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Transport Safety – The Analysis of Chinese and European Safety Regulation Systems in Railway Safety Context

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Abstract

The concept of safety, which can be considered from a tripartite perspective, can be achieved through a cooperative, synergistic interaction between the organisation, the people, and the infrastructure/technology system. It is asserted that safety represents a pivotal challenge in transport planning. The focal point of our research group's endeavours lies in the domain of railway safety within the broader transport system. The central research question guiding our efforts pertains to the identification of fundamental principles that can inform design methodologies aimed at enhancing safety.

Keywords: safety, standards, railway safety, safety lifecycle, safety through design

1. Introduction

The initial step in this process is to identify the three pillars of safety. The organization is identified as a project organization responsible for the construction of a comprehensive railway infrastructure that is integrated with other modes of transport. In the context of human factors, numerous considerations are taken into account, including the perspective of the passengers and the viewpoint of the professional workforce. As an infrastructure/technological system, we refer to a safety-critical unit within that infrastructure.

The question, therefore, arises as to what factor connects the three pillars into one. The answer to this question depends on where we are in the lifecycle of a particular infrastructure project.

The system lifecycle is generally defined as the process of moving through the following stages: requirements definition, infrastructure design phase, infrastructure construction, system testing, commissioning, operation, maintenance, and decommissioning [1].

Our research focuses on the first two phases of the lifecycle because Szymberski [2] has already shown that we can influence the safety of a project in the design and detailed engineering phases. This concept was subsequently refined by Karakhan et al., as illustrated in the accompanying figure.

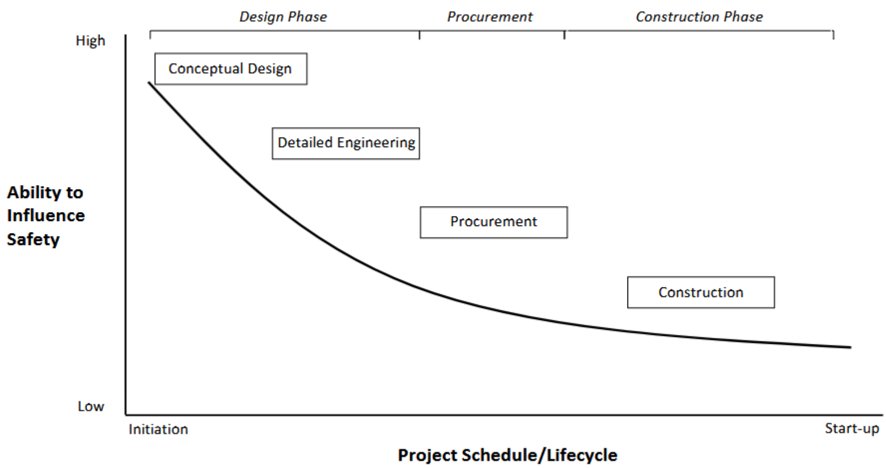


Figure 1. Szymberski's Time-safety influence curve refined by Karakhan et al. [2,3]

2. Safety Design and Safety Certification

Even in a railway construction project, especially if it is large enough, there is no comprehensive safety planning. The different disciplines collect the data for the design and carry out the design task themselves. This is then agreed upon with the other disciplines in design meetings. The lack of safety-oriented planning is obvious. It is not that the individual disciplines do not consider safety to be an important issue. According to Bartha and Majzik, *"Delays in development projects for safety-critical systems were partly due to a lack of clarity or technical inadequacy in the safety assessment process. Reliability assurance planning is an important project activity"* [4].

In our case, the thinking of the designers is mainly influenced by European regulations, directives, legislation, standards, national regulations, company regulations, and the accepted rules of the trade. The statements in the various designs always include references to these.

What can safety through design mean?

The concept of safety through design can be delineated as the incorporation of hazard analysis and risk assessment methodologies into the design and engineering phases of a project. This approach ensures that risk mitigation measures are in place to guarantee that the potential for injury or damage remains within an acceptable range [5].

How can safety be achieved through design thinking, and how can it be justified?

