Safety Assessment for the Maglev Vehicle TR09 – an approach based on CENELEC railway standards

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ABSTRACT: TÜV InterTraffic has been involved in the Safety Certification Process of the Maglev Vehicles operating on the Shanghai Maglev Line and the Transrapid test facility in Emsland, Germany (TVE). As the prototype of the Maglev Vehicle for the Munich Airport Maglev Application (TR09) will initially be operated on the TVE to achieve type approval, TÜV InterTraffic in its role as notified expert for the TVE is responsible for the safety assessment of the TR09 operation on the TVE. The type approval and safety case for the TR09 will be probably based on the CENELEC railway safety standards (EN 5012x) as accepted rules of technology. To ease cross-acceptance, the safety assessment of the safety related electronics and mechanics of the vehicle TR09 for the operation on the TVE will also be based on these CENELEC railway safety standards. The development of the TR09 as an adaptation of the TR08 on local transport requirements implies the implementation of a notable spectrum of modifications, from changed discrete components to new software and architecture in vehicle electronics and to new designs in vehicle mechanics. Due to that notable range of modifications the challenge will be the acceptance based on CENELEC standards of as many existing safety cases with appropriate consideration of all safety implications of modifications. The safety assessment for the vehicle TR09 had just started at the time this paper was written (31.05.2006) and therefore the planned assessment approach is described.

1 INTRODUCTION

1.1 Role of TÜV InterTraffic on TVE

1.1.1 General

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 /1/). According to this law the relevant approving authority for the TVE is the Technical Supervisory Body (Technische Aufsichtsbehörde TAB) of Lower Saxony (Niedersachsen) within the State Road Construction and Traffic Office of Lower Saxony (Niedersächsische Landesbehörde für Straßenbau und Verkehr, NLStBV).

In the course of the approval of the operation regulations according to §12 (4) of the law for test facilities the approving authority notified experts/ expert organisations to monitor the observance of the operation regulations. One of the two notified experts is the TÜV Arbeitsgemeinschaft Versuchsanlage Emsland (TÜV Arge VME), a joint venture of TÜV Rheinland InterTraffic GmbH (TRIT) and TÜV Nord. TRIT within the TÜV Rheinland Group as a member of the TÜV Arge VME is examining the following subsystems: maglev vehicle, operation facilities including service vehicles, operation control system, switches and transfer table, guideway equipment, propulsion, Inductive Power Supply (IPS). Furthermore TRIT is responsible for EMC, system technology, interfaces and the set of operation regulations. The second member of TÜV Arge VME TÜV Nord is responsible for the electrotechnical equipment of the facilities, of the guideway equipment and of the propulsion, furthermore for ESD and lightning protection.

The second expert notified by the approving authority is Dr.-Ing. S. Droese from the Institut für Baustoffe, Massivbau und Brandschutz (iBMB) at the TU Braunschweig, who examines the main structure of the guideway.

1.1.2 Maglev vehicle TR08

Testing of the 3-section pre-production vehicle TR08 started in September 1999 at the TVE.

This test site operation is one step within the certification process known as vehicle type approval which is regulated by the Federal Railway Authority (Eisenbahn-Bundesamt, EBA) together with the TVE operator and the industry. EBA is the supervisory and licensing authority for revenue service of Maglev Applications in Germany.

TÜV experts have been involved in the aforementioned process, partly as experts of the state authority for the TVE, partly as experts recognized by the federal authority EBA.

1.2 TR09 vehicle prototype on TVE

The first prototype of the vehicle generation Transrapid 09 (TR09) is currently under development and is planned to start operation on the TVE mid 2007.

The TR09 is an adaptation of the TR08 on local transport requirements.

2 ASSESSMENT OF THE TR08 ON THE TVE

2.1 General

The Transrapid 08 (TR08) is a prototype vehicle and consists of the three sections endsection E1, middle section M and endsection E2. It operates at the TVE since 7th September 1999. In the following the process of conducting the safety case for the authority approval is explained.

2.2 Prerequisites for the acceptance by the approving authority

In section 1.1 (5) of the operation regulations (/5/) for the TVE new or modified installations or vehicles can be put into service if the following prerequisites are fulfilled:

"New or modified installations or vehicles, which can influence safety and order of operation, must be – except for examining suitability for use - accepted by the approving authority before being put into operation."

Furthermore under section 1.2 (2) the following is written: "Installations and vehicles must be constituted according the requirements for safety and order. These requirements are fulfilled if the installations and vehicles are built and operated according to the present operation regulations or, if these do not contain explicit stipulations, according to the accepted rules of technology."

Basis of the decision of the approving authority for acceptance of the TR08 was an assessment report of the notified experts of TÜV InterTraffic. In this document the experts gave their advisory opinion regarding the question, if the operational safety with the TR08 is ensured

– for trial- and demonstration operation on the TVE
– for commercial service.

