

# Safety Assessment for the Maglev Operation Control and Overall System – Experience Gained and Lessons Learned

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**ABSTRACT:** TÜV Rheinland InterTraffic has been involved in the Safety Certification Process of the Operation Control System (OCS) implemented on the Shanghai Maglev Line and the Transrapid Test Facility Emsland (TVE). This paper describes the Assessment Approach by using applicable standards, State of the Art and contractual requirements with special emphasis to the needs and specialities of the TVE. The application and differences of available German Guidelines (e.g. so-called “Mü8004”) and European Railway Standards (EN 5012x) as well as the relationship between the OCS Assessment and the Overall System Safety Acceptance Process is presented in detail.

Based on the experience gained and lessons learned in Shanghai and on the TVE, an outlook for the planned Munich Airport Link from the Safety Assessor’s view will be provided.

## 1 INTRODUCTION

### *1.1 Role of TÜV Rheinland InterTraffic on TVE and Shanghai*

The Transrapid test facility (Transrapid Versuchsanlage Emsland, TVE) was built from 1979 to 1987.

From the beginning the TVE was subject to the law for test facilities (Versuchsanlagengesetz). According to this law the Technical Supervisory Body 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 (/8/) the approving authority appoints experts/ expert organisations to monitor 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.

Concerning the Shanghai Maglev Line, TÜV Rheinland InterTraffic acted as head of the joint task group (ATT - Arbeitsgemeinschaft TÜV Transrapid,

founded by TÜV Nord Gruppe, TÜV Süd Gruppe and TÜV Rheinland Group) carrying out the assessment of the so-called VIP-Run with high-ranking Chinese and German officials on New Years Eve 2002.

Furthermore, TÜV Rheinland InterTraffic was involved in the assessment of the sub-systems Operation Control System, Maglev vehicle and guideway switches and responsible for the overall system safety assessment for the German part of delivery including overall safety functions, interfaces to the Chinese part of delivery, safety concept, rules & regulations for operation and maintenance during commissioning and commercial operation and effectiveness of staff training. The final assessment report of TÜV Rheinland InterTraffic served as prerequisite in order to issue the operation certificate granted by the Chinese approval authority SHTPCH (Shanghai High Speed Transrapid Project Construction Headquarters).

### *1.2 Functionality of the Operation Control System (OCS)*

The OCS comprises all technical facilities for planning, monitoring and safeguarding of train operation which means a combination of automatic train operation (ATO) and automatic train protection (ATP) functions like e.g. providing a safe vehicle travel path in order to avoid collisions and the monitoring of vehicle travel speed range in order to assure stopping only at predefined stopping points.

The OCS consists of central, wayside and mobile components with interactions to other sub-systems respectively operational and maintenance staff (see figure 1).

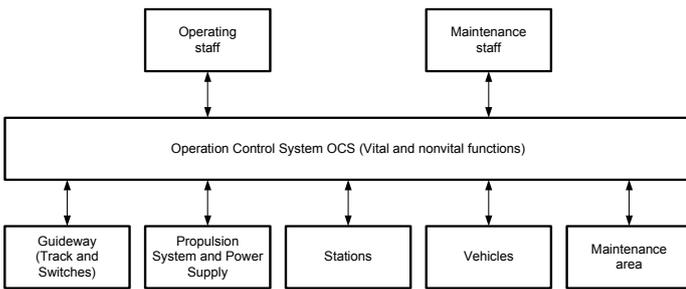


Figure 1: Structure of the OCS

### 1.3 Overall System

The Overall System comprises all technical sub-systems like OCS, propulsion system, vehicles, guideway, operational and maintenance facilities as well as their interfaces to each other and to operational and maintenance staff. The overall system was examined in order to reveal and eliminate discrepancies / gaps in the safety evidence process. These gaps can be caused by new developments or changes / updates in the technical systems, changes in regulations or staff availability and increased experience gained on existing Maglev applications as Shanghai Airport Line and Transrapid Test facility TVE. The current state of the art must also be taken into account in a proper manner.