Crossrail defines the Engineering Safety Justification as follows: *"A formal presentation of evidence, arguments and assumptions aimed at providing assurance that a system or product has met its safety requirements (including appropriate legislation and standards) and that the safety requirements are adequate."* [6]

The above suggests that by following the rules and guidelines, designers can create a safe system. The aforementioned study by Karakhan et al. [3] found that a significant proportion of construction accidents were due to design problems.

What could be the reason for this? There are many types of design errors, such as those resulting from non-compliance with regulations. In the points that follow, we briefly review the complex system of mandatory requirements.

3. Overview of the Chinese Railway Legislation System

In China, safety regulations are issued in the form of laws. The clauses listed in these standards impose behavioural constraints on practitioners, especially those involved in railway operations and management. The structure of the primary legislation can be seen in the following Figure 1. The laws and regulations promulgated by the Standing Committee of the National People's Congress, Ministry of Railways.

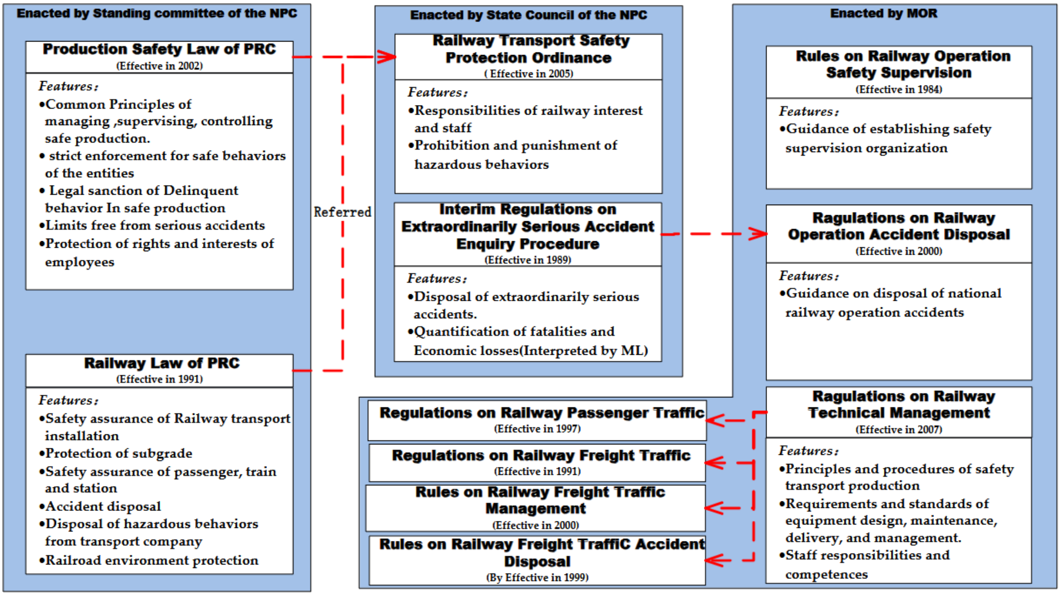


Figure 2. Railway safety legislation in China [7]

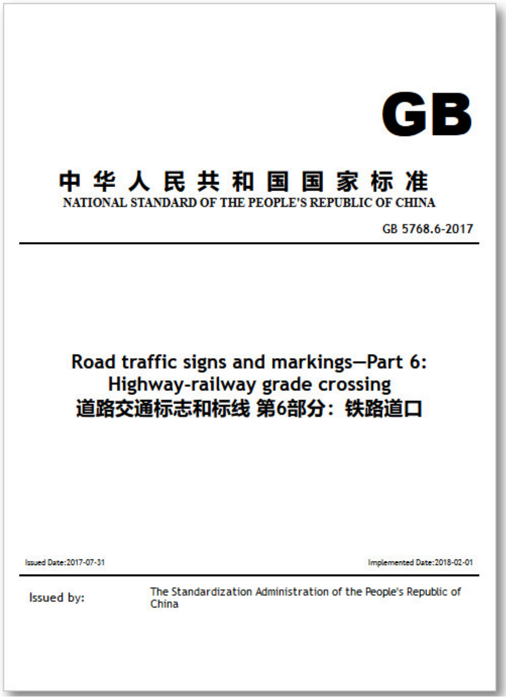
4. Overview of the Chinese Railway Standard System

The Chinese railway standard system has strong structural characteristics, which can directly guide and standardize the design, production, and inspection of systems, subsystems, and equipment. China's railway standards are classified according to the level of the published standards into national standards (GB category of the National Standards Administration), industry standards (TB category of the State Railway Administration), enterprise standards (Q/CR category of China Railway Group), and others (relevant standards of the railway enterprises).

