POLICY MESSAGES FOR PLANNING AND IMPLEMENTING HIGH-SPEED RAIL IN ASIA

EDITED BY:
Nikhil Bugalia, Sudhir Misra, Ashwin Mahalingam, and KE Seetha Ram
Policy Messages for Planning and Implementing High-Speed Rail in Asia

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<td>HSR</td>
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<td>km/h</td>
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<td>MAHSR</td>
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The cases, ideas, and concepts presented in these chapters were examined and refined rigorously through a series of seminars – the ADBI-JARTS-IIT Learning Series on High-Speed Railway and workshops on Human Resources and Capacity Development for Transport Operators in Asia. The learning series was facilitated by the Asian Development Bank Institute (ADBI) in Tokyo and organized in association with Japan Railway Technical Service (JARTS) and Indian Institute of Technology Kanpur (IITK) and Madras (IITM).

A total of four sessions and three workshops were organized with over 20 resource persons (from Australia, France, Germany, India, Japan, the People’s Republic of China, the Republic of Korea, and the United Kingdom) sharing their experiences, and over 450 registered attendees. These events enabled the contributors of this edited volume to present and refine their findings. Distinguished academicians, development leaders, government officials, consultants, and managers spoke on management, safety, training, and capacity building for high-speed rail projects.

We thank all the participants and the contributors to this handbook for their cooperation, efforts, and precious time, which helped finalize this edited volume. We deeply appreciate the contributors’ outstanding and thoughtful submissions, valuable comments, and continued patience in revising the chapters. We also thank and acknowledge the following institutions and organizations for their continuous support: Ministry of Land, Infrastructure, Transport and Tourism (MLIT), East Japan Railway Company (JR-East), National High Speed Rail Corporation Limited (NHSRCL), and the World Conference on Transport Research Society (WCTRS).

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Sudhir Misra
Ashwin Mahalingam
Nikhil Bugalia
KE Seetha Ram
Beginning with Japan in the 1960s, experiences in different parts of the world, especially in the People's Republic of China and Europe, have shown that high-speed rail (HSR) systems, which provide services at speeds in the range of 200 kilometers per hour to 300 kilometers per hour, are financially viable. However, they require substantial initial investment and meticulous maintenance across various engineering disciplines. Studies have also demonstrated that HSR systems could provide substantial direct and indirect employment and have other indirect benefits.

Given that work in creating new HSR links is currently in progress in various parts of the world, including India, Egypt, and Thailand, it is essential that the lessons learned so far are appropriately incorporated into the newer projects. However, it may be challenging to do that to the fullest extent due to (i) differences in local conditions and (ii) the absence of platforms for sharing such information. The need for pooling resources and promoting comprehensive research and the implementation of results is heightened by the emergence of parameters such as safety and sustainability in project efficiency evaluation. This group has endeavored to bring together professionals from various stakeholders from around the world to share their experiences regarding the diverse aspects of HSR construction and operation. We are delighted to present contributions from Professor Anjum Naweed, Dr. Gregory Rolina, Mr. Sandeep Srivastava, Ms. María José Alba Millán, and Ms. Norie Kobayashi, along with editors Professor Sudhir Misra, Professor Ashwin Mahalingam, Dr. Nikhil Bugalia, and Dr. KE Seetha Ram, in areas ranging from the technological features of HSR to human factors and risk management.

We hope this book will help HSR professionals, especially in areas where work on creating HSR links is presently underway, in terms of planning, design, and/or construction. We want to continue our efforts to bring the global HSR community together and create a platform for the exchange and dissemination of information regarding (i) developments in relevant technology, (ii) capacity building to handle various HSR operations, (iii) lessons learned in terms of operation and maintenance of HSR links, and (iv) the impact of HSR creation on society and development at large.
PART I

Innovations, Operations, and Governance for Successful High-Speed Rail Adaptation
Summary and Key Messages
Sakshi Pandey, Nikhil Bugalia, and KE Seetha Ram

High-speed rail (HSR) is a high-capacity, efficient, environment-friendly inter-city transport mode that has transformed the lives of millions. However, the essential condition for a positive socioeconomic impact is how effectively projects are implemented and operated.

The first chapter of this section, “Lessons from Global Experiences of High-Speed Rail Implementation” proposes the scope of understanding HSR using system-thinking principles, i.e., considering the non-linear and dynamic interactions among various technical and social components in the HSR system. The chapter articulates the importance of stakeholder coordination during the early stages of HSR planning and its positive effects on project implementation in terms of controlling cost and/or schedule overruns. Social media could also be leveraged to mobilize and gauge stakeholder engagement. The successful implementation of HSR projects requires a robust institutional framework delineating each stakeholder’s role(s), the standards used, and coordination and/or conflict resolution mechanisms.

Bugalia et al. point out that HSR systems are capable of adapting to users’ socioeconomic needs. However, this requires a long-term commitment from key stakeholder (operators, regulators, etc.) to facilitate continuous system improvement. The chapter draws attention to the critical need for proactive leadership from key decision-makers for effective implementation and operation of HSR projects.

The second chapter, “Determinants of the Selection of High-Speed Rolling Stock for Safe and Sustainable Operations,” highlights the critical aspects of selection of HSR technology, mainly rolling stock. This chapter compares the critical features of proven and available HSR rolling-stock technologies and their impact on performance, safety and stability, comfort, and sustainability. Various parameters and their benefits include concentrated and distributed power; articulated and non-articulated cars; single and double deck; tilting and non-tilting trains; airtightness and passenger comfort; ride comfort; noise; and aerodynamic requirements, which are analyzed for a suitable design. The chapter highlights the significant differences between each parameter and the reasons for these differences, and analyzes their impact on performance. Srivastava and Agarwal also discuss a strategy for choosing the optimal high-speed train solution for a proposed HSR given the boundaries set by project policies.

The third chapter, “RAMS Framework for Context-Specific Adaption of High-Speed Railways,” focuses on Reliability, Availability, Maintainability, and Safety (RAMS), a concept popularized in European countries in the late 20th century that provides a comprehensive framework to help facilitate continuous improvement, specifically for HSR rolling stock. This chapter demonstrates the capability of the RAMS framework to help facilitate the adaptation of HSR systems in different countries keeping their specific needs in mind. The railway-specific description of the RAMS framework is synthesized from existing literature, and practitioners share case studies from India and Europe as part of an ADBI-JARTS-IIT webinar series.

Bugalia and Misra discuss the essential concepts relating to the RAMS processes: (i) the importance of the system design phase for the whole life cycle, and (ii) the need for continuous risk management. The relevance of the essential concepts is demonstrated through a case study of successful HSR technology transfer in the Republic of Korea. Consequently, they identify RAMS-centered requirements for capacity building and training programs to enable countries to take a significant leap toward HSR from their existing conventional railway systems.
The fourth chapter, “Megaproject Governance and Innovation,” highlights the governance aspects of implementing megaprojects like HSR. According to the authors, the view that such projects often run over time and above budget, and show poor performance is a fallacy based on traditional cost-benefit analysis. The purpose of megaprojects often changes over time, leading to delays and cost increases, but also to an increase in project value.

Mahalingam points to the need for starting with project narratives, using these narratives to define the value that a project is intended to capture, and then deciding on the project designs. In this manner, cost and time overruns are likely to be controlled. Moving further, control of the “fuzzy front end” or the pre-construction phase, as well as strong leadership, are critical for creating project value and ensuring that time and cost targets are met. Innovation is crucial to helping achieve project performance and creating broader societal value. Therefore, formal innovation frameworks that allow projects to learn from one another can effectively improve megaproject performance in an interconnected world.

To summarize, HSR provides a viable transportation option that drives the economy to a great extent and meets the environmental and energy challenges. Demand for HSR projects is expected to grow across different parts of the world. Many countries such as India, Thailand, and Indonesia will soon have HSR corridors. When imported, complex socio-technical systems such as HSR may not provide the optimal performance desired by the importing nation. As a result, HSR practitioners also face challenges in ensuring continuous improvement in the imported system for optimal performance over its whole life cycle. Therefore, it is important to learn from global HSR implementation and derive evidence-based recommendations for the current and future generations of policy makers, practitioners, and researchers.
CHAPTER 1

Lessons from Global Experiences of High-Speed Rail Implementation

Nikhil Bugalia, Sudhir Misra, Ashwin Mahalingam, and KE Seetha Ram

1.1 Introduction

Over the past 3 years, the Asian Development Bank Institute (ADBI), in collaboration with a global community of researchers and policy makers, has developed reference materials to highlight the socioeconomic impact of investment in high-speed rail (HSR). HSR is a high-capacity, efficient, environment-friendly inter-city transport mode that has transformed the lives of millions of passengers and non-passengers alike. Consequently, ADBI has also contributed a significant number of evidence-based policies for improving HSR planning and project development, which have been well received by policy makers (Hayashi, Seetha Ram, and Bharule 2020).

However, a necessary condition for the benefits of HSR to accrue is effective implementation during all stages: planning, construction, and operation and maintenance. For example, effective cost, quality, and project duration controls are necessary for rapidly scaling HSR network construction. Over the last decade, the People’s Republic of China (PRC) has constructed, at unprecedented speed, more than 30,000 kilometers (km) of a 50,000 km HSR network (Figure 1.1a). Among several factors supporting such rapid HSR development, effective project management during the construction stage has played an essential role (Martha, Bullock, and Liu 2019). Similarly, continuous efforts to make HSR a safe and reliable transport mode, thereby making it competitive, is essential (Bugalia, Maemura and Ozawa 2021). Among HSR countries, Japan has an exemplary record of zero passenger fatalities in more than 50 years, resulting from effective safety practices adopted by operating organizations (Figure 1.1b) (Bugalia, Maemura and Ozawa 2020).

Hence, a general focus of ADBI activities in 2021/22 has been on learning from the global HSR implementation experience and deriving evidence-based recommendations for the current and future generations of HSR policymakers, practitioners, and researchers in developing capacity building and training activities. Typically, capacity building refers to the process by which individuals and organizations gain, enhance, and preserve the skills, knowledge, and tools, among other resources, to do their tasks capably while obtaining better results.

In this regard, four webinars and discussion sessions were organized in 2021. The discussion sessions gathered renowned academics, railway practitioners, and policy makers from various countries experienced or interested in HSR operations. The current book summarizes the essential messages and implications obtained through discussion sessions as well as through invited contributions from various experts. An overview of all webinars, speakers, and presentations can be found in Box 1.1. Among these discussion sessions, the inaugural session was organized as an ideation workshop, where various experts discussed some of the essential challenges facing HSR development. A logical conclusion of the ideation workshop is a set of important questions and concerns that need to be addressed during the planning and implementation phases of the upcoming HSR projects around the world. The remaining discussion sessions then focused on gathering experts to address one or two essential questions identified through the ideation workshop.

This book’s introductory chapter provides a brief overview of the ideation session to familiarize the reader with the overall context facing HSR systems worldwide and logically introduces essential
questions to be solved. The remaining chapters provide various experts’ takes on one or two specific questions from a comprehensive list obtained through the ideation session. A logical relationship between the questions and the book chapters has been described toward the end of the introduction section. However, an overview of a theoretical and practical framework necessary to conceptualize the HSR system is presented first. The specific interpretation of the framework for the central theme for each chapter will be further discussed in individual chapters.

Figure 1.1: Total Length of HSR Network and Instances of Fatal Accidents in Selected Countries

<table>
<thead>
<tr>
<th>Year</th>
<th>People’s Republic of China</th>
<th>Republic of Korea</th>
<th>Europe</th>
<th>Japan</th>
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<tr>
<td>1986</td>
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(a) Total Length of HSR Network among Major Operating Countries

(b) Instances of Fatal Accidents in Several HSR Operating Countries


Box 1.1: Guests and Themes of Their Remarks

- Haruhiko Kono, JARTS, Japan – HSR: A Complex System
- Ashwin Mahalingam, IIT Madras, India – Lessons from Vanguard’s Megaprojects
- Werner Rothengatter, KIT, Germany – Project Management Lessons from European HSR Projects
- Masahi Umeda, JRTT, Japan – Slab Track Construction for the Japanese HSR
- Sudhir Misra, IIT Kanpur, India – Panel Moderator
- Yoshitsugu Hayashi, Chubu University, Japan – Resilience of HSR System for Catering to Various Demands
- Yoshihiro Kumamoto, JR East, Japan – Efforts for System Evolution by HSR Operators in Japan
- Anjum Parvez, NHSRCL, India – Project Management for Ongoing HSR Projects in India


Source: Authors.
1.2 A “Systems-Thinking” Framework for Understanding HSR

HSR is best understood as a complex socio-technical system (Bugalia, Maemura, and Ozawa 2021). Thus, the interactions among the system components need to be understood simultaneously, rather than on a standalone basis. The technical components refer to physical systems such as the track, the rolling stock, and so on. The social components refer to human operators, HSR organizations, stakeholders, and regulators. While human operators and organizational decisions govern the technical components, the larger regulatory, economic, social, and political environments govern organizational decisions (Bugalia, Maemura, and Ozawa 2020; Kumamoto and Bugalia 2020). A schematic of the socio-technical HSR system is shown in Figure 1.2.

**Figure 1.2: HSR System and Interactions to Be Considered for Effective Implementation**

Various experts contributing to this book repeatedly emphasized the importance of such a systems-thinking framework for several aspects of HSR implementation. Systems-thinking is also visible in several microprocesses involved in HSR implementation. For example, the construction of the slab track involves seamless coordination between automated processes (for construction, transport, and placement of the pre-cast slab segments); human inputs (for operating the machines and supporting the process at the intersection of several intermediate steps); and management controls (for logistic management and quality control) (Box 1.1) (Umeda 2021). Therefore, understanding such a systems-thinking framework is essential for stakeholders looking to implement HSR projects in the future.

The next section introduces the overall context and the issues facing the HSR systems worldwide through a systems-thinking perspective for various life stages of the HSR system, i.e., system development and system operation.
1.3 Experiences from HSR System Development

Typical HSRs are large-scale projects, with long service lives (approximately 50 years), and are characterized by extensive planning phases. The benefits and drawbacks of these projects are also uncertain due to uncontrollable factors distributed unequally among stakeholders. Given the huge investment and wide-ranging implications, political factors also heavily influence these projects, adding to their overall complexity (Rothengatter 2019).

One commonly observed characteristic of these projects is their associated cost and time overruns during construction; however, to understand them, a systems-thinking perspective is necessary. One prominent school of thought points out the concept of “optimism bias” during the planning stage, or even purposeful deception by the project promoters to push for initial approval, as one of the contributing factors for underestimating and/or underplaying the project complexity and, therefore, its costs and duration (Flyvbjerg 2017). On the other hand, academics also theorize that, as a project’s concepts mature, several stakeholders enter its ecosystem, bringing hitherto unforeseen information and potentially some changes to the project design and contributing to the cost and time overruns (Box 1.2). Often these factors are beyond the control of the policy makers. Therefore, a general idea for project managers and policy makers is to recognize the potential for such overruns and develop sufficient buffers to absorb at least some of them (Mahalingam 2021a).

Moreover, the experience of cost and/or time overruns also highlights the importance of stakeholder engagement early in the project life-stages to reduce drastic design changes later. Research is also underway on how current digital tools, such as social media, could be effectively leveraged for this purpose. Social media can allow often-marginalized stakeholders to be heard and save the project from being led by only a handful of influential stakeholders (Box 1.2). It also allows for easy, widespread dissemination of messages surrounding the project. Therefore, social media management is essential for successfully implementing large-scale HSR projects (Ninan, Mahalingam, and Clegg 2019).

On the other hand, the experiences from countries with HSR also highlight the importance of establishing a clear institutional implementation framework. Institutional frameworks refer to the “rules” governing project implementation, which could be formal, such as standards and laws, and informal, such as the country-specific preferences or norms followed by the stakeholders (Box 1.2). The availability of a robust institutional structure also has a positive impact on project implementation as it helps all the necessary stakeholders understand their responsibility and systematically encourages conflict resolution. A clear institutional framework supporting the development of the first HSR project
in Japan was essential for its rapid implementation (Straszak 1981). By the same token, the lack of such a clear institutional structure was one of the leading causes of poor implementation of the Stuttgart-Ulm HSR project in Germany (Rothengatter 2019).

The systems-thinking framework also explains another essential dimension for managing large projects, i.e., project and/or risk management. Given the complexity of the typical HSR project, not all possible outcomes can be accurately predicted. Therefore, traditional project management, which is essentially deterministic in nature, is relatively static and linear and has its limitations. In other words, in such an approach, the project is divided into several parts, each of which works in isolation to achieve its objectives. However, a large-scale HSR project’s complexity requires a dynamic and nonlinear perspective on project and/or risk management, enabling flexible interaction among several stakeholders to manage issues dynamically as and when they begin to unravel (Bugalia, Maemura, and Ozawa 2020; Rothengatter 2019).

In principle, the effective planning framework, robust institutional structure, and multidisciplinary management framework provide the necessary support to manage a project’s complexities. However, these people-dominated systems also require effective leadership, which can increase the team’s motivation, ensure the inclusivity of and transparency toward stakeholders, and foster trust among stakeholders to ensure meeting project commitments (Mahalingam 2021b). Lack of such leadership can often hamper project progress when conflicts among stakeholders are not addressed expeditiously, as seen in the German HSR case (Box 1.3).

### Box 1.3: Case of Stuttgart–Ulm HSR Station by Professor Werner Rothengatter

**Project Brief:** Stuttgart21 is an underground railway station on the Stuttgart–Ulm high-speed rail line in Germany. The project was technically complex: construction of the main underground station and two underground stations at the airport having access links to both regional and urban public transport occurred while the existing freight station was being replaced, with this area utilized for a land-use project. Because of this, the project also involved several important stakeholders, including the national, regional, and city governments; railway and the airport operators; as well as the European Union for cofinancing. Starting from its announcement in 1994, the project has long been marred by institutional conflicts resulting in huge cost overruns (€5.1 billion in 2009 to €12.3 billion estimated in 2019) and time overruns (as of 2019, the start of operation is expected in late-2025). The main causes of such poor performance are:

1. Lack of in-depth analysis of the needs, designs, cost-benefits, and alternatives in the early planning phase.
2. Lack of governance structure and allocation of responsibilities among stakeholders.
3. No risk management and insufficient change management.
4. Lowest bidder selection, leading to supplementary claims and interruptions of work.
5. Conflicts, missing mediation, and lack of stakeholder participation and cooperation.

**Source:** Authors.

In principle, the effective planning framework, robust institutional structure, and multidisciplinary management framework provide the necessary support to manage a project’s complexities. However, these people-dominated systems also require effective leadership, which can increase the team’s motivation, ensure the inclusivity of and transparency toward stakeholders, and foster trust among stakeholders to ensure meeting project commitments (Mahalingam 2021b). Lack of such leadership can often hamper project progress when conflicts among stakeholders are not addressed expeditiously, as seen in the German HSR case (Box 1.3).

### 1.4 Experiences from System Operation and System Evolution

The experts also note the HSR system’s resilience and the efforts required to achieve this during the operation stage. The industrial ecology of the first-ever HSR line globally, the Tokyo–Osaka HSR corridor (inaugurated in 1964), has changed dramatically in the last 55 years. However, the HSR has been successful in consistently offering competitive services and is still highly relevant. In 1964,
approximately 46% of the industry on the Tokyo–Osaka corridor belonged to the tertiary sector, 42% to the secondary sector, and 13% to the primary sector. Even then, the Tokyo–Osaka HSR line was an immediate success in attracting passengers at a rate higher than that anticipated in the initial design stage. Now, even under a significantly different industrial ecology (1% primary, 12% secondary, 75% tertiary, as per 2010 figures), the Tokyo–Osaka HSR line continues to dominate the inter-city passenger market in the corridor, with only moderate competition from other transport modes such as highways. Such trends highlight the HSR system’s resilience over the long term, which is expected to continue in the context of Japan’s aging and declining populations.

On the other hand, a prominent HSR operator’s perspective presented in the webinar provided insights into the efforts required to achieve such a resilient HSR system. The essential strategy of the Japanese HSR operators has been to provide utmost priority to customer (passenger) requirements in terms of providing safe and reliable service. An increase in network length, state-of-the-art technology to improve operating speed while maintaining impeccable safety records, and reliable service are some of the significant steps taken to maintain HSR’s competitiveness. Moreover, to support such advancements, a competent team of human resources at the operator and the organizational level is also necessary (Mukoyama and Bugalia 2020). Once again, leadership from top management is essential to sustain efforts for continuous system improvement (Bugalia, Maemura, and Ozawa 2019, 2021).

The resilience of HSR operations has been demonstrated even during the ongoing COVID-19 pandemic, where systems globally are facing an unprecedented decline in passengers. Even so, HSR operators are effectively leveraging the system to recover as much as possible. For example, a few HSR operators in Japan have conducted comprehensive trials to transport fresh goods using the network. The strategy, if successful, could be a first step toward the long-term overhaul of passenger-dominated HSR services to mixed passenger and freight services, adding a new dimension to revenue generation. On the other hand, considering the increasing usage of bicycles due to the pandemic, HSR operators in Germany have started to make special arrangements for allowing them on board, thereby paving a path for further integration with other transport modes. Such trends highlight that a relatively long-term commitment by key stakeholders is required to ensure resilience; hence, the need to ensure HSR operations’ sustainability and integration of user needs.

1.5 Concerns Facing the New HSR Systems Being Developed

Some of the system development and system operation lessons noted above have already been incorporated into the upcoming HSR projects (Box 1.4). However, for countries planning to implement HSR, answers to the following two questions remain critical: (1) How can the transition from conventional railway lines to HSR lines be enabled? and (2) How can long-term sustainability for the HSR projects be achieved? Both questions are complex and have multiple dimensions, and can be better answered using a systems-thinking perspective.

It is also important that HSR planning and implementation are done within a broader framework of sustainability. The variety of sustainability aspects could also seem to put contradictory demands on the system, and efficient management of the trade-offs among these issues is necessary to adapt the HSR to the country-specific context.
LESSONS FROM GLOBAL EXPERIENCES OF HIGH-SPEED RAIL IMPLEMENTATION

Box 1.4: Experience from an Upcoming High-Speed Rail Project in India

Drawing on the lessons learned from high-speed rail (HSR) implementation around the world as well as from the several mega projects in India, the Mumbai-Ahmedabad HSR implementation agency has adopted several strategies during system development. Understanding the complexity of the project-management issues, the company has started to leverage digital project management tools, where real-time progress is shared transparently across decision-makers. Such tools also enable efficient approvals, etc., in a time-efficient manner. By utilizing such tools, decision-makers are able to devote more time to planning and controlling the project rather than gathering information to base the decisions on.

Further, realizing the importance of stakeholder engagement and coordination for land acquisition, the implementation agency is committed to establishing long-term trust with the people affected in the process. Specific activities include on-time payment, high compensation rates, creation of skill-development programs for the people affected, and so on. Such trust-building activities have allowed the agency to acquire land expeditiously. However, land acquisition continues to be a challenge for large infrastructure projects across the world and is an area where more context-specific solutions are needed.

Source: Authors.

Overall, the questions obtained from the ideation workshop are focused on two different levels of abstractions related to capacity building and training programs. The first level of abstraction sees the HSR project as a “megaproject” and calls for a paradigm shift that is necessary for governing and innovating them. Such a perspective is then necessary to identify the multipronged approach to capacity building that the HSR stakeholders need to adopt. The second level of abstraction focuses on more specific questions related to the complex HSR system and deals with ideas for successful capacity building and training programs specific to HSR. A more specific but not exhaustive list of unanswered questions obtained in the ideation workshop is given below.

Technology (Development, Operation, and Maintenance)

1. How different is the HSR technical system compared to the conventional railway system, and what technical advancements need to be transitioned to the HSR system?
2. What are the most effective strategies for transferring know-how when importing a technical system such as HSR?
3. For HSR-recipient countries, how should the technical standards and regulations be set considering the long-term (self-reliant development) and short-term implications (successful project implementation)?

Human Resources

4. How are training requirements different for an HSR system compared to those for a conventional railway system?
5. What factors affect the sustainability of organizational knowledge and human resource training in an organization, and what are the best strategies in this context?

Organization

6. What are the characteristics, in terms of interaction with technology and human resources, of successful organizations in constructing and operating HSR projects?
7. How do the regulatory and socioeconomic environments of a country affect the HSR organization’s performance?
Regulation

8. How should the regulatory and institutional factors evolve to successfully manage the modern-day complex HSR systems?
9. How should the impact of HSR projects be evaluated across different domains, such as the impact on industry ecology, land use, employment, and education?

1.6 Structure of the Book

In the context of these arguments, this book attempts to address some of these questions. The key themes relate to technology, organizational governance, safety, and organizational culture.

Chapter 2 by Srivastava and Agarwal provides a comprehensive summary of the essential performance requirements from HSR rolling stock and variations in the performance requirements across different countries. The chapter discusses the key technical features of the rolling-stock systems and their influence on achieving the performance requirements. The content of the chapter essentially helps to identify the complexity of the HSR system compared to the conventional system and provides qualitative guidelines on how countries with new HSR systems set their own performance parameters to tackle their context-specific requirements.

Building on the themes discussed in Chapter 2, Chapter 3 by Bugalia and Misra introduces a formal and systematic framework, called RAMS, to facilitate a context-specific adaptation of the HSR systems for HSR-importing countries. The chapter emphasizes the importance of continuous risk management and system improvement throughout the HSR lifecycle in achieving the best performance outcomes desired by local stakeholders. Both chapters address technology-specific questions.

Chapter 4 by Mahalingam addresses aspects related to technology and organization. The chapter describes how projects can be governed, particularly with regard to mitigating conflicts and creating social, economic, and environmental value. This is critical to the long-term sustainability of the project. In addition, innovation will be critical to achieving these aims. This chapter also sets out organizational mechanisms that can foster mechanisms based on experiences from rail projects in the United Kingdom.

Chapter 5 by Bugalia emphasizes the safety hazards regarding HSR projects and demonstrates the development of a systems-thinking-based framework called the System Theoretic Accident Model and Processes (STAMP), which helps to identify specific risks that HSR projects are likely to face as well as ways in which they can be best managed. This knowledge can be particularly useful to project organizations that are seeking to be vanguards in HSR adoption in their countries.

Chapter 6 by Rolina and Accou takes on the topic of safety and warns us that projects such as HSR are subject to large safety risks. Going beyond the hazard prevention measures that are to be undertaken onsite, they discuss the notions of safety culture and the safety climate, their evolution in Europe, and how critical they are to the safe functioning of HSR projects. They provide ideas on how to change organizational cultures to accommodate better safety practices.

Naweed and Golightly then round out this discussion on safety in Chapter 7 by providing technology as a lens to address issues related to sustainability, as well as human factors. They point out the advances in digital technology as well as the advantages of using these technologies to improve performance and value. However, they caution us that the use of technology to improve safety and productivity is still in its nascent stages and can be improved through the use of technology.
Countries trying to implement HSR for the first time are likely to require international expertise. This will lead to a situation where multiple cultures will be present on a project. Cultural differences that arise will then need to be managed. The case study by Millan provides us with some ideas on how to bridge cross-cultural gaps. She continues the empirical thread that runs through this volume and uses her experience as a safety traffic trainer to speak about cultural diversity, capacity building and cross-cultural training. She concludes on an optimistic note by pointing out how her experiences and actions have led to overall happiness and satisfaction. In another case study, Kobayashi sensitizes us to these dynamics by presenting a case study of the differences between Japanese and Indian cultural and professional environments.

Bugalia et al. conclude this volume with a discussion of the key questions that this book has answered, the key takeaways, and the way forward.
References


CHAPTER 2

Determinants of the Selection of High-Speed Rolling Stock for Safe and Sustainable Operations

Sandeep Srivastava and Deepanshu Agarwal

2.1 Introduction

Modern high-speed trains (HSTs) have already attained a speed of 574 kilometers per hour (km/h) (AGV from Alstom) on rail during a test run, and maglev trains under testing can attain much higher speeds. High-speed rail (HSR) is a rapidly expanding new transportation mode, which can be described as the “future mode of transportation.” Given the comfort, speed, punctuality, and safety features of HSR, it is just what is needed in today’s fast-changing world. HSR projects also have a significant positive impact on the environment by reducing carbon footprint as traffic shifts from roads and air to HSR. The key design features in HSTs depend on many technical aspects: infrastructure, environment, various land regulations, etc. HSR uses proven technologies and is a system that can be adapted for various environmental and social conditions.

