

Safety and Reliability Issues in Railways

Contributors: Ali G. Hessami , et al.



About the Book

Modern railways have moved a long way from the slow, noisy, polluting and poor safety record of their earlier ancestors and offer speed, comfort, convenience and enhanced safety approaching those of air travel these days. This is largely driven by incorporation of many modern innovations into the infrastructure, rolling stock and operations comprising advanced computing on-board and track side, high-speed communications, energy efficient traction systems and new track materials. These evolutionary changes have rendered railways a highly attractive mode of transportation in today's world. Electric railway traction chains (ERTCs) emerged at the end of the nineteenth century. Over the years, they have been consolidated as a better solution than their counterparts, i.e., the traction systems with generating power on board. In terms of performances, ERTCs show the highest power-to-weight ratio, fastest acceleration and highest traction effort on steep gradients of the railway traction scenario. They also offer other advantages; such as: less noise, lower maintenance requirements of the traction units, and a higher rational use of energy respecting and preserving the environment (e.g., energy harvesting systems as regenerative brakes or no greenhouse gasses' emissions). However, their drawback is the electrification line cost, which always entails an economical viability study according to a trade-off between line distance and volume traffic.

This book *Safety and Reliability Issues in Railways* covers railway traction fundamentals, providing engineering students and professionals with a collection of state-of-the-art methodological and technological notions to support the development and certification of 'real-time safety-critical' railway control systems, as well as the protection of rail transportation infrastructures. The book approaches the concerns over safety and security of modern mainline and light railways from a systems perspective. It addresses key concerns from the view point of systemic emergence arising from the interaction between all the principal constituents of the railway system, namely infrastructure, rolling stock, energy and human element comprising workers, passengers and the neighbors of the railways. It presents a system level perspective on the requirements of the railways that impact on all design, development, operations, maintenance and upgrades. It also offers a classification system for the requirements that includes safety and security concerns amongst in excess of twenty other requirement categories. The book reviews the trends in railway safety and security, and the impact of new control and command technologies on the safety performance of railways including a view of the emerging issues. The intention of the book is to serve as a valuable reference for students, educators, scientists, faculty members, researchers, and engineers.



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Preface

Modern railways have moved a long way from the slow, noisy, polluting and poor safety record of their earlier ancestors and offer speed, comfort, convenience and enhanced safety approaching those of air travel these days. This is largely driven by incorporation of many modern innovations into the infrastructure, rolling stock and operations comprising advanced computing on-board and track side, high-speed communications, energy efficient traction systems and new track materials. These evolutionary changes have rendered railways a highly attractive mode of transportation in today's world. Electric railway traction chains (ERTCs) emerged at the end of the nineteenth century. Over the years, they have been consolidated as a better solution than their counterparts, i.e., the traction systems with generating power on board. In terms of performances, ERTCs show the highest power-to-weight ratio, fastest acceleration and highest traction effort on steep gradients of the railway traction scenario. They also offer other advantages; such as: less noise, lower maintenance requirements of the traction units, and a higher rational use of energy respecting and preserving the environment (e.g., energy harvesting systems as regenerative brakes or no greenhouse gasses' emissions). However, their drawback is the electrification line cost, which always entails an economical viability study according to a trade-off between line distance and volume traffic.

This book *Safety and Reliability Issues in Railways* covers railway traction fundamentals, providing engineering students and professionals with a collection of state-of-the-art methodological and technological notions to support the development and certification of 'real-time safety-critical' railway control systems, as well as the protection of rail transportation infrastructures. The book approaches the concerns over safety and security of modern mainline and light railways from a systems perspective. It addresses key concerns from the view point of systemic emergence arising from the interaction between all the principal constituents of the railway system, namely infrastructure, rolling stock, energy and human element comprising workers, passengers and the neighbors of the railways. It presents a system level perspective on the requirements of the railways that impact on all design, development, operations, maintenance and upgrades. It also offers a classification system for the requirements that includes safety and security concerns amongst in excess of twenty other requirement categories. The book reviews the trends in railway safety and security, and the impact of new control and command technologies on the safety performance of railways including a view of the emerging issues. The intention of the book is to serve as a valuable reference for students, educators, scientists, faculty members, researchers, and engineers.

