SAFETY ASSESSMENT OF THE EMSLAND TRANSRAPID TEST FACILITY FOLLOWING MAJOR TECHNICAL MODIFICATIONS

No. 15

Wolfgang Otto

TÜV Rheinland InterTraffic GmbH
ISA – Independent Safety Assessment
Cologne, Germany
Email: Wolfgang.Otto@de.tuv.com

ABSTRACT: The TÜV Rheinland InterTraffic GmbH (TRIT) has been in charge of the safety assessment on the Emsland Transrapid Test Facility (TVE) for over 30 years.

In recent years, a lot of technical subsystems or components have been modified or completely exchanged: e.g. new Maglev vehicle TR09, new guideway beams, upgrade of operation control and propulsion system. As a consequence, the operational rules have also been revised.

This paper describes the assessment procedure chosen by TRIT to examine technical systems and operational aspects. This examination is a prerequisite for the TVE operator to get the approval for the operation of TVE as requested in the legal act for test facilities. The assessment comprises all tasks and steps to judge the effectiveness, suitability and completeness of technical measures and all foreseen operational procedures to be applied to TVE.

The assessment starts with the examination of a system hazard and safety analysis and ends with the overall system evidence demonstration provided by the TVE Operator. It is based on general accepted rules and standards for railway systems.

1. Introduction

The Transrapid test facility ("Transrapid Versuchsanlage Emsland", TVE) was built from 1979 to 1987 for testing Maglev vehicles and related sub-systems at high speed (see figure 1).

Figure 1: Transrapid test facility: Track layout

From the beginning, the TVE was subject to the law for test facilities (Versuchsanlagengesetz). According to this law the Approval Authority is the "Niedersächsische Landesbehörde für Straßenbau und Verkehr" (NLStBV) within the state of Lower Saxony. In the course of the approval of the operation regulations according to §12 (4) of the law for test facilities ("Versuchsanlagengesetz", /1/), the Approval Authority appoints experts / expert organisations to assess technical and operational safety and to supervise the observance of the operation regulations.

One of the two appointed expert organization is the "TÜV Arbeitsgemeinschaft Versuchsanlage Emsland" (TÜV Arge VME), a joint venture of TÜV Rheinland Group and TÜV Nord Gruppe.

TÜV Rheinland InterTraffic (TRIT) as part of TÜV Rheinland Group examines the following subsystems: maglev vehicle, operation facilities including service vehicles, operation control system, switches and transfer table, guideway equipment, propulsion. Furthermore TRIT is responsible for system technology, interfaces and the set of operation regulations.

According to the "Versuchsanlagengesetz" /1/ the permission for TVE operation is granted after the high-level Rules & Regulations document "Betriebsvorschrift" (Rule Book) is inspected by TRIT experts and the results are accepted by NLStBV.

However, the Approval Authority also requires an assessment on the

- Risk Analyses
- Technical Subsystems installed on TVE
- Other subordinated Rules & Regulations documents
- Overall System Safety Evidence

as well as

- Regular Supervision of TVE-operation
- Follow-up of conditions / restrictions raised in assessment reports
- Regular meetings with the TVE Operator IABG and Approval Authority.

Please refer to figure 2.