Historically, the development of HSTs has been influenced by the existing railway technology in the region, such as the Japanese Shinkansen with electric multiple unit (EMU) and wider body; Europe with Loco hauled and narrower body; and Talgo’s gauge-changing trains for mixed international high-speed traffic. Modern HSTs have evolved based on these trains; however, the requirements of the upcoming projects may require a combination of these technologies.

This chapter reviews the existing technologies required and discusses the issues faced by decision-makers for the technology selection for HSR. Section 2.2 describes the development of HSTs in Japan, Europe, the Republic of Korea, the People’s Republic of China (PRC), and India. Sections 2.3 and 2.4 cover the various features and parameters required in the development of HSTs. Section 2.5 summarizes the various parameters of HSTs used throughout the world for designing and building capacity for future HSR projects.

2.2 Historical and Political Overview of High-Speed Train Development

2.2.1 Japanese HST

In 1964, Japan inaugurated the world’s first HSR, the Tokkaido Shinkansen, between Tokyo and Osaka with Series 0 trains, a 3,383-millimeter (mm)-wide and steel car body, based on the Super Express platform of Odakyu Electric Railway, and followed EMU type propulsion based on the then Japanese Private Railways proven EMUs with DC Motors.

Thereafter, Japan had made quite a few developments such as the introduction of aluminum cars and regenerative braking and vibration control system.
Japanese rail companies started expanding their technological reach beyond Japan’s borders. In 2007, an HSR service in the PRC (CRH2), as well as the Taipei, China Shinkansen (700t), began operations. The United States– Texas (N700s) and India (E5) are currently using Shinkansen technology.

### 2.2.2 European HST

The HST race in Europe started with France’s TGV operations in 1981, which were inspired by Japan. This was followed by the introduction of Germany’s Inter-City Express in 1991, and other high-speed lines on the continent. Contrary to the Japanese, the French went with a concentrated traction system with fewer power traction motors and other propulsion equipment, requiring minimal maintenance. From then on, expansion of HSR has seen an exponential increase in countries like France, Germany, the United Kingdom, Spain, and Italy.

In order to reduce the impact on the infrastructure, Siemens and DB in 1995 initiated development of a train with distributed traction, which was later followed by Alstom in 1998 with the development of AGV.

France’s TGV has also been exported to the Republic of Korea under the transfer of technology contract between Korail/KHSR and KTGV Consortium in 1994, with revenue operations starting in April 2004.

### 2.2.3 Republic of Korea HST

HST development in the Republic of Korea started in 2004 with KTGV, which was based on France’s TGV. Within 5 months of operations, KTX saw travel demand of 1 million within 14 days and 10 million within 142 days; revenue increased by 91.4% over the same period last year. Apart from the improvement in long-distance travel, this has also revolutionized the manufacturing capabilities of domestic manufacturers (such as Hyundai Rotem), who later went on to develop KTX-II and KTX-III on their own.

KTX-III (also known as KTX-Eum) made its commercial debut in January 2021. It is the first electric multiple unit train developed solely with indigenous technologies.

### 2.2.4 People’s Republic of China HST

Prior to 2003, the PRC had been trying to increase train speed, but found it was unable to catch up with the country’s fast-growing economy. Therefore, the government decided to incorporate technologies from other countries that had already developed HSR. This marked the inception of Hexie series trains, with the establishment of joint ventures and technology transfer from Japan (CRH2) and Europe (CRH1, CRH3, and CRH5). The first substantial increase in speed took place in 2007, with CRH1 and CRH2 at 250 km/h. Also, the PRC adopted a wide car body structure (3,360 mm) unlike the European design of a narrower car body (2,950 mm).

According to the guidelines of the State Council, the China Railway Corporation (CRC) fosters the ideals of original and integrated innovation, along with the absorption and re-innovation of imported technologies. The first Fuxing train rolled off the production line on 30 June 2015, with a wide car body of 3,360 mm and an operating speed of 350 km/h for the CR400AF and CR400BF models. The factors leading to the development of the HSR network in the PRC are strong government support, long-term planning, joint ventures, and collaboration.
2.2.5 Indian HST

India has long and rich experience regarding manufacturing and operation of various conventional passenger and freight trains, including mass rapid transit. The country presently runs trains at 160 km/h on the broad gauge line. Taking forward the experience gained from conventional trains along with the need for high speed given the vast geographical reach, India intends to run HST services.

The Mumbai–Ahmedabad High Speed Rail (MAHSR) project is being built using Japanese technology and Japan’s official development assistance (ODA). Due to the ODA’s terms and conditions, the HST will be based on Japanese Shinkansen technology.

India’s National Rail Plan 2020 proposes building an HSR network with a total of 8,555 km by 2051 among 13 corridors in the country, which includes the under construction MAHSR project. To achieve such an ambitious goal, the selection of HSR technologies, which mainly revolve around the type of HST, has to be strategized so that an efficient, economical, energy-efficient, and long-lasting HSR can be developed.

2.3 Key Guiding Features of High-Speed Trains

High-speed trains transformed transportation in the 20th century. Japan made a breakthrough in this regard by launching Shinkansen in 1964. HSTs have reduced the travel time significantly between cities. Technological advancements in the rolling stock are required for future need of higher speeds. We provide an overview of the various standards regarding HST’s performance.

2.3.1 Standards for Key Design Features of HST

Requirement of Sealing and Pressure Comfort Limits for Sealed Trains

When a train enters a tunnel at high speed, it generates air pressure waves inside the tunnel. A compressive pressure wave occurs ahead of the nose and a rarefaction (negative) pressure wave is caused by the entry of the tail of the train. The wave propagates along the tunnel at the speed of sound, reflecting at the portals. At each reflection, the sign of the pressure wave changes so that a compression wave becomes a rarefaction wave, and vice versa. While pressure inside the train is maintained near atmospheric pressure, the outside pressure changes depending on the compression wave and expansion wave generated inside the tunnel and the impacts generated by the opposite passing train.

These rapid pressure changes can cause aural discomfort to passengers, depending on the pressure change amplitude, pressure change speed, and the aural health of passengers. When given sufficient time, the pressure in the ear can equalize with the external pressure by venting through the Eustachian tube.

The HSTs are sealed to prolong the rate of change of pressure and provide comfort to passengers. Figure 2.1 illustrates the pressure variation in the passenger cabin of a good sealing system.
Pressure Comfort Criteria for Sealed Trains

Pressure sealing of HSTs offers operators an opportunity to provide a more comfortable travel experience. It is therefore appropriate to set optimized limits on pressure changes for sealed trains than for unsealed trains. The criteria for sealed trains are compared in Table 2.1. Pressure comfort achieved by various manufacturers/operators are summarized in Table 2.2.

Table 2.1: Pressure Comfort Criteria

<table>
<thead>
<tr>
<th></th>
<th>Time Period (seconds)</th>
<th></th>
<th></th>
<th></th>
<th>Unlimited</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>10</td>
<td>Unlimited</td>
</tr>
<tr>
<td></td>
<td>psi/kPa</td>
<td>psi/kPa</td>
<td>psi/kPa</td>
<td>psi/kPa</td>
<td>psi/kPa</td>
</tr>
<tr>
<td>UIC 660</td>
<td>0.072/0.5</td>
<td>0.12/0.8</td>
<td>–</td>
<td>0.15/1.0</td>
<td>–</td>
</tr>
<tr>
<td>UIC 779-11</td>
<td>0.15/1.0</td>
<td>–</td>
<td>0.23/1.6</td>
<td>0.29/2.0</td>
<td>–</td>
</tr>
<tr>
<td>Netherlands (single train)</td>
<td>0.072/0.5</td>
<td>–</td>
<td>0.123/0.85</td>
<td>0.203/1.4</td>
<td>–</td>
</tr>
<tr>
<td>Netherlands (meeting train)</td>
<td>0.123/0.85</td>
<td>–</td>
<td>0.196/1.35</td>
<td>0.305/2.1</td>
<td>–</td>
</tr>
<tr>
<td>Italy</td>
<td>0.072/0.5</td>
<td>–</td>
<td></td>
<td></td>
<td>0.218/1.5</td>
</tr>
<tr>
<td>Japan</td>
<td>0.058/0.4</td>
<td>–</td>
<td></td>
<td></td>
<td>0.144/1.0</td>
</tr>
</tbody>
</table>

kPa = kilopascal, psi = pounds per square inch.
Source: Authors’ compilation from various sources.
Pressure comfort criteria as per TSI_RS (EN 14067-5) is similar to UIC 779-11, the PRC standard limits are similar to UIC 660. The sealing requirement also depends on tunnel cross section. The tunnel cross-section in Europe is generally in the range 90-100 square meters ($m^2$), whereas in Japan it is 64 $m^2$. A lower tunnel cross-section requires better sealing. That is why pressure sealing criteria and actual achieved values are best for Shinkansen trains (Tables 2.1 and 2.2).

### 2.3.2 Ride Comfort

Increasing the speed of the train may lead to significant vibration issues, which may cause discomfort to the passengers along with issues related to track maintenance and stability. There are some criteria used worldwide for measuring the ride comfort, as shown below.

**Metric According to ISO 2631**

ISO 2631 deals with “whole-body vibrations,” i.e., vibrations transmitted to the human body as a whole through the supporting surfaces. It defines the methods of quantifying vibrations in relation to human health and comfort, the probability of vibration perception, and the incidence of motion sickness. It does not contain vibration exposure limits. The frequency range considered is 0.5–80 hertz (Hz) for comfort and 0.1–0.5 Hz for motion sickness.

According to ISO 2631, vibrations transmitted to the body need to be measured on the surface between the body and that surface. The duration of the measurement needs to be sufficient to ensure that the vibration is typical of the exposures being assessed.

This ISO defined a basic evaluation method, using frequency-weighted r.m.s (root mean square) accelerations according to the following Equation (1)

$$a_{wrms} = \left[ \frac{1}{T} \int_0^T [a^w(t)]^2 \, dt \right]^{\frac{1}{2}}$$

(1)

Where $a^w(t)$ is frequency-weighted acceleration as a function of time (t), $m/s^2$, $T$ is duration of the measurement, in seconds.

---

**Table 2.2: Pressure Comfort Criteria Achieved by Some Manufacturers/Operators**

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Comfort Obtained (Pa)</th>
<th>Train Speed (km/h)</th>
<th>Vehicle Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 sec</td>
<td>3 sec</td>
<td></td>
</tr>
<tr>
<td>BT (for PRC)</td>
<td>200</td>
<td>–</td>
<td>330</td>
</tr>
<tr>
<td>CSR-sifang</td>
<td>181</td>
<td>205</td>
<td>350</td>
</tr>
<tr>
<td>CSR-sifang</td>
<td>246</td>
<td>280</td>
<td>350</td>
</tr>
<tr>
<td>CSR-sifang</td>
<td>–</td>
<td>464</td>
<td>350</td>
</tr>
<tr>
<td>SNCF (Alstom)</td>
<td>&lt;500</td>
<td>–</td>
<td>SNCF confirmed for Sealed HSR</td>
</tr>
<tr>
<td>Siemens</td>
<td>200</td>
<td>–</td>
<td>Advised for Spain HSR</td>
</tr>
<tr>
<td>Shinkansen</td>
<td>120</td>
<td>–</td>
<td>300-320</td>
</tr>
</tbody>
</table>

Source: Authors’ compilation from various sources.
Criteria According to EN 12299/ UIC 513

EN12299 provides several methods by calculating different passenger comfort indices, Mean Comfort (\(N_{\text{MV}}\)), Continuous Comfort (\(C_{\text{cx}}, C_{\text{cy}}, C_{\text{cz}}\)), Comfort on Curve Transitions (\(P_{\text{ct}}\)), and Comfort on Discrete Events (\(P_{\text{de}}\)). In most cases, the Mean Comfort index and Continuous Comfort indices are often used to assess vehicle vibrations on the floor.

Continuous Comfort (\(C_{\text{cx}}, C_{\text{cy}}, C_{\text{cz}}\)):
It is defined as the 5-second frequency-weighted r.m.s. values of acceleration on floor level, similar to the basic evaluation method (ISO 2631).

A preliminary scale to evaluate the ride comfort in the individual \(y\) (lateral) and \(z\) (vertical) directions are given in below Table 2.3 based on certain experiences with the index reported in two decimals.

<table>
<thead>
<tr>
<th>Ride Index</th>
<th>Vibration Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>(C_{\text{cy}}, C_{\text{cz}}(t) &lt; 0.2\text{m/s}^2)</td>
<td>Very comfortable</td>
</tr>
<tr>
<td>(0.2\text{m/s}^2 \leq C_{\text{cy}}(t), C_{\text{cz}}(t) &lt; 0.3\text{m/s}^2)</td>
<td>Comfortable</td>
</tr>
<tr>
<td>(0.3\text{m/s}^2 \leq C_{\text{cy}}(t), C_{\text{cz}}(t) &lt; 0.4\text{m/s}^2)</td>
<td>Medium</td>
</tr>
<tr>
<td>(0.4\text{m/s}^2 \leq C_{\text{cy}}(t), C_{\text{cz}}(t))</td>
<td>Less comfortable</td>
</tr>
</tbody>
</table>

Source: Standard ISO 2631.

Limits
For newly built high-speed railway vehicles, 0.2 m/s\(^2\) is used as a target criterion. For Shinkansen HSTs in Japan, the values are generally lower than given in Table 2.3, i.e., EN limits.

The Mean Comfort Index (\(N_{\text{MV}}\))
It is defined as the 95th percentile of 5-minute frequency-weighted r.m.s values on the floor level, using a similar method to Continuous Comfort. The accelerations are measured in the longitudinal (X), lateral (Y), and vertical (Z) directions, and then the 5-second weighting r.m.s accelerations are calculated for each direction over the entire tested track. The 95th percentile (i.e., the fourth-highest value) is selected and used for further processing. Finally, the 95th percentiles of the weighted accelerations in the three directions are combined with an r.s.s (root-sum-square) calculation as shown in Equation (2).

\[
N_{\text{MV}} = 6 \times \sqrt{\left(\frac{W_d}{a_{X95}}\right)^2 + \left(\frac{W_d}{a_{Y95}}\right)^2 + \left(\frac{W_d}{a_{Z95}}\right)^2}
\]  

(2)

A scale for the comfort index \(N_{\text{MV}}\) is given in Table 2.4 with the index reported for each test zone in one decimal.
Comfort index $W$ is another comfort evaluation method, which has a longer history and is widely used in the railway industry. $W$ is well described in the Chinese standard GB 5599-85 and defined in Equation (3)

$$W = 7.08 \times 10^3 \sqrt{\frac{A^3}{f} F(f)}$$

where $A$, $f$, and $F(f)$ refer to the peak acceleration amplitude of a frequency component derived from an FFT analysis of measured accelerations, its corresponding frequency, and frequency-weighted function, respectively.

It is seen that human beings are considered to be most sensitive to frequencies in the 4–7 Hz range in the vertical direction. The proposed evaluation scales for ride comfort according to GB5599-85 are listed in below Table 2.5. For the newly built high-speed railway, it is described to confine $W$ below 2.5.

### Actual values of various high-speed rail (HSR):

- BT has achieved $N_{MV}$ (HSR) ~ 1.3 in Italy
- CSR (at 350 km/h) < 1.5
- ETR 1000 (300 km/h) by BT/Hitachi $N_{MV}$ < 2
- Alstom Euro duplex (320 km/h) by Alstom $N_{MV}$ < 2
- ETR 610/Pendolino (250 km/h) by Alstom $N_{MV}$ < 2
- Velaro D (ICE3) (320 km/h) by Siemens – $N_{MV}$ range from 1.1 to 1.8 at $v = 300$ km/h
- Seimens Railjet (230 km/h) – $N_{MV}$ < 2

### Criteria According to GB 5599-85

Comfort index $W$ is another comfort evaluation method, which has a longer history and is widely used in the railway industry. $W$ is well described in the Chinese standard GB 5599-85 and defined in Equation (3)

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### Table 2.4: Scale for the $N_{MV}$ Comfort Index

<table>
<thead>
<tr>
<th>Ride Index</th>
<th>Vibration Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_{MV} &lt; 1.5$</td>
<td>Very comfortable</td>
</tr>
<tr>
<td>$1.5 \leq N_{MV} &lt; 2.5$</td>
<td>Comfortable</td>
</tr>
<tr>
<td>$2.5 \leq N_{MV} &lt; 3.5$</td>
<td>Medium</td>
</tr>
<tr>
<td>$3.5 \leq N_{MV} &lt; 4.5$</td>
<td>Uncomfortable</td>
</tr>
<tr>
<td>$N_{MV} \geq 4.5$</td>
<td>Very uncomfortable</td>
</tr>
</tbody>
</table>

Source: Standard EN12299.

### Table 2.5: Evaluation Scale for Comfort Indexes According to GB 5599-85

<table>
<thead>
<tr>
<th>$W$ (GB 5599-85)</th>
<th>Ride Comfort</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W &lt; 2.5$</td>
<td>Excellent</td>
</tr>
<tr>
<td>$2.5 \leq W &lt; 2.75$</td>
<td>All right</td>
</tr>
<tr>
<td>$2.75 \leq W &lt; 3.0$</td>
<td>Qualified</td>
</tr>
</tbody>
</table>

Source: Standard GB 5599-85.
2.3.3 Noise

At higher speeds, along with the vibrations, one must account for the external noise caused by the operations of HSR. Effective control of external noise is necessary for the development of HSR in a region. Identifying the source and defining the permissible decibel limits are crucial in designing HSR.

**Noise Distribution of the Sound Source**

Four kinds of sounds are considered omnidirectional point sound sources as explained in the Environmental Impact Assessment Report for Mumbai-Ahmedabad High-Speed Rail Project. These are sound from lower rolling stock, aerodynamic sound from upper rolling stock, electric power collection sound, and sound from the structure. Distribution of the sound source is shown in Figure 2.2.

The position of these sound sources and generated sound levels vary depending on the kind of rolling stock and its speed. The effectiveness of sound mitigation is expressed by the correction values of power level.

As a noise counter measure, underfloor equipment and bogie are covered with side covers, low-noise pantographs are used, and car gaps and hoods are covered.
Noise generated from pantograph such as current collection noise, aerodynamic noise from the pantograph components is reduced by installing a noise insulation plate on both sides of the pantograph.

**Noise Metrics**

A-weighted equivalent continuous sound pressure level on the pass-by time (dB), \( L_{\text{PAeq,Tp}} \):

\[
L_{\text{PAeq,Tp}} = 10 \log_{10} \left( \frac{1/T_p \int_{T_1}^{T_2} P^2(t)dt}{P_0^2} \right) \tag{4}
\]

where

- \( L_{\text{PAeq,Tp}} \): A-weighted equivalent continuous sound pressure level on the pass-by time (dB)
- \( T_p \): Passing time from \( T_1 \) to \( T_2 \) (sec)
- \( T_1 \): Passing time of the front of the train (refer to Figure 2.3)
- \( T_2 \): Passing time of the end of the train (refer to Figure 2.3)
- \( P_A(t) \): A-weighted instantaneous sound pressure level (Pa)
- \( P_0 \): Standard value of A-weighted sound pressure level (20µPa)

---

**Figure 2.3: Example of Selection of Measurement Time Interval T**

(when targeting the entire train)

Source: Authors.

**Environmental Quality Standards for Shinkansen Super Express Railway Noise in Japan**

The values of the environmental quality standards are explained in the Environmental Quality Standards for Shinkansen Superexpress Railway Noise, which can be categorized into two categories: (I) 70 dB or less and (II) 75 dB or less. For residential areas, Category I is considered, while for commercial and industrial areas Category II is taken into account as shown in Table 2.6.
Measurement and evaluation method:

- Measurements shall be carried out by recording the peak noise level of each of the Shinkansen trains passing in both directions, in principle, for 20 successive trains.
- Measurements shall be carried out outdoors and in principle at the height of 1.2 meters (m) above the ground and at a distance of 25 m from the center of track. Measurement points shall be selected to represent the Shinkansen railway noise levels in the area concerned, as well as points where the noise is posing a problem.
- Any period when there are special weather conditions or when the speed of the trains is considered lower than normal shall be avoided when selecting the measurement time.
- The Shinkansen railway noise shall be evaluated by the energy mean value of the higher half of the measured peak noise levels.
- The measuring instrument used shall be with A-weighted calibration and slow dynamic response.

The environmental quality standards provided shall apply to Shinkansen railway noise from 6 a.m. to 12 a.m.

**EU Commission Regulation—TSI Rolling Stock-Noise Limits for Pass-By Noise**

The limit values for the A-weighted equivalent continuous sound pressure level at a speed of 80 km/h ($L_{pAeq,Tp(80 \, \text{km/h})}$) and, if applicable, at 250 km/h ($L_{pAeq,Tp(250 \, \text{km/h})}$) regarding the pass-by noise allocated to EMUs are set out in Table 2.7. The limit values are defined at a distance of 7.5 m from the center of the track and 1.2 m above top of rail.

Measurement at speeds higher than or equal to 250 km/h shall also be made at the “additional measurement position” with a height of 3.5 m above top of rail in accordance with EN ISO 3095:2013 and assessed against the applicable limit values of Table 2.7.

### Table 2.6: Noise Guidelines in Japan

<table>
<thead>
<tr>
<th>Category of Area</th>
<th>Standard Value [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>70 or less</td>
</tr>
<tr>
<td>II</td>
<td>75 or less</td>
</tr>
</tbody>
</table>

dB = decibel.  

### Table 2.7: Limit Values for Pass-By Noise

<table>
<thead>
<tr>
<th>Category of the rolling-Stock Subsystem</th>
<th>$L_{pAeq,Tp(80 , \text{km/h})}$ [dB]</th>
<th>$L_{pAeq,Tp(250 , \text{km/h})}$ [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMUs</td>
<td>80</td>
<td>95</td>
</tr>
</tbody>
</table>

EMU = electric multiple unit.  
Source: EU Commission Regulation — TSI “Rolling Stock-Noise.”
For EMUs, there are three classes of maximum operational speed:

If the maximum operational speed \( V_{\text{max}} \) of the unit is equal to or higher than 250 km/h, the pass-by noise shall be measured at 80 km/h and at its maximum speed with an upper test speed limit of 320 km/h. The measured pass-by noise value \( L_{\text{PAeq,Tp}}(V_{\text{test}}) \) shall be normalized to the reference speed of 80 km/h \( L_{\text{PAeq,Tp}}(80 \text{ km/h}) \) using Equation (5). The normalized value shall not exceed the limit value \( L_{\text{PAeq,Tp}}(80 \text{ km/h}) \) as set out in Table 2.7. The measured pass-by noise value at maximum speed \( L_{\text{PAeq,Tp}}(V_{\text{test}}) \) shall be normalized to the reference speed of 250 km/h \( L_{\text{PAeq,Tp}}(250 \text{ km/h}) \) using Equation (6). The normalized value shall not exceed the limit value \( L_{\text{PAeq,Tp}}(250 \text{ km/h}) \) as set out in Table 2.7.

\[
L_{\text{PAeq,Tp}}(80 \text{km/h}) = L_{\text{PAeq,Tp}}(V_{\text{test}}) - 30\log(V_{\text{test}}/80 \text{ km/h})
\] (5)

\[
L_{\text{PAeq,Tp}}(250 \text{km/h}) = L_{\text{PAeq,Tp}}(V_{\text{test}}) - 50\log(V_{\text{test}}/250 \text{ km/h})
\] (6)

\( V_{\text{test}} \) = Actual speed during the measurement.

**UIC 660: Measures to Ensure the Technical Compatibility of High-Speed Trains:**

**External noise: When the train is running**

The maximum values permitted in terms of equivalent noise level emission when an HST passes \( L_{\text{PAeq,Tp}} \) are measured at a distance of 25 m from the center of the track and 3.5 m above the rail level:

\[
L_{\text{PAeq,Tp}} \text{ max} = 91 \text{ dB(A)} \text{ at 300 km/h}
\]

where \( L_{\text{PAeq,Tp}} \text{ max} \) is the mean of the A-weighted equivalent continuous sound pressure level concerning the pass-by noise measured for each train set.

It is clear that the external noise standards followed in Japan for Shinkansen HSTs are much stricter than in Europe.

### 2.3.4 Aerodynamic Effects of High-Speed Trains

Trains at higher speed cause significant pressure variation in the open and tunnel sections. With the increase in train speed turbulence increases and cause aerodynamic drag, noise, and vibrations. A lesser aerodynamically shaped train provides higher resistance and consumes more energy. The train resistance is generally represented by the Davis Equation:

\[
R = A + BV + CV^2
\] (7)

where the coefficients “A” and “B” account for mass and mechanical resistance and the coefficient “C” accounts for air resistance due to aerodynamic drag, which is proportional to the square of the train speed.

The aerodynamic drag increases significantly with the increase in train speed. When the train is running at a 300 km/h speed, 85% of the total resistance is caused by this resistance. Baker notes that an x% reduction of a train’s aerodynamic drag can reduce fuel consumption by 0.5x%. Therefore, a decrease in aerodynamic drag forces reduces HSTs’ overall resistance and energy consumption.
An HST running at open field will have a zone of highly compressed air, which moves ahead of the train’s nose. Immediately behind the nose will be a zone of low pressure (negative pressure) and vice versa at the tail of the train. This causes pull or push of the wayside object toward the center of track or away from the track. Meanwhile, the pressure fluctuation in between nose and tail (passenger area) is significantly lower (Figure 2.4).

**Figure 2.4: Pressure Near the Nose and Tail of a Train**

<table>
<thead>
<tr>
<th>Nose</th>
<th>Wall</th>
<th>Tail</th>
</tr>
</thead>
<tbody>
<tr>
<td>High pressure zone</td>
<td>Low pressure zone</td>
<td>Low pressure zone</td>
</tr>
<tr>
<td>Pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak-to-peak pressure</td>
<td>Distance</td>
<td></td>
</tr>
<tr>
<td>Source: Authors.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

High speed causes significant pressure variations for shorter duration, which affects the person standing near the track and wayside structure (Figure 2.5). These pressure variations mainly depend on the distance from the center of track, speed of the vehicle, and train shape factor \( K_t \), i.e., aerodynamic shape. \( h_p \) is taken as 5 m above rail level. Graph is valid for \( y > 2.3 \) m and shows the pressure distribution according to EN14067-4 at a height \( h_p \) of 5 m and from track distance \( y \) of 2.3 m.

Well-accepted formulae exist in Europe for estimating loads on the surfaces of wayside structures. These have been adopted in the Standards EN14067-4 and UIC leaflet 779-1.

Equation (8) gives the area-averaged pressure. A factor 1.3 converts area-averaged to localized peak value for small structural elements up to 1.0 m high or up to 2.5 m long.
The formula may be written as (valid for $y > 2.3$ m):

$$P_+ = P_- = k_uk_apC_{p,y} \frac{1}{2} pv^2 = k_uk_apk_t \left( \frac{A_t}{(y+e)^2} + C_2 \right)^{\frac{1}{2pv^2}} \tag{8}$$

The definitions of the formulae symbols are shown in Table 2.8.

### Table 2.8: Definitions of Formulae Symbols

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Meaning</th>
<th>Metric Units</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_+$</td>
<td>Amplitude of positive pressure pulse</td>
<td>Pa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_-$</td>
<td>Amplitude of negative pressure pulse</td>
<td>Pa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$k_u$</td>
<td>Unit conversion constant</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>$k_ap$</td>
<td>Factor to convert from area-averaged to localized peak pressure, if required</td>
<td></td>
<td></td>
<td>-1.3</td>
</tr>
<tr>
<td>$C_{p,y}$</td>
<td>Pressure coefficient at a distance $y$ from the track centerline</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\rho$</td>
<td>Air density</td>
<td>Kg/m$^3$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$v$</td>
<td>Speed of the train</td>
<td>m/s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$k_t$</td>
<td>Train shape factor</td>
<td></td>
<td></td>
<td>(*)</td>
</tr>
<tr>
<td>$A_0$</td>
<td>Reference area</td>
<td>m$^2$</td>
<td></td>
<td>2.5</td>
</tr>
<tr>
<td>$y$</td>
<td>Distance from track center</td>
<td>m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$e$</td>
<td>Constant distance</td>
<td>m</td>
<td></td>
<td>0.25</td>
</tr>
<tr>
<td>$C_2$</td>
<td>Constant</td>
<td></td>
<td></td>
<td>0.02</td>
</tr>
</tbody>
</table>

Notes: Actual values for $k_t$ may be derived from moving-model scale model testing, full-scale testing on air tunnel or CFD analysis based on the shape of the particular train. According to EN 14067-4, $k_t$ may be considered as 1.0 for freight trains, 0.85 for passenger trains, or 0.6 for aerodynamically shaped high-speed trains.