## 2 ASSESSMENT TASKS ALREADY DONE

### 2.1 Assessment Approach on the Shanghai Maglev Line

#### 2.1.1 OCS

For the Shanghai Maglev project the German guideline Mü8004 (Technical Principles for the approval of Railway Signalling Equipment, /3/) issued by the Federal Railway Authority (Eisenbahn-Bundesamt, EBA) was agreed as the contractual basis for the assessment and approval of OCS since final versions of the European railway standards (/1/, /2/) weren't available at this time. The Guideline Mü8004 distinguishes safety relevant ("vital") and not safety-relevant ("non-vital") requirements. Further graduations of safety levels do not exist (see figure 2).

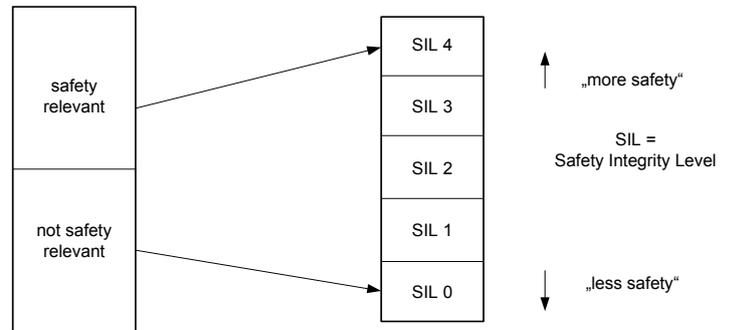


Figure 2: Comparison Mü8004 – EN 50129

However, in general, the development of OCS and the verification and validation activities have been executed similar to the approach stated in EN 50126 and EN 50159 (/1/, /2/). For "key safety functions" quantitative hazard rates have been calculated and verified in addition and included in the respective safety evidence documents.

The Assessment of OCS was successfully conducted and served as an important input to grant an operations license for automated driverless train operation by the responsible Chinese Authority.

#### 2.1.2 Overall System

After any deliverer has completed his specific verification and validation of the requirements, parameters and boundary conditions, the Overall System Assessment continued the process. This means the evaluation of the overall system requirements stated in the Safety Concept, Approval Declarations and Rules & Regulations for Operations and Maintenance in order to avoid possible gaps in the proof of safety process. This process paved the way for Maglev operator to apply successfully for the Operating Licence as a pre-requisite for starting the commercial operation of the Maglev (see figure 3).

The central part and basis of the Overall System Assessment was the Safety Concept agreed between manufacturer, operator and approving authority. It divides the entire safety into:

- Safety of the technical systems and
- Safety of operation & maintenance.

The Assessment dealt with the deliveries and services within the responsibility of the German suppliers and their interfaces to Chinese contributions. The Chinese deliveries and services (e.g. construction of the guideway, operation and maintenance facilities, manning-up & readiness of staff) were not assessed since this was within the responsibility of the Chinese suppliers.

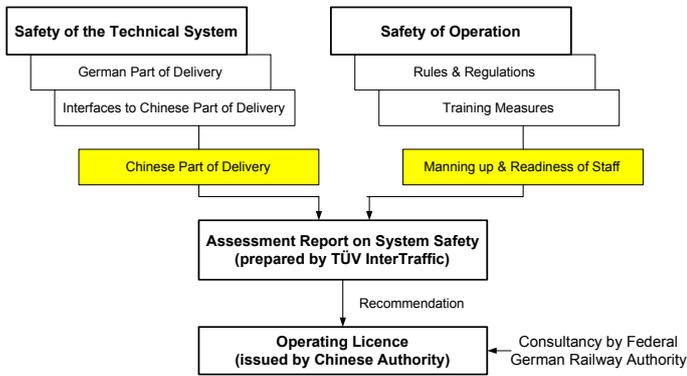


Figure 3: Overall System Assessment

## 2.2 Assessment Approach on the TVE

### 2.2.1 OCS

On the TVE the OCS was updated by using components already applied in Shanghai. Due to necessary technical modifications to adapt the Shanghai OCS to the existing sub-systems on the TVE and different laws and administrative regulations (/8/, /9/) to be followed, additional assessment activities had to be carried out. Therefore, the assessment approach taken over from Shanghai was slightly modified and agreed with the approving authority of Lower Saxony NLStBV.