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A SYSTEMS VIEW OF RAILWAY SAFETY AND SECURITY

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Keywords: Railway safety, Railway security, Railway system, Requirements, Emergence

ABSTRACT

This chapter approaches the concerns over safety and security of modern mainline and light railways from a systems perspective. It addresses the two key concerns from the view point of systemic emergence arising from the interaction between all the principal constituents of the railway system, namely infrastructure, rolling stock, energy and human element comprising workers, passengers and the neighbours of the railways. It presents a system level perspective on the requirements of the railways that impact on all design, development, operations, maintenance and upgrades. It offers a classification system for the requirements that includes safety and security concerns amongst in excess of twenty other requirement categories. The chapter subsequently covers a whole railway safety study carried out in the United Kingdom that is the only example of such analysis globally and will give an overview of the findings of this holistic safety study that may provide a reference for all international mainline railways. Finally, the chapter reviews the trends in railway safety and security, and the impact of new control and command technologies on the safety performance of railways including a view of the emerging issues.

INTRODUCTION

Modern railways have moved a long way from the slow, noisy, polluting and poor safety record of their earlier ancestors and offer speed, comfort, convenience and enhanced safety approaching those of air travel these days. This is largely driven by incorporation of many modern innovations into the infrastructure, rolling stock and operations comprising advanced computing on-board and track side, high-speed communications, energy efficient traction systems and new track materials. These evolutionary changes have rendered railways a highly attractive mode of transportation in today's world.

A LIFE-CYCLE PERSPECTIVE

The systematic safety assurance of a product, system or process (PSP) requires the consideration of key activities at each phase of the development and deployment. This is referred to as the life-cycle perspective and constitutes the backbone of the most standards and codes of practice.

The generic PSP safety life-cycle comprises 12 phases as follows:

- Concept Definition
- Detailed Definition and Operational Context
- Risk Analysis and Evaluation
- Requirements (including Safety Requirements) Specification
- Architecture and Apportionment
- Design and Implementation
- Manufacture/Production
- System Integration
- Validation
- Acceptance
- Operation, Maintenance and Performance Monitoring
- Decommissioning.

The life-cycle concept constitutes the backbone of the systems engineering practice and the most system safety processes, standards and codes of practice. It exists in a variety of forms and detailed stages depending on the source. One old reference from railway safety standards [1,2] depicts this as a 12–14 phase process by separating many of the later stages such as monitoring and modification into distinct phases as depicted in Figure 1.