The Chinese railway standard system can be divided into two parts: professional technology and engineering construction. The professional and technical category is divided into three standard systems: high-speed railway, general-speed railway, and heavy-haul railway. It is divided into many sub-systems in detail, including general and comprehensive technology, rolling stock, public works engineering, communication signals, traction power supply, operation services, etc.

Among these, the communication signal technology standard subsystem is divided into basic general standards, system standards, product standards, interface standards, protection standards, etc.; the engineering construction standards are mainly used to guide and regulate railway engineering constructions by taking a large comprehensive approach, and are divided into common standards and special standards, among which common standards include basic categories, survey and design categories, construction categories and acceptance categories.

Special standards include high-speed railways, normal-speed railways, heavy-haul railways, and plateau and alpine railways. There are also several other specific standards, including terminology, graphics symbols, survey and design specifications, construction regulations, acceptance and management specifications, etc.


GB

中华人民共和国国家标准
NATIONAL STANDARD OF THE PEOPLE'S REPUBLIC OF CHINA

GB 5768.6-2017

Road traffic signs and markings—Part 6:
Highway-railway grade crossing
道路交通标志和标线 第6部分：铁路道口

Issued Date:2017-07-31 Implemented Date:2018-02-01

Issued by: The Standardization Administration of the People's Republic of China

Figure 3. GB 5768.6-2017 Chinese national standard English version [8]

5. Overview of the European Railway Legislation System

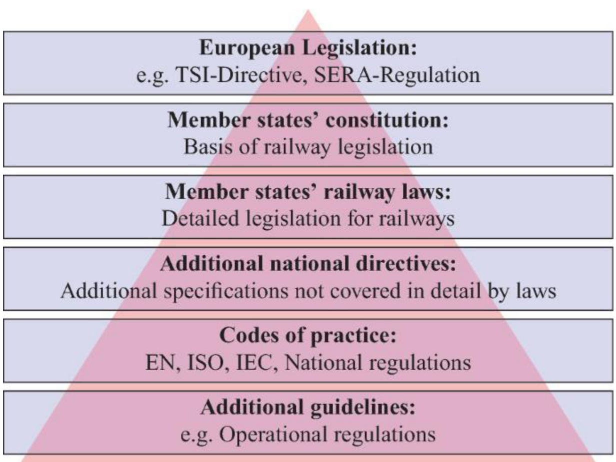


Figure 4. Regulatory pyramid of the European Railway [9]

Insufficient railway interconnectivity has become a major obstacle to European economic development. The EU is paying increasing attention to this issue and has adopted various directives and regulations to promote railway interconnection within the European regions. At present, the EU railway package has three main 'technical pillars' (the 4th Railway Package is a set of 6 legislative texts), which respectively regulate the responsibilities of the European Union Agency for Railways, European railway interoperability, and **European railway safety.** The purpose is to change the management of railway operations among European countries, and a history of incoherence with equipment, to create a single European railway system that is interconnected, safe, and acceptable, and enhances the competitive advantage of rail transport over other modes of transport [10,11].

Safety requirements: The EU Railway Safety Directive 2004/49/EC [12] proposes Common Safety Targets (CSTs) and Common Safety Methods (CSMs). Among them, CST represents the minimum safety level (Safety Level) reached by the railway system, and CSM is used to evaluate whether CST and other safety requirements are met. The public safety method CSM for safety risk assessment was developed through 352/2009/EC [13] and later updated through 402/2013/EU [14]. The core hazard of ETCS is exceeding speed and/or distance limits advised to ETCS. 2016/919/EU stipulates that the tolerable risk rate (THR) of random failures of ETCS core hazards is defined as: 10^(-9) h^(-1) for both the ETCS station part and the ETCS trackside part, thereby unifying this in the EU. It was subsequently updated to (EU) 2023/1695.