Source: Authors.
**Head Pressure Pulse**

Units with a maximum design speed higher than 160 km/h and lower than 250 km/h, running in the open air at their maximum speed shall not cause the maximum peak-to-peak pressure of changes to exceed a value of 800 Pascal (Pa) as assessed over the range of height between 1.5 m and 3 m above the top of the rail, and at a distance of 2.5 m from the track center, during the passage of the head.

Units with a maximum design speed higher or equal to 250 km/h running in the open air at the given reference speed 250 km/h shall not cause the maximum peak-to-peak pressure of changes to exceed a value of 800 Pa as assessed over the range of height between 1.5 m and 3 m above the top of the rail, and at a distance of 2.5 m from the track center, during the passage of the head as shown in Figure 2.6.

![Figure 2.6: Head Pressure Pulse](image)

Source: Authors.

**Slipstream Effects on Passengers on Platform and Workers Trackside**

Units of maximum design speed $V_{tr} > 160$ km/h, running in the open air at a reference speed specified in Figure 2.7 and 2.8, shall not cause the air speed to exceed the value, as measured at a height of 0.2 m and 1.4 m above top of the rail at a distance of 3 m from the track center, during the passage of the unit.

The HSTs are designed to have head pressure pulse and slip stream effect values under the limits, as discussed above.
**Figure 2.7:** Slipstream Effects/Permissible Air Speed for Train Speed Less Than 250 km/h

For $160 < v_{w, \text{max}} < 250$ km/h

- 15.5 m/s @ 1.4 m from TOR (Ref. speed: 200 km/h or max. design speed whichever is lower)
- 20 m/s @ 0.2 m from TOR (Ref. speed: Max. design speed)

Source: Authors.

**Figure 2.8:** Slipstream effects/Permissible air speed for Train Speed More Than 250 km/h

For $250$ km/h $\leq v_{w, \text{max}}$

- 15.5 m/s @ 1.4 m from TOR (Ref. speed: 200 km/h)
- 22 m/s @ 0.2 m from TOR (Ref. speed: 300 km/h or max. design speed whichever is lower)

Source: Authors.
2.4 Technical Features of High-Speed Trains

2.4.1 Car Body Width

Vehicle widths are classified as standard widths that range from 2.9–3.0 m and a wide-body width that range from 3.2–3.4 m. The standard width trains are operated in Europe, whereas the wide-body trains can be found in Asian counties like Japan and the PRC. Soon, India, with the E5 series for the MAHSR project, will be using a 3,350 mm wide body.

A standard width trainset typically has a seating arrangement of 2x2 in standard class; the wide-body width configuration provides an option of increased seating capacity with 3x2 seating arrangement in standard class.

Car body width plays a vital role in the selection of rolling stock and infrastructure. A narrower car body has an advantage of mitigating air pressure inside tunnel compared to wider car body thus reduces aerodynamic fatigue load. Also, a narrower car body allows to use shorter nose.

Table 2.9 shows the car body width of various HSTs.

<table>
<thead>
<tr>
<th>Country</th>
<th>Owner/Operator</th>
<th>Class</th>
<th>Operational Speed (km/h)</th>
<th>Width (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>SNCG</td>
<td>TGV (all variants) TGV (Duplex)</td>
<td>320</td>
<td>2,904</td>
</tr>
<tr>
<td>UK</td>
<td>Eurostar</td>
<td>374 e320</td>
<td>320</td>
<td>2,950</td>
</tr>
<tr>
<td>Germany</td>
<td>DB AG</td>
<td>403(ICE), 406(ICE3M), DB 406(ICE3MF), 407(ICE3)</td>
<td>320</td>
<td>2,950</td>
</tr>
<tr>
<td>Italy</td>
<td>Trenitalia</td>
<td>ETR1000</td>
<td>300</td>
<td>2,924</td>
</tr>
<tr>
<td></td>
<td>NTV</td>
<td>AGV575</td>
<td>300</td>
<td>3,000</td>
</tr>
<tr>
<td>Spain</td>
<td>Renge Operanora</td>
<td>S103</td>
<td>300</td>
<td>2,950</td>
</tr>
<tr>
<td>PRC</td>
<td>CR</td>
<td>CRH2C, CRH2C2, CRH380A, CRH380AL, CIT400A</td>
<td>300</td>
<td>3,380</td>
</tr>
<tr>
<td></td>
<td>CR</td>
<td>CRH3C, CRH380B, CRH380BL, CRH380BG</td>
<td>300</td>
<td>3,260</td>
</tr>
<tr>
<td></td>
<td>CR</td>
<td>CRH380D</td>
<td>300</td>
<td>3,358</td>
</tr>
<tr>
<td>Japan</td>
<td>JRW</td>
<td>500</td>
<td>300</td>
<td>3,380</td>
</tr>
<tr>
<td></td>
<td>JRC, JRW</td>
<td>N700, N700A</td>
<td>300</td>
<td>3,360</td>
</tr>
<tr>
<td></td>
<td>JRE</td>
<td>E5</td>
<td>320</td>
<td>3,350</td>
</tr>
<tr>
<td></td>
<td>JRH</td>
<td>H5</td>
<td>320</td>
<td>3,350</td>
</tr>
</tbody>
</table>

PRC = People’s Republic of China, UK = United Kingdom.
Source: Authors’ compilation from various sources.
2.4.2 Distributed and Concentrated Power

The propulsion system is generally realized either by concentrating all the motive power inside two end cars, i.e., concentrated power, or distributing all the motive power among the cars in their underframe, i.e., distributed power.

Distributed power adopted in HSTs provides higher acceleration to weight, speed to weight, and seat per length ratios. It enables a flexible compilation of cars in the HST by reducing the traction force transmission distance between powered (motor) cars and trailer cars. Also, due to the traction control of individual cars, its wheels do not slip away easily in low-adhesion conditions. We show a comparison of distributed and concentrated power in Table 2.10.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Distributed Power</th>
<th>Concentrated Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of motors</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Adhesion</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Redundancy</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Maximum axle load</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Seat capacity</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Noise in passenger area</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Maintenance</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

Source: Authors.

Concentrated power adopted in HST has an advantage of lower maintenance due to the lower number of propulsion equipment and reduced noise levels in the passenger area as propulsion equipment is kept in the non-passenger end cars. However, the recent trend is toward distributed power as it offers more passenger capacity, traction performance, higher adhesion at higher speeds (leading to a lower probability of wheel slip), lower maximum axle load (reducing the cost of maintenance because of less impact on the track), and greater reliability of rolling-stock operation. The issue of noise inside the car in distributed power is being successfully addressed by reducing the effect of noise sources (e.g., improvements in traction motors) and installing noise absorption panels made from special materials in the floor, side of underframe, and bogies.

Distributed power HSTs such as Shinkansen, Siemen’s ICE, Alstom’s Pendolino and AGV, CRH series etc. are running in Japan, Germany, Italy, and the PRC predominantly. Whereas “concentrated power” HSTs such as TGV, Avril, KTX etc. are running in France, Spain, and the Republic of Korea predominantly.

2.4.3 Double-Deck Trains

The need for double-deck trains mainly arises from situations where most of the infrastructure is frozen or existing to a definite length of trainset. The general seating arrangement of the double-deck car is shown in Figure 2.9.
Duplex trainset configuration comes with challenges regarding overcoming the design issues of the overall design of the structure to fit into the existing structure gauge, minimizing axle loading, impact on fatigue life due to higher differential pressure, influence of crosswinds, location of equipment, and their access for maintainability. Notwithstanding the above, the double-deck configuration gives an advantage of higher seating capacity of around 15%–25% in distributed power and 25%–40% in concentrated power.

Some of the double-deck trains are TGV Duplex and E4 Shinkansen running in France and Japan, respectively. Whereas ICE, ETR series, CRH series, E5 Shinkansen, KTX, etc., which have a single deck arrangement are running in Germany, Italy, the PRC, Japan, the Republic of Korea, etc.

2.4.4 Articulated and Non-articulated Trains

Train dynamics are highly dependent on train formations. Trains can be characterized based on mechanical connection pattern into two types of bogie and coupling patterns: (a) articulated trains and (b) non-articulated trains. The mechanical connection pattern includes the bogie’s position to the car body and inter-car coupling arrangement.

The basic difference between articulated and non-articulated trains lies with bogie support to the car-body. Articulated trains are supported on a shared bogie between two cars and the cab car or locomotive is supported on two bogies. The end structures of these articulated trains (two coupled) car-body ends are non-symmetrical; one of them is equipped with a hinge (male end) and the other with hinge carrier (female end). In a non-articulated train, each of the car bodies are rested on two bogies and interconnection between car is provided by a central coupler (rigid bar connection allowing rotation at end of bar), thus having identical intermediate vehicles, and a symmetrical end structure. Figure 2.10 shows the bogie and coupling arrangement for the two types of car configuration.
Articulated trains are further divided into double axle and single axle bogies. Figure 2.11 shows a single axle articulated bogie manufactured by Talgo (Spain).
Besides that, the number of bogies required in an articulated train is lower than that required in non-articulated trains. The total number of bogies has a significant impact on cost. Thus, a reduction in the number of bogies can cut the maintenance costs by 30%.

Decoupling of articulated trains requires a dedicated workshop and support to rest on the end of the car. However, decoupling of non-articulated trains does not require any support or dedicated place as the body rests on two bogies.

As bogies are installed at the end of the car in articulated trains compared with non-articulated trains, this provides passengers with better comfort in terms of internal noise and track vibration.

The lateral movement of articulated and non-articulated trains differs because of the support system of the bogie. The former’s lateral movement is restricted because the coupling position follows the path of the bogie and track center line. However, in the latter, the support position is inside the of the car body end, thus producing vehicle overthrows at the coupling position Figure 2.12 shows the coupling position in both types of train.

Figure 2.12: Car Body Position with Respect to Track Center Line for Non-articulated and Articulated Trains

HSTs have been proven in service in both formats, i.e., with articulated bogies by Talgo’s Avril, Alstom’s TGV and with conventional bogies as in Shinkansen, CRRC’s CRH series, Alstom’s Pendolino, Siemen’s Velaro, etc.

Therefore, the advantage of using articulated trains is that it provides more comfort to the passengers; however, they have increased axle load and the maintenance is cumbersome unlike in the case of non-articulated trains.
2.4.5 Tilting and Non-tilting Trains

When the speed of the vehicle on a curve exceeds a certain limit, the car body’s floor plane will experience high lateral acceleration, resulting in unacceptable levels of ride comfort. To improve this situation but still be able to run fairly fast on a curve, various car body tilt systems have been developed. These systems tilt the car body inward when negotiating a curve and reduce the lateral acceleration on the car body’s floor plane.

There are two types of tilting systems technology available for HSTs.

**Passive Tilt (Natural Tilt)**

The tilt center of these type of tilt systems is above the car body’s center of gravity. The centrifugal force through the car body’s center of gravity gives the car body a tilt motion like a pendulum as shown in Figure 2.13 (e.g., pendulum tilting system (swing bolster with circular arc guide)).

![Figure 2.13: Natural Tilting System](source: Persson, Goodall, and Sasaki (2009)).

**Active Tilt**

The tilt center of this type of tilt systems is below the car body’s center of gravity; the tilt is enforced by a special tilt system powered by pneumatics, hydraulics, or electricity.

In Figure 2.14 (a) the centrifugal force counteracts the active tilt system, which means that a high-power system is required. In Figure 2.14 (b), the tilt center is close to the center of gravity and the required power is limited. Therefore, it is desirable to have tilt center and center of gravity closely located.
**Figure 2.14: Types of Tilting Systems**

(a) Active type-1  
(b) Active type-2

Source: Authors.

**Figure 2.15: Different Types of Tilting Cars**

(a) Pneumatic tilting  
(b) Hydraulic tilting  
(c) Hydraulic pendolino  
(d) Pendulum motion

Source: Authors’ compilation from various sources.
On existing infrastructure, tilting system installed on trains allow it to negotiate curves at a higher speed than a non-tilting train. Also, it is a less costly alternative than building new lines with large curve radius. Different types of tilting systems are shown in Figure 2.15.

Italy’s Pendolino class ETR485, ETR600, ETR610 etc. are designed with a maximum tilting angle of 8 degrees and Japan’s E6, H5, E5, N700 series Shinkansen are designed with a maximum tilting angle of 2 degrees.

Advantages of tilting:

- Higher speeds in sharper curves
- Can be used in existing sharper curved infrastructure
- Reduction in travel time by 10%-15%

Disadvantages of tilting:

- Reduced level of ride comfort
- Motion sickness
- Add on costs on infrastructure and higher maintenance in track and rolling stock
- Excess wheel wear
- Risk of overturning by crosswinds > 83 km/h.

### 2.5 Discussion and Conclusions

From the above parameters, it is evident that there is no single international standard for HSTs. For developing an HSR network in a region, the rolling stock can either be built or bought from abroad. It is important to understand the necessity and feasibility of the development of HSR in a region, which can be learned from existing technologies (Table 2.11).

<table>
<thead>
<tr>
<th>Table 2.11: Rolling Stock Design in the Existing Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Width (m)</strong></td>
</tr>
<tr>
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<tr>
<td>3.2 – 3.4</td>
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<tr>
<td><strong>Distributed Power/Concentrated Power</strong></td>
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<tr>
<td><strong>Double Deck/Single Deck</strong></td>
</tr>
<tr>
<td><strong>Articulated/Non-articulated</strong></td>
</tr>
</tbody>
</table>

m = meter, PRC = People’s Republic of China.
Source: Authors.

The key design parameters of HSTs are discussed extensively in section 2.4, and we learned that one technology is better than others in its own manner; however, it is difficult to bring all the necessary technologies in one place because they are manufacturers’ intellectual property.
Although Japan and the PRC are convinced of the advantages of distributed power generation, it took a while for France and the Republic of Korea to accept this view. Also, the wider car body (width around 3,350 mm) had been the norm for Japan and the PRC from the beginning; however, Europe continued to use the narrower body of cars (width around 2,900 mm) due to the existing conventional lines even though Europe-PRC joint ventures had manufactured the wide car body for the PRC. Recently, Talgo has adopted the 3,200 mm wide car body in its Avril model. Similarly, articulation was mainly limited to European design, whereas Japan and the PRC followed non-articulated bogies considering their requirement of lowering the axle load. Therefore, it is obvious that each manufacturer has its own design philosophy and platform derived from its rich experience. So, it becomes difficult to adapt different technologies in their platforms.

Notwithstanding the above, HSR projects, being capital intensive, are usually assisted by external funding, which is an important criteria in the selection of HSTs. This can be witnessed in the cases of India and Taipei, China.

Hence, given the vision for HSR and for capacity building, there are two options: (a) import finished HSTs like India (for MAHSR) and Taipei, China; or (2) develop a long-term plan involving imports, which include technology transfer, research, and development of one’s own platform like the PRC and the Republic of Korea, meeting domestic high-speed transport needs.

With the prospects mentioned in the National Rail Plan 2020, India may also consider developing its own HST platform similar to the approach adopted by the PRC and the Republic of Korea to become independent and self-reliant in HSR.
References


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CHAPTER 3

RAMS Framework for Context-Specific Adaption of High-Speed Rail

Nikhil Bugalia and Sudhir Misra

3.1 Introduction

Demand for new high-speed rail (HSR) projects is expected to grow across different parts of the world (Asian Infrastructure Investment Bank 2018; Hayashi, Seetha Ram, and Bharule 2020). However, the capability to develop HSR technology and fulfill global demand is concentrated in a handful of HSR-developing countries such as Japan, the People’s Republic of China (PRC), and a few countries in Europe, including France, Spain, Germany, and Italy (Yanase 2010). Naturally, many features of these HSRs cater to the context-specific requirements of the countries that initially led the development. For example, for the Japanese HSR, the emergency braking system during earthquakes was an essential requirement due to the country’s high exposure to natural hazards, whereas for HSR systems in Europe, such a requirement was not deemed necessary (Iwasa, Ishido, and Suga 2015). However, countries importing HSR systems may not always have the luxury to import HSR systems that best fit their context. When imported, complex socio-technical systems such as HSR may not provide the most optimal performances as desired by the importing nation. For example, for completing its only HSR project, Taipei, China relied on importing the technical elements from both Japanese and European countries; however, many compatibility issues between these systems had to be resolved during the implementation and operations of the Tapei, China HSR (Kao, Lai, and Shih 2010). Hence, efforts are also needed to assure continuous improvement in the system to achieve optimal performance over the whole life cycle of the system.

Box 3.1: Guests and Themes of Their Remarks

- Sandeep Srivastava, NHSRCL, India – Key Design Features of High-Speed Rolling Stock
- Subrat Nath, Talgo, India – Talgo – A sustainable concept in continuous growth
- Panel Discussion – Capacity Building for domestic manufacturing, operating and maintaining imported rolling-stock systems – how can developing countries create indigenous capabilities to meet these standards
- Sudhir Misra, IIT Kanpur, India – Panel Moderator
- Nikhil Bugalia, IIT Madras, India – Panel Moderator
- Manish Jain, Railway Board of India, India – Panelist
- Suhanshu Mani, Train 18 Program, India – Panelist
- Professor Yong Cui, University of Stuttgart, Germany – Panelist
- Byung-il OH, Korail, Republic of Korea – Panelist

IIT = Indian Institute of Technology, NHSRCL = National High-Speed Railway Corporation Limited.
Source: Authors.

This chapter aims to identify essential lessons for HSR practitioners worldwide about the characteristics of the continuous HSR system improvement programs that can help achieve optimal life-cycle performance local to the HSR-importing countries. It relies on multiple case studies shared during the ADBI-JARTS-IIT Learning Series on High-Speed Railway: Setting and Maintaining Performance Standards for Railway Assets¹ organized on 27 July 2021 to synthesize the lessons.

3.2 Framework for Understanding the Requirements of the High-Speed Rail System

Railway systems everywhere in the world face multiple demands from various stakeholders. For example, the user expects a high level of performance on safety, passenger comfort, and reliability of the services. On the other hand, profitability becomes an essential goal for railway operators (Doi 2016). As railway systems have become large, complex, and long-lasting, coupled with the rapid environmental changes in surrounding technologies and markets, system properties to cope with the dynamic evolution of exogenous circumstances and the system itself have become more critical. Hence, nontraditional design criteria such as flexibility, reliability, and sustainability are becoming more critical than static functional requirements such as speed (Doi 2016). Such criteria, often called life-cycle properties or “ilities,” are defined by De Weck, Ross, and Rhodes (2012) as “desired properties of systems that often manifest themselves after a system has been put to its initial use.” In other words, the “ilities” can be seen as long-term life-cycle system attributes that emerge after systems are put into operation. Doi (2016) describes the plethora of “ilities” relevant to HSR systems. Modifiability, modularity, and interoperability are some of them. However, among these “ilities,” recently, sustainability is emerging as an essential requirement for railway systems worldwide (De Weck, Ross, and Rhodes 2012; Doi 2016). Sustainability also received prominent mentions by the practitioners in the learning series. Sustainability means meeting own needs without compromising the ability of future generations to meet their needs. It is a comprehensive concept relating to environmentalism, social equity, and economic development.

However, in the last few years, an internationally recognized framework defining the “ilities” requirements of railway systems incorporating Reliability, Availability, Maintainability, and Safety (RAMS) has emerged. Modern railway systems have become complex so that the identification of exact system responses and behaviors has some limitations. Therefore, a systems-thinking-based systematic approach, often focusing on risks across different life stages of the system, is necessary to simultaneously manage the performance requirements on many fronts (Bugalia, Maemura, and Ozawa 2021b; Doi 2016; Hayashi, Seetha Ram, and Bharule 2020; Mahboob and Zio 2018). RAMS is an internationally recognized framework for the railway sector that can enable methodical considerations of the risks in the system life-cycle (Park 2014). Reliability is the ability of a system or component to perform its required function under stated conditions for a specified period. Availability refers to the ease and speed with which a system can be restored to operational status after a failure. Safety is defined as the absence of accidents that can generate unacceptable losses for stakeholders (Mahboob and Zio 2018). Today, many railway organizations worldwide rely on the RAMS standard and associated guidelines to achieve highly safe, reliable, and operationally profitable railway systems (Mahboob and Zio 2018).

The sections ahead describe the formal process involved in the RAMS process to achieve the variety of performance requirements for railway systems. The railway-specific description of the RAMS framework is synthesized from existing literature, and case studies from India and Europe shared by practitioners as part of the webinar series.

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### 3.3 The Reliability, Availability, Maintainability, and Safety (RAMS) Framework

As shown in Figure 3.1, the RAMS management process consists of 14 distinct steps in three areas and a life-cycle perspective generally applicable for any railway product or subsystem (Doi 2016; Mahboob and Zio 2018). The details of the 14 steps have also been briefly summarized in Table 3.1. In the RAMS framework, functional requirements related to the system's safety receive the highest priority and have been highlighted distinctly from RAMS requirements in Table 3.1. In addition, the factors causing reliability and maintainability are also known to enhance the availability of the system, and hence, RAMS requirements are often discussed together (Doi 2016). As summarized in the general task column of Table 3.1, the 14 steps relate to concept development and setting up system requirements (steps 1–4); design, manufacture, and implementation (steps 5–10); operation, maintenance, and decommissioning (steps 11–14).

Furthermore, the RAMS framework does not cater explicitly to recently emerging “ilities” such as sustainability. However, the discussion in the learning series pertinent to the experience of Spanish HSR manufacturing company, i.e., Talgo, also highlighted that a life-cycle perspective like RAMS could also enable sustainability. The case study of Talgo (Box 3.2) highlights that simultaneous achievement of multiple “ilities” is possible in railway operations through a systematic framework such as RAMS if sufficient innovative measures are made in the design of the railway systems satisfying the contemporary and context-specific demands.

Based on the key issues emphasized in the webinar, the two essential concepts relating to the RAMS process are: (i) the importance of the system-design phase (steps 1–4) for its effect on the whole life-cycle and (ii) the importance of continuous risk management (shown through arrows emanating from steps 3 and 13 in Figure 3.1). These RAMS concepts are consistent with the contemporary systems-thinking-based theoretical and analytical approaches (Doi 2016; Leveson 2011; Ota 2008). The details of these concepts are discussed below.

**Figure 3.1: RAMS Life-Stages Specific to Railways**

RAMS = Reliability, Availability, Maintainability, and Safety.

Source: Adapted from Mahboob and Zio (2018) and Doi (2016).
<table>
<thead>
<tr>
<th>Life-Cycle Phases</th>
<th>RAMS Tasks</th>
<th>Safety Tasks</th>
<th>General Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Concept</td>
<td>Consider previously achieved RAMS performance of similar projects and define RAMS target for new projects</td>
<td>Consider previously achieved safety performance of similar projects and define the safety target for new projects</td>
<td>Establish and define scope, purpose, and concept of the project; carry out financial feasibility studies; set up management</td>
</tr>
<tr>
<td>2. System Definition and Application Condition</td>
<td>Perform preliminary RAMS analysis; identify life-cycle operation and maintenance conditions; identify the influence of RAMS on existing interfaces and further constraints</td>
<td>Perform preliminary hazard analysis; identify life-cycle operation and maintenance conditions; identify the influence of safety on existing interfaces and further constraints</td>
<td>Provide system-level technical description; identify operation and maintenance strategies and conditions</td>
</tr>
<tr>
<td>3. Risk Analysis</td>
<td>N/A</td>
<td>Systematic hazard analysis; risk analysis and risk evaluation</td>
<td>Project-level risk analysis</td>
</tr>
<tr>
<td>4. System Requirement</td>
<td>Specify system RAMS requirements and RAMS acceptance criteria; establish RAMS management at the system level</td>
<td>Specify system safety requirements and safety acceptance criteria; establish safety management at the system level</td>
<td>Specify local environment; define system assurance, demonstration, and acceptance criteria; establish verification and validation plan; introduce and implement change control procedure</td>
</tr>
<tr>
<td>5. Apportionment of System Requirements</td>
<td>Define subsystem and component RAMS requirements and acceptance criteria</td>
<td>Define subsystem and component safety requirements and acceptance criteria</td>
<td>Define requirements and acceptance criteria for subsystem and components</td>
</tr>
<tr>
<td>6. Design and Implementation</td>
<td>Implement the RAMS program through review, analysis, testing, and data assessment; RAMS program management; control of suppliers and contractors</td>
<td>Implement safety plan through review, analysis, testing, and data assessment; undertake program control for safety management and supplier control</td>
<td>Design analysis, development, and testing</td>
</tr>
<tr>
<td>7. Manufacturing</td>
<td>Requires environmental stress screening; requires RAMS improvement testing</td>
<td>Implement safety plan</td>
<td>Production planning; manufacture and test subassembly of components; documentation management</td>
</tr>
<tr>
<td>8. Installation</td>
<td>Subsystem assembly and system-level integration; multiple subsystems installations; start training for maintenance people; establish spare parts and tool-related inventory</td>
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<tr>
<td>9. System Validation</td>
<td>RAMS demonstration</td>
<td>Establish and then commission program</td>
<td>System-level commissioning; perform transition to operation; carry out related training</td>
</tr>
<tr>
<td>10. System Acceptance</td>
<td>Adhere to acceptance procedures based on acceptance criteria; document evidence for acceptance</td>
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Table 3.1 continued

<table>
<thead>
<tr>
<th>Life-Cycle Phases</th>
<th>RAMS Tasks</th>
<th>Safety Tasks</th>
<th>General Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. Operation and Maintenance</td>
<td>Procurement of spare parts and tools, apply reliability centered maintenance</td>
<td>Safety-centered maintenance, safety performance monitoring</td>
<td>Maintenance activities based on system-level considerations</td>
</tr>
<tr>
<td>12. Performance Monitoring</td>
<td>Collect operational performance statistics for analyzing and evaluating the collected data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Modification and Retrofit</td>
<td>Reconsider RAMS implications for modification; retrofit, revise, and update requirements</td>
<td>Reconsider safety implications for modification; retrofit, revise, and update the requirements</td>
<td>Take care of change request procedures</td>
</tr>
<tr>
<td>14. Decommissioning and Disposal</td>
<td>Planning and procedure of decommissioning and disposal</td>
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<td></td>
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</tbody>
</table>

Source: Adapted from Mahboob and Zio (2018).

Box 3.2: Case of Talgo and Sustainability

The journey of Talgo’s operations, a prominent rolling-stock manufacturer in Europe, emphasizes the essential aspects of managing sustainability over the past 80 years. These fundamental aspects relate to focusing on making changes in the system’s design to capture the current needs of the society where Talgo conducts its business. Considering the recent momentum on sustainability, Talgo’s focus has been on material and energy optimization. Regarding material, the design process has been changed to incorporate lighter materials for the rolling-stock wheelset and car-body, which can help overall life-cycle costs both from a material savings perspective and the impact on infrastructure perspective. Additionally, new manufacturing processes such as additive manufacturing have been incorporated to help reduce material consumption and enhance the maintainability of the rolling-stock system. Other design innovations for energy consumption optimization for Talgo are pantograph embedded in the car body and eco-driving system, among others. The automatic driving system of Talgo trains applies energy-efficient criteria to the management of traction and braking. The train runs punctually through drifting while relying on time margins in the timetable. The system also automatically calculates a more efficient gear in the event of a delay, making it more energy efficient. Each of these design systems complies with the existing Reliability, Availability, Maintainability, and Safety (RAMS) requirements of the European nations. Hence, the case study of Talgo highlights that simultaneous achievement of multiple functional requirements, such as accessibility, sustainability, and maintainability, is possible in railway operations, given sufficient innovative measures are made in the design of the railway systems satisfying the contemporary and context-specific demands on the railway system.

Source: Authors (based on a presentation by Mr. Subrat Nath).

3.4 Importance of the System-Design Phase in RAMS

Upstream functions, such as decisions made during the system-concept development and initial design (steps 1–4), impact downstream processes, such as implementation, operation and maintenance, and overall system performance to a great extent (Bugalia, Maemura, and Ozawa 2021a)—a topic rarely discussed in previous literature despite the prominence of HSR as an advanced transport mode. Risk factors pertinent to inter-organizational coordination between HSR stakeholders and solutions for managing these risk factors are critically examined through the functional resonance analysis method (FRAM). The information shared by experts during the webinar further highlights the importance of the system-design phase (steps 1–4) for the overall life-cycle performance and characteristics of the HSR rolling-stock system.
Box 3.3: Key Design Features of High-Speed Rolling Stock

This talk made a qualitative comparison of the critical features of proven and available high-speed rail rolling-stock technologies and their impact on performance, safety and stability, comfort, and sustainability. The detailed analysis presented by the talk has also been summarized in Chapter 2 of this book. A relevant example is briefly described here.