Special focus on the assessor's side was placed on at site acceptance tests and the execution of pre-defined operating scenarios in normal, degraded and failure modes of the OCS (observing of system reactions and acting of staff).

### 2.2.2 Overall System

On the TVE, in addition to the update of OCS already mentioned before, other sub-systems were modified (implementation of new Guideway beams, update of the Propulsion System...). Consequently, the existing operational Rules & Regulations had also been adapted. To avoid possibly existing gaps in the safety evidence due to

- Installation of approved components which must be adapted to special conditions on the TVE or
- Technical changes (completely new or further developments of components or complete sub-systems) or
- Changes in the Rules & Regulations for operation and maintenance or
- Improved experience / knowledge / state of the art (lessons learned)

TÜV Rheinland InterTraffic requested a Safety Case for the Overall System consisting of the following 4 elements and their respective interrelation:

- Consideration of existing unchanged technical sub-systems,
- Consideration of -modified or completely new components / sub-systems,
- Consideration of the applied Rules & Regulations for operation and maintenance,
- Consideration of the Safety Concept including Evacuation & Rescue measures.

The Assessment concluded with a recommendation to grant the Operating Licence under adherence to some restrictions. For the removal of the stated restrictions a follow-up process is still ongoing which -on behalf of the licensing authority - is supervised by TÜV Rheinland InterTraffic to ensure a sufficient safety level at all times.

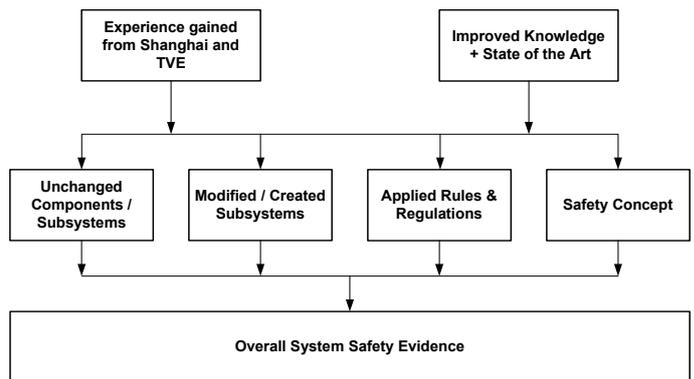


Figure 4: Overall System Safety Evidence for TVE

## 3 CONTINUATION OF THE ASSESSMENT

### 3.1 Further Development Program (WEP)

#### 3.1.1 Guidelines for Maglev Applications

The essential objective of the WEP program is the technological development for the Maglev operation both in long-distance transport and shuttle services as well as the realisation of cost-reduction potentials of the Maglev sub-systems.

With the support of the German Federal Ministry of Transport, Building and Housing, the existing generic Maglev system documents were taken as the basis in order to create new guidelines for planning, manufacturing and operating Maglev applications. The documents created provide technical characteristics and requirements to be observed in the whole process of creating a new Maglev line. They refer to international and German laws and standards and are split into overall system and sub-system descriptions (see table 1).

Table 1: Simplified list of the created German Guidelines for Maglev Applications

MSB Ausführungsgrundlage <b>Gesamtsystem</b>
MSB Ausführungsgrundlage <b>Antrieb und Energieversorgung</b>
MSB Ausführungsgrundlage <b>Betriebsleittechnik</b>
MSB Ausführungsgrundlage <b>Fahrweg</b>
MSB Ausführungsgrundlage <b>Fahrzeug</b>

The Documents (“Ausführungsgrundlagen”) were written by Maglev experts under management of the German Federal Railway Authority (Eisenbahn-Bundesamt, EBA). They were published in May 2006 as draft versions in order to get qualified feedback.