2.3 Assessment prior to approval

2.3.1 Bases of assessment

The following documents formed the basis of assessment for the inspection of TR08 documentation:

- Law for test facilities /1/
- Operation regulation for the TVE /2/
- System specification Transrapid /3/
- Requirement specification vehicle /4/
- Other applicable norms and standards

Further bases of assessment regarding type approval

- Rulebook Maglev-Trains /5/
- General Maglev Systems' Act /6/
- German ordinance on the construction and operation of maglev systems /7/

2.3.2 Evidence for operational safety

For all safety relevant functions as well as for safety relevant electronic and mechanical components the requirements were defined in the system specification, the requirement specification vehicle and the norms and standards applicable at that time (/12/-/14/).

The apportionment of requirements for the subsystems and components as well as architecture and design were laid down by the manufacturer in technical reports, drawings and wiring diagrams.

Evidence of fulfilment of the safety requirements was provided by analyses like FMEA, FTA and strength analysis, which were supplemented by experimental verification as far as needed.

The requirements for analyses and experimental verification were documented in verification specifications for each component. Verification reports and documents for FMEAs, FTAs and stability verification completed the evidence.

For the safety relevant vehicle functions levitation, guidance and braking quantitative requirements were defined in the requirement specification. The tolerable rate for dangerous failures for these safe-life[1] functions was given as $R \leq 10^{-6} / year$.

The fulfilment of these quantitative safety targets was demonstrated by fault tree analyses.

2.3.3 Performance of assessment

The assessment for approval regarding sections 1.1 (5) and (6) of the operation regulations was performed by the notified experts.

The system specification Transrapid and the underlying requirement specifications for subsystems like vehicle etc. were assessed by TÜV InterTraffic et al based on expert knowledge.

[1] safe-life: lifetime availability, realised (a) by failure exclusion based on operation proof design or (b) redundancy

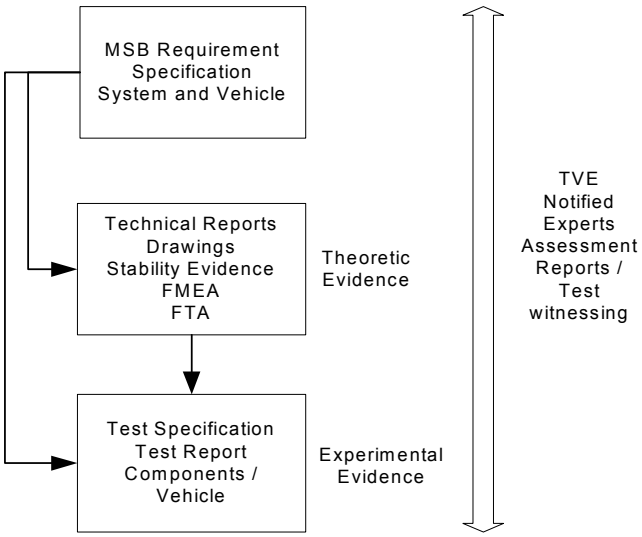

Figure 1: Illustration of Assessment process

The assessment of the vehicle TR08 comprised document inspections as well as inspections on the manufacturer's site and on the TVE. Furthermore verification and validation tests have been witnessed. The assessment was focused on the evidence of functional and technical safety. Verification and Validation was partly performed by the notified experts. See figure 1.

2.4 Initial operation to determine serviceability

After completion of the essential theoretical examinations the vehicle TR08 started operation on the TVE to demonstrate suitability for use.

The initial operation was performed to verify and validate the TR08 on the TVE based on a test specification which had been agreed between manufacturer and the notified experts.

After test completion and the agreement of the notified experts to start regular operation the initial operation phase was completed in March 2000.

2.5 Approval

After completion of a final assessment report by the notified experts the vehicle TR08 was approved by the authority and the regular operation commenced.

Based on that report EBA agreed to type approval of the TR08 on 12th April 2000.

3 REQUIREMENTS FOR APPROVAL OF THE TR09

3.1 General remarks

The vehicles TR08 and TR09 differ in a notable range of modifications (see chapter 4.2). Furthermore the relevant system documentation has changed as well as the applicable standards[2]. The assessment challenge will be the acceptance of as many existing safety cases as possible with appropriate consideration of the modified assessment bases and of all modifications which might have impact on safety.

3.2 Operation regulations

The operation regulations remained almost unchanged since approval of the TR08. Hence they are valid for approval of the TR09 on the TVE.

The assessment bases have changed as follows:

- The system documentation relevant for approval of the TR08 has been replaced by the "Ausführungsgrundlagen Magnetschnellbahnen" /8/. The system documents valid for the TR08 had actually been manufacturer documents and hence been part of the safety case. The "Ausführungsgrundlagen Magnetschnellbahnen" in contrast are based on a broad expert opinion and are published as a rule of technology (Regel der Technik).
- The CENELEC- railway standards EN50126 /9/, EN50128 /10/ and EN50129 /11/ have to be applied – also regarding a type approval for the application in Munich

3.3 Risk analysis

For the TR08 and previous vehicles no risk analysis of the operator had been performed to provide tolerable hazard rates (THR) for the vehicle. For the safety relevant functions THRs were agreed between manufacturer and assessor based on expert knowledge.