The propulsion system in high-speed trains (HSTs) is generally realized either by concentrating all the motive power inside two end cars, i.e., concentrated power; or distributing all the motive power among the vehicles in their underframe, i.e., distributed power. Distributed power adopted in HSTs provides higher acceleration, speed to weight, and seat per length ratios. It enables a flexible compination of cars in an HST by reducing the traction force transmission distance between powered (motor) cars and trailer cars. Also, due to the traction control of individual vehicles, their wheels do not slip away quickly. In contrast, the concentrated power adopted in HSTs has the advantage of lower maintenance due to a lower number propulsion equipment, and less noise in the passenger area as propulsion equipment is provided in non-passenger end cars. However, the recent trend is toward distributed power as it offers more passenger capacity, better traction performance, higher adhesion at higher speeds leading to less probability of wheel slip, and lower maximum axle load, reducing the cost of maintenance (because of less impact on the track) and increasing the reliability of rolling-stock operation. The noise inside the car in distributed power is being successfully addressed by reducing the effect of noise sources (e.g., improvements in traction motors) and installing noise absorption panels made from unique materials in the floor, side of the underframe, and bogies. Distributed power HSTs are running predominantly in Japan, Germany, Italy, and the People’s Republic of China. At the same time, concentrated power HSTs are mainly operating in France, Spain, and the Republic of Korea.

Source: Authors (based on a presentation by Mr. Sandeep Srivastava).

For example, HSR rolling stocks based on various technical features exist globally (Box 3.3). A variation in rolling-stock types relates to the coupling arrangements between the bogies and car body for the rolling stock. A bogie is a steel frame consisting of wheel sets, suspension, and damper. The bogie carries the car’s body and guides it on track. The primary objectives of bogies are to provide running safety and to absorb track vibrations. There are two types of bogies and coupling systems available: (i) articulated and (ii) non-articulated. Articulated trains are supported on a shared bogie between two cars, and the cab cars/locomotives are kept on two bogies. The end structures of these two coupled car-body ends are non-symmetrical. In a non-articulated train, each car body is rested on two bogies, and a central coupler provides interconnection between cars. Thus, there are identical intermediate vehicles and a symmetrical end structure. These two design concepts have a variety of effects on system performance for the whole life cycle. Bogies installed at the end of the car in articulated trains provide better comfort to passengers with respect to interior noise and rail-borne vibration than non-articulated trains. However, the length of vehicles is reduced due to bogie center limitation in articulated trains, thereby reducing passenger capacity. Besides that, the number of bogies required in an articulated train is lower than in non-articulated trains. The total number of bogies has a significant impact on cost. The reduction in the number of bogies can yield important “whole life” savings; therefore, there is a vastly different maintainability performance between the two types of rolling-stock systems. The two types of design concepts also differ greatly in terms of their requirements for safe operations (more details in Chapter 2 of this book).

Another example showcasing the effect of the system-concept development stage on the life-cycle system requirements relates to the difference in maintenance requirements between conventional and high-speed trains (Box 3.4). The traditional system of maintenance is based on the philosophy of scheduled maintenance. The rolling stock is examined only when it reaches the maintenance depot at a fixed periodicity or in the event of a failure. Such a system is simple, as it does not require extensive monitoring of the system’s current state. However, it is intuitively clear that such a system is not optimal from a system-performance perspective. Resources may have been allocated to rolling stock that does not require maintenance. Also, this approach is not proactive, and the system may face extensive downtimes to correct the failures once they have occurred.
POLICY MESSAGES FOR PLANNING AND IMPLEMENTING HIGH-SPEED RAIL IN ASIA

The concept of HSR is fundamentally different from the conventional railway system. The performance requirements of HSR systems in terms of RAMS requirements are far more stringent than those of traditional systems. Hence, the maintenance approach also needs to shift from scheduled to condition-based maintenance (Mukoyama and Bugalia 2020). Advanced technology sensor-systems are also required such that the rolling stock is monitored through onboard and wayside equipment. The data collected in real-time through this equipment are transmitted to designated servers and used for analysis. The analysis is used for various purposes such as giving advance alerts to the operation and maintenance teams, pinpointing and eliminating operational bottlenecks, and designing improvements in rolling stock, enhancing the system’s maintainability. The analysis also helps prevent en-route failures, which result in loss of revenue for the railway systems. Some examples are wheel condition monitoring, bearing monitoring through acoustic and temperature sensors, and vision-based equipment.

During a shift toward high-speed rolling stock, the safety-related aspects need greater attention. The tolerance of various parameters is expected to be tighter in such a case. Hence for HSR, the sensors and equipment also require upgradation in terms of better accuracy and to capture data at higher speeds. In general, the data transmission alerts generation and corrective action transfer are faster for HSR systems.

Source: Authors (based on talking points by Mr. Manish Jain).

3.5 Relevance of Continuous Risk Management in RAMS

The concept of HSR is fundamentally different from the conventional railway system. The performance requirements of HSR systems in terms of RAMS requirements are far more stringent than those of traditional systems. Hence, the maintenance approach also needs to shift from scheduled to condition-based maintenance (Mukoyama and Bugalia 2020). Advanced technology sensor-systems are also required such that the rolling stock is monitored through onboard and wayside equipment. The data collected in real-time through this equipment are transmitted to designated servers and used for analysis. The analysis is used for various purposes such as giving advance alerts to the operation and maintenance teams, pinpointing and eliminating operational bottlenecks, and designing improvements in rolling stock, enhancing the system’s maintainability (Bugalia, Maemura, and Ozawa 2021b; Kumamoto and Bugalia 2020). The RAMS requirements for the HSR systems then also extend to maintaining the additional equipment and facilities incorporated into the railway system. Needless to say, the organizational processes and structure should also be adapted to promote efficient transmission, decision-making, and action capable of managing the enormous amount of digital information being generated.

Box 3.4: Differences between the Maintenance Strategies of High-Speed Rail and Conventional Railways

In conventional railway systems, the maintenance of rolling stock essentially relies equally on human skills and technology. While technology is helpful for things like recognizing defects and fault diagnostics, human skill and experience come into play for rectifying the defect or fault as per the standards. In some cases, experienced technicians and engineers can also detect faults by visual inspection quickly and comprehensively.

However, as technology advances as part of high-speed rail (HSR) import, a shift takes place from scheduled and preventive maintenance to predictive maintenance. The conventional system of maintenance is based on the philosophy of scheduled maintenance. The rolling stock is examined only when it reaches the maintenance depot at a fixed periodicity or in the event of a failure. However, with advancements in technology, the rolling stock is monitored through onboard and wayside equipment. The data collected are transmitted to designated servers and used for analysis. The analysis is used for various purposes such as giving advance alerts to the operation and maintenance teams, pinpointing and eliminating operational bottlenecks, and designing improvements in rolling stock, enhancing the system’s maintainability. The analysis also helps prevent en-route failures, which result in loss of revenue for the railway systems. Some examples are wheel condition monitoring, bearing monitoring through acoustic and temperature sensors, and vision-based equipment.

During a shift toward high-speed rolling stock, the safety-related aspects need greater attention. The tolerance of various parameters is expected to be tighter in such a case. Hence for HSR, the sensors and equipment also require upgradation in terms of better accuracy and to capture data at higher speeds. In general, the data transmission alerts generation and corrective action transfer are faster for HSR systems.

Source: Authors (based on talking points by Mr. Manish Jain).
picture at the end of the lifetime of a technology/system to confirm whether the “risk expectations” were met during the whole lifetime.” (Mahboob and Zio 2018). The European standards provide considerable information about the specific analysis that needs to be carried out for evaluating RAM requirements and safety risks. A full review of these concepts is beyond the scope of this chapter, and the readers are directed to materials elsewhere (Mahboob and Zio 2018). The importance of continuous risk assessment throughout the life cycle was emphasized through various examples discussed during the webinar. These focused on risks related to technical and non-technical or social elements of the system. A summary of the examples and the essential lessons have been summarized as follows.

3.5.1 Risk Management for Technical System Components of HSR Rolling Stock

The best possible strategy to identify the most suitable rolling stock for a given set of design and operational requirements from a whole-life-cycle perspective is an essential question that practitioners face. The experience from Europe suggests that determining the most suitable piece of technology, for example, a rolling stock, is very challenging. A contradiction between standardization and customization is inherent in such a decision (Box 3.4). A concept to combine the platform-based design of rolling stocks and modularization of components has been gaining momentum in the European context (Lacôte 2005; Peris and Goikoetxea 2016). From a RAMS perspective, the platform-based design can shorten the risk assessment phase, as instead of an entirely new concept, only a part of the system needs change (Box 3.5). Furthermore, the RAMS performance of the modularized design can then be enhanced further through numerical simulation techniques. The design concepts and alternatives can be quickly modeled and simulated to evaluate their performance. The potential gains in the shortening of the RAMS process due to the concepts of modularization and simulation have been graphically represented in Figure 3.2.

**Figure 3.2: Graphical Representation of Modularization and RAMS Simulation**

RAMS = Reliability, Availability, Maintainability, and Safety.

Source: Authors.
However, it is essential to mention that the risk-assessment step cannot be omitted even in the modularized concept. Any change in the subsystem may interact with other parts of the system, which may prove detrimental to the safety and RAMS functions of the system. For example, the modularization-based solution has been successfully implemented in the aviation industry in the last few decades. In a recent accident involving Boeing’s 737 Max aircraft, a new technical system was introduced on the original design of Boeing’s 5-decade-old 737 platforms. However, a full risk assessment of the new system was not performed, and its impact on other parts of the system, such as the human operators, was not assessed, leading to two fatal crashes in 2019 and 2020 (Campbell 2019; Johnston and Harris 2019; Sgobba 2019).

Similarly, caution is also warranted here regarding using a simulation-based strategy for RAMS assurance. Simulations are based on a conceptualization of reality and the predicted behavior may differ under actual conditions. Such assumptions in conceptualization may have implications for safety-critical systems. For example, in a recent accident involving a crack in the bogie of the Japanese HSR, critical locations of the bogie where stress could concentrate were not identified in the numerical simulation model used. Finally, the crack had started from one such area that could not be designated as critical. The location where the crack originated did not receive any special inspection or checks specified only for critical sites as per the Japanese process (Bugalia, Maemura, and Ozawa 2020, 2021a). Therefore, efforts are needed to mention the assumptions underlying the simulations explicitly and confirm these assumptions’ sensitivity to the required performance (Bugalia, Maemura, and Ozawa 2021a).

In summary, platform-based concepts and modularization are the trends for rolling stock design to solve the conflict between standardization and customization. Macroscopic operational simulation is carried out to determine local conditions, which are served as input for a microscopic simulation. RAMS performance can be quickly evaluated and optimized within the holistic simulation framework. However, even these innovations in the RAMS implementation process present new risks for the system life-cycle and should be adequately addressed.
3.5.2 Risk Management for Social System Components of Railway Rolling-Stock

Consistent with the focus on rolling-stock technology, the risk examples discussed above related to technical elements in the system. However, as illustrated in previous chapters of the book, HSR is a socio-technical system. Hence, the risk management framework for RAMS can also be extended to system components such as the human, organizational, and management levels. The case study of Vande-Bharat Express development in India describes the importance of continuous risk management for non-technical systems (Box 3.6).

**Box 3.6: Successful Development of Vande-Bharat Express – India’s Indigenous Semi-High-Speed Train**

Vande-Bharat Express, also known as Train 18, is an Indian semi-high-speed train designed and manufactured by Integral Coach Factory (ICF) at Chennai. The development was completed in a record 18 months, and the cost of the first unit was approximately half the cost of the alternative to import a train with similar capabilities. Nearly the entire intellectual property utilized during the development of Train 18 is now indigenously owned.

ICF is one of the most extensive rolling-stock manufacturing facilities globally, with talented human and technical resources. However, the energy and creativity of a large team of qualified engineers had become latent in the absence of any challenge facing them. Such latent energy later proved invaluable, as these members readily accepted the challenges of developing something new. An additional enabling factor for the success of the project was a commitment from the top. Such dedication was assured by the project lead, Mr. Mani himself.

The project approach began with a vision and goal. The goal was not to reach 180 kilometers per hour (km/h) speed, but to develop expertise and enable resources to reach 220 km/h. Once the plan was set, an objective assessment of the current capabilities was made. Through such an exercise, all the areas where special attention was needed were identified. Here, external consultants were utilized to transfer knowledge for areas requiring special attention.

In areas beyond the team’s capability, partnership with industries abroad was set up in a win-win manner even after relying on consultants. Further, an ecosystem for indigenous designs was set up. The uncertainty typically associated with research and development projects was formally recognized, and fear of failure among all employees involved was eliminated. Conventionally, in the Indian railway sector, domestic manufacturers face considerable barriers to entering the market. Hence, this project has used an opportunity to challenge the existing Indian manufacturers to improve their capability. All the vendors who took a long-term view and not immediate business prospects were involved throughout the process.

Source: Authors (based on talking points by Mr. Sudhanshu Mani).

For Vande-Bharat Express, the system-level goals (step 1) were set to develop and manufacture India’s first semi-high-speed train, indigenously created and owned (full rights to all intellectual property thus developed). The RAMS risk analysis (step 3) received feedback from stakeholders involved in subsequent life stages, which was essential to plan mitigation strategies and suitably modify system requirements (Figure 3.3). For example, an objective assessment of the human resources’ technical capacity (feedback from step 6 to step 3 in Figure 3.3) needed to be made to understand where system design could become a bottleneck for the local engineers.

Furthermore, feedback from manufacturers about their capacity to produce the required parts with desired quality standards in a cost-effective manner was also essential (feedback from step 7 to step 3 in Figure 3.3). Once such risks related to the social aspects of the socio-technical system were recognized, several mitigation strategies could be adopted. Example mitigation strategies include engaging with a technical consultant to train local engineers in areas where the human resources’ capacity was limited. More examples of mitigation strategies have been discussed in Box 3.5.
The two examples of risk assessment (sections 3.5.1 and 3.5.2) also demonstrate the non-linearity of the RAMS process, where risks should be anticipated local to the context as much as possible. A stakeholder participatory approach involving transport authorities, operators, manufacturers of rolling stocks, suppliers, and research institutions should be established at the beginning. The standard and context-specific requirements are investigated first, which form the basis for implementing the RAMS process. The essential learning from the RAMS concepts and various cases emphasizes the importance of optimization in the design stage, which could significantly affect the operation stages. At the same time, any changes in the design should be thoroughly examined for potential risk factors throughout the subsequent life stages. The cases highlight the non-linearity of the RAMS process, where risk analysis is an iterative process, and several context-specific risks can be identified through stakeholder participation.

The relevance of the two concepts mentioned above is demonstrated through a case study of successful HSR technology transfer in the Republic Korea. Consequently, RAMS-centered requirements for capacity building and training programs are identified to enable countries to take a significant leap toward HSR from their existing conventional railway systems.
3.6 Reliability, Availability, Maintainability, and Safety Framework for High-Speed Rail-Importing Countries

High-speed rail in the Republic of Korea (KHSR) was implemented in 2004 with two strategic objectives of the government, i.e., provide HSR service to the Seoul–Busan corridor and acquire the HSR technology (Kao et al. 2010). KHSR relied on renowned French company Alstom for the core system contract to achieve the technical transfer of the high-speed trains. The scope of the contract included the supply of core systems and technology transfer. Out of the 46 high-speed train sets, 12 were manufactured in France, and 34 train sets were required to be manufactured in the Republic of Korea (Kao et al. 2010).

When the Republic of Korea’s High-Speed Train (KTX) was first launched, the French HSR (i.e., TGV) RAMS standard was applied (Box 3.7). To develop the know-how as part of the technology transfer agreement, the KHSR project received 350,000 documents and 23,000 pages in operation and maintenance manuals. In addition, about 1,000 engineers from the Republic of Korea received training in France, and 400 French engineers worked in the Republic of Korea (Kao et al. 2010). However, the French RAMS concept was still not considered the best from the Republic of Korea’s perspective. The Republic of Korea’s engineers’ know-how was also considered in developing relevant operating procedures. For example, passengers in the Republic of Korea demand very high levels of reliability from the railway services; hence, stricter acceptance criteria were set up than those prevalent in European countries. A team of French consultants was engaged to develop the capability for conducting RAMS analysis and developed detailed operation and maintenance guidelines utilizing local know-how as much as possible. Such local knowledge and experience helped the HSR operators reliably estimate the time to failure. The information was used to shorten the overhaul maintenance cycle and improve maintenance methods. As emphasized by the RAMS process in section 3.3, the overall process of RAMS management is non-linear and relies on feedback to continuously learn and improve. The Republic of Korea’s experience was also similar, and RAMS capability has reached its current levels after significant improvement and iterations. However, subsequently, the operational experience for the first-generation KTX train was extensively analyzed and shared with local rolling-stock manufacturers for the second-generation KTX rolling stock. Consequently, the second-generation KTX trains are highly reliable and acceptable to stakeholders in the Republic of Korea.

Box 3.7: Reliability, Availability, Maintainability, and Safety Framework and Its Adaptation – Case of the Republic of Korea

When the Republic of Korea’s High-Speed Train (KTX) was first launched, the French high-speed rail (i.e., TGV) Reliability, Availability, Maintainability, and Safety (RAMS) standard was applied. However, the French RAMS concept was still not optimal from the Republic of Korea’s perspective. Hence, at the time of technology transfer, the Republic of Korean engineers’ local know-how was utilized as much as possible. For example, passengers in the Republic of Korea demand very high levels of reliability from the railway services; hence, the acceptance criteria were set up to be stricter than those prevalent in European countries. A team of French consultants was engaged to develop the capability for conducting RAMS analysis and developing detailed operation and maintenance guidelines utilizing local know-how as much as possible. Such local knowledge and experience helped the high-speed rail operators reliably estimate time to failure. The information was used to shorten the overhaul maintenance cycle and improve maintenance methods. The RAMS capability for the Republic of Korea’s railway operators has reached its current levels after significant improvement and iterations. However, subsequently, the operational experience for the first-generation KTX train was extensively analyzed and shared with local rolling-stock manufacturers for the second-generation KTX rolling stock. Consequently, the second-generation KTX trains are highly reliable and acceptable to the Republic of Korea’s stakeholders.

Source: Authors (based on talking points by Mr. Byung-II OH).
The success story of the Republic of Korea’s HSR in continuous improvement in improving the system and RAMS implementation is shown in Figure 3.4 through multiple iterations of the RAMS life stages. The left-most diagram represents the existing French rolling-stock system, which was subsequently adapted through a combination of the Republic of Korea’s societal preferences and knowledge transfer from French experts for the first-generation KTX. In the subsequent cycle, the know-how from the operation of KTX-1 was further utilized to develop the entire RAMS life stage for second-generation KTX trains. The essential learning from the case study emphasizes the necessity of continuously improving the system design based on the local goals and know-how as much as possible by repeating and contextualizing the RAMS cycles.

**Figure 3.4: Continuous System Improvement for South-Korean High-Speed Rail**

KTX = Korea Train eXpress; RAMS = Reliability, Availability, Maintainability, and Safety.

Source: Authors.

### 3.7 Conclusions

Based on the introduction of the RAMS framework and the practitioners’ experience mapped to the RAMS cycle, we can identify several lessons for capacity building for domestic manufacturing, operating, and maintaining imported rolling-stock systems. These lessons are relevant for practitioners so that HSR-importing countries can indigenously adapt HSR to their requirements and develop capabilities to meet these standards.

Given the complexity of modern-day railway systems, especially HSR, a systematic method for in-depth analysis of various performance level requirements is necessary. For a detailed review of the contemporary system-thinking-based risk-management practices and their relative advantages and
disadvantages, readers may refer to Aven (2022) and Bugalia et al. (2020; 2021b). Our analysis shows that RAMS is a versatile and widely applicable framework for conducting such analysis. However, RAMS is not the only approach, and different methods for systematic analysis exist. For example, in Japan, the risk-assessment processes are not as formal as described in RAMS. While such a practice may be acceptable for Japanese stakeholders, transferring the know-how from the Japanese system to another country could then become challenging. Under such circumstances, knowledge of a systematic approach such as RAMS could be developed in both the technology-exporting and -importing countries. Critical assumptions about systems are well highlighted during the technology transfer.

A full review of the contemporary risk-management practices and their relative advantages and disadvantages is beyond the scope of this study. However, it is essential to note that systems-thinking-based risk assessment and management approaches are necessary to tackle the full complexity of modern-day complex systems such as HSR (Aven 2022; Bugalia, Maemura, and Ozawa 2020, 2021a).

The overview of the RAMS framework presented across different cases in this study also highlights the importance of the design phase and its impact on the life-cycle outcomes. Furthermore, the case studies discussed here illustrate that extensive efforts are needed to specify the system goals and requirements of the country importing HSR technology early in the adoption process. Hence, capacity building and training efforts should also concentrate on participatory principles, where the existing local experience and expertise should also be synthesized and utilized to set up the recipient country’s system-level requirements.

Finally, the importance of continuous risk assessment throughout the life cycle of the system is revealed. No system is risk-free, and risk is dependent on many contextual factors. Hence, new risks can emerge in imported systems that were not present in the system in its origin country. Therefore, capacity building and training efforts are also needed to develop risk-assessment capabilities in the HSR-recipient countries.
References


4.1 Introduction

The high-speed rail (HSR) project that India is embarking upon, which will link the cities of Mumbai and Ahmedabad, is an example of a megaproject—colossal in scope, complex in nature, and costly by value (Frick 2008). Traditional project management theories based on principles of operations management such as the critical path method (CPM) are necessary but insufficient in managing megaprojects, which face a wide range of regulatory, social, environmental, economic, and technical challenges. Consequently, cost and time overruns are often the norm on such megaprojects (Flyvbjerg, Bruzelius, and Rothengatter 2003). How then can such megaprojects be better managed to deliver their expected outcomes on time and on budget? What additional and innovative project management techniques can help supplement traditional tools that project managers have used in the past? We provide some insights to these questions by identifying “Project Management 2.0” as a paradigm for megaprojects (Levitt 2011). In this paradigm, projects are no longer governed in a hierarchical or centralized manner, but rather in a “craft-based,” decentralized, and agile manner (Stinchcombe 1959). However, in order to operationalize this paradigm, it is necessary to dig deeper to understand how governance structures and processes in megaprojects need to be changed in order to meet their realities. Further, given the fast pace of change and the uniqueness of such projects, megaprojects such as the HSR will need to innovate in order to succeed. How do they innovate? What can the National High Speed Rail Corporation Limited (NHSRCL) learn from these experiences? These are the questions this chapter attempts to answer.

In order to answer these questions, data were collected from the second webinar in the ADBI-JARTS-IIT Learning Series on High-Speed Rail. Four speakers joined the webinar and presented their experiences on governance issues. An overview of the speakers and the key themes of their talk is presented below:

- Nuno Gil, Manchester School of Business – Rethinking Megaproject Governance
- Andrew Davies, University of Sussex – Innovating in Megaprojects
- Rajendra Prasad, National High Speed Rail Corporation Ltd. – Innovation on High-Speed Rail in India
- Shailesh Pathak, Larsen & Toubro – Governance Challenges for Indian Megaprojects

The speakers at this event discussed precisely the research questions that this chapter raises. The webinar was recorded, and the remarks of the speakers were later transcribed by the author. These transcripts were then analyzed using open coding techniques to identify key themes that emerged from the discussions. A process of axial coding was then used to identify interlinkages between these themes, which then allowed us to arrive at the innovation and governance paradigms that the experts at the seminar had suggested as being most relevant in the current context.

We first discuss an alternative governance paradigm for megaprojects that focuses on value creation and then discuss how megaprojects can innovate based on examples from the United Kingdom (UK). This is followed by a discussion on Indian megaprojects, and we conclude with suggestions regarding the way forward.

4.2 Challenges Faced and a Governance Paradigm

Railways are prevalent all over the world, across continents. However, they are often extremely contentious undertakings, prone to conflicts. While several people gain through the development of railways—commuters and freight operators, for instance—there are also losers—displaced people, destroyed environments, and so on. In addition, evidence shows that it is very difficult to finish large rail projects on time and on budget. Several of these projects often “derail” in terms of cost, time, and other targets, and this is true all over the world. A recent rail project in the UK provides some insights into these challenges.

One of the largest rail infrastructure development efforts in the UK in recent times is the High-Speed Rail 2 or HS2 project. The project organization was set up in 2009 with an initial budget of £20 billion. Currently, the revised budget now stands at £70 billion. Construction has barely started, and costs have already escalated significantly. Time scales are also large – quarter of a century.

In addition, a study of the evolution of the cost-benefit ratio is also telling. In 2009 when the project was initiated, this ratio was pegged at between 2.5 and 2.9, inclusive of the wider economic impact that the project would create. In other words, the benefits of the project were expected to be about 3 times its costs. In 2020, this ratio was revised to 1.1 without wider economic benefits and to between 1.3 and 1.5. with these benefits included—a significant reduction that has now led to questions as to why this project is being developed in the first place. This dynamic is often called the “white elephant” syndrome as a project that had numerous benefits and a reasonable budget now seems to have morphed into a costly endeavor with limited benefits.

These dynamics seem to be the norm regarding large infrastructure megaprojects. What can we do about this? The answer lies in the fact that we need a change in our project governance paradigm. Our current dominant paradigm, the “golden triangle,” which is a century old, is the problem. This paradigm exhorts managers to control time, cost, and scope; relies on freezing the scope of work early on in the project; and was relevant when decision-making was highly centralized. Projects today are significantly different, and decisions cannot be made centrally. As a solution, we first need to widen our definition of “value.” Traditionally, we have considered projects as vehicles for the creation of economic value. However, this definition should be expanded to the creation of economic and social value. In this new paradigm, one may have to build tunnels instead of viaducts when passing through areas of outstanding natural beauty, in order to create value. One may need to increase the scope of stations if people believe more grandiose stations can stimulate economic growth. We may need to increase compensation for stakeholders who are displaced or change the alignment of the rail systems for the benefit of stakeholders. All these changes cannot be predicted at the start of the project. Legitimate interests will emerge during the way through democratic negotiations. These are risks, but they also create value. Therefore, if we add another socio-environmental dimension to the way we address value (currently social value is not considered at all), we create a paradigm where time and cost overruns are legitimate value-creating outcomes and not indications of project failure. Furthermore, project benefits will continue to outweigh costs as these interests are accommodated. Projects today appear to be “white elephants” when they are not, and this new paradigm can go a long way in changing the way we think about and govern projects to create value.

To meet environmental and sustainability goals, there is no reason why projects such as railways cannot lead the way. We need to attempt to decarbonize our projects, respect human rights and biodiversity, provide equal opportunities, and tackle social inequality. Project organizations face massive pressures in the current environment as they are held accountable for balancing these outcomes. Therefore, it is essential to show taxpayers that we are creating environmental and social value for projects to attain their objectives going forward.
The key points from the Rethinking Megaproject Governance session are summarized below:

- Cost and time overruns are the norm on megaprojects.
- Rethinking our definition of “value” and incorporating social and environmental components of value will go a long way in justifying the interventions needed to help a project deliver its intended outcomes.

### 4.3 Innovations in Megaprojects

In addition to a change in governance practices and our definition of values, megaprojects will also need to innovate to improve performance. In this context, the case of Crossrail in the UK is instructive. Prior to Crossrail, several projects in the UK until the early 2000s displayed terrible track records. The Channel Tunnel rail link was delivered 1 year late and over budget. The Jubilee line extension was £1.4 billion over budget and 2 years late. When Heathrow Airport was considering building Terminal 5 (T5), the British Airports Authority wanted to avoid these outcomes and decided that a radically different strategy was needed for T5. Consequently, ideas were brought in from different industries: modularity and prefabrication from the North Sea oil and gas industry, just-in-time principles from the automotive industry, and digital models from aerospace. T5 wanted to change their project delivery strategy and place innovation at the heart of this new strategy (Doherty 2008). This approach was key to stimulating a new way of project management based on collaboration, flexibility, and innovation. Similar ideas were used in subsequent projects such as the London Olympics and HS2. T5, therefore, initiated a movement for innovation.