6. Overview of the EU Railway Standard System

In the present work, the focus is exclusively on the most significant safety-related standards for railway systems (Fig. 3.), which are the CENELEC standards. The development of these standards commenced in the 1990s, drawing upon best practice and other standards to establish a foundation for safety in railway development and software-based systems. The EN 61508 standard underwent a transformation from a generic standard to an industry standard, thereby acquiring a domain-specific character. These standards serve as the benchmark for railway functional safety.

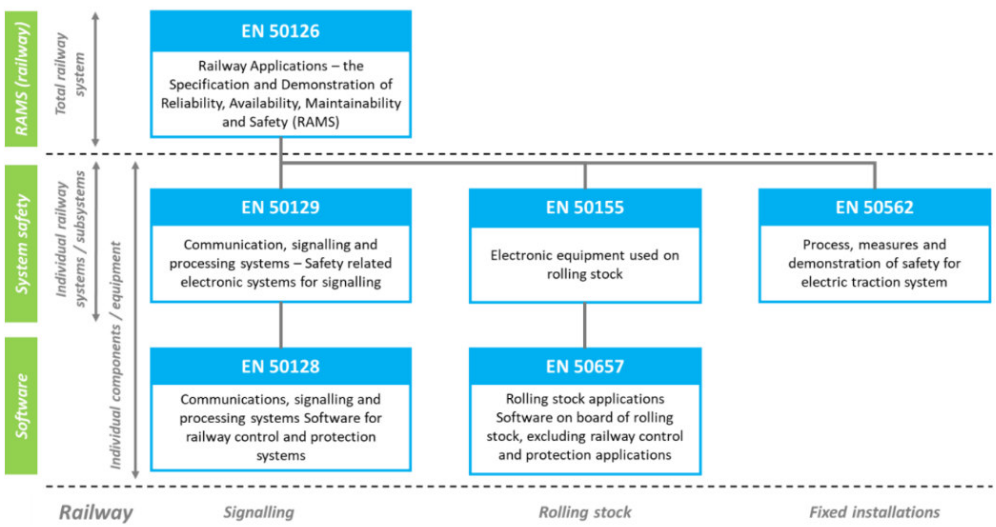


Figure 5. CENELEC standards for railway safety [15]

7. Difference analysis

The China Railway Signalling Standard System has a more complete division of various areas and more detailed specifications within the areas. It fully considers product research and development, engineering design, project implementation, operation management, and maintenance, etc., and supports the national development of the Chinese railway public network. Overall, consideration and unified standards have played a significant role in reducing costs and increasing efficiency. The design, equipment supply, integration, and construction of copper materials related to railway engineering construction are tendered separately and then organized and implemented by the employer. The control over progress and cost is usually strong. Based on the unified and specific Chinese railway standards, each such enterprise has a clear division of labour, so that they can be well applied to the large-scale railway system of Chine [16]. For the implementation of signalling systems, China has formed a mature system integration construction model, which specifically includes integrated design, integrated management, integrated testing, etc., ensuring the effective implementation of railway signalling system constructions.

In comparison, in Europe, standards are not mandatory, except in cases where they are required by law. The European rail standards mentioned above are mandatory for European rail developments. However, there is an absence of a comprehensive and coherent system of technological regulations for the efficient construction of safe railway infrastructure.

8. Conclusion and Future Work– Designing Safety Lifecycle in a Construction Project

In our view, the European railway community is trailing behind due to its prolonged struggle with two main issues: the European standardisation of future safety equipment and automation interfaces, and the recognition of the importance of cybersecurity. These issues have slowly become decades old. In fact, the problems of rail transport have not yet been solved. Knowledge of these requirements and many others is necessary to carry out the design work and to create a safety-critical system. How can we improve on procedures that have existed since 1990?

It is proposed that construction projects should adopt a safety lifecycle approach encompassing the design and construction phases of the infrastructure. This approach involves the utilisation of artificial intelligence to check for inconsistencies in regulations from a safety perspective.