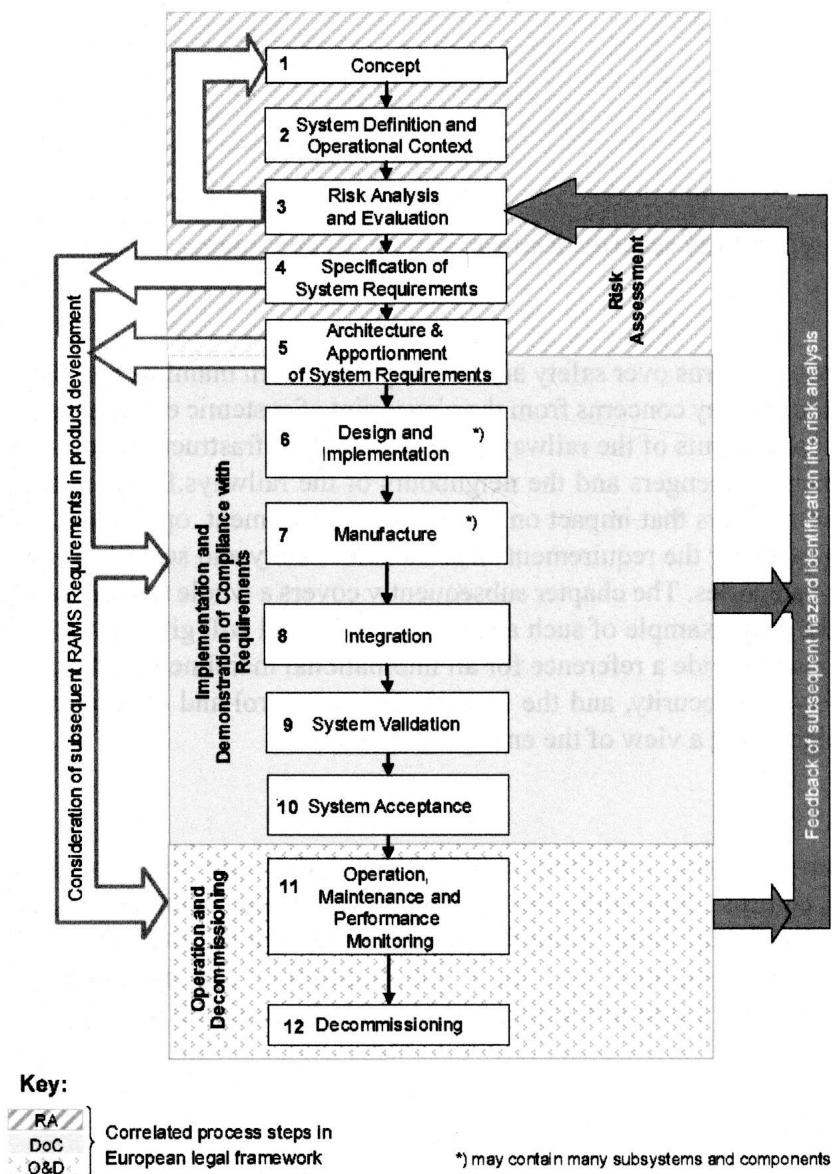


Figure 1: System Safety Life-cycle According to CENELEC Standards.

SYSTEM LEVEL REQUIREMENTS AND CLASSIFICATIONS

The starting point of a comprehensive understanding of a desired or existing system is the so-called system level perspective. Once a level of interest in the hierarchy is stated, then the clear description of the system is the principal starting step.

System Level Perspective

The question of perspective and level is quite fundamental to understanding the system, its constituents, the topology, interfaces and dynamic behaviour. The so-called 'top-level' system perspective is a vision and representation that includes four classes of constituents, namely

- People comprising users, operators, suppliers and the public (the latter category is relevant to the safety and security issues) that is sometimes referred to as stakeholders,
- Control and automation system that performs functions based on embedded logic and algorithms in machines of mechanical, electro-mechanical or electronic nature,
- The infrastructure that supports the functioning of the system. This includes supporting systems and the host environment that surrounds the system including the energy supply, major interfaces with neighbouring or supporting systems/sub-systems, etc.,
- Processes and rules that govern the interactions between people, automation and the infrastructure. These are a broad range of operational, legal, commercial and emergency response conventions that create a common understanding for all system stakeholders. The socio-economic setting within which a system is realized and operated can also be considered as a part of the environmental rules and constraints that influence the functions and behaviours of the systems.

A general view of the broad system composition is depicted in Figure 2 as the so-called top-level system perspective.