A key turning point in this journey was the development of an innovation strategy for Crossrail. Andrew Wolstenhome who was on the T5 project moved to Crossrail and took ideas from T5 with him. In collaboration with Imperial College, Crossrail developed the first-ever innovation strategy used on an infrastructure project. Prior to Crossrail, no other project in the world had a formal, published, innovation strategy. Crossrail’s was therefore the world’s first innovation program for infrastructure, and this sent a powerful message to other projects. Today, most megaprojects in the UK have an innovation strategy. For instance, Mark Thurston, one of the authors of the Crossrail Innovation Strategy, then moved to HS2 and developed an innovation strategy for HS2.

At the start of this exercise, a vision statement was developed at Imperial College. This vision clearly stated that lessons were to be brought in from other projects and used to create something world-class. Lessons from Crossrail in turn were to be made available to other projects. The innovation program was called Innovate 18. This program was run on a digital platform that brought in ideas from all members in the supply chain and from other stakeholders such as academics in universities. The platform was supported by a small team that helped move ideas from the idea stage to implementation. A Governance Board met periodically to select ideas from the list that was collected on the platform for implementation. Each supplier and/or contractor invested £25,000 for the platform, as well as the costs of the innovation implementation program. This sum was then matched by the client. The Governance Board also established themes along which they encouraged innovative ideas. Safety, for instance, was one such theme. These themes also changed over the life cycle of the project depending on the project’s needs.

As this system evolved, not all ideas that were suggested were original. Some ideas were copied and adopted and/or adapted from other projects. These were collectively named “pinched with pride,” sending a message that there was nothing wrong in innovating through borrowing ideas from other projects. Other ideas were taken from the discovery stage and implemented. Some ideas that were either not implementable at the time, or which should have been implemented earlier, were “parked” for the future. All ideas, whether implemented or not, were published so that they could be picked up...
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on other projects as well. Some examples of innovative ideas that were implemented were ultra-low carbon concrete, safety gloves that had messages printed on them reminding workers about safety practices, and the use of lightweight aggregate.

What were the benefits of this entire exercise? Some were tangible, while others were intangible. First, this was a first-of-its-kind experiment, and there were some signs that innovation improved project performance. An initial performance assessment was done and the cost-benefit ratio was pegged at 2:1. Given the nature of innovations that were being implemented, there was an expectation that this would increase to 3:1 by 2017, indicating the positive impact of innovation. A strong message was sent to other projects that innovation can be used throughout the project. In addition, there were many wider benefits to consider. As part of the entire innovation process, people were encouraged to work together to solve problems. This created a collaborative culture—a necessary feature of governance arrangements in contemporary megaprojects. Furthermore, this program was adopted in other projects—Thames tideway, HS2, etc. Importantly, executives moved from Crossrail to other megaprojects, carrying these ideas with them, and consequently leading to the implementation of both an innovation process and a collaborative culture on other projects as well. Crossrail therefore catalyzed industry-wide change.

Some of the key players also realized the need for an industry platform to support innovation and so they created something called the Infrastructure Industry Innovation Partnership (I3P). While the Crossrail platform was used as a base, the I3P allows for sharing of ideas between projects so that solutions to similar problems can be shared. Several large megaprojects such as the HS2 are now a part of this platform. Innovation in megaprojects in the UK has therefore been institutionalized, leading to better performance outcomes overall.

The Crossrail experience led to the identification of four windows of opportunity for innovation in projects (Davies et al. 2014). The first is the bridging window at the start of the project, where ideas from other projects can be brought in for consideration. The second is the engaging window, where contracts can be used to incentivize innovation between project stakeholders. The third is called the leveraging window, where a project can leverage ideas from the supply chain and other stakeholders who can now provide inputs on the innovation platform. This typically happens as the project completes the design stage and goes toward procurement and construction. Finally, there is the exchanging window, where ideas generated on a project are published, become a legacy, and can be used on other projects. The I3P movement as well as the digital platform used in Crossrail have enabled this transformation of infrastructure megaprojects in the UK to innovation-friendly projects.

The key points from the Innovating in Megaprojects session are summarized below:

- Crossrail was the first infrastructure megaproject in the world to develop a formal innovation strategy, and this led to project-wide benefits.
- The creation of an industry-wide platform and the movement of executives between megaprojects have facilitated the exchange of innovative ideas on megaprojects in the UK.

4.4 The Indian Experience on Megaprojects

Indian projects are also quite often behind time and cost. However, while this is a general trend, there are a few projects that buck this trend and are done within budget and on time. One shining example is the Delhi Metro. Given its initial cost of ₹30,000 crore, several questions were raised as to whether this project was even necessary for the country. However, it was delivered on cost and time. Once it was delivered successfully, every state in India started to demand a metro of their own. This experience was similar to that of the UK where lessons from successful projects were in demand for other projects. As
a result, the first phase of the new HSR project in India becomes critical. It is very important that this phase gets delivered on time and on budget so that it can serve as an example and other phases and HSR projects can follow in India.

In order to achieve this goal, the Mumbai-Ahmedabad High-Speed Rail Project is also relying on innovation. Innovation is also necessary since this is the first HSR system in the country and there are no fixed templates to borrow from. Some of the innovations being implemented on the project are listed below:

- Disaster management system. Several parameters such as temperature and wind pressure on the rail line will be continuously monitored and controlled and relayed to a control center so that a train can be stopped at any time if a disaster has been anticipated.
- LiDAR-based survey system. This system reduced the overall mapping time considerably. Once proven on this project, it has been used in other projects as well.
- Static refraction tomography. One of the tunnels was a 7-kilometer stretch under water. In order to find out the geology underground, this technique was used for the first time in India.
- Shinso piles. There were several space constraints on the site that prevented the use of traditional excavating and pile-driving techniques. As a result, narrow Shinso piles were used for open excavations.
- Full launching system. In most rail projects, viaducts were built through segmental construction techniques. This would involve considerable time in casting and launching. In this project, a full-scale launching system was planned to launch a 1,000-ton girder directly. This was the first time such a system had been used in India.

The NHSRCL has also attempted to create a system for innovating, although it is very different from the digital platform pioneered at Crossrail. A High-Speed Innovation Center was started in January 2019. Eight of the Indian Institutes of Technology and the East Japan Railway Company are involved in this center. Five collaborative research and development projects have been undertaken as a part of this center. Some examples are an investigation into whether earth retaining walls should be used, development of indigenous simulation models for various applications, etc. The intention is to make this center a hub of innovation that will then feed into the HSR project.

In terms of governance, projects go through a variety of stages. Design is the first stage, and this is where seeds of future conflicts are sown. The second phase is the financing phase, the third is the construction, and the fourth relates to operations. An integrated life-cycle governance approach across these phases needs to be taken in India, as opposed to the traditional approach of governing only the construction phase and trying to get the project to meet time, cost, and quality targets in this phase. While cost hikes and delays are the norm in India, there are several success stories of projects that have innovated in the operations phase. One such project is the Mumbai–Pune expressway, which is an outstanding example of execution within time and budget. Such projects rely a lot on dynamic and effective leadership. The earlier Delhi Metro example that was cited had Mr. E. Sreedharan, a dynamic leader, at the helm. Similarly, the Mumbai–Pune expressway had a good leader driving the Maharashtra State Road Development Corporation. Such leaders tend to be boundary spanners. Their expertise and roles span construction, financing, and dealing with stakeholders. Given the extent to which megaprojects will be executed in India over the next decade, it is imperative that megaproject professionals be boundary spanners with multiple skills.

When looking closely at failures, an earlier railway project that was not completed on time is the Dedicated Freight Corridor. A key lesson from such projects is that more time should be spent on the design phase. Otherwise, we “tender in haste” and “repent at leisure.” Furthermore, governance of
Indian megaprojects has to go beyond construction and encompass operations, as well as innovation within operations.

Another key point to consider is how to increase social value. Generally projects are assessed based on their internal rate of return (IRR) and economic rate of return (ERR). The first is purely financial, while the second attempts to capture some broader economic gains and costs. For megaprojects, the ERR is almost always higher than the IRR. However, the private sector is oblivious to this as their focus is on the IRR. Highlighting the ERR is the government’s responsibility. In successful projects, the ERR has driven investment commitments and returns—rather than the IRR. In several European cities, railway stations are also the hub of development and contribute greatly to social and economic welfare. They are not merely assets for the successful running of a train system. How can we replicate this model India? How can we highlight and capture the social and economic value that such stations bring in the project equation? This will be critical to creating successful megaprojects.

Cost and time overruns are unlikely to disappear as a number of eventualities are not within the control of the project manager, particularly in the pre-construction phase. However, there is a lesson to be learned. Construction presents somewhat similar challenges across geographies. It is what you do before construction that is often the difference between projects, say in India and in the UK. Therefore, considerable attention needs to be paid to the pre-construction phase, particularly in India. Finally, there is an incentive to underbudget and increase costs as projects evolve. This is not restricted to megaprojects or public sector projects (Flyvbjerg, Bruzelius, and Rothengatter 2003). Again, there are processes that are prevalent in the UK, which can be copied in the Indian context. Heathrow Terminal 5, for instance, is an example of a project that was successfully completed on time and on budget. This project was extremely well-documented, and lessons could be learned and transferred across projects. Similar documentation needs to happen in the Indian context. The Delhi Metro, a successful project, has led the way for 13–15 metros in India and should be documented in much greater detail. India is in the same phase that Europe was between 1890 and 1920 when there was a competitive railway metro building spree in Europe. Transfer of knowledge across projects can help the entire ecosystem deliver projects successfully.

4.5 Conclusions and the Way Forward

While the creation of social value is important in theory, how does one actually accomplish this in practice when projects consist of stakeholders with different and separate interests? Such change can be brought about by conducting systematic reviews, and then publishing and legitimizing them. One example is the Oakerveree review (Oakerveree 2019) that was commissioned by the UK government motivated by the skyrocketing budget of HS2. In line with the discussions above, this review noted that the current metrics for measuring project performance are misaligned with expectations. Only economic gains were measured, while key stakeholders were looking for other societal benefits from these projects as well. For instance, stakeholders wanted London Euston station to be modernized as a part of HS2, and the budget consequently increased from £1 billion to about £4 billion. A megaproject then faces two choices. Either agree to these concerns and/or demands and increase the budget, or contest them. In the latter case, contestations against a wide variety of influential stakeholders may not be successful, leading to project distress. The Oakerveree review therefore suggests placing less emphasis on traditional cost-benefit analysis methods of project evaluation, and instead suggests emphasizing the narrative of the project and its purpose. This is an issue that is sorely lacking at the moment. There needs to be more discussion of the purpose of the project, from which we can derive the social and economic value that we would like the project to achieve and design accordingly. In current practice, there is a strong commitment to stay on cost while there are simultaneous pressures to create social
gains. Consequently, additional budgets or designated funds are created. Projects then claim that they are on time and on budget, and look to another pot of money to draw upon to finance concessions to stakeholders. In other words, core budget targets are met, but the overall cost and scope increases. This makes project assessment quite confusing. Designing based on social value can lead to an initial cost that can be maintained throughout the project.

Projects evolve organically. Crossrail is considered to be a success across a variety of metrics. However, it is still criticized for not finishing in 2017 as planned. The key difference is that the purpose of Crossrail has changed considerably. Crossrail is no longer just a rail project, but an engine of economic recovery, and so became a vehicle to create more local jobs, boost manufacturing, and so on. This “value” came at the expense of time and cost. For instance, a decision was made to manufacture trains in the UK to boost the domestic manufacturing sector, and this caused delays. Therefore, after the Oakervvee review, there has been a fundamental change in the paradigm of project governance; and now the paradigm is shifting from purpose first, then distribution of value, and then design.

Megaprojects are significant levers of value creation. Euston station in London is less than a mile away from St Pancras. However, there are problems with linkages between these stations that could have been solved with more systemic thinking that is often absent. Systemic thinking creates greater value, and the design phase is critical. It is important to note that because these projects last a long time—several decades in some cases—we cannot freeze innovation in design. Innovation has to be unlocked all the way through the project. For instance, in Crossrail, the iPad was adopted as a project management tool well after the project was underway. Therefore, it is important to leverage innovations that are compatible with the times to create greater stakeholder value. The connection between innovation, stakeholder value, and wider economic value creation is very important.

Public–private partnerships are often touted as a way to govern megaprojects. If the project risks are high, private sector return expectations are also priced high, and this can be detrimental to value creation. Therefore, perhaps the best way to handle early-stage risk is for the state to take the risk. Governments construct, and once there is cash flow visibility, the project is handed over to the private sector. The Shinkansen, for instance, was built with government funds and 20 years later was given to private parties to operate. A similar strategy can be followed on the Indian HSR project. This mirrors the Indian government’s current asset privatization strategy.

Capacity building and training are also very important for project success. In HSR, training is being done at different levels. First, NHSRCL officials are being trained in Japan. Second, since this type of track construction is being done for the first time in India, employees of the contractors are being trained in Japan for 2–3 months. Japan Railway Technical Service (JARTS) representatives are coming to India, and they will be training supervisors and workers for trackwork. The contractors are also selecting project-affected people, training them, and using them on HSR. All of these people represent assets for other projects. Shinkansen is successful because of the culture of maintenance. There is an effort to bring this culture to India.

India and the Mumbai–Ahmedabad High Speed Rail Project need to adopt a multipronged strategy. There is a need to educate the public at large that such large projects create value. India needs to remove the perception that large projects create “white elephants” by showing how expectations of a project can change. India also needs to invest a lot in training. From a policy perspective, India can “steal” from economies that have faced these problems and have found solutions. India can leapfrog a lot of the obstacles that advanced economies have faced and develop policies based on the best knowledge and insight.
It is clear that there is no one-size-fits-all model for projects, and innovation and value creation need to be tailored from project to project. Learning from other projects is key. Adopting ideas that have worked elsewhere is also a good strategy. India has a large pool of young workers, and their skills need to be improved. This can only come from a combined effort between the private and public sectors.

Overall, value capture is critical and innovation is a key tool in helping us deliver value. Innovation is not just using a slightly better technology, but also applies to ways in which we rethink the project process and how we reframe the narrative to bring stakeholders on board. Better narratives and innovation lead to better value capture and creation, which ultimately lead to projects that deliver greater benefits over the long term.
References


PART II
Safety Management for High-Speed Rail
Summary and Key Messages

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The safety of high-speed rail (HSR) operations is one of the significant factors contributing to HSR’s competitive advantage over other inter-city transport modes. Thus, it is essential to achieve its long-term sustainability. The second section of this book highlights the critical aspects of the safety of HSR operations. There is a mistaken belief among policy makers and HSR practitioners that a technically sophisticated system such as HSR, with a proven safety record elsewhere, can also guarantee its safety in any country.

The first chapter of this section, “Safety Management for High-Speed Railway Systems: Lessons from Previous Incidents” by Bugalia, aims to address the issues facing the mistaken belief mentioned above. The chapter focuses on identifying essential lessons for policy makers, HSR practitioners, industry practitioners, and researchers on what factors can cause accidents even in HSR systems with such advanced technologies and how to best manage them.

The author relies on the in-depth case study on the HSR accident in the People’s Republic of China (PRC). The case study is discussed through a state-of-the-art systems-thinking-based safety theory, i.e., System Theoretic Accident Model and Processes (STAMP). The generalizability of the lessons from the PRC’s case is also established. The global experiences regarding HSR systems have suggested that proven performance in the past does not guarantee good, safe performance in the future. Hence, continuous efforts are needed to maintain safety-critical preparedness at all system levels. Countries importing HSR systems with proven safety records elsewhere will need to make seemingly minor changes in the system to accommodate various local requirements. The safety implications of such minor modification should be thoroughly examined through extensive efforts for system integration, hazard identification through comprehensive systems-thinking-based approaches, and system validation.

The second chapter, “A Safety Culture Model for the European Railways: Key Considerations and Current Developments,” highlights the key considerations and developments of the European safety model. The chapter presents two main deliverables of the safety culture program. First, the European Railway Safety Culture Model, an original framework that underlines the fundamental distinction between organizational culture and safety culture, integrates the main features of those key concepts. Second, based on the model, the European Rail Safety Climate Survey is a tool for companies to evaluate and improve their safety culture.

Rolina and Accou in the chapter describe these instruments’ development process, emphasizing the participation of various stakeholders in the design and the performance of pilot tests in an operational context. The chapter proposes enhancing tool usability and fostering stakeholder buy-in, as the critical success factors to be considered by rail companies and policy makers to significantly improve safety in a sustainable manner.

The third chapter of this section, “Advancement in Rail Transportation and Safety: Key Themes for Human Factors and Systems Thinking” by Naweed and Golightly, presents current themes associated with the critical trends for advancement in rail transportation and explores the challenges and opportunities they create to deliver a safer and potentially more user-centered railway. The authors have conceptualized these key trends as interconnected spokes on an ever-advancing “technology
wheel” that requires human factors and focus on systems thinking to circumvent pitfalls. The spokes mentioned are modelling (and simulating) human performance, big data, accessibility, decarbonization, worker health and well-being, and track worker protection.

To summarize, technology has advanced dramatically in recent decades and heralded a digital revolution. In the rail context, there is growing recognition that rail transit can be fast, create mobility and flexibility, and lead us closer to smart cities. However, the rhetoric around technology and performance makes a concomitant need for growth and maturity in rail safety culture. In order to design and deliver rail safety in a way that enriches work and enhances the passenger experience, we must take into consideration human factors such as variability, fragility, and adaptability of involved stakeholders and their behavior. The section thus examines the distinct aspects of safety pertinent to HSR implementation.
CHAPTER 5

Safety Management for High-Speed Railway Systems: Lessons from Previous Incidents

Nikhil Bugalia

5.1 Introduction

High-speed railways are known for their impeccable operational safety performance. For example, the Japanese high-speed rail (HSR) system is known for its record of zero passenger fatalities for more than 55 years (Bugalia, Maemura, and Ozawa 2021b). Safety is also one of the significant factors contributing to HSR’s competitive advantage over other inter-city transport modes and is essential to achieving its long-term sustainability (Hidema 2017). However, there is a typical mistaken belief among policy makers and HSR practitioners that a technically sophisticated system, such as HSR, with a proven safety record elsewhere, can also guarantee its safety in the country that is venturing into new HSR programs. For example, the zero fatality record of the Japanese HSR is considered one of its essential competitive advantages over some of the other HSR systems developed elsewhere in the world (Iwasa et al. 2015). However, the 2011 fatal accident on HSR in the People’s Republic of China (PRC), which killed 40 people, proves otherwise. Between 2004 and 2007, the PRC relied on HSR technology imported from France, Japan, Canada, and Germany for nine of the core technologies, i.e., system integration, bodyshell, network control system, traction control system, braking system, traction converter, traction transformer, traction motor, and bogie (Sun 2015). This import was followed by extensive efforts to develop HSR trains within the PRC indigenously (Sun 2015). Despite the significant efforts to have state-of-the-art HSR technologies, a fatal accident occurred in 2011 (Dong 2012; Fan et al. 2015).

Box 5.1: Webinar Guests and the Themes of Their Remarks

- Airong Dong, Signal Manager, BYD Communications and Signalling, People’s Republic of China – Systems-Thinking for System-Integration: Lessons from PRC’s HSR
- Gregory Rolina, Program Manager, European Union Agency for Railways, France – A Safety Culture Programme for the European Railways: Key Considerations and Current Developments
- Anjum Naweed, Associate Professor, School of Health, Medical and Applied Sciences, Central Queensland University, Australia – Advancement in Rail Transportation: Current & Emerging Trends, Challenges and Opportunities for Safety and Performance
- Nikhil Bugalia, Assistant Professor, Indian Institute of Technology Madras, India – Session Moderator

Source: Authors.

The views highlighted above, among others, were also the focus of discussion during the ADBI-JARTS-IIT Learning Series on High-Speed Railway: Global Experiences on High-Speed Railway Safety Management1 organized on 17 September 2021. This chapter aims to identify essential lessons for policy makers, HSR practitioners, industry practitioners, and researchers regarding factors that can cause accidents even in HSR systems with such advanced technologies and how to best manage them. The chapter relies on the in-depth case study on the HSR accident in the PRC and other issues discussed in the learning series to synthesize lessons. Section 5.2 introduces a systems-thinking-

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based framework to understand accidents in HSR. The details of the accident for HSR in the PRC are summarized in section 5.3. The essential lessons drawn from the accident based on the framework are presented in section 5.4. Section 5.5 discusses the generalizability of the lessons from the PRC’s HSR by drawing insights from other HSR accidents around the globe. The conclusions are presented in section 5.6. A summary of the speakers and their presentations is provided in Box 5.1.

5.2 A Systems-Thinking-Based Framework to Understand Accidents in HSR

State-of-the-art safety theory emphasizes considering HSR as a complex system and analyzing safety through the lens of systems thinking. Under such a theoretical perspective, safety is seen as a feature emerging through interactions between various system subcomponents such as technology, humans, organizations, and regulators (Hidema 2017). System Theoretic Accident Model and Processes (STAMP) (Leveson 2011) is one such framework that has been extensively used in understanding and improving safety in various systems, including aviation, nuclear, and HSR (Bugalia, Maemura, and Ozawa 2020b; Leveson 2011). While an in-depth overview of the essential concepts and the associated methodology (Leveson 2011; Leveson and Thomas 2018) is beyond the scope of this chapter, a brief review is provided to highlight the essential concepts required to understand the complexity of causal factors involved in the fatal accident in the PRC’s HSR.

STAMP argues that control-feedback structures are necessary to maintain safety in complex systems. In a typical control-feedback structure, a system component at a higher level provides safety-related actions to lower-level system components to prevent the system from producing hazardous behaviors. The system component at a higher level also relies on the feedback from lower-level elements about its current state. Such feedback then helps the system component at the higher level to determine the continued safety-related actions it needs to execute to keep the system in a safe state. STAMP conceptualizes such control-feedback structures at all hierarchical levels in a system, from technical components at the bottom to the organization and regulatory elements at the top in a system. Furthermore, STAMP emphasizes the importance of two parallel hierarchies, one each of System Development and System Operations and the continuous interactions between them for assuring the safety of the complex systems (Figure 5.1). According to STAMP literature, accidents can happen when one or more control-feedback relationships do not perform as designed. This often occurs when feedback about the system's current state does not reach the suitable component high in the hierarchy, or contextual factors affect decision-making based on the feedback received. Then, using STAMP, for any accident, the functional interactions among all system components can be analyzed systematically across all levels to trace any dysfunctional interaction from physical systems upward to the regulatory and institutional levels (Leveson 2011).

The subsequent section provides a brief overview of the accident in the PRC’s HSR and a summary of the in-depth STAMP analysis of the accident as presented in the learning series by Ms. Airong Dong (Box 5.1). The findings in the current chapter related to the concerned accident are drawn exclusively from her analysis of the accident, summarized in Dong (2012) and Fan et al. (2015).
5.2.1 Overview of the Wenzhou Train Collision of 23 July 2011 (7.23 Accident)

On 23 July 2011, two trains running in the same direction crashed on the Yong-Wen High-Speed Line, leading to the death of 40 people; 120 others were injured. The collision resulted in a service interruption for 32 hours and 35 minutes on the busy HSR line, resulting in a direct economic loss of CNY193.7 million (Dong 2012; Fan et al. 2015). One of the prominent issues that triggered the accident was damage to an indigenously developed signaling system due to the striking of a lightning event. The signaling system included a wayside system, an onboard system, and a centralized train control system. The wayside equipment provides the movement authority to the train and track circuits. The onboard system provides real-time speed monitoring based on the wayside information it receives. A brief overview of the proximate events leading to accidents is provided below:

1. At about 19:30, after multiple lightning surges along the rail line from Yongjia to Wenzhou South station, the power circuit of the wayside equipment was damaged. Due to the deficiency in the design of this wayside equipment, it provided control information based on the track circuit occupancy status before the damage. In this case, there was no train on the track section before lightning had struck, and hence a status of the track being unoccupied was provided. Lightning also caused the communication failure between the track circuit and wayside equipment, resulting in abnormal code transmission.
2. At about 19:39, the station operator was made aware of the track circuit failure, and this was also communicated to the centralized train controller.
3. At about 20:09, the leading train was allowed to proceed ahead with a warning about track failure by a centralized train controller. The leading train driver was also instructed that the train may stop if the onboard system detects the failure in the wayside equipment. Under such circumstances, the leading train driver can switch to visual mode and manually operate the train at less than 20 kilometers per hour.

4. Between 20:21 and 20:27, the leading train stopped. The driver attempted to start the train in visual mode (three attempts) but did not succeed. All communication attempts between the driver, station operator, and centralized train controller were unsuccessful.

5. At 20:24, as the signal status was shown to be unoccupied, the centralized train controller commanded the trailing train to proceed normally.

6. At 20:29, the leading train was successful in starting in visual mode. However, the following train collided with the leading train in the same section of the track, where the wayside equipment was damaged. More details of the accident can be found in Dong (2012) and Fan et al. (2015).

5.2.2 Causal Factors as per the STAMP Analysis

The STAMP process can be systematically utilized to identify accident causal factors at all system levels. Although such an in-depth analysis of the case is beyond the scope of this study, we describe the essential and common issues faced across different parts of the system here (Dong 2012; Fan et al. 2015). The factors are summarized from two main perspectives. First, factors related to the response of various staff members as the events leading to the accidents unfolded. Second, factors related to the design issue where the faulty wayside equipment provided information about track conditions before the failure, i.e., the track was shown to be empty.

5.3 Response of Human Operators at Various Levels during System Operation

5.3.1 A Belief That the System Is “Fail-Safe”

“A fail-safe system is one which, due to the characteristics of its equipment and components and how they are integrated, guarantees that, in the event of any fault appearing, the system will always go to a safe status, normally affecting availability but never, and in no case, affecting safety.”

Ever since the earliest design of the HSR system in the PRC, the principle of “fail-safe” design was always emphasized across the organizations designing and operating the systems. However, research in numerous cases has suggested that a strong emphasis on fail-safe principles for the technical parts of the system can often impact the performance of non-technical parts of the system (Bainbridge 1983; Crawford and Kift 2018). People involved in various decision-making stages of the operating processes may start putting blind trust in the ability of the technical system to assure safety. Such a belief can gradually lead to overreliance on technology to make decisions, leading to deterioration in the human capacity to make decisions when emergencies arise (Bainbridge 1983; Belmonte et al. 2011; Papadimitriou et al. 2020). This was also observed in the 7.23 accident, where communication and other responses from train operators, station managers, and centralized train controllers were inadequate in assuring safe operations. These decisions were influenced by their firm belief that the system is “fail-safe” and that safety is assured. Therefore, their actions were not commensurate with the emergency response plan for the system (Dong 2012).

See https://www.leedeo.es/l/fail-safe-system/#:~:text=A%20fail%20safe%20system%20is,in%20no%20case%2C%20affecting%20safety.
5.3.2 Schedule, Performance, and Image Pressures

State-of-the-art systems-thinking-based safety theories recognize the variability in the performance of non-technical system components as one of the essential factors that can make systems drift toward being unsafe (Hollnagel 2012; Leveson 2011; Rasmussen 1997). People involved throughout the system are constantly making decisions, which are often influenced by performance pressure and thoughts about how others will perceive them. Such pressures may then lead to situations where safety-related decision-making becomes secondary to achieving other types of performance requirements. In the case of the 7.23 accident, the two trains involved were already behind schedule, creating pressure on the already overworked centralized train controller to restore on-time performance. Furthermore, unexpected train stops could have negatively impacted the performance and image of the railway bureau where the centralized train controller was working. Such pressures had an essential role in marginalizing the safety-critical decision-making and actions of the personnel involved (Dong 2012; Fan et al. 2015).

5.4 The Design Issue

5.4.1 Lack of Formal System Validation and the Integration Process

Even though the PRC’s HSR system was thought to be based on “fail-safe” principles, such an assumption was not valid at the time of the accident. When the wayside equipment was damaged, the communication provided by the wayside system was inadequate in maintaining safe operations. The subsequent systematic analyses of the accident revealed several factors that contributed to such a design issue not being corrected before the system was approved for operations. One such factor was the absence of a formal project team that could review, test for potential faults, and maintain comprehensive documentation about the system’s potential risks and assumptions under which it needs to operate. Modern-day complex systems such as HSR are also complex because of the fragmented supply chain involved in developing the system. Many specialized entities are involved in the system development phase, each responsible for completing specific tasks (Bugalia, Maemura, and Ozawa 2020a, 2021b). However, many times, parts of the systems and their functioning, often worked out independently, may not be compatible with each other (Bugalia, Maemura, and Ozawa 2021b). Hence, systems-thinking-based safety theory emphasizes the necessity of formal approaches for system validation, hazard analysis, and system testing (Leveson 2011). However, such functions were often marginalized during the development of the early HSR system in the PRC. The product was put into operation even before research and development was completed. There was a strong belief among stakeholders that errors and defects could be discovered and solved during system operations. STAMP literature often highlights the shortcomings of such a belief. It strongly emphasizes that operators can perform only limited actions to keep the system safe once they have been designed. Hence, fault detection, hazard analysis, validation, and integration are essential steps before transitioning any system or component from the design stage to the operation stage (Leveson 2011).