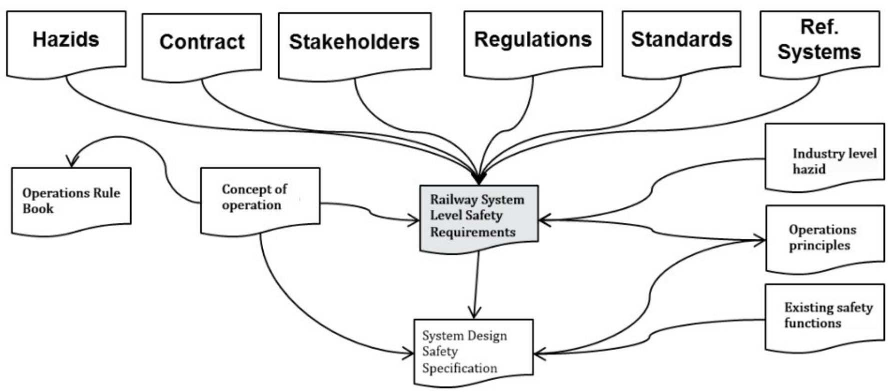


Figure 6. Model to implement Railway System Level Safety Requirements [17]

A system engineering tool is proposed to create System Level Requirements for a railway context. We propose the use of artificial intelligence to create the SLR. If we take into account the baseline of safety lifecycle design, we can also create the (Railway) System Level Safety Requirements. (Figure 6)

Safety Level Requirements (SLR) are a set of system-level specifications that define the safety criteria and constraints for a railway system. These requirements ensure that the system operates within acceptable risk levels, adhering to safety standards and regulations. SLRs are derived from a comprehensive analysis of hazards, risks, and safety goals, and they form the foundation for the design, implementation, and validation of safety-critical systems. In the context of railway systems, SLRs address functional safety, operational safety, and maintenance safety, ensuring the protection of passengers, staff, and infrastructure. We envision that they should be defined and validated from the outset and at all levels of the project structure throughout the life of the project.

The utilisation of artificial intelligence in the domain of SLR development has emerged as a pivotal subject in contemporary research. When applying artificial intelligence to the development of SLR and SLSR, the roles of AI can be categorized as follows:

- The utilisation of artificial intelligence as a support mechanism for engineers entails the automation of repetitive tasks, the analysis of extensive datasets, and the generation of preliminary requirements based on historical data and safety standards. Moreover, AI has the capacity to analyse past railway incidents and safety reports in order to identify common hazards and propose mitigation strategies.
- The utilisation of artificial intelligence as a supervisory mechanism means that it is responsible for the monitoring of the requirement development process, with the objective of ensuring compliance with safety standards. In addition, it is able to identify inconsistencies or gaps in the requirements. Furthermore, AI is capable of cross-checking SLRs against international safety standards, such as those established by CENELEC and ISO, and highlighting any discrepancies.
- The utilisation of artificial intelligence in decision-making processes harnesses its capability of making informed decisions based on predefined rules, risk assessments and optimisation algorithms. It is important to note that this role is limited to non-critical decisions, with the aim of avoiding over-reliance on AI. The ability of AI to prioritize safety requirements based on risk levels and resource constraints is also a key consideration.

The utilisation of artificial intelligence has the potential to influence the security of both the system and the project. Consequently, the research team is developing an AI risk balance rate metric.

In the context of developing metrics, the utilisation of artificial intelligence has proven to be particularly advantageous in the management of complex systems characterised by voluminous datasets. The manual analysis of such systems is often time-consuming and susceptible to errors, rendering AI a valuable tool for enhancing efficiency and accuracy in decision-making processes. However, it is important to note that AI is not suitable for highly critical decisions where human judgment and accountability are essential.

The application of AI in the development of SLR and SLSR for railway systems has the potential to enhance efficiency and accuracy to a significant degree. However, it is crucial to maintain a balance between the risk reduction capabilities of AI and the additional risks it introduces. By delineating explicit roles for AI (e.g., assistant, supervisor, or decision maker) and adhering to the balance rate principle, engineers can leverage AI effectively while ensuring the safety and reliability of railway systems.

9. Acknowledgment

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