After a final reviewing process, these documents will serve as a national standard and can also be used to obtain criteria for the assessment and approval of future Maglev lines.

For the planned Maglev airport link Munich central station to Munich airport these set of guidelines in connection with German laws and administrative regulations have to be followed.

### 3.1.2 OCS upgrade on TVE

In the context of the above-mentioned WEP program, the OCS sub-system on the TVE originating from the Shanghai application shall be amended by new features. These innovations will be tested and assessed by TÜV Rheinland InterTraffic on the TVE starting in 2007.

Based on nature and extent of the changes, the Assessor proposes an assessment approach for the TVE application as presented in Table 2. The approach, aiming for a smooth transition to the application of the European standards EN 5012x, has already been agreed with the responsible authority NLStBV.

Table 2: Assessment Approach to be applied for the TVE depending on kind or extension of changes

No.	Kind / Extend of changes	Assessment Approach to be applied
1	Software changes without functional changes (minor modifications)	Further on application of the guideline Mü8004. Transition to follow the European standards EN 5012x not regarded as reasonable / necessary.
2	Software changes: Functional changes of existing functions	In principle further on application of the guideline Mü8004. However check in the individual case whether European standards will be applied.
3	Software changes: Creating of new functions	In principle transition to the application of the European standards EN 5012x. However check for each individual case whether guideline Mü8004 will be applied.
4	Hardware Changes	Check for each individual case which standard / guideline will be applied.
5	Development of a completely new OCS sub-system	Transition from Mü8004 guideline to follow the European standards 5012x.

The updated guideline Mü8004 (part 10520E, draft 2002-08-01) already considers the existence of functions / sub-systems approved according to the European standards EN 50126 and EN 50129 (see Figure 5).

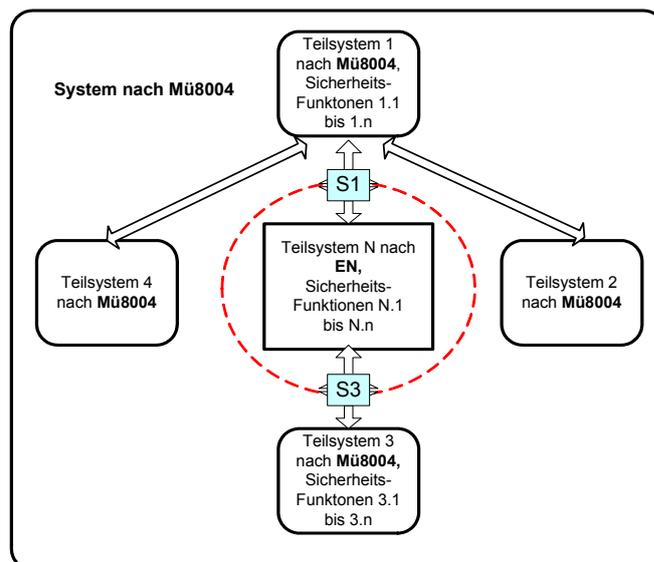


Figure 5: Integration of system parts already approved according EN standards into the approval process according Mü8004

As EN50129 states: “This standard is not applicable to existing systems / sub-systems / equipment (i.e. those which had already been accepted prior to the creation of this standard). However, as far as reasonably practicable, this standard should be applied to modifications and extensions to existing systems, sub-systems and equipment”, the degree of application of this standard has to be agreed between manufacturer and assessor for each subsystem and component.