5.4.2 Systemic Pressures

For the 7.23 accident, the lack of a formal system validation and integration process is also seen as a manifestation of a more significant systemic pressure facing the development program at that time. Over the past decade, beginning in 2008, the PRC has rapidly constructed an extensive network of HSR services. In the early stages of the project involving the 7.23 accident, there was considerable pressure for all stakeholders, including the Ministry of Railways and corporate-level management for the
Chinese Railway Corporation, to design, construct, and start operating at a rapid pace. Such pressures often led to the prioritization of the project schedule, delivery management, and time efficiency over safety and quality concerns, which played a role in the 7.23 accident. For example, there was no formal team to look for this project’s system integration and validation phase. Detailed operational procedures, especially for emergencies, were not well thought out. There was not enough monitoring of safety management systems’ effectiveness. The design assumptions were not effectively communicated to the operational team through training. Blind faith that robust technology is fail-safe and can cater to all situations further reinforced the gradual marginalization of safety-critical activities and processes within the organization, which created the fundamental weakness of the 7.23 accident.

5.5 The Generalizability of the Lessons from the 7.23 Accident

Even though each HSR system is unique in its technology and the contextual scenario under which it operates, the lessons learned from the 7.23 accident are deemed generalizable to a great extent, especially at the higher levels of system components. To support the argument, we provide a brief overview of incidents occurring in Japanese HSR based on some of the extensive work on the topic (Bugalia, Maemura, and Ozawa 2019, 2020b, 2021b, 2021a).

5.5.1 Safety Culture and the Need for a Lifelong Perspective

HSR systems around the world usually operate in a highly efficient manner, with frequent services carrying many passengers with highly punctual performance. Hence, even for well-established systems such as the Japanese HSR, achieving efficiency in operation is one of the essential goals that organizations managing HSR operations are committed to achieving during the system operation stage. In such high-pressure situations, there is always a risk that the management’s strong commitment to safety is not adequately reflected in the day-to-day organizational practices, requiring a very high priority on operational efficiency. Such conflicting practices can negatively affect the safety culture and employees’ actions regarding safety in railway operations. Improvement of such micro-level practices for all employees in the organizations cannot be achieved quickly and often requires a persistent management commitment. Even in Japan, several HSR companies, even though improving, continue to face the challenge of assuring high priority to safety at all levels in the organization (Bugalia, Maemura, and Ozawa 2021a). The importance of such “soft” issues in improving safety was also recognized in the learning series. Despite the tremendous improvement in technology adoption and automation in the railway system, people are playing, and will continue to play, an essential role in designing, operating, and maintaining the system for its safe and efficient operation. However, the potential variability in human performance and a person’s ability to adapt in a system could often be seen as problematic in coping with known solutions. The same variability and adaptability also allow people to tackle unprecedented challenges. Chapters 6 and 7 further emphasize the necessity of continued relevance of “soft” issues in railway safety and other operations.

5.5.2 Relevance of Formal Approaches to Hazard Identification and System Validation

For a new system such as the PRC’s HSR at the time of the 7.23 accident, the importance of formal processes of evaluating system risks and validating its functionality has already been shown in section 5.4.1. However, such factors remain relevant even for well-established systems such as the

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Footnote:
3 These events could have potentially resulted in a fatality, had the circumstances been slightly different. Such events are also essential to learning, especially for complex systems where accidents are rather rare.
Japanese HSR. The HSR systems continue to evolve during their entire life cycle as the technologies involved in the elements evolve rapidly. Hence, system modifications are necessary to cope with the availability constraints for the old technical systems. On the other hand, the level of performance requirements also keeps increasing as a continuous improvement in service levels is necessary to maintain a competitive advantage.

Many studies analyzing accidents from a systems-thinking perspective have established that even minor modifications and changes in the system, if not managed well, can significantly affect system performance, including safety (Leveson 2011). Such “change management” continues to be a significant issue even for well-established HSR systems. For example, in a recent incident involving a crack in the bogie frame in the Japanese HSR, a change in the supplier of a part using a slightly different manufacturing method could have triggered a potentially fatal accident (Bugalia, Maemura, and Ozawa 2020b, 2021b). In particular, the challenges that such well-established systems face are that the fast pace of change in the system at the technical and operational level does not match the usually slow change in organizational processes, standards, and regulations governing the system (Leveson 2011). Coupled with this, strong trust in existing organizational processes, standards, and regulations based on their past performance breeds complacency in the stakeholders, which can lead to accidents even in a well-established HSR system (Bugalia, Maemura, and Ozawa 2021b). Furthermore, a general practice to validate railway systems is often through test runs (Bugalia, Maemura, and Ozawa 2021b). However, test runs are often limited in representing all the operating scenarios that may unfold in actual operations. Hence, a formal hazard identification process, such as STAMP, is necessary to help enhance the quality of system validation. Globally, the current practices adopted by railway companies still do not rely on systems-thinking based systematic approaches to hazard analysis, and system validation is an area that all HSR systems could improve on (Bugalia, Maemura, and Ozawa 2020b, 2021b).

5.6 Conclusions

A brief review of past HSR accidents has provided several generalizable lessons for improving the safety of the HSR systems. For “new” HSR systems, it is essential to note that proven performance in the past does not guarantee good safety performance in the future or in a different context. Countries importing HSR systems with proven safety records elsewhere will likely have to make seemingly minor changes in the system to accommodate various local requirements. The safety implications of such seemingly minor changes should be thoroughly examined through extensive efforts of system integration, hazard identification through comprehensive systems-thinking-based approaches, and system validation. These minor changes in the technical details can often result in catastrophic failures when combined with various behaviors, processes, and beliefs at the human and organizational levels. Modern-day HSR systems are complex, and a slight change in the system at any of its levels can significantly affect safety performance. Furthermore, continuous efforts are needed to maintain safety-critical preparedness at all system levels, even for a well-functioning HSR system. We list a few examples of the activities that need to be steadily carried out throughout the HSR systems in Box 5.2, based on the suggested changes to the PRC’s HSR system after the 7.23 accident. Organizations involved in the railway business (designers, operators, and regulators) should constantly assess if their current processes adequately prioritize safety, as the marginalization of safety-critical processes may have disastrous consequences, as seen in the 7.23 accident in the PRC.
Box 5.2: Suggested Activities in the PRC Railway System after the 7.23 Accident

At the Ministry Level (Regulatory Level)

- Thoroughly promote the safety culture across the whole organization and all its subordinate units.
- Set up internal institutions, define functions and responsibilities in a scientific way, to solve the problems of responsibility overlapping, and weak coordination.
- Plan the construction period of high-speed rail projects scientifically, avoid rushing to schedule.
- Effectively strengthen the management of high-speed rail research and development (R&D) and manufacturing enterprises.
- Effectively improve the rules, regulations, and standards for the safe operation of high-speed rail.
- Strengthen the R&D management of high-speed rail technology and equipment.
- Carry out third-party safety certification for high-speed rail equipment.
- Strengthen the safety management in high-speed rail operations, provide sufficient training to railway operators.
- Establish contingency plans for various accidents at all levels.

At the Organizational Level (For technology development organizations)

- Strengthen the organization and leadership of product R&D; establish the Chief Engineer responsibility system under the leadership of the General Manager.
- Strictly implement the safety responsibility system at all levels.
- Strictly follow the principle of “fail-safe” to carry out the design and development work.
- Conduct in-depth hazard analysis on the train control system.
- Ensure that project initiation, planning, analysis, change, and risk management is carried out in strict accordance with relevant regulations.
- Carry out unit, integration, and third-party testing, not only a functional requirements test, but also safety constraints and failure situations.
- Define clearly the roles and responsibilities of the R&D department and personnel.
- Strictly manage product R&D documentation.

At the Organizational Level (For railway operating organizations)

- Comprehensively clarify the safety responsibilities of each position of the decision-making, management, and operation levels.
- Fully implement the safety responsibility system.
- Strengthen safety education and training for employees.
- Maintain a high degree of safety alertness and continuously improve safety skills, especially emergency response capabilities.
- Attach high importance to abnormal situations in train operation, and strictly ensure that the train is not released without identifying the cause and eliminating the failures.
- Strengthen daily safety inspection and troubleshooting of hidden dangers, systematically sort out and deeply analyze the problems, and take measures in time.
- Formulate traffic organization plan under abnormal conditions, and continuously strengthen traffic safety control.

PRC = People’s Republic of China.

Source: Airong Dong’s presentation at the ADBI-JARTS-IIT Learning Series on High-Speed Railway: Global Experiences on High-Speed Railway Safety Management.
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6.1 Introduction

In high-risk industries, the management of safety has greatly evolved over the last few decades. It progressively became paramount to not only look at the technical aspects of the production process, but also consider the human and organizational factors influencing operations. Indeed, several catastrophic events highlighted the importance of such factors, and in the aftermath of the nuclear power plant accident at Chernobyl in 1986, emerged the concept of “safety culture.” Analyses revealed many failures at all levels in the system, not only in the design of the reactor and the procedures, but a lack of commitment to safety, reflected by inappropriate behavior and decision-making (INSAG 1986, 1991; Reason 1987, 1990). Since then, managers, safety specialists, and academics have been elaborating on this concept to devise and implement approaches that not only aim to achieve a high-level of compliance with the rules, but also nurture organizational learning, continuous improvement, and proactive safe behaviors. The concept spread outside the nuclear sector and was adopted in process safety, occupational safety, and transportation safety measures, among others.

In the European railways, several accidents, including the Ladbroke Grove accident in 1999 (Health and Safety Commission 2000), the Viareggio derailment in 2009, and the Santiago de Compostela derailment and the Brétigny-sur-Orge train crash, both in 2013, led to the introduction of the concept of safety culture via legislation in 2016, underpinned 2 years later by the Common Safety Methods on Safety Management Systems requirements. Companies are required to implement conditions to continually improve the safety culture, overseen by public authorities during their supervision and certification. Toward this end, as a key player in the sector, the European Union Agency for Railways launched a dedicated safety culture program, aiming at devising dissemination and evaluation instruments to support the development of a positive safety culture.

This chapter presents two main deliverables of the safety culture program. First, the European Railway Safety Culture Model is an original framework, which underlines the fundamental distinction between organizational culture and safety culture and integrates the main features of those key concepts. Within a few years, the model has become a pedagogical tool for European stakeholders, establishing a common understanding within the sector. Second, based on the model, the European Rail Safety Climate Survey is an initiative to raise safety awareness among all individuals contributing to the European rail system and a tool for companies to evaluate and improve their safety culture.

This chapter describes the development process of these instruments, emphasizing two aspects: (i) the participation of a variety of stakeholders in the design and (ii) the performance of pilot tests in an operational context. By enhancing tool usability and fostering stakeholder buy-in, both these characteristics are also deemed key success factors, to be considered by any rail company and policy maker in their approach to significantly improving safety in a sustainable way. The detailed information on the underlying process presented in this study is aimed to provide guidance for others to lead changes in their respective organizations.
6.2 The European Railway Safety Culture Model: A New Framework to Improve Safety Culture

The introduction of the safety culture program came with the intention of having a definition of safety culture that would help establish a common understanding of a complex concept that covers a wide range of practices, values, and assumptions, applied in various contexts shaped by many parameters, such as nationality and activity.

However, the team quickly decided that a definition would not satisfy this desire to establish a shared understanding. First, because of the existence of a high number of definitions of organizational culture and safety culture. Second, because experience shows that in sectors known for achieving highest levels of safety, and in which the concept of safety culture has been put into practice, detailed frameworks were elaborated and implemented.

The team therefore decided to design a specific framework, a model, which would support developing a common understanding among the sector and serve as a tool to evaluate and improve the safety culture in railway companies. Toward this end, the team reviewed the existing frameworks (section 6.2.1), created a task force to benefit from a larger expertise and experience (section 6.2.2), and extensively tested a first version of the model (section 6.2.3) before the publication of the European Railway Safety Culture Model 2.0 (section 6.2.4).

6.2.1 Reviewing the Literature: The Key Distinction between Organizational Culture and Safety Culture

The review of literature revealed an ambiguity. The existing frameworks of safety culture were not reflecting what appeared to be a key distinction to us: many authors have insisted on an essential difference between the concepts of “organizational culture” and “safety culture.” Guldenmund (2010) explained this distinction in his seminal work: “The study of culture – any culture, for that matter – should be non-judgemental, i.e., value free. This notion echoes the idea of cultural relativism; i.e., cultures cannot be really judged from the outside; a notion which is important to many sociologists and anthropologists. (...) A problem with the notion of cultural relativism in combination with safety is that the latter is not value free. If some culture harbours unsafety this is undesirable.”

Indeed, all companies develop an organizational culture but not necessarily a safety culture. “How do organizational cultures develop?” (Q1) and “What characteristics are to be fulfilled by an organizational culture to become a safety culture?” (Q2) became the central questions to be addressed.

We found answers to Q1 in the works of Antonsen (2009) and Guldenmund (2015). Through interacting, members of a group exchange ideas through formal and informal dialogue, giving rise to mutual adjustments, agreements, and expectations about each other’s behaviors. Based on this shared understanding, the organization starts formalizing the description of procedures and rules, as well as more physical structures like technology, through the distribution of tasks, roles, and responsibility. In the disseminating stage, organizational structures, rules, and procedures are conveyed through various forms of information and education. Through reinforcing, meanings, standards, and expectations are accepted as the “way to do things.” Members of the group now share a common and comparable understanding of reality, and structures and meanings are enforced and reinforced through various organizational processes, with an important role played by organization leaders.
The four critical moments through which organizational cultures develop are called “cultural enablers.” The organizational culture will be reflected in shared ways of thinking and acting, labeled in the model as “behavior patterns.”

Analyzing several safety culture frameworks led to address Q2 (What characteristics are to be fulfilled by an organizational culture to become a safety culture?). Based on the experience of the team, the many characteristics available in literature were clustered into four big principles. The capacity of the organization to identify and manage its major risks with anticipation and resilience was highlighted (Wildavsky 1988; Hollnagel, Woods, and Leveson 2006). The necessity to understand the work as it is practically done (Guérin et al. 1997), collect and process safety concerns, and foster organizational learning (IAEA 2006; WANO 2013) was considered a key characteristic. The team also stressed the need to integrate safety into business processes at the strategic and operational levels of the company (IAEA 2006).

6.2.2 Stimulating Collective Thinking: The First Version of the Model

This initial work shaped the reflection conducted within a dedicated task force gathering European rail professionals and safety experts. The composition of the group aimed at reflecting the diversity of organizations involved in the European railway sector: infrastructure managers, railway undertakings, entities in charge of maintenance, national safety authorities, and investigating bodies from 12 European Member States participated. In addition, the team cooperated with the Institute for an Industrial Safety Culture (ICSI), which supported the work, sharing their cross-industry framework (ICSI 2017) and up-to-date applications.

The task force members met three times during April and September 2018. The meetings relied on interactive working methods to foster exchanges, in order to progressively complete the basic framework. During the first meeting, the group agreed upon the key considerations previously introduced, in particular the mechanisms through which organizational culture develops and the relationship between organizational culture and safety culture through behavior patterns.

During the second meeting, four railway safety fundamentals were devised: (i) manage major railway risks with anticipation and resilience, (ii) understand workplace reality, (iii) cultivate a continuous learning environment, and (iv) integrate safety into business at all levels. Each principle was broken down into lower-level attributes. A similar treatment was done for the four cultural enablers. The third and last meeting of the group focused on the structure of the framework and the wording of the attributes. In total, 24 attributes were drafted to form a practical framework to assess the safety culture of any organization contributing to the railway system.

Efforts were put into the look of the framework. The high-level visualization shown in Figure 6.1 was designed to articulate the concepts of organizational culture and safety culture, with the four cultural enablers, behavior patterns, and the four railway safety fundamentals (Rolina and Accou 2018).

A second and more detailed visualization shows the 24 safety culture attributes. This led to the first version of the European Railway Safety Culture Model. The work was presented at the International Rail Safety Council Conference in Dublin in October 2018 and, a few weeks after, at the European Rail Human and Organisational Factors Seminar in Valenciennes.
6.2.3 Conducting the Assessment: The Pilot Phase

These events were opportunities to express our interest to test this new framework in the context of a safety culture assessment, as regularly performed in the nuclear field (IAEA 2008). Following this, in early 2019, the team was approached by the safety manager of Nordjyske Jernbaner (NJ), a Danish rail company.

After agreeing on the scope and methods of the safety culture assessment with NJ, the evaluation took place between February and August 2019 with the support of ICSI, following the plan shown in Figure 6.2 and further detailed in Drews and Jakobsen (2021).

As part of the assessment, a safety survey was developed and deployed among the NJ staff. The survey had demographic questions and three questions relating to each of the 24 safety culture attributes. The final participation level was 73% of the staff.

Interaction with the staff is key to discovering and understanding the existing strengths, weaknesses, and gaps between workplace reality and procedures, but also more fundamental issues like differences in beliefs, perceptions, and values within the organization. The core of the assessment was the 4 days of data collection among staff and management. During this time, five observations, eight individual interviews, and seven focus group sessions, with a total of 24 people were conducted.
The final output and main value for the assessed organization is the final report presented during the closing meeting. All collected data were analyzed against the model to identify strengths and weaknesses. The following areas for improvement were identified: dissemination of safety issues and lessons learned from internal and external occurrences; integration of human and organizational factors expertise into new projects, changes, and occurrence analysis; development of safety leadership and soft skills; understanding of roles and responsibilities, in particular for emergency situations; recognition of the contribution of the track maintenance workers and the train service staff; and fight against complacency.

The most relevant captures within the safety culture attributes were presented to the executive committee, supported by an explanation of the circumstances leading to the conclusions.

According to the NJ safety director, the safety culture assessment provided many benefits to the company. Following the assessment, NJ implemented the model in the safety management system as the foundation for the ongoing safety culture development. “The safety culture work is now anchored in the Cooperation Committee where all employee groups are represented. Anchoring the work in this existing forum means that safety culture is considered in all future projects. At the management level, the Fundamentals and Enablers are used actively in relation to changes and decision-making. In the annual training program, conducted by the safety department, safety has always been a fixed topic consisting of safety targets and performance, policies, and previous incidents shown by the trainer. Today, safety is given a higher priority and the safety culture attributes are introduced to facilitate more discussion about safety and safety management, to raise awareness about major risks and the personal contribution to safety. In addition, the safety culture attributes are introduced in the annual career development review to facilitate the discussion on operational and safety responsibilities and development” (Drews and Jakobsen 2021).

Likewise, there were many learnings for the team on the European Railway Safety Culture Model and the assessment methodology.
6.2.4 Establishing a New Reference: The European Railway Safety Culture Model 2.0

The pilot led to some significant changes in the text and in the structure of the model. In particular, the railway safety fundamentals were reworded and key words to summarize the safety culture attributes were introduced. The high-level visualization is shown in Figure 6.3 and the attribute-level representation is provided in the Appendix.

The European Railway Safety Culture Model 2.0 was presented at the 12th World Congress on Railway Research in Tokyo, in October 2019 (Rolina and Accou 2019). The model and its attributes were then translated into 24 European languages and further disseminated via training, guidelines, and events. An interactive version is available on the agency’s website.¹

After this experience, the European Railway Safety Culture Model has progressively become a reference document in the European railways; more and more companies are adopting the model as a tool to evaluate and improve their safety culture. This has been particularly reinforced this year, with the deployment of the European Rail Safety Climate Survey.

¹ See https://www.era.europa.eu/safety-culture-model/.
6.3 The European Rail Safety Climate Survey: An Unprecedented Safety Awareness-Raising Initiative

Safety climate surveys are appropriate means to collect information on staff’s risk perceptions. In the NJ pilot, it was one step in a safety culture assessment. Therefore, the team decided to develop a survey based on the European Railway Safety Culture Model that would be applicable to any type of organization contributing to the European railway system.

The European Rail Safety Climate Survey was developed and tested in 2020, with the support of a new dedicated task force (section 6.3.1). A partnership program with European companies led to a wide dissemination of the survey within the European railway system (section 6.3.2). The high-level survey results have been presented at the European Rail Safety Days in Porto (section 6.3.3). While these results deserve further analysis, this initiative has already been recognized as a success by the community (section 6.3.4).

6.3.1 Developing and Testing a New Questionnaire to Collect Safety Perceptions

Since the development process of the model was recognized as successful, a similar approach was conducted. A task force was created, where infrastructure managers, railway undertakings, manufacturers, entities in charge of maintenance, national safety authorities, and investigating bodies from 11 European Member States were represented. The group met 4 times between April and December 2020 (online) to review and improve the questionnaire prepared by the team.

A review of the literature (National Academies of Sciences, Engineering and Medicine 2015, Wiegmann et al. 2002; O’Toole 2002; Cox and Cheyne 2000) led to important survey design specifications. It was highlighted that a recognized framework to formulate and classify the safety statements was necessary. This is the role played by the European Railway Safety Culture Model. We initially decided to address each safety culture attribute with three statements, leading to a safety questionnaire of 72 statements. To express safety perceptions, a six-level Likert scale was proposed: three graded negative perceptions and three positive perceptions. An additional response would also be available when the respondent does not feel capable to answer. Negative statements would be used to reactivate the respondent’s attention throughout the survey. The length of the questionnaire was identified as an important success factor. It was therefore decided to limit as much as possible the demographic data that provide information on the profile of the respondent. Toward this end, while gender and age considerations seemed to be standard parameters in such surveys, we decided to disregard those questions.

The first draft was based on the work performed during the NJ pilot. It also benefited from an ambitious safety culture diagnosis, relying on the European Railway Safety Culture Model 2.0, carried out by ICSI at the Spanish infrastructure manager (ADIF), where more than 4,000 responses were collected. The draft questionnaire was presented during the first task force meeting, where it was decided to establish two different questionnaires, according to the respondent’s type of organization and contribution to safety management: one questionnaire applicable to any railway company (e.g., infrastructure manager, railway undertaking, entity in charge of maintenance, railway manufacturer, service provider) and the other one applicable to any regulatory body (e.g., national safety authority, national investigating body, European administration).
The two questionnaires (in English) were reviewed and improved in a second task force meeting. They were then implemented in the IT tool “EU Survey,” the survey management system hosted by the European Commission. EU Survey appeared to be a cost-effective solution, ensuring high quality and support, as well as anonymity and confidentiality, which are identified as success factors in this kind of initiative. In addition, the platform is accessible on any electronic device (computer, tablet, and smartphone) and supports all European languages.

The survey was ready to be tested by a European sample during July–August 2020. The pilot consisted of 193 contributions from 20 member states. Overall feedback was positive, and no critical issue was identified. The pilot was a good opportunity for the team to learn about how to implement, launch, and manage a survey on the IT system. The respondents' feedback led to significant design improvements. One important modification was to reduce the number of statements down to 48, addressing each safety culture attribute with only two statements, as one of the main criticisms expressed by the testers was the length of the survey. To improve calibration, we decided to have half negative and half positive statements. Indeed, it was observed in the pilot version that negative statements led to less positive perceptions. This balanced solution would avoid putting the spot on one safety culture attribute that would be addressed by a higher number of negative statements.

Also, several statements were simplified to improve respondents' understanding. The scoring scale was also modified, and a neutral level was inserted. Lastly, a reliability analysis was successfully carried out. Results of the tests were presented to the group and discussed in September 2021.

Improvements were first implemented in the English version. The survey was then translated into 21 European languages and proofread, ready to be deployed in 2021, designated as the European Year of Rail by the European institutions.

6.3.2 Establishing Partnerships with Railway Companies to Foster Dissemination

Once the quality of the survey is ensured, communication is one of the most critical aspects of any survey management. In such campaigns, it is critical to collect as many individual contributions as possible, with a satisfactory representation of the different trades.

As we had little knowledge of the demographics of the European railway sector, which employs more than 1 million workers, our communication strategy was not focused on a specific trade or country. It could be qualified as “opportunistic,” seeking any occasion and support to foster its dissemination. A central idea emerged during one of our task force meetings: As the survey is an appropriate tool for companies to improve safety, we could partner with them and benefit from their communication means to collect many contributions. In the context of the partnership, we would possibly slightly customize the survey to a certain extent (introduction, profile questions, possible additional safety statements) and issue a survey report to the partner.

Therefore, we established a partnership program and started to inform two official networks of the European Union Agency for Railways, the network of national safety authorities and the network of representative bodies, involving sectorial associations such as CER and UNIFE. A cooperation protocol was set up, translated, and promoted during webinars held in the last quarter of 2020.
Endorsed by the European Union Commissioner for Transport, the campaign quickly became a viral marketing phenomenon. During the first quarter of 2021, we received more than 100 expressions of interest from many of the biggest European players, such as SNCF Réseau, SNCF Voyageurs, ÖBB, RENFE, PKP PLK, Trenitalia, MÁV, and Hitachi Rail, covering a large part of the European territory.

The first partner surveys were launched in February. Completion periods varied from a couple of weeks to a couple of months. The team started to prepare a standard report to transmit the results to the partners. At the end of the campaign in June 2021, 100 surveys had been customized and disseminated by the partners, bringing in more than 40,000 responses to the European Rail Safety Climate Survey.

For a second period of disseminating the survey, we contacted two European associations of unions and workers, which are also representative bodies of the agency: the European Transport Workers’ Federation (ETF) and the Autonomous Train Drivers’ Unions of Europe (ALE), who agreed to cooperate with the team. During the summer and fall of 2021, they disseminated the survey link and QR code to their members. With their support, on 31 October, the date of closure of the European Rail Safety Climate Survey, we completed the sample with more than 1,600 additional responses.

6.3.3 Presenting High-Level Results to Identify Strengths and Weaknesses

In total, the team was able to collect 46,500 responses to the European Rail Safety Climate Survey. Indeed, the 4,412 responses collected by ADIF and ICSI during the summer of 2020, in which the safety questionnaire was based on the European Railway Safety Culture Model, were integrated in the final sample.

The same principles used for presenting the results to the partners were adopted: we decided not to present the results at the statement level, which would narrow the scope of application, but rather at the attribute level to support a culture change. A second important choice was not to use a numerical score, which would oversimplify the results, but a color grid to identify strengths and weaknesses. The grid would give importance to very negative perceptions, i.e., a complete disagreement with a positive safety statement or a complete agreement with a negative statement.

The high-level results were presented during the European Rail Safety Days in Porto, on 3–5 November 2021 (Rolina 2021). The key words introduced in the model to characterize the attributes appeared to be very useful. Figure 6.4 highlights those safety culture attributes for which perceptions were found to be extreme.

This first presentation confirms some areas for improvement regarding safety leadership and the integration of human and organizational factors. Demographics also highlight that train drivers, professionals working in safety authorities, and infrastructure managers expressed more negative perceptions, while managers and professionals working in rail manufacturers expressed more positive perceptions. We will carry out further analysis in 2022.
6.3.4 Learning from an Awareness-Raising Initiative to Improve Safety

Overall feedback from this unprecedented cross-company experience, especially at that scale in any high-risk sector, has been very positive.

For the company partners, the representatives highlighted that the learnings do not only come from the survey results. The internal discussions to customize and disseminate the survey were important opportunities where safety was collectively discussed and put on the top management’s agenda. In other words, the survey was an opportunity for those companies to raise safety awareness. Among the lessons learned, the communication aspects appeared to be quite challenging, resulting in some companies failing to achieve a high response rate. Strong senior management support and engagement are also critical success factors.

Many companies are now willing to design and implement an action plan based on the survey results. The agency strongly recommends acquiring additional qualitative data to complement the survey results before elaborating such a plan.

At the European level, a task force will be created to further analyze the sample and the additional qualitative data to be captured. Experience-related feedback will also be considered to devise an updated version of the European Rail Safety Climate Survey. Indeed, the company partners almost all expressed their wish to repeat the exercise on a regular basis (every 2–4 years).

In order to address the weaknesses already identified and to continually improve safety, the team is currently designing a peer review pilot together with CER, SNCF, Trenitalia, ÖBB, and SBB. This approach is similar to the one established for many years in the nuclear sector, where it is highly appreciated by safety managers. The deployment of the existing training to develop safety leadership skills will also be reinforced (Rolina 2019).