The MbBO will be the legal basis for a new service application. The MbBO requires to draw up a safety concept. The safety concept has to contain a risk analysis which derives the THRs for safety functions.

To ease cross-acceptance of the TR09 for an application the assessor proposes, that the manufac-

[2] The type approval and safety case for the TR09 will probaly be based on the CENELEC railway safety standards (EN 5012x). To ease type approval, the safety assessment of the TR09 for the operation on TVE will already be based on these CENELEC railway safety standards as far as possible.

turer[3] performs a risk analysis for operation of the TR09 on the TVE. The analysis can be used to verify the applicability of the current (TR08) THRs for the TR09.

Whether the achieved THRs do fulfil the requirements of the Munich project has to be checked during type approval for Munich.

4 ASSESSMENT PROCESS FOR THE TR09 ON TVE

4.1 General

The following paragraphs describe a proposal from the notified experts point of view, how the CENELEC standards can be applied to the TR09 development, manufacturing and assessment process. It is particularly taken into account, that the TR09 is based on the TR08.

4.2 Modifications between TR08 and TR09

The development of the TR09 includes the implementation of a wide range of potentially[4] safety related modifications: Different discrete components, new hard- and software in vehicle electronics and modified or new mechanical design.

In the following table 1 the main differences are illustrated to get an impression about the extent of modifications. Focus of the illustration lies on the differences which might have impact on safety.

Table 1: safety relevant modifications from TR08 to TR09

Feature	Changes
Car body, dimensions Entrance doors	carbody dimensions modified, position of doors altered and door width increased
Weight	maximum load capacity increased.
Nose	Driverless operation, therefore omission of front windows
Maglev undercarriage, nose casing	Adaption of the geometry according to modified dimensions of car body
Maglev undercarriage, casing	Optimisation regarding winter conditions
Safe vehicle brake	Adaptation to increased vehicle weight
Onboard power supply shut down	Automatic onboard power supply shut down under certain conditions
Onboard power supply	Contactless onboard power supply at low speed and standstill by inductive power supply (TR08: power rail)
Entrance doors, door control	door control functionality modified
Magnets	Product adaptation[5]
Sensors	Product adaptation
Magnet control electronics	Product adaptation
Onboard power supply	Product adaptation
Onboard control	Product adaptation
Wiring	Product adaptation

4.3 Application of EN 50126 - RAMS for railway applications

4.3.1 The Lifecycle according to EN50126

The European railway standard EN 50126

- defines a process, based on the system lifecycle including RAMS-Management (reliability, availability, maintainability and safety) and
- is applicable to modifications of existing systems in operation prior to the creation of the standard (e.g. introduction of the TR09), although it is not generally applicable to other aspects of the existing system.

Figure 3 depicts an example for a lifecycle. For each phase of this lifecycle EN50126 defines the phase related safety tasks, which are summarised in Table 2.

Another common graphical representation of the lifecycle, the V-Model, is given in figure 4. The figure shows the application of the lifecycle model for a system decomposed in subordinated subsystems. In phase 5-*apportionment of system requirements* the system requirements are refined into subsystem requirements. Each subsystem has to pass through its own lifecycle, which ends in phase 9-*validation of the subsystem*. All validated subsystems are integrated in the system (phase 8-*installation*), and the system is validated against the system requirements, which have been defined in phase 4. It has to be noted, that the phases 6-*design* and 7-*manufacture* do also apply for certain aspects of the system lifecycle, e.g. safety management, generic safety case generation and parts of the system which are not split into subsystems. Phase 5 is only applied in subsystem lifecycles if the subsystem is refined further.

Usually subsystems are broken down to components. The lifecycle in figure 5 shows, how the lifecycle can be applied in this case. The subsystem re-

[3] According to EN50126 and EN50129 the system definition as well as the risk analysis have to be provided by the operator. As the TVE is a test facility for industry, these TVE specific documents should be provided by the manufacturer.

[4] The definite decision about safety relevance of modifications must be based on a safety impact analysis.

[5] Within the scope of the adaptation of vehicle assemblies the following adaptations are implemented: (a) reduction of production costs by reduction of design complexity and design improvement (b) adaptation of electronic assemblies for marketable electronic components (replacing non-available components and use new improved generations of components)

quirements are refined further to component requirements and the phases 6 and 7 are only applied for the component lifecycle.