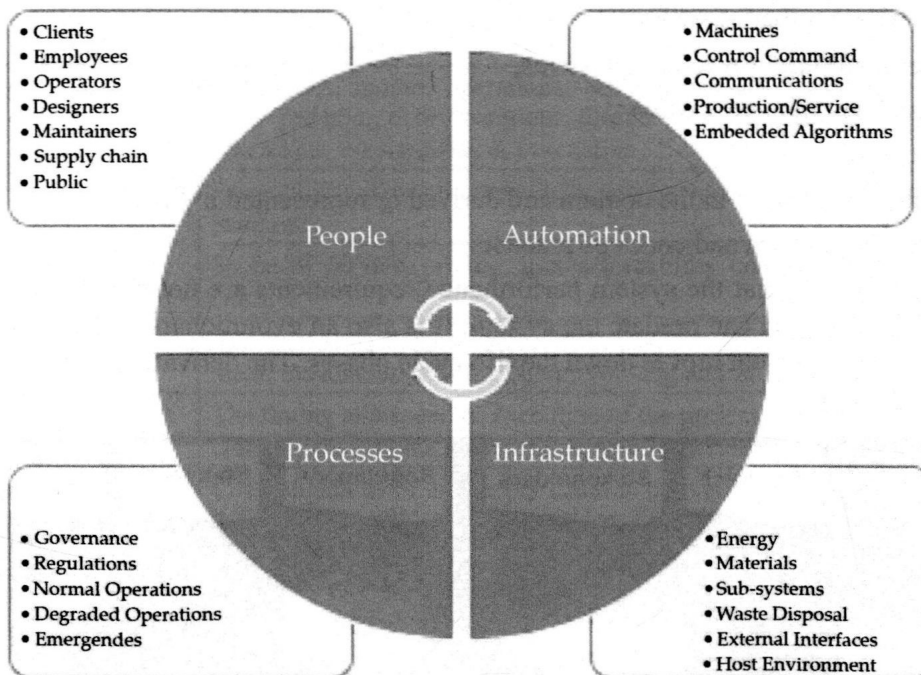


Figure 2: Top-level Railway System Constituents Perspective.

The system of interest exists within such a setting and delivers a utility function or service as part of a larger natural or socio-economic system. However, the systematic study and analysis of the most systems requires the forms of conceptualisation, representation and formalisation that provides a backdrop for the study and understanding of the system properties.

Most system studies start with a 'rich-picture' representation that places the system in its host environment and where possible, includes many of the four classes of information detailed above. One such illustration is given in Figure 3 for the safety study of a school within the proximity of a railway environment.



Figure 3: Rich-picture Representation of a Top-level System Perspective.

The rich-picture representation and associated often pictorial forms of top-level system representation are largely employed in requirements capture and safety studies at the early phases of the life cycle.

System Level Requirements

In the life-cycle perspective, especially the one depicted in Figure 1 above, the specification of requirements including the safety requirements commence in phase 4 of the system life cycle. This in practice is unreal and untrue. Most system requirements and indeed some high-level safety requirements are known at the start of the life cycle. These are broadly derived from a number of sources comprising:

- Past experience of similar or reference systems,
- Customer and stakeholder expectations,
- Contractual documents,
- Operational principles known in the domain and derived or represented in the concept of operation (ConOps),
- Regulations, standards, rules and codes of practice.

It is worth noting therefore that the system performance requirements are not strictly the matter for a specific time or phase in the life cycle and can predate the system. It is also an evolutionary and iterative process that gains more details the further development moves down the life-cycle phases. The derivation of system level requirements (SLR) is depicted in Figure 4.

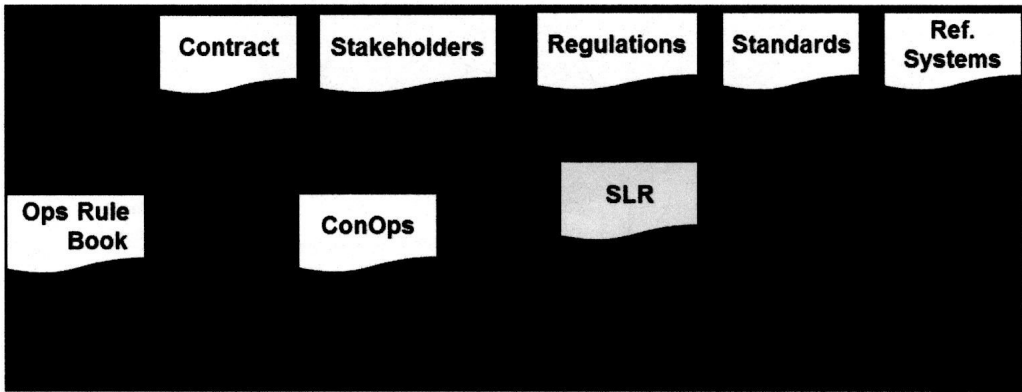


Figure 4: Derivation of System Level Requirements.

The feedback loop from later phases of the life cycle such as the system integration phases back to the SLR is quite normal and in the same sense that system safety properties evolve in terms of understanding and detail, requirements, especially at system level may emerge much later than desired. This is a natural consequence of complexity of requirements, expected functions and behaviours as well as the evolving understanding or operational expectations of the client that may impose additional expectations on the system after the early phases of the life cycle.