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Figure 6.4: High-Level Results of the First European Rail Safety Climate Survey

<table>
<thead>
<tr>
<th>More Positive Perceptions</th>
<th>More Negative Perceptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Expressed by</strong></td>
<td><strong>Expressed by</strong></td>
</tr>
<tr>
<td>Professionals working within rail manufacturers</td>
<td>Professionals working within authorities and infrastructure managers</td>
</tr>
<tr>
<td>Managers</td>
<td>Train drivers</td>
</tr>
<tr>
<td><strong>Related with</strong></td>
<td><strong>Related with</strong></td>
</tr>
<tr>
<td>E12 Interpersonal values</td>
<td>E42 Management intervention</td>
</tr>
<tr>
<td>E23 Organisational systems</td>
<td>E23 Soft skills</td>
</tr>
<tr>
<td>F23 Reporting</td>
<td>E43 Integration of HOF expertise</td>
</tr>
<tr>
<td></td>
<td>F22 System complexity</td>
</tr>
<tr>
<td></td>
<td>E22 Organisational design</td>
</tr>
<tr>
<td></td>
<td>E13 Regulatory relationships</td>
</tr>
</tbody>
</table>

6.4 Conclusion: Toward a More Inclusive and Resilient Railway Safety

The European Railway Safety Culture Model, along with one of its most visible applications, the European Rail Safety Climate Survey, should be considered a tool to disseminate a new approach to railway safety.

Safety cannot be exclusively seen as a systematic application of existing rules. The approach followed by the safety culture encompasses many other critical aspects, such as promoting and acting upon reporting by staff, cultivating a questioning attitude, building a resilient system able to tolerate human errors, nurturing appropriate relationships with contractors and regulatory authorities, learning from incidents, and sharing learnings with other companies. These principles have been established for several years by researchers and specialists, and implemented in many safety-critical sectors.

Despite overall good safety performance when compared to other land transportation means, this approach has not yet become a standard in the railway sector. The outstanding collective success of the European Rail Safety Climate Survey is however a strong sign that a change is occurring. The detailed information on the underlying process presented in this study is aimed to provide guidance for others to lead changes in their respective organizations. In particular, two aspects should be emphasized: (i) the participation of a variety of stakeholders in the design stage and (ii) the performance of pilot tests in an operational context. By enhancing tool usability and fostering stakeholder buy-in, these demanding characteristics are also key success factors to be considered by any rail company and policy maker in order to significantly improve safety in a sustainable way. With its ambitious safety culture program and the related instruments to evaluate and improve the safety culture, the European Union Agency for Railways intends to be a leader in guiding this major change.
References


ICSI. 2017. L’essentiel de la Culture de Sécurité. Toulouse, France.


Appendix: ERA Safety Culture Attributes (European Railway Safety Culture Model 2.0)

**Fundamentals**

- **Control**
- **Major Risks**

**Behavior Patterns**

- **Understanding Workplace Reality**
- **Learning from Experience**
- **Integrating Safety Consistently**

**Enablers**

- **Interacting**
- **Formalizing**
- **Disseminating**
- **Reinforcing**

**Interacting**

- **Teamwork and collaboration**
  - **Interpersonal values**
  - **Regulatory systems**

**Formalizing**

- **Roles and responsibilities**
  - **Organizational design**
  - **Organizational systems**

**Disseminating**

- **Communication**
  - **Competence management**
  - **Soft skills**

**Reinforcing**

- **Leading by example**
  - **Management intervention**
  - **HOF expertise**

**Interpersonal values**

- Trust, respect, and openness permeate the organization and characterize inter-organizational relationships at all levels.

**Regulatory systems**

- Healthy regulatory relationships exist and ensure that the accountability for safety remains with the operating organization.

**Roles and responsibilities**

- Roles, responsibilities, and authorities are understood and accepted.

**Organizational design**

- Organizational structures support sustainable and safe performance.

**Organizational systems**

- Processes, tools, and documentation support sustainable and safe performance.

**Communication**

- Safety information is openly shared within and across organizations.

**Competence management**

- Competence management ensures a knowledgeable workforce.

**Soft skills**

- Safety leadership and non-technical skills are systematically developed.

**Leading by example**

- Managers exhibit behaviors that set the standard for safety.

**Management intervention**

- Managers ensure that incentives, sanctions, and recognition reinforce behaviors and outcomes that support sustainable and safe performance.

**HOF expertise**

- Human and organizational factors, including frontline experience, are systematically considered during design and change.

**Questioning attitude**

- Individuals at all levels avoid complacency, challenge assumptions, and encourage and consider opposing views.

**Resilience**

- The capability to operate safely under unexpected situations is developed.

**Risk awareness**

- Individuals at all levels are aware of major risks and understand their personal contribution to safety.

**Reporting**

- Routine and abnormal deviations are recognized and reported. Measures to identify and mitigate organizational silence are implemented.

**System complexity**

- The organization recognizes that its technologies and systems are complex and can fail in unpredictable ways.

**Working conditions**

- The organization recognizes that working conditions, such as time pressure, workload, and fatigue influence safe behaviours.

**Learning from others**

- The organization actively seeks learning opportunities.

**Improvement**

- Safety-related feedback is perceived as an opportunity to improve performance and is acted upon.

**Analysis**

- Reporting is systematically analyzed to identify those factors that allow organizational learning and improvement.

**Safety vision**

- The organization develops and implements a safety vision to support the achievement of business objectives.

**Decision-making**

- Individuals at all levels are convinced that safety and operations go hand in hand.

**Resource allocation**

- Safety is a primary consideration in the allocation of resources.

**Sustainable and safe performance**

- The capability to operate safely under unexpected situations is developed.

- Individuals at all levels are aware of major risks and understand their personal contribution to safety.

- Collaboration within and across organizations is nurtured to operate safely.

- Roles, responsibilities, and authorities are understood and accepted.

- Safety information is openly shared within and across organizations.

- Managers exhibit behaviours that set the standard for safety.

- Managers ensure that incentives, sanctions, and recognition reinforce behaviors and outcomes that support sustainable and safe performance.

- Human and organizational factors, including frontline experience, are systematically considered during design and change.
CHAPTER 7

Advancement in Rail Transportation and Safety: Key Themes for Human Factors and Systems Thinking

Anjum Naweed and David Golightly

7.1 Introduction

The “dieselization” of trains (i.e., change from steam to electric power) in the 1930s transformed the rail industry and impacted nearly every discipline involved in the delivery of rail. But it was only a sign of things to come. Almost a century later, the pace of technology has advanced at increasing rates, resulting in changes in all industries, processes, and societal patterns due to increasing interconnectivity and smarter automation. Through all this, rail disciplines have also evolved, with innovations fostered throughout the rail ecosystem – from technical engineering (Sun 2015) to the more people-focused and non-technical training end of the spectrum (Naweed 2017). The digital revolution that has characterized our place within the age of information is now heralding a new age, accelerated by the rise of exponentially advancing technologies, such as mobile internet, Internet of Things, big data, and artificial intelligence (Mashelkar 2018). This is Industry 5.0, where humans work alongside robots and smart machines in systems that can create even more efficiency gains. For railways, there is now growing recognition that rail transit can not only be fast but also create intermodal mobilities and flexibilities and lead us closer to seamless human-technology coexistence in smart cities (Grey 2018). The need for evolution in rail is all the more vital given the centrality of rail as a low-carbon transit mode for both passengers and freight (IEA 2019), and to survive in the face of current and future transport alternatives (e.g., electric autonomous private vehicles) in the aftermath of the coronavirus disease (COVID-19) pandemic.

As a socio-technical system, rail is safety-critical and complex, and has highly dynamic and opaque ways of functioning (Naweed, Hockey, and Clarke 2013) that interact with similar systems within the broader environment (Larue et al. 2018). Rail operations are driven by targets and performance measures set out in franchise agreements, which generally include both service delivery and safety indicators (Read, Naweed, and Salmon 2019), and within financial constraints. However, as with most transport sectors, it is a broad and distributed system that, in many instances, relies on the actions of one (or sometimes two) individual(s) (Naweed, Balakrishnan, and Dorrian 2018; Ryan et al. 2021). Rail is also a paradox because in many ways this system remains traditional even as it becomes modern. Unlike other transport modalities, traditional and modern rail systems exist as a function of gross domestic product, level of industrialization, and status of living across different countries. Thus, modern passenger rail systems with dedicated infrastructure and sophisticated signaling and traffic management systems are often the province of developed countries (e.g., Japan, Germany, France) in comparison with the more traditional and conventional systems in emerging and developing countries (e.g., India), or those with mixed economies (e.g., Brazil). Despite this, many now have modern rail (e.g., high speed) networks that are either planned or under construction. Differences between modern and conventional systems can also be found within countries and self-governed states, and the ultra-modern must often integrate with a range of legacy technologies and processes. Rail is thus a highly unique system with a culture replete with contrasts.

The speed of change in rail means that anticipating and maximizing new developments is vital if performance benefits are to be achieved while maintaining, and ideally improving, safety. It is also important to take an approach based on socio-technical systems thinking—i.e., an approach that
understands that railway functions are interconnected, that demands may be competing and require constant trade-offs, and that successful delivery is as much about humans and processes as it is about engineering (Wilson 2014). In the rest of this chapter, we identify and examine six key themes of change and their implications within the railways as a system.

7.2 Six Themes in a Perpetually Advancing “Technology Wheel”

Many of the working practices and dynamics in the rail industry are culturally bound, from the use of level crossings (Naweed and Larue 2018) to areas such as training and mentoring (Naweed and Ambrosetti 2015; Naweed and Balakrishnan 2012), track maintenance (Naweed, Young, and Aitken 2019), and rail suicide prevention (Australasian Centre for Rail Innovation 2019). Railways remain male-dominated, highly regulated, and unionized. The biggest indicator of tension between technological advancement and culture in rail is reflected in the tension between performance and safety. On the one hand, there are systems like those in Japan where ostensibly unblemished safety records have entered popular parlance; on the other hand, there are systems such as those in India, which seemingly suffer from heavy passenger death tolls. Culturally speaking, however, things may not always be as they appear. There is growing concern, for example, regarding limited discussion of the organizational and institutional factors that affect rail safety cultures in Japan (Bugalia, Maemura, and Ozawa 2020); the story of disciplinary action against a train driver who needed a toilet break, detected only because the train was a minute late, made global news (McCurry 2021). Meanwhile, India recently recorded its best...
performance in the safety of passengers with zero fatalities over the 2019–2020 period (Nag 2020),
even as 2020 saw over 8,700 deaths on its railway tracks (Press Trust of India 2021). The rhetoric
around technology and performance presents a clear need for concomitant growth and maturity in all
aspects of rail safety culture, and for consideration of human factors and systems thinking in helping
to attain that.

With the foregoing discussion in mind, this chapter explores contemporary themes associated with
key trends in rail transportation, with corresponding implications for safety in terms of the challenges
and the opportunities they create. Figure 7.1 conceptualizes these themes as six spokes on a technology
wheel. Given the unfolding human story, the technology wheel is always advancing, but it may only
avoid major pitfalls in its path if adequate development and maturity are able to occur in other areas,
some of which correspond with the biggest issues of our time (e.g., climate change). The themes are
(1) modeling (and simulating) human performance; (2) big data; (3) accessibility; (4) decarbonization;
(5) worker health and well-being; and (6) track worker protection. The inability to effectively avoid
major pitfalls may not necessarily slow down the technology wheel, but it will have a massive impact
(e.g., disasters, deleterious effects, loss of human life).

7.2.1 Modeling (and Simulating) Human Performance

The modeling and simulation of human performance have become very sophisticated, but they remain
an inexact science. There is a tendency to assume that humans perform in two extremes—either
perfectly with no error, or highly randomly in ways that defy prediction. While human variability is
bound by (human) factors that may threaten, destabilize, or adversely influence how well a human
being works, human performance in an operational context is, in practice, relatively rational, and often
adapted to local needs and conditions. It is therefore eminently predictable. Failing to model human
performance in ways that do not reflect nor consider this predictability risks misinforming models
and developing simulacra with limited fidelity that do not reflect real-world rail contexts (Golightly
et al. 2021).

For example, human performance modeling in track maintenance work may assume that all track
workers will work perfectly, meaning, for example, that they will inherently comply with site work
safety requirements. It may also assume that performance will be highly random and unpredictable,
and humans will do seemingly unpredictable things, such as move out of their positions of safety into
the path of rail traffic. The manner in which a track worker performs reflects the demands of the
task, their own human factors (e.g., fatigue, distraction), interaction with others, and constraints of the
environment. Thus, track workers who continue to perform maintenance works when they should
be moving to a position of safety (i.e., a new and more safety-critical task) are entirely rational if there is
a domain-normative system focus on productivity and time pressure. The planning and implementation
of systems of safe work are a major contributory factor to incidents (Naweed et al. 2019), but also an
example where humans are working in relatively rational and predictable ways. Inadequate modeling of
human performance may therefore draw incorrect assumptions from the broader environment. To have
real value, approaches for modeling human performance should parameterize the imperfections of the
broader system around the human in ways that correspond with the factors driving their performance.
The same principles may also be extended to how a human operator is expected to work—and works
in practice—with an autonomously driven train. Here, human performance is also relatively rational if
the tasks are congruent with how humans perform.

Human beings are imperfect and flawed, and there is a metaphysical aspect to them that is invariably
unknowable, but that does not make their performance less rational or highly random. Modeling
human performance to better understand human variability within the limits of acceptability has many
implications. Importantly, it may proliferate inaccurate assumptions or beliefs in those responsible for designing policies and work practices. Understanding these limitations is therefore key, and good human factors and ergonomic practices and knowledge need to be accessed.

7.2.2 Big Data

Big data analytics is a cornerstone of exponentially advancing technology and is increasingly being seen as a foundation for building resilience in future rail systems. Drones for railway monitoring and inspection are beginning to dominate operations in some corners of the globe (Zasiadko 2019), and along with sensor technology, offer the opportunity to collect data on whole networks. The hope is that these data may then be analyzed by highly sophisticated software to pinpoint problems for immediate action. In parallel, machine learning and artificial intelligence may identify trends to inform important business decisions, which may, in turn, pave the way for improved operations and infrastructure.

The impact of big data in rail depends, much like it does anywhere else, on the effective access, use, and application of large data repositories. However, questions linger regarding how useful such big data and complex collections of data are for improving decision-making and processes in rail transportation (Gulijk et al. 2015). While technology and software may indeed be able to curate and analyze data, decision-making is still a human prerogative, and how these decisions are made is still a relatively opaque area. To explore this issue, it is worth considering the status quo for data analytics in an example outside track engineering. In the rail operations context, onboard train performance dataloggers capture all data for train running. This provides a valuable means of understanding the true picture from a safety as well as a performance perspective (e.g., train operation, handling) and in a way that can be used for planning mitigative approaches and preempting problems. Unfortunately, there is a tendency for certain types of big data (e.g., onboard train performance datalogger data) to be used reactively—if at all. So, it is there when needed; for example, if a safety incident requires investigating, but a big data analytics approach may offer more value than this. Part of the issue here is that time in rail is always at a premium; thus, while proactive or even predictive use of collected data would go a long way toward forecasting issues for middle management, there is neither the time nor potentially, in the face of competing priorities, the will for this to happen.

The impact of big data ultimately depends on human factors and systems thinking related to effective access, use, and application of large data repositories. Looking at how operators are using data currently, adopting this approach across all parts of the industry may constitute a paradigmatic step-change in both technology and culture that is as big as the data in question (Ciocoiu, Siemieniuch, and Hubbard 2017; Dadashi et al. 2014).

7.2.3 Accessibility

Technology advancement in rail tends to focus on making things faster, smoother, and more autonomous. From the passenger perspective, this corresponds with transportation from A to B that is as efficient as possible. Safety is a big part of this equation, and lots of examples of good design in physical ergonomics can be found in modern rail, particularly in high-speed systems (e.g., Guo and Song 2014). However, this is less so the case for traditional or conventional rail systems, which for example, still suffer from many issues including passenger loading, onboard crowding, and the platform-train interface (Anderson and Hunter-Zaworski 2015; Evans and Wener 2007; Poirier, Adélé, and Burkhardt 2021; Sehgal and Surayya 2011). Some of these issues may be attributed to poor fit, brought on by factors such as legacy infrastructure, or specific rail cultures, such as norms around crush-loading, and female-male segregation in countries where this is an important consideration. There is, however, a distinct need for advancement in design to ensure rail is fully available and usable by people with disabilities.
Most of the technological accessibility innovations in rail appear to resonate with approaches centered around individual empowerment (Australasian Centre for Rail Innovation 2021). This ranges from alerting systems designed to communicate “hidden” disabilities such as multiple sclerosis, autism, and Asperger’s syndrome; and cognitive and learning disabilities (e.g., JAM [Just a Minute] card n.d.; Sunflower Laynard 2020; Wheeler 2019) to apps that augment the visual, auditory, and/or sensory planes, such as for disabilities that are fully or partially visible to the naked eye (e.g., blindness, deafness, facial features that show a disability) (Australasian Centre for Rail Innovation 2021). Lots of ideas for dynamic apps may be applied to rail from other domains, for example, pre-journey planning with smart assistance (City of Melbourne n.d.), virtual touring (Vitracom n.d.), social storytelling (i.e., guides and tools to better support individuals with autism) (National Autistic Society n.d.), and dynamic ticketing apps for use at stations or at stops (Amazon 2016). Once on the service itself, communication aids might be used to empower individuals in ways that develop a large data repository (e.g., passengers themselves may identify issues as they see them and share them with local councils) (Molloy 2016).

From an individual consumer perspective, the use of apps, aids, and designs that cater to those with certain disabilities (e.g., door opening aids, hands-free intercoms, Sunflower lanyards) carry clear benefits, but by the same token, also draw attention to a growing need and opportunity for universal design—that is, designing every facet of the (rail) environment (e.g., stations, buildings, trains) in a way that makes them accessible to all people, regardless of their age, disability, or any other factors (Steinfeld and Maisel 2012). This is an example where systems thinking approaches have particular value and require investment in rail architecture that appeals to a system level rather than an individual level. This goes beyond rail travel itself, to include accessible rail within an end-to-end approach to accessible mobility that takes into account first- and last-mile travel (Shaheen and Chan 2016).

7.2.4 Decarbonization

The dieselization of trains in the 1930s was driven by many factors, but especially a need to dramatically cut costs following the economic depression. Nearly a century later, rail advancement is being encouraged by a completely different socioeconomic driver—and ironically, one that has been gravely impacted by dieselization. Climate change became front-page news in the late-1980s (Carvalho 2007), only to become one of (if not) the biggest challenge(s) facing the world today. Transport contributes approximately 20%–25% of emissions, and the reduction of emissions in rail is just one item on the climate change agenda that it can contribute substantially (Golightly et al. 2021). For the most part, this means the replacement, re-engineering, or conversion of current diesel-powered assets to decarbonize (Golightly and Palacin 2021). This implies a need for early involvement and application of tried and tested systems methods and analyses in the specification and standards development processes. This can be achieved through high-fidelity simulation that incorporates human performance as part of different decarbonization options (Hotzel Escardo et al. 2021). This is a particularly salient point because of the systemic interactions that occur from alternative approaches to powering trains (Golightly et al. 2021).

Altering the status quo by changing from diesel to an electric, battery, or hydro-powered rail system impacts other areas in ways that may readily address the emissions of greenhouse gasses (Golightly and Palacin 2021). However, the electrification of rails is not always possible in large countries because of geographical constraints. Introducing overhead line electrification carries a large burden because it may create significant disruption as part of the implementation, and then lead to energy supply issues or mechanical failure as part of its running. It also mandates heavy construction work. Battery power is not a feasible option currently, but if it is, then battery charging times may build a dependency on more trains, adding a burden to infrastructure and requiring change there. Hydrogen is perhaps the biggest industrial trend (Yue et al. 2021), including rail (Piraino, Genovese, and Fragiacomo 2021), but
it is replete with issues that need to be explored to make a change from diesel feasible (Golightly and Palacin 2021). This includes questions from the transportation and storage of fuel to the examination of economies of scale.

Decarbonization has many barriers for rail, which likely carry an additional toll from a climate change perspective, at least in the short or medium term. Each option may also impact the entire system in unpredictable ways and lead to unforeseen changes over time. We know that diesel-powered operation is not sustainable in the long term, so understanding what the changes will be is key. Finally, we note that decarbonization goes beyond traction to cover a whole range of operational systems (e.g., depot operations, stations, ventilation in underground railway) (González-Gilet et al. 2014), all of which may have implications for passengers and staff.

7.2.5 Worker Health and Well-being

The health and well-being of rail workers is an area of concern that is nearly always eclipsed by the emphasis on safety and performance. Research illustrates how rail worker health is nearly always seen through a safety lens (Naweed et al. 2020, 2022; Naweed et al. 2018). As a result, the overriding focus tends to be on mitigating health-related issues, which could impact immediate safety, such as fatigue and cardiac risk leading to sudden incapacity (Chapman et al. 2019; Filtness and Naweed 2017). Depending on design and configuration, commuter trains (single/double deck, carriages) can carry about 1,000 (seated and standing) passengers—more than an Airbus A380-800 (currently the biggest passenger airplane in the world)—so, passenger and system safety is ultimately paramount, but just like tensions between safety and performance, we can assume similar tensions between safety and health.

Given the role and responsibility vested in rail transport operators, there is a clear need to effectively manage their health. Workers in transport industries are generally disproportionately impacted by specific health conditions and risk factors, which affect their well-being and fitness for work. These include diabetes, cardiovascular disease, sleep disorders, musculoskeletal and chronic pain conditions, and mental health problems. Of note is the disproportionately high incidence of obesity in the transportation sector, which is closely linked with the development of Type 2 diabetes (Chapman and Naweed 2015; Mina and Casolin 2007). In general, mental health conditions including anxiety, depression, and substance abuse occur at higher rates in the transport sector than observed in the general population (Crizzle, McLean, and Malkin 2020; Ruiz-Grosso et al. 2014). In Australia, the rail industry features in the top four most at-risk occupations for mental health (Safe Work Australia 2015). Furthermore, male-dominated industries are particularly impacted by suicide.

In relation to specific conditions that require greater focus, mental health needs in the rail sector are not being met (Naweed et al. 2018; Rail Safety and Standards Board 2021). In addition to high stress and psychosocial risk factors inherent to these jobs (e.g., long and irregular hours, work-life conflict, high performance and time pressure, isolation and monotony, risk of witnessing traumatic events, and abuse), COVID-19 has added an additional layer of insecurity, fear, and sense of endangerment (Naweed, Jackson, and Read 2021). Recent evidence shows that the mental health issues in transport have been further exacerbated by the pandemic, placing professional drivers under far greater stress than the general frontline workforce (May et al. 2021).

A focus on health management in rail is typically piecemeal, and very much ad hoc, building a reliance on the autonomy and initiative of individuals to manage their own health, for example, with train drivers (Naweed et al. 2017). Pressing safety imperatives, therefore, drive health management approaches. The management of worker health and well-being is about more than safety—the case of the Japanese train driver who was disciplined for going on a toilet break despite assessing the level of risk and taking
Figure 7.2: The Layers within the Rail System from the Perspective of Safety, Health, and Well-being Using Rail Drivers as an Example

RAIL VEHICLE (RV)
- Traction
- Carriages/wagons
- Weight
- Speed

RAIL DRIVER (RD)
- Throttle control
- Sustained attention and vigilance
- Shift work and fatigue
- Reaction time

INFRASTRUCTURE AND TERRAIN (IT)
- Tracks, points, and traffic flow
- Signals and crossings, and safe working rules
- Movement authority
- Tunnels, gradients, and curvature

GOALS AND PURPOSE (GP)
- Schedule
- Time keeping
- Conductors/Train dispatchers
- Service delivery

VALUES AND PHILOSOPHIES (VP)
- Motivations
- Pressures
- Cultural norms
- Social influences

WEATHER/ADVERSE EVENTS (WA)
- Visibility
- Railhead condition
- Adhesion
- Temperature

Performance within the RV-RD system is defined by the RD comprehending RV dynamics (train handling) and making informed control decisions. This involves understanding how throttle inputs impact speed and how different types of braking and driving styles affect RV state.

Health and well-being is represented by the awareness of the RD’s own physical and psychological limitations, fitness for work, and being able to self-regulate in real-time (e.g., self-identify fatigue and then apply fatigue mitigation strategies).

Like the RV-RD system, health and well-being is represented by RD’s being aware of their own limitations and fitness for duty, but with an understanding of the wider implications of impaired health state on network safety.

Performance within the RV-RD-IT system is defined by knowing the route, movement authorities, and rules governing safe and efficient train movement. Knowledge of the terrain supports the application of driving strategies that effectively optimize use of energy/fuel, and manage train forces to create a smoother, safer, and more secure journey.

Health and well-being here is defined by an awareness of the influence of different pressures and presiding cultural norms on the RV-RD system, and how this impacts RD workload.

Performance within the RV-RD-IT-GP system is defined by incorporating the goals of the system as they relate to the safety and efficiency needs of the network. This involves working with other individuals (e.g., network controllers) and effectively coordinating the schedule with the train conditions to optimize service delivery.

Health and well-being is represented by the organization being aware of work demand on RD’s and implementing shifts and rosters to maintain RD health and well-being.

Performance is also defined by the organization being aware of work demand on RD’s and implementing shifts and rosters to maintain RD health and well-being.

The addition of the WA (RV-RD-IT-GP-WA) introduces an aspect of the system that cannot be controlled, but on that may change performance requirements through modification of what the RD does and how the rest of the layers behave. Health and well-being is defined by effectively regulating operations in degraded situations (e.g., suicide risk) and environmental conditions (e.g., uncomfortable or unsafe temperatures).

The addition of the VP layer (e.g., RV-RD-IT-GP-VP), performance is defined by an awareness of the influence of different pressures and presiding cultural norms on the RV-RD system, and how this impacts RD workload.

Through the addition of the VP layer (e.g., RV-RD-IT-GP-VP), performance is defined by an awareness of the influence of different pressures and presiding cultural norms on the RV-RD system, and how this impacts RD workload.

Health and well-being here is represented through attitudinal behaviors, philosophies of shift work, and general work ethic (e.g., coming to work well-rested; managing distractions from work/non-work-related events).

From a broader perspective, the organization must remain aware of RD’s as more than a machine and with limitations that extend beyond the physical to psychological.

Source: Author.
measures to mitigate it (McCurry 2021) is a story that highlights safety at the expense of worker health and well-being. Addressing health and well-being issues after the fact is unhelpful, and prevention is needed from a more systems perspective.

Figure 7.2 illustrates the broad layers of the rail system using the rudimentary point of view of the driver as an example and emphasizes the health and well-being aspects of the system. What is clear from this is that in addition to the drivers’ awareness of their own health and well-being needs, the awareness from the organization is greater. While general guidelines and tool kits to manage rail worker health are beginning to emerge (e.g., Rail Industry Safety and Standards Board 2019), a strategy that appropriately recognizes the tensions between safety and health and manages them holistically is key and more important than ever.

7.2.6 Track Worker Protection

The last section concerns a specific subset of workers in the rail population—the track worker. These are the people that build, inspect, and maintain the railways. Protecting track workers from the very thing that they work to ensure the safety of is a fundamental paradox of rail (Naweed et al. 2019). Given contemporary concerns for being able to manage this risk effectively around the world (Office of the National Rail Safety Regulator 2016; RAIB 2017), it is important enough to warrant its own spoke in our “technology wheel.”

Tracks workers epitomize the original workings of the rail system and serve as an example of how the rail industry continues to remain traditional even as it modernizes. Figure 7.3 depicts an original track worker (referred to as a “Platelayer”) and a photo of a contemporary track worker. There is little to separate the appearance or the basic tools in each image, even though the environment itself has changed. Today, trains are faster and quieter, and although most run to timetables, un-timetabled traffic, and slow running (e.g., freight) trains confound predictability. Further, increasingly sophisticated tools for track maintenance also create more noise and distraction, introducing even more complexity for effectively managing track worker safety when work must be performed on lines that are active. Thus, while the human factors profile in the modern environment is different, the nature of track

**Figure 7.3: An illustration of a Platelayer (c. 1890) and a Contemporary Track Worker (c. 2015)**

Sources: W. and R. Chambers Ltd. (1892, p. 107); Contemporary track worker figure used with permission from Jeanette Aitkin.
maintenance work (i.e., physical labor, shift work) and substantive human cognition (e.g., information processing, reaction times) remain relatively unchanged (Naweed et al. 2019).