Table 2: Safety tasks related to each lifecycle phase according to EN50126

No	Lifecycle phase	Phase related safety tasks
1	Concept	• Review Previously Achieved Safety Performance • Consider Safety Implications of Project • Review Safety Policy & Safety Targets
2	System definition and application conditions	• Evaluate Past Experience Data for Safety • Perform Preliminary Hazard Analysis • Establish Safety Plan (Overall) • Define Tolerability of Risk Criteria • Identify Influence on Safety of Existing Infrastructure Constraints
3	Risk analysis	• Perform System Hazard & Safety Risk Analysis • Set-Up Hazard Log • Perform Risk Assessment
4	System requirements	• Specify System Safety Requirements (Overall) • Define Safety Acceptance Criteria (Overall) • Define Safety Related Functional Requirements • Establish Safety Management
5	Apportionment of system requirements	• Apportion System Safety Targets & Requirements • Specify Sub-System & Component Safety Requirements • Define Sub-System & Component Safety Acceptance Criteria • Update System Safety Plan
6	Design and implementation	• Implement Safety Plan by Review, Analysis, Testing • and Data Assessment, addressing: • Hazard Log • Hazard Analysis & Risk Assessment • Justify Safety Related Design Decisions • Undertake Programme Control, covering: • Safety Management • Control of Sub-Contractors & Suppliers • Prepare Generic Safety Case • Prepare (if appropriate) Generic Application Safety Case
7	Manufacturing	• Implement Safety Plan by: Review, Analysis, • Testing & Data Assessment • Use Hazard Log
8	Installation	• Establish Installation Programme • Implement Installation Programme
9	System validation	• Establish Commissioning Programme • Implement Commissioning Programme • Prepare Application Specific Safety Case
10	System acceptance	• Assess Application Specific Safety Case
11	Operation and maintenance	• Undertake On Going Safety Centred Maintenance • Perform On Going Safety Performance • Monitoring and Hazard Log Maintenance
12	Performance monitoring	• Collect, Analyse, Evaluate and Use • Performance & Safety Statistics
13	Modification and retrofit	• Establish Safety Plan • Consider Safety Implications for Modification & Retrofit
14	Decommissioning and disposal	• Establish Safety Plan • Perform Hazard Analysis & Risk Assessment • Implement Safety Plan