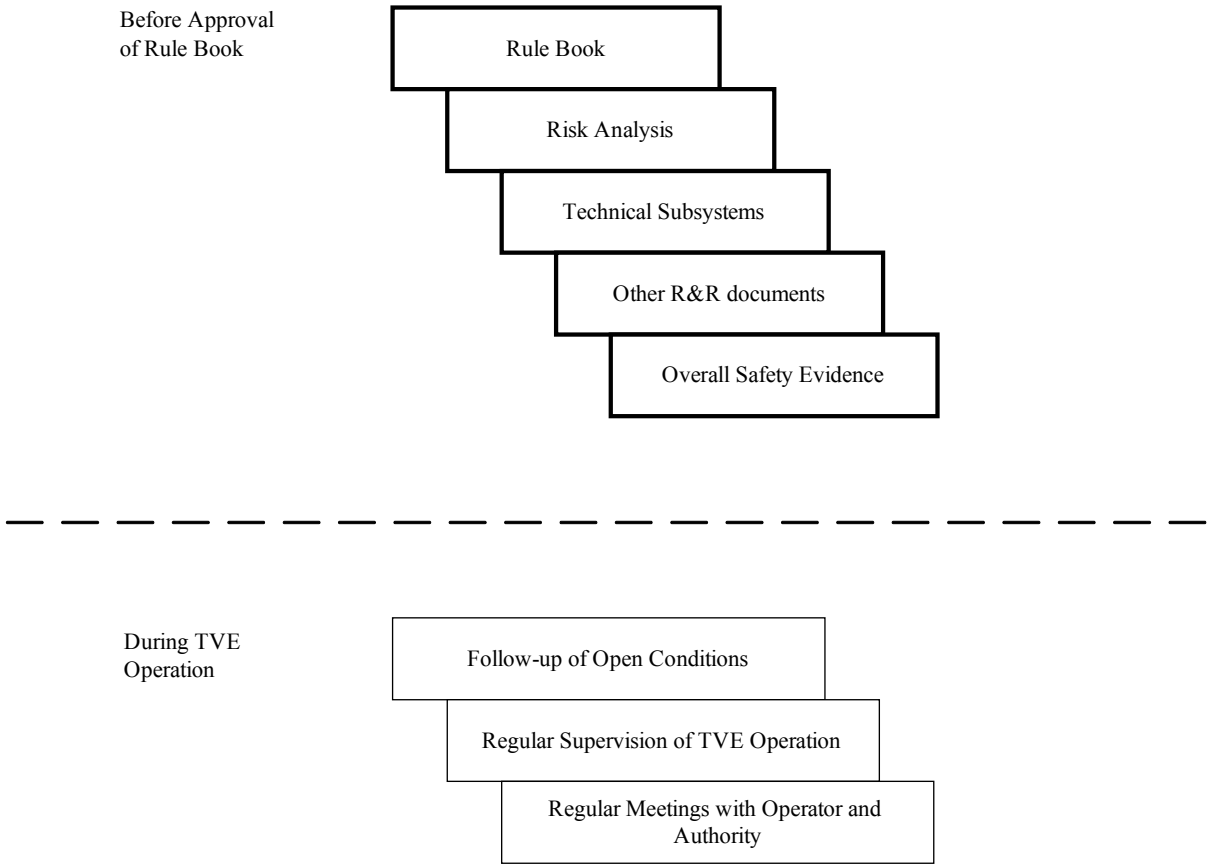

Figure 2: Assessment steps necessary for TVE operation

2. Safety Concept

The presented Safety Concept consists of 2 parts:

1. Hazard Identification & Risk Analysis,
2. List of prevention / mitigation measures.

2.1 Hazard Identification & Risk Analysis

For conducting the risk analysis, all possible Hazards relevant to TVE application have been collected and listed by IABG staff. In order to do this, the current and future TVE configuration as well as the indented operational scenarios must be considered.

All Hazards to be regarded for TVE have been discussed with TRIT experts in order to get a complete list of relevant Hazards.

General Hazards to be regarded (examples) are:

- Collision,
- Maximum / Minimum Speed,
- Derailment,
- Excessive Accelerations / Decelerations.

The Hazard Identification will be followed by a risk evaluation.

The primary analysis was carried out by the TVE Operator IABG, supported by analysis performed by Maglev manufacturers for their part of delivery (e.g. Maglev Vehicle, Operation Control System).

Further inputs were taken over from other guided transport systems.

The Risk Evaluation Process was carried out based on the approach given in standard EN 50126 /2/.

The Risk judgment was made by using a qualitative approach:

1. Consideration of the frequency of occurrence of Hazards on Events (estimation based on experience),
2. Classification of hazard severity levels (consequences to involved persons / environment, service mission),
3. Determination of risks levels (classification in a frequency-consequence matrix).