However, there are no objections from the Assessor's side to follow the European standards in any case and integrate existing safety cases granted according to Mü8004 (see figure 6) as so called related safety cases in the view of the EN standards. The safety case document "Sicherheitsnachweis" according to Mü8004 is regarded as being equivalent to Safety Case part 4 (Technical Safety Report), see Table 3 as well as figure 7 and 8 for further details.

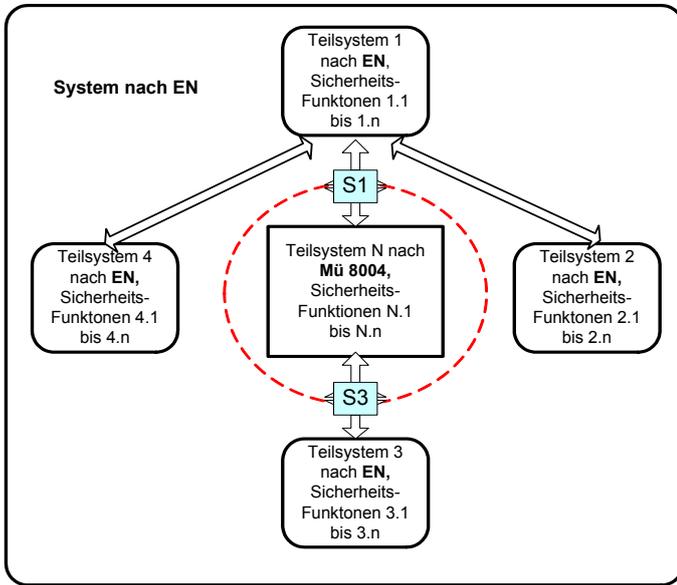


Figure 6: Integration of system parts already approved according to the Mü8004 guideline into the approval process according to EN standards

Table 3: Content of a safety case according to EN50126

<p><i>The Safety Case according to EN50126 requires approval by the Safety Authority, and should include an overview of the system;</i></p> <ul style="list-style-type: none"> <li>• a summary or reference to the safety requirements, including a consideration of</li> <li>• the SIL justifications for safety functions;</li> <li>• a summary of the quality and safety management controls adopted within the lifecycle;</li> <li>• a summary of safety assessment and safety audit tasks;</li> <li>• a summary of safety analysis tasks;</li> <li>• an overview of the safety engineering techniques employed within the system</li> <li>• verification of the manufacturing process;</li> <li>• adequacy of compliance with safety requirements, including any SIL requirements of the system;</li> <li>• a summary of any limitations and constraints applying to the system;</li> <li>• any special exemption (or specificity) imposed and justified by the contract, to the usual requirements of this Standard</li> </ul>
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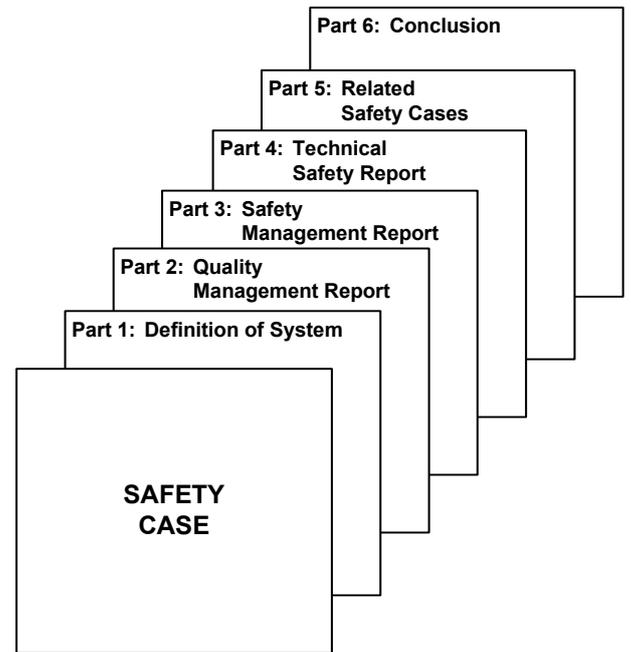