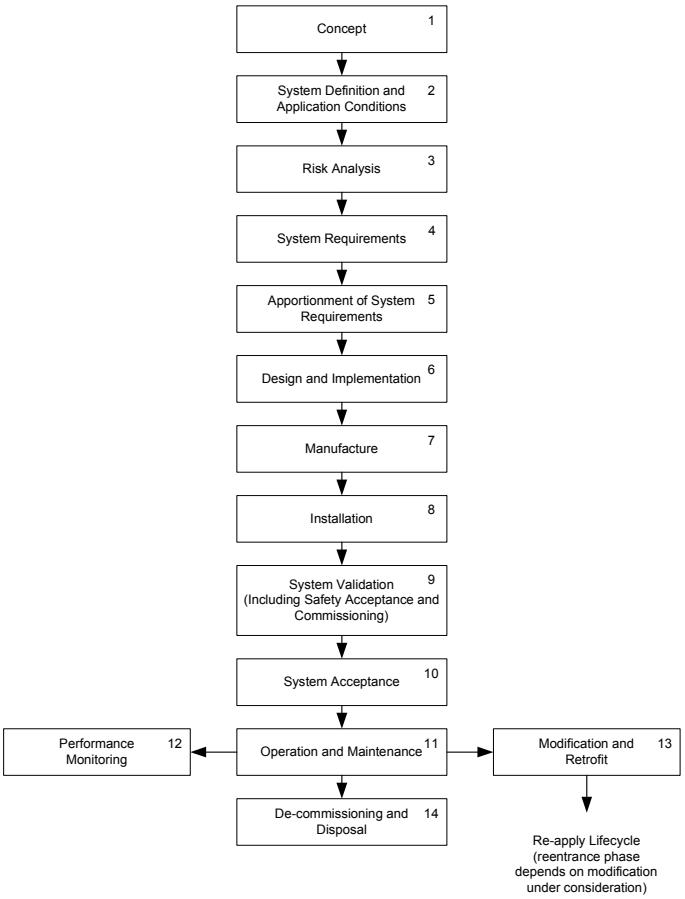

Figure 3: Lifecycle according to EN50126

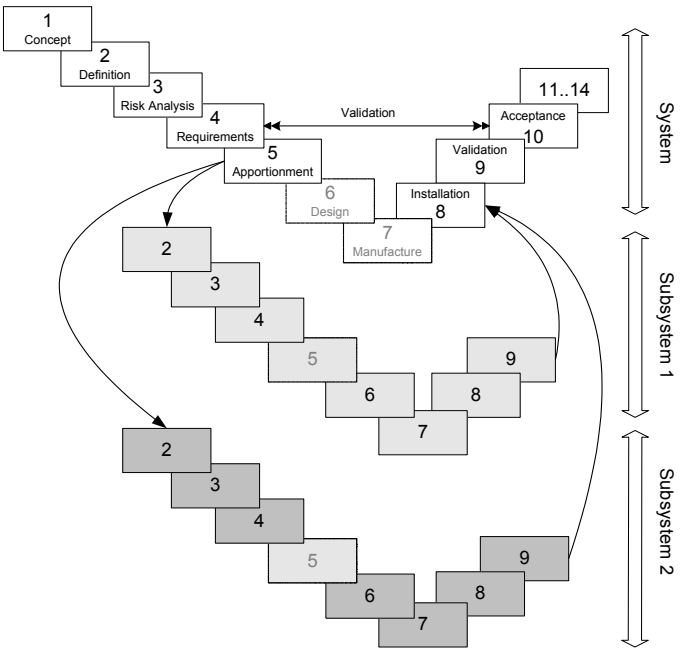

Figure 4: Application of the lifecycle for a system and its subsystems

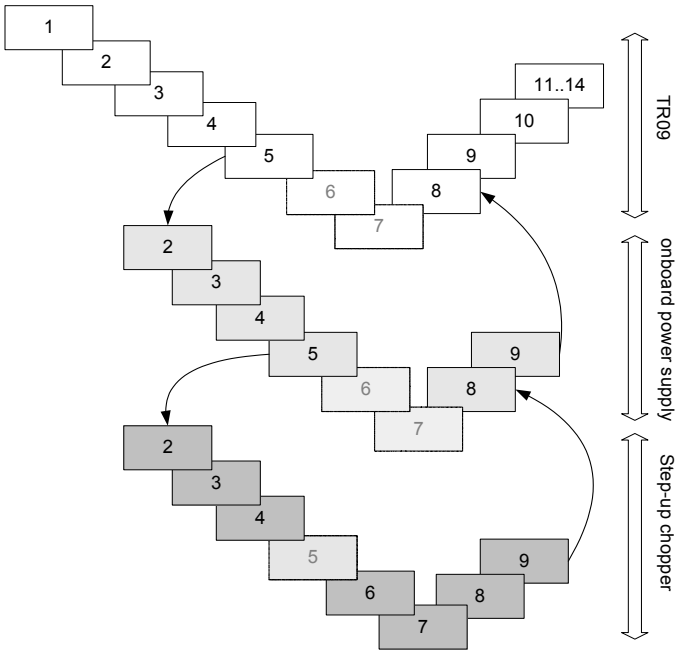

Figure 5: Application of the lifecycle for a system and subordinated subsystems

4.3.2 Application of EN5026 for TR09 design and manufacturing

As described in chapter 4.2, the TR09 will undergo a number of modifications compared with the TR08. This means that phase 13-*modification* has to be the entry phase for the lifecycle of the TR09.

The most important requirements of phase 13 are

a) establishment of a safety plan[6]

b) performance of a safety impact analysis for each modification[7]

According to figure 3 continuing from phase 13 the lifecycle has to be re-applied. The reentrance phase depends on the modification under consideration, i.e. on the result of the safety impact analysis.

As the TR09 is defined by the industry based on operator requirements and has to be integrated into the infrastructure existing on the TVE, for the entire maglev vehicle the re-entry phase is defined to be phase 2 (see figure 6).

For subsystems the re-entry phase can be set to be phase 4-*system requirements* (of the subsystem) or phase 5-*apportionment of system requirements* or 6-*design* (of the subsystem). The decision for a re-entry phase can be for example dependent on the fact whether functional requirements of a subsystem or component do change or do not change and whether the subsystem will be split up in subsystems or not.

An example for that approach is depicted in figure 6. The carbody has to be modified due to new functional requirements, which means re-entry in phase 4. The functional and safety requirements for the onboard control unit remain unchanged, but some non-available components are replaced by new improved generations of components, which means re-entry in phase 6.

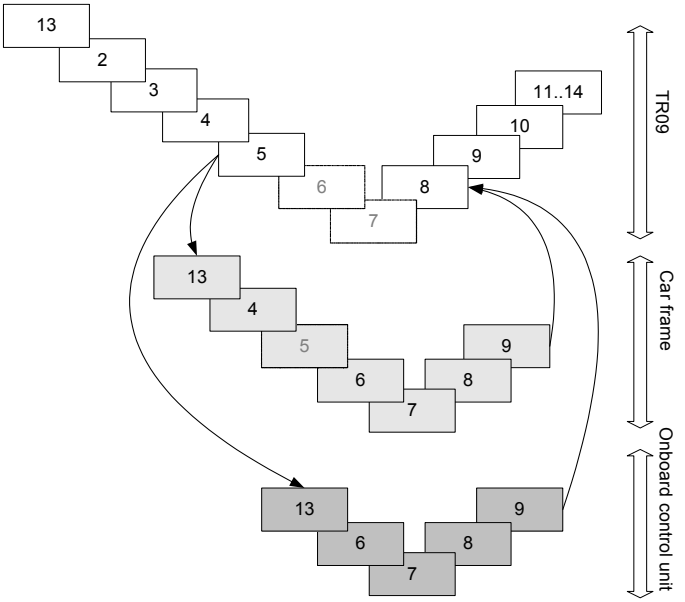

Figure 6: Application of the lifecycle for a system and its subsystems, beginning with phase 13-*modification*

Figure 7 illustrates the lifecycle application in case of subordinated subsystems by example of the subsystem *onboard power supply* and its component *step-up chopper*. For both the subsystem and the component new functional requirements do exist, so re-entry phase is 4-requirements for both the subsystem and the component.

4.4 Application of EN50129 – safety related electronic systems for signalling

4.4.1 General remarks

Though the scope of EN50129 is declared to be railway signalling, its applicability for any safety related electronic system for railways is widely accepted. For that reason the Ausführungsgrundlagen /9/ require the application of EN50129 for the safety relevant maglev vehicle electronics.