Schemes for risk classification and evaluation can be found in the standard EN 50126 (figure 3).

Table 6 – Typical example of risk evaluation and acceptance

Frequency of occurrence of a hazardous event *	Risk levels			
Frequent	Undesirable	Intolerable	Intolerable	Intolerable
Probable	Tolerable	Undesirable	Intolerable	Intolerable
Occasional	Tolerable	Undesirable	Undesirable	Intolerable
Remote	Negligible	Tolerable	Undesirable	Undesirable
Improbable	Negligible	Negligible	Tolerable	Tolerable
Incredible	Negligible	Negligible	Negligible	Negligible
	Insignificant	Marginal	Critical	Catastrophic
	Severity levels of hazard consequence			
* Scaling for the frequency of occurrence of hazardous events will depend on the application under consideration (4.6.2.2).				

Figure 3: Table 6 of EN 50126

Remark: The European Standard EN 50126 was also issued as international Standard IEC 62278.

A flow chart of the different working tasks of TVE examination can be found in figure 4.

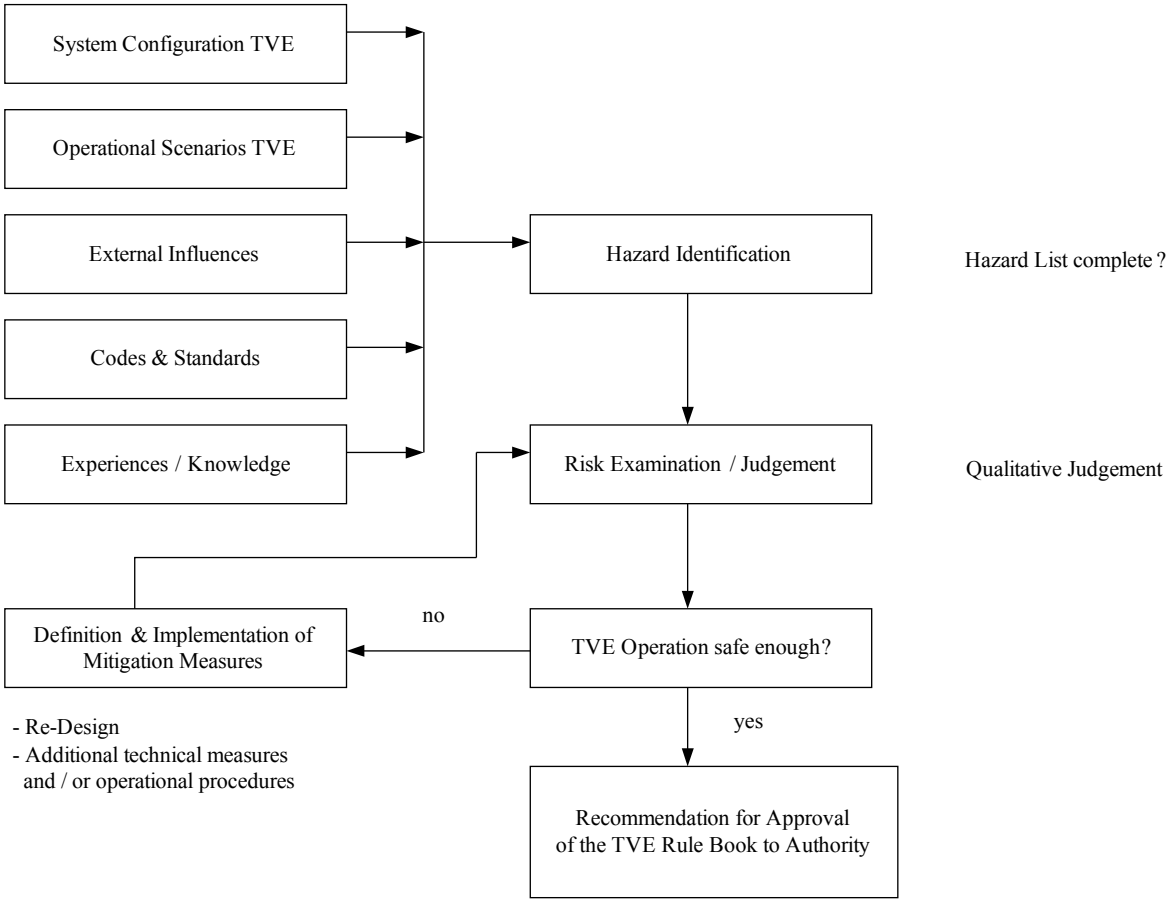

Figure 4: Risk Evaluation Process

2.2 Mitigation / Protection Measures

Measures to eliminate or to reduce hazard consequences to an acceptable level drawn up on the Risk Analysis Process and during System Design can be split up in

a) Design features (characteristics of technical systems, vital functions),
b) Operational aspects (Rules & Regulations to be applied, readiness of staff).

They are related to

1) The existing (unchanged) technical systems
   - Design / implementation documents
   - Assessment Reports and Approval Declarations with conditions / restrictions to be observed
2) Modified sub-systems / components
   - New Maglev Vehicle TR09
   - Modified Operation Control System (adoption to TR09, new functions)
   - Modified Propulsion System (new functions, new technology)
   - New guideway beams
3) Additional measures for commissioning