Figure 7: Safety Case structure according to EN50129

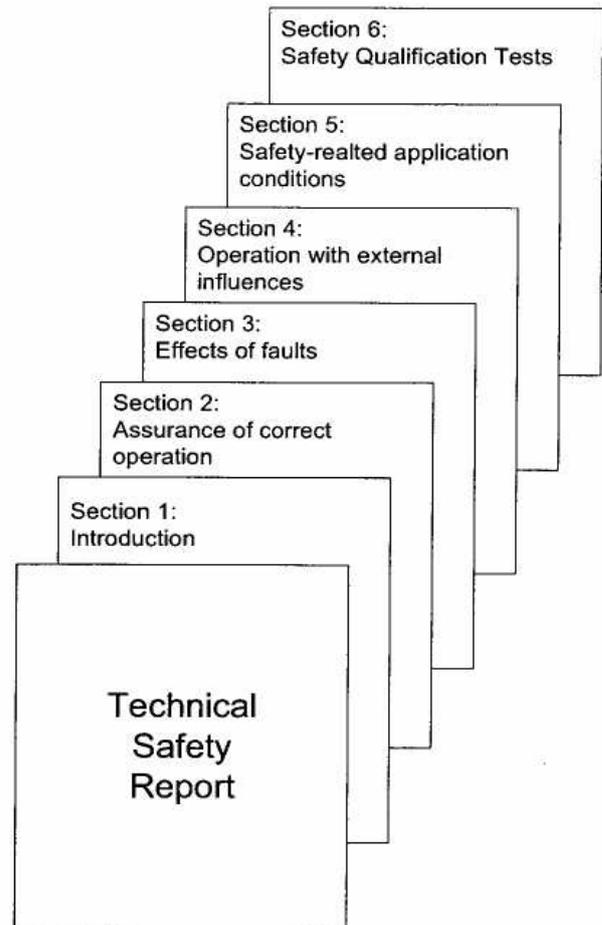


Figure 8: Structure of a Technical Safety Report according to EN50129

## 3.2 Future Maglev Applications

### 3.2.1 Extension Shanghai - Hangzhou

For the extension of the Shanghai Line to Hangzhou the future assessment activities could be executed in the same way as already done before and depicted in Chapter 2.1 of this contribution.

However, TÜV Rheinland InterTraffic is willing and capable of supporting any kind of assessment approach agreed between customer, manufacturer, operator and approval authority due to the long experience in carrying-out safety ensuring tasks in Maglev and Railway projects throughout the world.

### 3.2.2 Munich Airport Link

For the Munich Airport Link, German law /5/, administrative regulations like MbBO /6/ and the guidelines "Ausführungsgrundlagen" /4/ must be applied. The technical standards to be followed are mentioned in the guidelines and subject to contractual agreements between the customer and the responsible approval authority Federal Railway Authority (Eisenbahn-Bundesamt, EBA).

TÜV Rheinland InterTraffic with its accredited experts and broad knowledge and experience is willing to contribute to this challenging business field as already done in the past.

## 4 OUTLOOK

Concerning the extension of the Shanghai Maglev Line to Hangzhou the negotiations between the German and Chinese sides were still in progress when this paper was written. Moreover, the Munich Airport Link is still in the planning phase at this time. For this reason the approach described in Chapter 3.2 of this contribution may be subject to change.

The Assessor TÜV Rheinland InterTraffic can deal successfully and effectively with different kinds of assessment approaches like international, European or national standards or guidelines. However, it is deemed necessary to agree in a very early project phase which assessment / approval approach should be applied.

A common understanding between customer, manufacturer, operator, authority and assessor concerning the "rules of the game" helps to avoid a waste of money and time and to realize successful Maglev projects!

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## 6 KEY WORDS

Safety Assessment, Safety Approval, Operation Control System, Overall System Safety, Guidelines & Standards, Transrapid.