[6] a safety plan defines – among others – (a) applied safety lifecycle including milestones and verification and validation, (b) safety management organisation, (c) independence of parties, (d) quality and configuration management, (e) safety requirements, (f) safety case concept, (g) system description, (h) hazard and risk analysis process, (i) subcontractor management, (j) performance of safety audits

[7] the impact analysis has to comprise (a) description of the modifications, (b) analysis of safety relevance of the modifications, (c) required regression tests for hardware and software

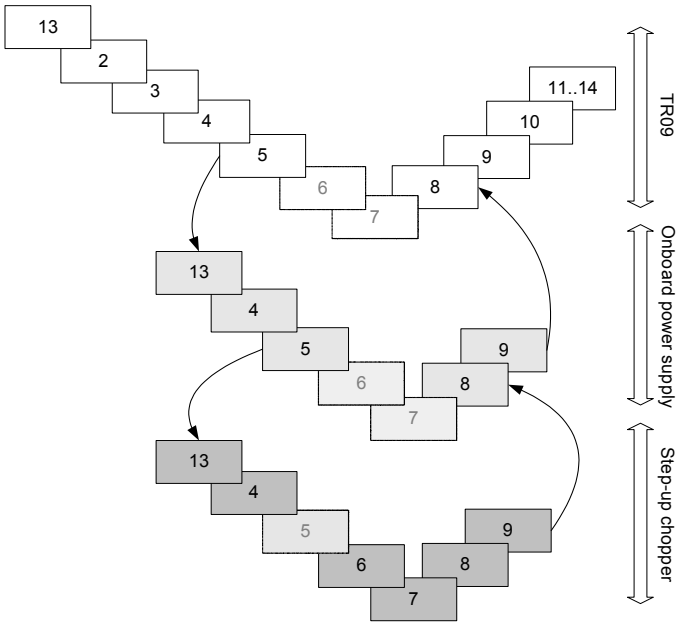

Figure 7: Application of the lifecycle for a system and subordinated subsystems, beginning with phase 13-*modification*

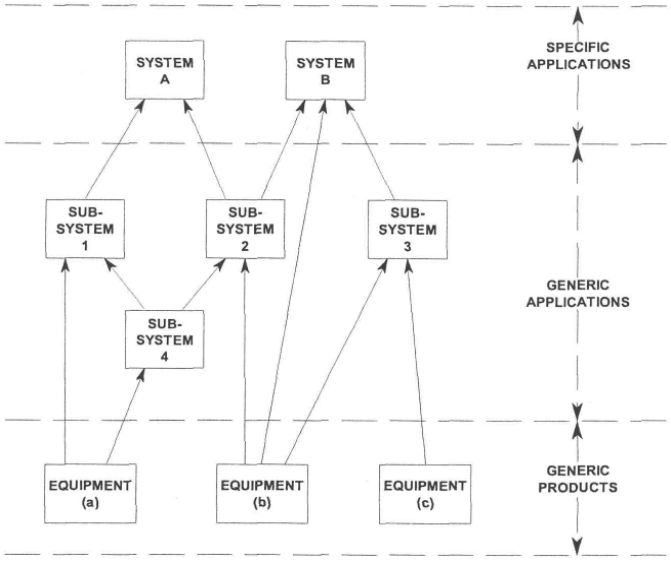

Figure 8: Interrelationship between generic products, generic applications and specific applications according to EN50129

4.4.2 The safety case concept according to EN50129

The standards do distinguish between generic product/ generic application and specific application safety cases. Generic product / application safety cases are used for a product designed to operate in a class of applications. Specific safety cases are applicable for an individual system, e.g. the TR09 operating on the TVE. See figure 8 for an example.

Figure 9 shows the structure of a safety case according to EN 50129.

Besides the *quality management report* and the *safety management report* the technical safety report is the main content of the safety case. The content of the *technical safety report* is further refined in EN50129 according to figure 10.

Moreover the application guide for EN50126, the future EN50126-2, recommends to apply the safety case structure described in EN50129 for all safety cases regardless of technology and provides a list of clauses and their applicability to systems other than signalling.

EN50126 requirements for a safety case are summarised in table 3.

Table 3: content of a safety case according to EN50126

The Safety Case according to EN50126 requires approval by the Railway Authority, and should include

- an overview of the system,
- a summary or reference to the safety requirements, including a consideration of
- the SIL justifications for safety functions;
- a summary of the quality and safety management controls adopted within the lifecycle;
- a summary of safety assessment and safety audit tasks;
- a summary of safety analysis tasks;
- an overview of the safety engineering techniques employed within the system
- verification of the manufacturing process;
- adequacy of compliance with safety requirements, including any SIL requirements of the system;
- a summary of any limitations and constraints applying to the system;
- any special exemption (or specificity) imposed and justified by the contract, to the usual requirements of this Standard