   - Until safety acceptance tests have been finished and final safety approval is granted
   - To ensure safety during commissioning and checking the new installed safety systems
4) Operation & Maintenance of TVE
   - Set of Rules & Regulations to be applied
   - Staff allocation and readiness of staff (acting in normal, abnormal and emergency situations).

The primary goal is to ensure safety reactions and safety functionality by technical means, operational aspects are regarded as supporting elements. During commissioning, testing of new components as well as operational issues to be applied in abnormal and emergency situations are the focus of TRIT experts.

TVE is safe enough if all examined risks have been classified “Negligible” or at least “Tolerable” in few special cases only.

For vital system functions (safe-life characteristics), the qualitative judgement was supported by presenting quantitative examinations on system behaviour / system reactions by means of Fault Tree Analysis and Failure Mode and Effective Analysis.

TRIT has checked all the analysis performed by IABG and other industrial partners in an interactive and iterative process.

3. Assessment of Technical Subsystems and Operational aspects on TVE

3.1 Assessment of Technical Aspects

The assessment of technical subsystems is to assure that Safety Requirements have been met. It is divided into:

1. Document inspection (system concept, requirement specification, design and implementation documents, handling instructions)
2. Visual inspection of installations on TVE (implementation on TVE must be in line with pre-checked documentation)
3. Performing or witnessing of functional and safety related tests (normal and abnormal / degraded situations, fault injection).

Examined subsystems respectively safety functions are presented in figures 5 and 6. Assessment Tasks in general are shown in figures 7 and 8.

