of the art and are performed in accordance with current practice and monitors compliance with all specifications during planning, manufacture and operation.

The procedures described for the renewal of the operating licence and for setting up the maintenance programme have been implemented by DB Magnetbahn as the future maglev system operator on the high-speed link between Munich Central Station and the Airport. The "principles and procedures for setting up the maintenance programme" have been prepared and submitted to the Federal Railway Authority for approval. The next step is to set up the management system and quality system for maintenance on schedule.