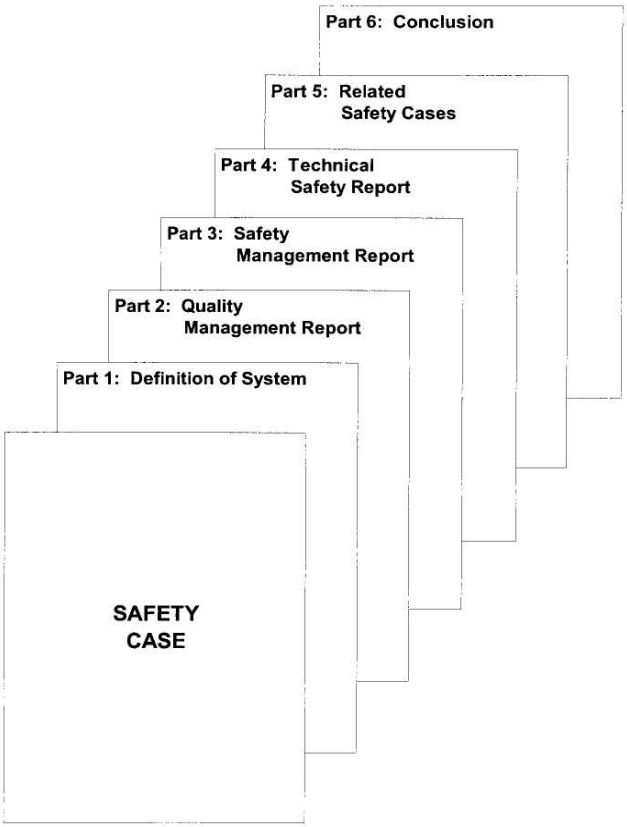

Figure 9: safety case structure according to EN50129

4.4.3 Application of EN50129 for TR09 design and manufacture

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. In the following the proposal of the notified experts is illustrated.

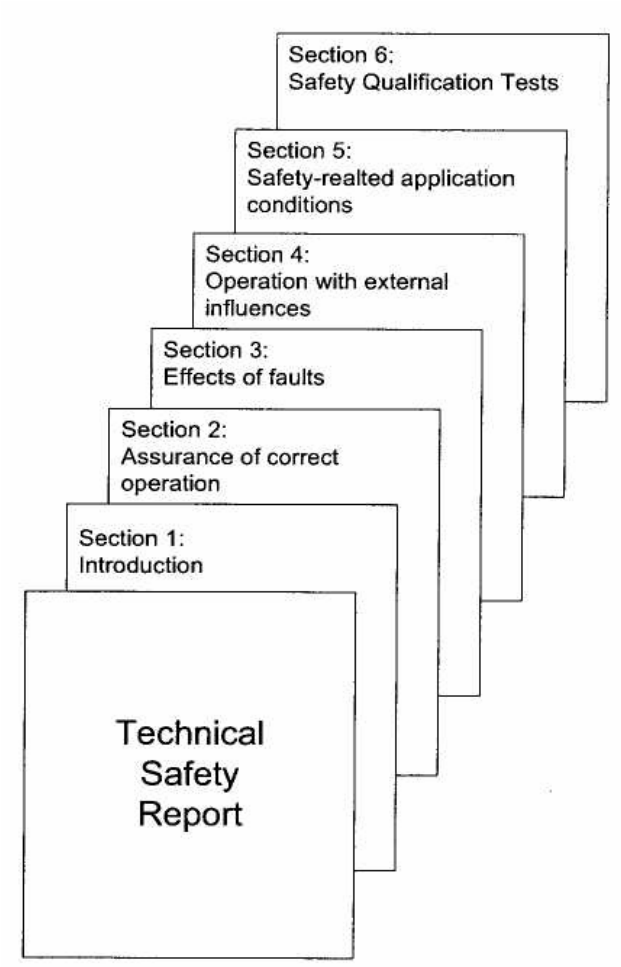

Figure 10: structure of a technical safety report according to EN50129

Again the main criteria are the outcome of the safety impact analysis for the modification of a component and the fact whether functional requirements or attributes are altered or remain unchanged.

The following classification for safety relevant components and subsystems is proposed and has to be laid down in the system safety plan in case of agreement with the manufacturer:

A1: components/ subsystems which remain unchanged (identical) and are conforming to the new Ausführungsgrundlagen /8/

A2: components/ subsystems with marginal design changes (i.e. are conforming to the new Ausführungsgrundlagen /8/ and the functional requirements and attributes remain unchanged)

B: components/ subsystems with safety relevant changes (i.e. changed design due to changed functional requirements or attributes)

Table 4 illustrates the tasks to be performed by the manufacturer and the assessor dependent on the classification.