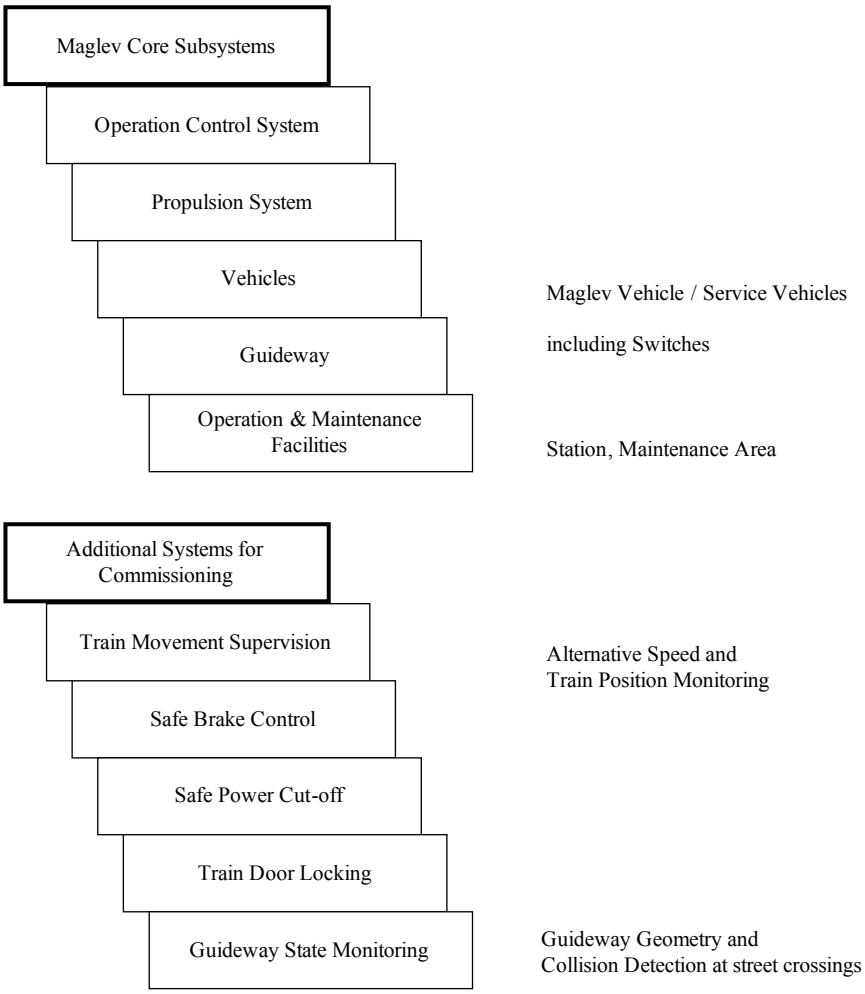

Figure 5: Examined Technical Systems on TVE

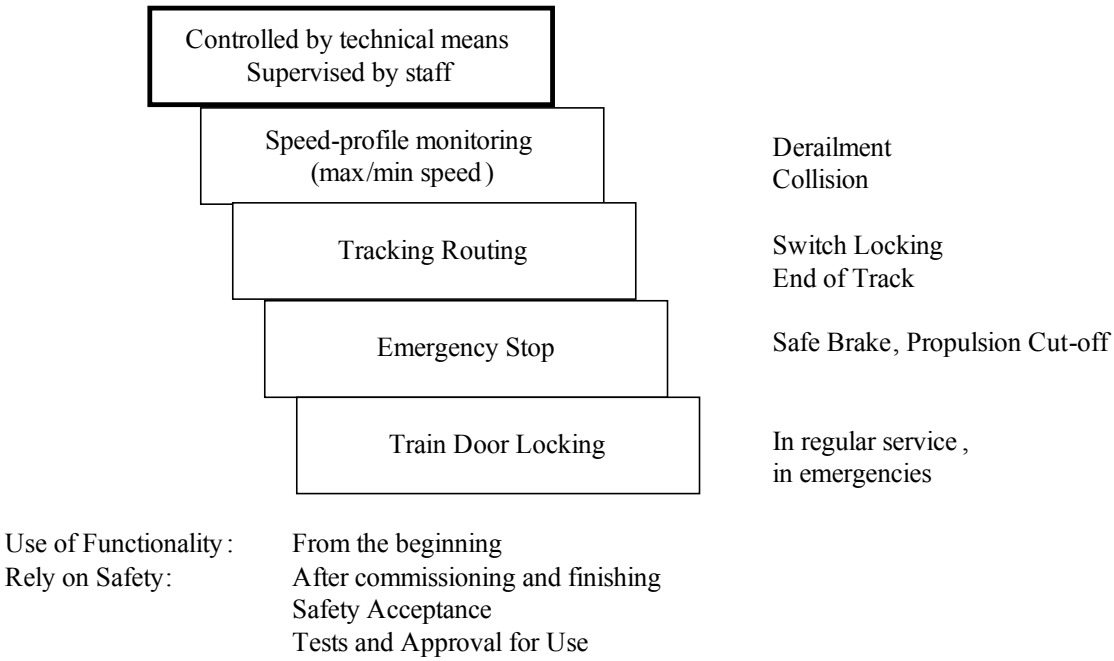

Figure 6: Safety Functions on TVE

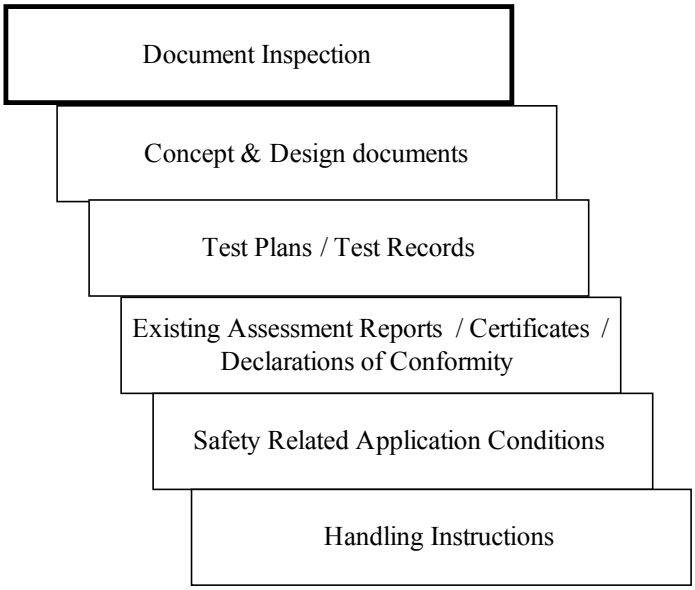

Figure 7: Assessment Tasks related to Technical Systems (1)

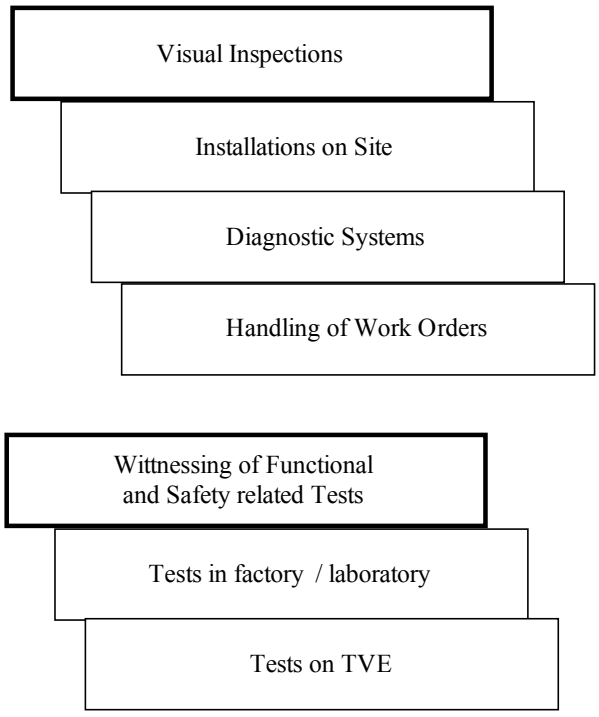

Figure 8: Assessment Tasks related to Technical Systems (2)

3.2 Assessment of Operational Aspects

The Assessment of operational aspects shall demonstrate the suitability of applied Rules & Regulations and the readiness of staff.

It comprises

1. Inspection of Rules & Regulations documents (high level procedures and detailed working instructions)
2. Witnessing of staff training (theoretical and practical parts, emergency scenarios)
3. Supervision of train operation (regular

announced and non-announced visits on TVE).

The respective assessment tasks are laid down in figures 9, 10 and 11.

Remark: The inspection of Rules & Regulation documents carried out by TRIT experts will be presented in detail in lecture No. 16 within the Maglev Conference.

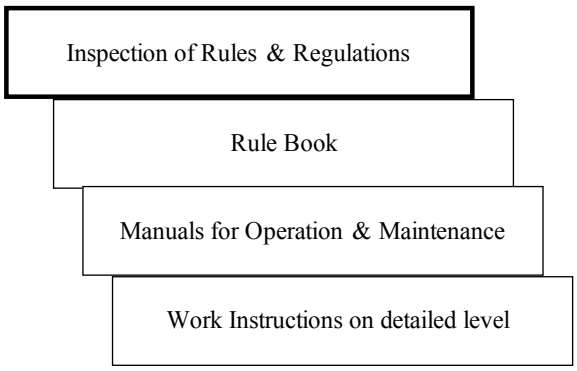

Figure 9: Assessment Tasks related to operational aspects (1)

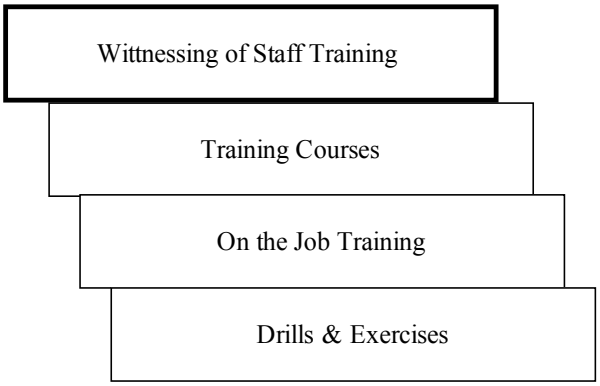

Figure 10: Assessment Tasks related to operational aspects (2)

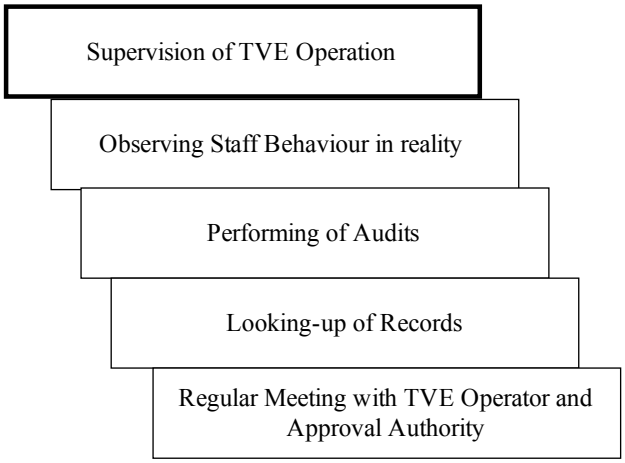

Figure 11: Assessment Tasks related to operational aspects (3)

Assessment results are reported to the TVE operator IABG, respective manufacturer and Approval Authority.

They may contain a list of deviations from requirements and links to rectify them as well as conditions to be:

- Fulfilled prior to putting in use,
- To be observed during TVE operation.

The deficiencies revealed so far have been followed, major aspects are closed.

For TVE, the assessment and continuous supervision is still ongoing.

4. Overall System Safety Evidence

The final assessment task in the sequence of required assessment steps is to verify, if all safety related requirements on an overall system level have been followed.

A document named "Gesamtsicherheitsnachweis" (Overall System Safety Evidence) was created by IABG summarising the assessment results issued in the past and presenting the current configuration of TVE.

The presented paper contained statements or references to other documents concerning following topics already mentioned before:

1. Unchanged technical subsystems,
2. Modified technical subsystems,
3. Completely new technical subsystems,
4. Updated set of Rules & Regulations,
5. Presentation of Safety Concept outcome.

The Assessment on the Overall System Safety carried out by the experts of TRIT shall avoid possible existing gaps in the safety evidence and validate all assessment steps previously carried out due to:

- Changes made in the meantime in technical and operational affairs and
- Improved knowledge or changes in the state of the art ("lessons learned").

It concentrates on

1. Overall safety functions / safety reactions,
2. Interfaces between technical subsystems,
3. Interfaces between staff and technical equipment,
4. Consideration of current knowledge and state of the art.

See figure 12 for presenting all this information at a glance.