Table 4: manufacturers and assessors tasks according to current agreement

Class	Manufacturers tasks	Assessors tasks
all	• establishment of a safety plan • Performance of an impact analysis which justifies the classification	• review of the safety plan • review of the impact analysis
A1	• the existing safety case documentation including assessment reports can be taken over unchanged	• review to validate applicability for TR09
A2	• the existing safety case documentation has to be updated (e.g. FMEA) and shall provide the content required by EN50129 (EN50126 or EN50126-2 for mechanics) as far as reasonable, e.g. fully documented V&V, Hazard Log, Quality- and Safety Management. No formal safety case for electronics according to EN50129 required	• review of the updated safety documentation, performance of safety and quality audits and test witnessing where appropriate
B	• the existing safety case documentation has to be updated to fulfil EN50129 (EN50126 or EN50126-2 for mechanics) requirements in format and content, i.e. - full safety management report - full quality management report - full technical safety report	• review of the updated safety documentation, performance of safety and quality audits and test witnessing

4.5 Applicability of EN50128 for TR09 software development

EN50129 requires the application of EN50128 "*Software for railway control and protection systems*" for functions realised in software. This standard defines measures to reduce systematic software faults dependent from the required safety integrity level.

The standard has to be applied for all safety relevant TR09 software applications where the code resp. the execution environment (hardware) or the functional requirements change compared to TR08.

5 EXAMPLE FOR APPLICATION OF EN50126

The following table 5 gives a proposal for the application of the lifecycle according to EN50126 for the TR09 starting with phase 13. The example is limited to the activities required prior to demonstration of suitability for use on the TVE.

Table 5: example for lifecycle application on TR09

	Lifecycle phase & general manufacturer activities	Safety activities of the manufacturer	Assessor activities
13.	Modification and retrofit (concept TR09) Document for comparison of TR08 and TR09 („Soll-Ist-Vergleich TR08 / TR09“)	1.preparation of a safety plan 2.preparation of a modification safety impact analysis 3.definition of phase 2 for re-entry in lifecycle	1.: assessment report 2.: assessment report
2.	System definition and application conditions	1.preparation of the delivery specification (LS WEP TR09) based on the Ausführungsgrundlagen 2.analysis of the impact of the new Ausführungsgrundlagen 3.preparation of a preliminary hazard analysis	1.: assessment report (s) 2.: assessment report 3.: assessment report
3.	Risk analysis	1.Perform System Hazard & Safety Risk Analysis 2.Set-Up Hazard Log 3.Perform Risk Assessment	1.: assessment report 2.: assessment report(s) (the hazard log has to be updated and re-assessed during development) 3.: assessment report
4.	Definition of requirements for TR09 on the TVE TVE-specific: • operation • maintenance • infrastructure	1.preparation of the safety requirement specification TR09 TVE (separated into generic and specific requirements) 2.preparation of the test spec vehicle (PS Fahrzeug) 3.establish safety management	1.: assessment report 2.: assessment report 3.: audit
5.	Apportionment of system requirements for subsystems and components	1.specification of subsystem and component safety requirements including traceability for safety related electronic components of cat. B 2.preparation of test specifications for subsystems and components 3.update of system safety plan	1.: assessment report 2.: assessment report 3.: assessment report
6.	Design and implementation	1. start preparation of generic application safety case for TR09 (based on EN50126) 2. start preparation of specific safety case for TR09 TVE 3. update of hazard log	1.: assessment report 2.: assessment report 3.: assessment report
7.	Manufacturing	See phase 8 installation	See phase 8 installation
8.	Installation	Establish and implement installation programme	• assessment report (s), • audits, • test witnessing
9.	System validation Start of operation to determine serviceability (trial run)	1. Establish and implement commissioning programme 2. supplement specific application safety case (prior to operation) 3. complete final generic application safety case TR09 4. complete final specific application safety case (after determination of serviceability) TR09 TVE	1.: assessment report 2.: assessment report 3.: assessment report

Table 5 shows the lifecycle of the TR09 on the TVE, as far as in the scope of this paper. The lifecycle starts with phase 13 – *modification and retrofit* and continues with phase 2. Focus of the hazard analysis and the hazard log (phases 2 and 3) has to be laid on the potential hazards introduced by the changes. In phase 4 the safety requirements for the

TR09 have to be defined. It is proposed to divide the requirements into generic safety requirements (basis for the generic safety case TR09) and TVE-specific safety requirements (basis for the specific safety case TR09 TVE). A generic application safety case TR09 has to be started in phase 6 as well as the specific application safety case TR09 TVE. In phase 9 the application specific safety case TR09 TVE has to be supplemented and assessed before operation to determine suitability for use (trial run) can be started. The final application specific safety case TR09 TVE as well as the generic application safety case TR09, which could be basis for type approval, have to be prepared and assessed after successful completion of trial run.

6 OUTLOOK

Assessment of the TR09 had just started when this paper was written and the extent of the modifications was not yet fully aware to the assessors. For this reason the described approach may be subject to change.

According to the current planning the assessment will be concluded by TÜV experts before the integration and demonstration of suitability for use on the TVE begins.

The demonstration of suitability for use as well as the afterwards required update of the TVE system safety case will also be assessed by TÜV experts.

The paper on hand is exclusively dealing with TVE safety aspects under consideration of current safety standards. Conclusions regarding the Munich Airport Maglev Application are reserved for Transrapid International, DB Magnetbahn and Eisenbahn-Bundesamt. The authors of this article are prepared – and would be delighted - to contribute to that project.

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