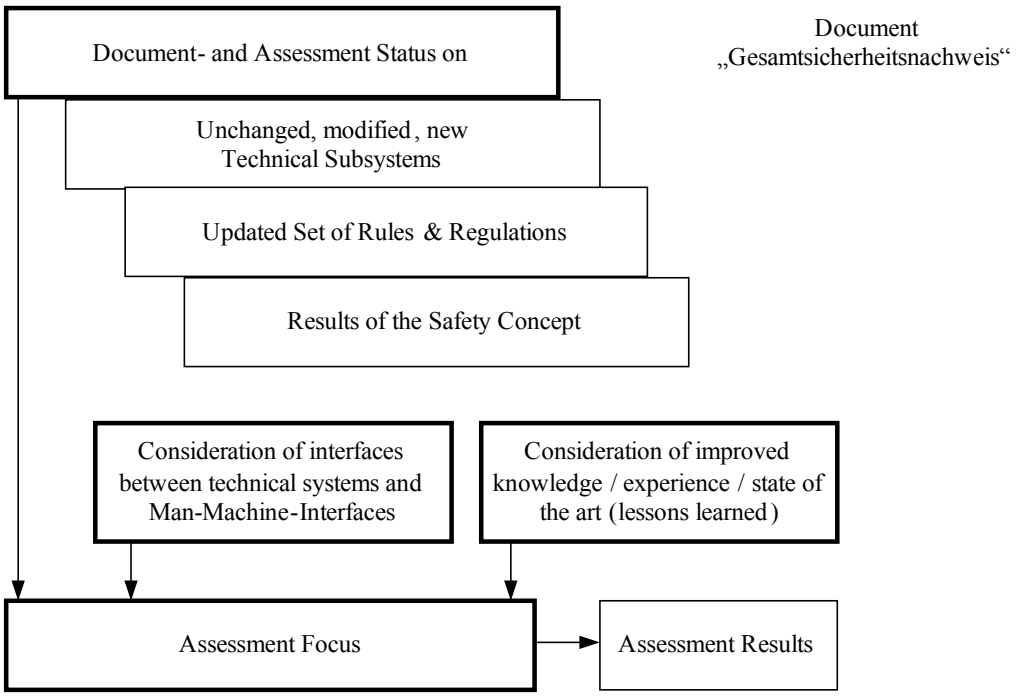

Figure 12: Overall System Safety Evidence Approach

In the course of the Overall System Safety Assessment, a lot of safety functions have been verified again. Furthermore, TRIT experts witnessed handling of TVE operation and suggested additional improvement possibilities.

It was agreed with TVE Operator and the Approval Authority that the foreseen technical measures are effective, suitable and sufficient for the required safety level and well balanced compared to operational procedures in use.

Lecture No. 16 also presents further examples of balancing technical and operational issues on the TVE.

5. Outlook

Due to the well-prepared work, the project outcome of IABG and the industrial partners, the close communication with TRIT experts and the Approval Authority, all tasks could be finished successfully.

The approval of the TVE Rule Book as a pre-requisite for TVE operation for the new Maglev Vehicle TR09 and modified technical sub-systems was granted. TR09 and other technical systems have started test programs to proof their suitability of use.

As per the beginning of September (date of issue of this paper) the comprehensive tests of all new technical systems and checking of operational regulations are ongoing.

The assessor TÜV Rheinland InterTrafffic GmbH has shown his ability to deal successfully and effectively with the assessment of complex technical facilities such as the TVE. Clients can reap the benefits of this experience both nowadays and in future.

6. References

/1/ Gesetz über den Bau und den Betrieb von Versuchsanlagen zur Erprobung von Techniken für den spurgeführten Verkehr (Versuchsanlagengesetz) 29.01.1976, zuletzt geändert am 31.10.2006

/2/ EN 50126 / IEC 62278 Railway applications – The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS), March 2000

7. Key words

Emsland Transrapid Test Facility, measures, system hazard and safety analysis, overall system evidence demonstration, evaluation of technical systems, operational rules