For track work, the technology focus is ostensibly on sensor system integration, to provide a better way of telling who (or what) is located where in relation to the red/danger zone, and maintaining separation between hazards and humans, for example via remote control of other devices. This includes autonomous robotics as well as drones (Galar and Kumar 2021; Zasiadko 2019) and creates enormous potential for advancing systems of work. However, research tells us that introducing new technology leads to other issues, such as with trust and acceptance and disconnects in human-machine distributed cognition (Bearman et al. 2017; Naweed and Rose 2018). This means that to predict and mitigate looming issues, there is a need to understand the system impacts of introducing such technologies. Besides technology, there are bigger issues in track work, as intentionally exemplified in the earlier modeling (and simulating) human performance section. To reiterate, research has shown that the majority of track worker accidents (in an Australian and United Kingdom rail context, but highly likely applicable elsewhere) implicate the actual planning and implementation of site work, along with group dynamic factors of track working. Anecdotally speaking, reduced confidence in identifying and applying worksites with high levels of protection is an issue because this may induce preferences to go with options where there is increased track worker risk. Systems methods and analyses offer value here, but it is important to examine historical data and do more work in situ to better understand the barriers to uptake. In the long term, technologies such as robotic maintenance and inspection may remove the need for people to go out on tracks, but this shift will require significant change in terms of users, teams, and organizational processes (Golightly et al. 2022).

## 7.3 Conclusions

Change in the railways is occurring at an increasing rate. We have explored six key “spokes” in technology advancement in the railway system where the need to reflect on the role of people (as staff, as passengers, and as the public) is most urgent. Critically, these spokes are interconnected. In some ways, this can be positive—for example, disruption due to failed assets is felt most acutely by those with accessibility needs. Making the railways more reliable through big data therefore helps those who are most dependent upon it. However, these interactions can make the picture more complex. For example, the introduction of robotics in maintenance is not taking place in isolation but in a railway where digital train control and new forms of data are also being deployed (Golightly et al. 2022).

In our pursuit of technological advancement, where most rail budgets are invariably spent, fundamental issues are being overlooked—from the mental health and well-being of frontline workers to the cardiometabolic issues and level of sedentary exposure faced by train drivers and rail network controllers. Whatever change occurs we must look at the wider reverberations across the whole rail system and the nature of work. This has two implications. First, change must be understood through formalized systems models of the railways that anticipate the role of people. Examples include Read et al.’s (2019) systems model that reflects the integration of build and operations at multiple levels, and the whole systems model of human functions on the railways developed for the European Railway Research Advisory Council (Ryan et al. 2021). Second, such models must reflect not just idealized work (or “Work as Imagined”), but the realities of work and human activity in and around the railways (“Word as Done”) (Hollnagel 2016). Our understanding of people and behavior must take into account their variability, fragilities, and adaptations so that we design and deploy change in a way that enriches work and enhances the passenger experience, thus ensuring the long-term appeal and prosperity of global rail.
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PART III

Knowledge Delivery through Cross-Cultural Training for Implementing High-Speed Rail
PART III

Summary and Key Messages
Sakshi Pandey, Nikhil Bugalia, and KE Seetha Ram

Introduction

Capacity building and training are crucial for project success, particularly in areas involving technology and knowledge transfer between countries. High-speed rail (HSR) was first implemented in Japan in 1964 as the Tokaido Shinkansen and has become a popular mode of intercity transport across the globe (Takatsu 2007).

In 2015, India joined this cohort by initiating an electrified HSR system called the Mumbai-Ahmedabad High-Speed Rail (MAHSR) Corridor with assistance from the East Japan Railway Company. The Memorandum of Cooperation between the Government of Japan and India on High-Speed Railways was signed in December 2015. The memorandum highlighted Japan's bullet train system—the Shinkansen—as the most suitable method for the MAHSR plan. The MAHSR project is being coordinated by the National High-Speed Rail Corporation Limited (NHSRCL). This special purpose vehicle has been designed with equal participation from the Government of India through the Ministry of Railways and the state governments of Gujarat and Maharashtra (HSRC 2013).

Indian Railways is one of the largest organizations globally, with more than 1.3 million employees across the country (Pereira et al. 2013). National Rail Plan (NRP) 2030 proposes building an HSR network with 8,555 kilometers by 2051 among 13 corridors, including the under-construction MAHSR project. Given technical and managerial challenges in the successful implementation of HSR, human resource development is the need of the hour in India.

Importantly, lessons learned from diverse international experiences and their success and failure factors are vital for making informed decisions. In the HSR project, training is being done at the distinct level. NHSRCL has signed a memorandum of understanding with Japan Railway Technical Service (JARTS), a Japanese organization for overseas railway technology cooperation, for training, certification, and advisory services.

Over the past 3 years, the Asian Development Bank Institute (ADBI), in collaboration with JARTS and a global network of researchers and policy makers, has undertaken successful capacity building and training programs to assist India in implementing the HSR system.

This section presents an overview of cross-cultural training methods by drawing inputs from case studies presented in the ADBI-JARTS-IIT Learning Series on High-Speed Rail. The studies are based on another recently developed HSR system — the Haramain HSR by Adif (Spanish Railway Infrastructure Manager) and India-Japan training programs by IIT Madras and Nagaoka Institute of Technology. The authors presented their personal training experiences in a cross-cultural environment in the online seminar. The speakers and the key themes of their remarks are:

1. Norie Kobayashi K., IITM-NUT Office Coordinator, Nagaoka University of Technology: Sharing experiences on training of staff with consideration of language, culture, education background, and learning style – India and Japan.
2. María José Alba Millán, Traffic Safety Trainer, ADIF (Spanish Railway Infrastructure Manager): Capacity-building strategies and cross-cultural training competence

Key Guiding Features of Cross-Cultural Training

The two case studies highlight several aspects of capacity-development programs in an overseas and inter-cultural setting. Boxes III.1 and III.2 summarize the experiences of the authors based on the presentations of the case studies and the Q&A sessions that followed.

**Box III.1: In Designing and Planning Capacity Development Programs in an Intercultural Setting, What Are Some of the Essential Differences Policy Makers Should Consider?**

1. **Accounting for differences in education and work environment:** Education patterns and work culture may differ significantly in cross-cultural settings, thus affecting the ability of stakeholders to connect and understand.

2. **Cultural diversity and inclusivity:** Incorporate the positive aspects of the culture and environment of both the trainer and the trainee into the training to improve learning outcomes.

3. **Language barrier:** Nowadays, English is the standard language in formal settings. However, a basic understanding of the native language plays a crucial role in effective communication and knowledge delivery in a multicultural training environment.

**Box III.2: What Aspects of Capacity Building and Training Program Implementation Require Leadership from the (Technical) Knowledge-Transferring Stakeholders?**

Being the "best edition" or "vitamin person": Experts bring the knowledge and methods. Therefore, they should stop managing the situation and begin leading it by demonstrating a motivated attitude and social competence in their behavior.

The following points encapsulate the success factors in training leadership in cross-cultural environments by becoming a “vitamin person.”

1. **Intercultural competence:** Understanding cultural differences, rules, and norms of behavior and respecting them in order to transfer knowledge and competency in a cross-cultural environment.

2. **A Balanced approach:** Integrate with the trainee’s culture focusing on its positive aspects while using your own experiences and best practices to create a comfortable and robust learning environment.

3. **Language:** During training sessions, use of English is necessary. However, emphasis should be on the clarity of the message rather than grammatical correctness of the language.

**Box III.3: What Aspects of Capacity Building and Training Program Implementation Require Leadership from the (Technical) Knowledge-Receiving Stakeholders?**

1. **Looking beyond cultural differences:** In cross-cultural interactions, cultural differences are often reflected through language, accent, or actions. As a learner, one must look beyond these differences to improve learning and skills.

2. **Adaptability to new learning methods:** Trainers bring novel ideas to the training process and sometimes adopt innovative and unconventional teaching methods. Therefore, it becomes crucial for learners to be accommodative and open-minded.
Conclusion

In summary, no HSR systems in this world are identical, and neither are their requirements. Each design needs to be adapted to its own unique context. However, a framework should be developed to institutionalize capacity building and training programs considering cross-cultural factors. Based on the two case studies, the following points summarize the methods to institutionalize leadership development across the knowledge-transferring and receiving stakeholders for the success of capacity building and training programs.

1. **Framework to facilitate continued learning**: An effort must be made to clarify the overall organizational structure, roles, and responsibilities of key stakeholders. Further, an outline of facilities and a detailed training plan should be developed to ensure continuity of the training programs.

2. **Integrating training programs in the early education system**: Often, the education system is confined to theoretical knowledge in cross-cultural settings. However, to improve the learning outcomes, skill-based training programs should become a part of the early education system.

3. **Pre-planning of training curriculum**: In order to improve training curriculums in an organization, human resource development plans should be prepared a few years ahead of the implementation schedule, for example, planned technical interventions.

4. **Task-based training**: In addition to generalized training, it is essential to provide individuals with training tailored to their organizational roles, environment, and needs.

5. **Innovative training methods**: To facilitate effective knowledge transfer, innovative training methods should be developed that adapt to individual learning capabilities.

For further elaboration, detailed case studies are included in the next section of this book. The inputs and recommendations are derived from the authors’ best practices based on their cross-cultural training experiences. However, we do not mean to imply that their practices are better than those of developing HSR operators like India. Instead, the presentation of inputs is intended to draw attention to specific features that may not have been considered earlier while conducting technical overseas training programs for HSR systems and other cross-country programs worldwide. We hope that the inputs serve as valuable reference points to more recent HSR actors.
References


Case Study: Capacity-Building Strategies and Cross-Cultural Training Competence

María José Alba Millán

8.1 Introduction

My work at Adif is, in a word, exciting. Currently, as a trainer in traffic safety regulations and a human factor expert, my mission is to train new and experienced railway people on this vision of safety and responsibility. I aim to raise awareness regarding the critical-safety duties they perform as qualified professionals, as well as the performance of the technological tools required for developing their traffic safety processes in a reliable manner.

Adif is a public company attached to the Spanish Ministry of Transport, Mobility and Urban Agenda. In Spain, my company is responsible for the design, construction, maintenance, and renewal of rail networks (stations, freight terminals, and communications), as well as station and network traffic management. Adif is responsible for traffic safety, including railway traffic management and control. There is a directorate for Traffic and Capacity Management, responsible for planning and managing traffic on the General Interest Railway Network (RFIG), guaranteeing the safety and punctuality of railway traffic, and responding to the needs of operating companies via their operation control centers spread throughout the country. Moreover, the training directorate, to which I belong, regularly promotes talent management of teams by improving their skills or helping them acquire new ones. It does so by taking a closer look at human and organizational factors and the safety culture. Training sessions consider working conditions, quality, and dialogue, so that employees are encouraged to be open about their mistakes, and feel free to submit honest reports. This means embracing an attitude of trust and fairness within an environment of confidence and cooperation where there are role models and examples of staff empowered to take part in safety measures, and where risks are identified by linking technical factors, rules, and procedures.

In recent years, Spain has invested heavily in the modernization and improvement of both conventional and high-speed railway networks, which has enabled Adif and the companies we work with to accumulate top-level experience in all aspects. Also, the company has a lot of experience in foreign partnerships, where experts abroad provide knowledge transfer regarding both technical and operational assistance, feasibility studies, and information technology (IT) systems to support traffic management and training.

8.2 Adif around the World

One of the modes of international collaboration in which Adif participates is as a consortium member in partnership with other Spanish companies in an international railway project. This is the case of the Haramain Project in Saudi Arabia, the first high-speed train in the Middle East. It links holy Muslim cities, from Mecca to Medina, in a 447+688-kilometer (km) European Rail Traffic Management System (ERTMS) Level 2 railway line, including five commercial stations for passengers (Mecca, Jeddah, KAIA, King Abdullah Economic City, and Medina Central).
In the Haramain Project, Adif participates in a complex international project with many actors and phases. In the operation phase, Adif is responsible for rail traffic control and traffic safety management, and it also supports infrastructure maintenance companies by training work forepersons so that they can perform traffic safety duties. When working on international projects, Adif adapts its know-how to the local geographic, cultural, and social environment relying upon a well-trained cadre of staff who are prepared to settle abroad to discharge their duties and share their technical know-how. The transfer of technical expertise is critical to the success of a project as it trains local professionals who will inherit the project once the transfer is completed.

This thrilling challenge offered me the opportunity to participate in the management and administrative follow-up, as well as in the design and development of railway activities (seminars, training courses) in such an international, multicultural, and demanding environment, providing technical and professional advice at the service of one of the world’s most important religious and cultural events: the pilgrimage to Mecca. In addition, I gained experience working on a project that is a model of intercultural cooperation, involving companies with more than 25 years at the forefront of design, construction, management, and high-speed railway operation.

8.3 To Go or Not to Go?

Leaving my comfort zone to work more than 5,000 kilometers away from home, alone, in an unfamiliar cross-cultural environment and conducting myself in a language in which no one would be a native speaker was daunting. The prospect of living in an unknown environment, with overwhelming heat, in one of the most complicated societies in the world where the separation between genders was extreme, as a single woman, honestly scared me.

And it scared me because human beings are afraid of adversity, of the unknown, of what they do not control.

Paradoxically, this happiness of having everything “under control” and this uneasiness of “not knowing” happens to all of us, when, in truth, uncertainty is the natural state of being human. We cannot control the external environment, the circumstances and situations that surround us, or what will happen tomorrow, and yet, we preoccupy ourselves with it when, in fact, we cannot even be sure if we will be alive to experience it. However, we can look for answers within to try and find out what we want. Then we discover that what we really want to do is understand the mind-heart pairing. All things considered, I understood that my university studies in translation and interpreting and in intercultural mediation (that I had taken some time ago) made perfect sense, as they had blended in a perfect combination with the 8 years of experience I had in the railways as a traffic operator. I was simply being prepared for the starting point of my Saudi Arabia trip that was about to begin.

Until I reached the goal, every obstacle I found was dismembered in its entirety by the factors that contributed to it: lack of awareness, cultural differences, and language barriers. And I began to discover along the way that we are all different, and by living in different places, we also adopt different ways of living while still remaining who we are.

When adversity becomes an opportunity, your inner self grows because you have managed to gain the capacity to adapt in the face of that adverse agent, state, or situation that you thought was disturbing you. And you have also gained the ability to be flexible because you transform yourself by respect and integrity toward others.
For all that, it was funny just being aware that in my list of advantages and disadvantages in accepting this career path, some key points were unintentionally hidden. Critical aspects of the work, such as professional commitment, emigration, the challenges of doing it in another language, living in demanding weather conditions, change of time and habits, in a new workplace, schedule, office, different facilities and tools, new duties, work teams, and colleagues (all men!) were exhausting to deal with. But all this was somehow overshadowed by the magnitude of the challenge and by the real curiosity about this closed-up kingdom (there was not an open border for tourists when I first traveled, and it was somewhat hard to obtain a visa).

8.4 The First Day of My New Life

When I arrived at the office, I remember not knowing how to put on my *hijab* properly—it was slippery around my neck—and I was worried about stepping on my black *abaya* when I went upstairs. I had my first reality check when my (Spanish) boss welcomed me and told me that he had made room in his office for me to work inside the office with him because it was frowned upon for a woman to be with the rest of the colleagues (men) and the women’s office was a bit far from my department.

Then, each of the questions I was bombarded with before taking the decision and whenever I mention becoming an expat in Saudi Arabia rose again in my mind: “Are you sure?” “How can they want to take advice from you, a Western female?” “Why would you want to go to such a country where women do not have it as easy?” “Do you have to wear a burka?” “Is it safe?”

Some past images also emerged in my head. My brain focused on some experiences when we (the expat group) were preparing ourselves in Madrid for our posting as overseas workers. I could watch myself in a third dimension, like in a film clip, during those preparation and training days, when I was surrounded by all my male Spanish colleagues in class, and then the camera went to slow motion at the moment we were given our passports with visas: they all were given visas with 2 years of interrupted permission to live and work in Saudi Arabia. For me, only a 6-month visa was given, with the requirement to leave the country every 30 days.

The women’s office was at the end of the floor, literally in a corner: the walls were made of translucent glass and did not allow seeing inside. I noticed that there were small spaces where the glass was transparent, and they had been covered with sheets of paper. My new boss knocked on the door, and in a few seconds, the door opened: “Maria! Come in, we’ve been waiting for you!” She took my hand and literally dragged me into the room with a big smile on her face. As soon as they let my boss introduce me, they closed the door and locked it. What followed was a barrage of comments (the first one about feeling free and not covering my head if I am not Muslim) in a deep and warm welcome, thanking me for coming, as they took off their *abayas* and scarves and looked like Western women, peppering me with questions, asking me to stay in that office with them not in the boss’s office, while offering me a place to sit, something to eat, mentioning any plans to go out on the town together, going shopping for colorful *abayas* “you who can,” or visit their homes and families in Ramadan. As tired as I was from the long flight, I was stunned to see and feel so much kindness from my thoughtful and generous hosts who were so curious about me and my Western life. I felt truly shocked: In a supposedly difficult country, one where I wasn’t sure I wanted to be, I was actually enjoying what I did not expect to find.
8.5 Culture and Work

Happiness is a skill. The wonderful thing is that this skill, like driving or cooking, can be learned, and is something that can stay with you for a lifetime. What followed are some of my own experiences in a kingdom that came to feel nearly like “home,” due to the kind and generous Saudi people, both women and men, I had the opportunity to spend time with. I will treasure forever the memories of that amazing kindness.

“Culture is embedded in language. I am a translator, I know that language is part of culture...so I must integrate!” I thought. And that was the reason why I offered to teach Spanish in exchange for some Arabic language classes.

As experiences build our identity, mine was also shaped forever, especially my view of the world. Adif experts moved to the foreign country to master the Haramain Project until the locals were prepared to do it on their own. We moved and left everything behind for years. It is easy to get an idea about how challenging the project is, and the professional development and personal growth we achieved. My duties as a trainer in traffic safety regulations included teaching the contents of the Railway Rule Book and Safety procedures to staff in order to obtain a safety qualification. The audience were upcoming traffic operators and work forepersons for the operation and maintenance of the HHR Line from Mecca to Medina. This qualification is mandatory for the performance of their duties, and that was the biggest commitment: to check if they were suitable for the safety job position, taking into account how exhausting and eye-opening it is to see that the class group is not homogeneous at all. Students did not have the same technical and academic profiles, the same level of English proficiency, or the same experience in railways.

My duties as a trainer involved training in a multicultural environment, which presented challenges that I overcame. I encountered up to nine different nationalities in one classroom: Turkish, Spanish, Indian, Saudi, Polish, Filipino, Pakistani, Sudanese, Egyptian, and Yemeni. How could I manage training in an intercultural environment? Also, me being a woman in Saudi Arabia was a challenge.

I did not lead the first Adif qualification training classroom in Saudi Arabia. Being integrated and respectful, my company was careful when thinking about the cultural barrier. So, I acted as an interpreter for my colleague (of course, a man). But they say “life sends you gifts wrapped in trouble,” and guess what? This training seminar ended with me participating actively, in the same capacity as the trainer I am in Europe. So here comes the first lesson I learned: in an intercultural environment, we should stop managing the situation and start leading it!

8.6 Stop Managing the Situation and Start Leading It!

The first thing we think of when working with other nationalities and cross-cultural communication is “Let’s look at the other cultures.” I take a slightly different approach: I would say “better take a look at yourself.” Change your point of view. See things with perspective. It is all about perception. In other words, work on your global mindset.

Working on our global mindset implies firstly working on our cultural humility. The ultimate expression of love is “respect for oneself and for others.” But there is nothing more despicable than respect based on fear. In cross-cultural communication, culture equips us with behaviors that allow us to act in an accepted or familiar way, so we must first recognize our barriers to full intercultural understanding.
Cultural humility calls for self-reflection and acknowledgment of our limitations from our own cultural perspectives that might be colored by assumptions and prejudices in relation to people from other cultures. With this in mind, there are no weird or odd ideas from others. There are just “codes” that we do not use in our culture and that we should be equipped with. This way, we stop facing a culture by integrating with it.

Once, in a qualification training course, a student arrived late to class on the very first day. The class had begun and I was handing out textbooks and the rule book to the students. When the student suddenly arrived and stood at the door, I looked at him and could see how embarrassed he was, not sure how to act... where to sit... (Probably he did also not expect the teacher to be a woman, and may have been wondering if he was in the right location?). I started walking toward him, directly, with a big smile on my face (with the intention of giving him the teaching materials in hand and accompanying him to a seat). All trainers know how important the very first day of the class is; no trainee should feel shy or uncomfortable, so I was just trying to prevent him from feeling humiliated by his delay. What happened next came as a shock to me: the expression on his face changed completely, he avoided eye contact with me, turned back and left the class, almost running away from me.

What had happened? I only wanted to be polite and welcoming. In fact, I had forgotten the code. I had lost my situational awareness: I was acting normally, but I forgot that for Saudi men, it is not usual for an unknown woman to communicate with them in such a close, powerful, strong, and direct manner. I was polite in my culture and inadequate in his. I forgot the values and codes of the cultural environment I was in, and my behavior became offensive to him.

It was my fourth course and I should have known, but I forgot the code and found myself in a difficult situation. Truthfully, I felt unhappy. It was an appalling event. “How should I feel after that? Irritated? Socially and culturally, it was not easy for me to live this moment. However, it was I who really had the wrong perception. In my attempt to be right, I had failed. And to be able to see this, it is necessary to look at our own culture and behavior from an outsider’s perspective. In a difficult situation caused by cross-cultural misunderstanding, the expert (the leader) should work on accepting the situation and adapting.

And this is a challenge. When working with other nationalities we have different ideas of what is accepted and familiar. Avoid culture shocks by identifying value clashes and applying the codes, and when the exception arrives, remember people from different cultures have different expectations. Once we apply this thinking, it is a step forward. Achieving this understanding will give us intercultural competence.

8.7 Intercultural Workshop

A situation is not fully intercultural; it has some elements of multiculturalism. People from different backgrounds and assumptions need to communicate with each other. Every situation in which we encounter a person who comes from a different context to us and who does not share much of our understanding calls for greater multicultural awareness.

Sometimes, some situations that are usual for us are not often perceived very positively by other nationalities. We are not here to say what is right or what is wrong; sometimes, we tend to jump to negative conclusions, rather than understanding why the situation is like it is. What can we do? Be aware, and avoid misperception. “Working across borders” is not about going across borders, but it is
about merging them. It is about extending our borders as leaders and creating new ones. It is about respect and integration.

Seeing and perceiving different cultures as one human and unique culture; in my intercultural experience, in front of nine nationalities, I realized I had to understand that some things I am unfamiliar with can be acceptable and familiar to someone else, and I must adapt to become a leader.

We need intercultural competence because “working across borders” implies “working in diverse and unfamiliar situations.” This competence allows us to communicate and interact constructively and effectively. The big challenge is not so much to be cross-cultural but to think in an intercultural manner. It will be hard to achieve; it is like you become aware of all nuances, and then create a new culture inside you, which will let you achieve intercultural competence. And this competence is an ongoing process in a constant state of flux, so it will require skills from you, in order to transfer familiar competence to unfamiliar contexts.

We can get prepared by looking within ourselves and making our own intercultural workshop. First, we should be curious and learn to avoid misperceptions. Therefore, we respect those cultures that are different to our own, allowing for greater integration.

While we can be confident of the rules and norms of behavior in many typical situations, in many intercultural situations we feel insecure: this makes an intercultural encounter difficult, especially for communication, because we do not interact and communicate in a natural way. It is not that our backgrounds are completely different—maybe there are some similarities and overlaps. Plus, we reflect our culture via language; for example, the way we welcome, our greetings, and in our communication style. In my experience, to solve this problem, I attended some Arabic language classes. My students spoke many different languages, but the common ground was the culture of the country where we were located. So, learning Arabic gave me greater understanding and confidence. I was able to introduce some Arabic words in my classes, which brought me closer to the group, and not be seen as a stranger. This helped me to create comfortable situations to obtain the best results.

The experts bring with them the knowledge and the methods, so they should be the ones to start leading. Making room for an appropriate and motivated attitude and social competence and putting them into practice creates an intercultural workshop where we welcome cross-cultural interactions, learn from new situations, and accept constructive criticism.

In my daily work as a traffic safety trainer, I transfer (not just transmit) thinking regarding why it is necessary to apply an accurate rule book and regulated procedures in a railway system, and going further, being aware that all of this requires a methodology for communication. And when the rule is well-known, one needs to remember why it was taught. Only by understanding the power of why we apply railway rules can we understand the strength of the safety that is implied. We are human after all; when we truly understand something, we feel relieved.

8.8 Language Barrier

On the one hand, people from different countries interact with one another, having different dialects and accents. On the other, we do not interact and communicate in a natural way, as we have actions and behaviors that can be seen as offensive. So, we say there is a language barrier when speaking a language properly is not enough.
CASE STUDY: CAPACITY-BUILDING STRATEGIES AND CROSS-CULTURAL TRAINING COMPETENCE

If there is a multicultural environment, we will face situations where no one speaks the same language naturally. This is a big challenge, the barrier of language, because a common language is necessary to communicate effectively, but sometimes no matter how fluent you are in English or good at the grammar and vocabulary, there is an accent that you have to work with, in order to make yourself understood.

There is a competitive spirit with a balance between correctness and clarity. Not having full command of the foreign language often hampers the speaker, who may also feel embarrassed and judged by the audience. This is a consequence of learning English via comprehension exams at school, which focus more on correctness rather than on clarity. However, speaking perfect English with the wrong rhythm is a problem for the listener. The listener could understand everything you are saying but may misunderstand the meaning.

Facing an intercultural environment requires taking a larger outlook to gain perspective. Who is actually speaking English in the world today? If we looked at all of the English conversations in the world taking place right now, we would see that for every native speaker speaking English, there are five non-native speakers doing so. If we could listen to every conversation in English in the world right now, we would notice that 96% of those conversations involve non-native English speakers. Only 4% of those conversations are among native speakers. We focus on being grammatically correct in English, when in fact, it is just a tool to get a result.

Consequently, we should focus on being good communicators. Paradoxically, having a strong command of English helps me in my career and makes me more confident, but in this multicultural context, it may cause me to be ineffective in my communication. On the other hand, if I choose to speak with a lower level of competence in English, I will go slowly and I will be clear, and most importantly, I will focus on the person I am talking to and be more effective in my communication.

8.9 Best Version of Yourself: Being a Vitamin Person

Our universe is constantly converging, changing, and reinventing itself just for one purpose: connecting like never before. Nowadays, in this global business world, we do not even need to leave our homes to take part in such an intercultural scenario. We are attending multicultural video meetings from home, just fresh out of our beds, while maybe our colleagues are having lunch or finishing their day on the other side of the world. “Long live teleworking!” implies being prepared for the adventure to get involved interculturally, naturally.

Whether we encounter difficult situations, it is heartening to know that there are natural and simple ways of creating things you need and solving problems to successfully integrate: serenity and equanimity. Life changes from moment to moment; every change brings new learning. Equality and constancy of spirit with the impartiality of judgment will give you the capacity to see the bright side. Taking adversity and turning it into an opportunity. When we are in a brutal environment, and we need to work on resilience, we begin to see the bright side of things. And then we start spreading our passion, motivation, positivity, and joy. In so doing, we show our best version, the premium and enhanced version of ourselves, and become “vitamin people” for others.

Vitamins are a group of substances that are necessary for normal cell function, growth, and development. The word vitamin comes from the Latin word “vita,” which means “life.” Being “vitamin people” implies spreading positivity and motivation.
Listening to our inner voice and our inner wisdom and putting our heart into it will make us integrate and improve the well-being of our audience. We will catch up their attention. The decision to pursue integration depends on each one of us. If you enjoy being with your audience and feel comfortable, others are comfortable as well. If you enjoy yourself, others do too. If you feel you are “at home,” then you are integrated. So, stop managing things and start leading them. “To lead” in English means to direct, to guide, or to orient. In other words, the engine needed to make this effort is passion and curiosity. Our intercultural competence needs curiosity to look beyond the negative side and find out what is next, and passion to move forward.

One day, at the end of a training course, after taking the exam that granted the students the safety qualification, a Saudi student approached me to thank me for such an interesting course. He added:

“María, I do not know if I have ever had a woman teacher, maybe in my childhood, but I do not see you as a teacher anymore, I see you as an engineer man.”

“An engineer man?” ...A shiver ran down my spine as I stood there for a few seconds. I confess that I was not sure whether to burst into tears or into laughter. Then, the gleam in his eyes awakened my intercultural competence. And I noticed the compliment: I understood that if I had a wrong perception of that, it was completely mine, not his. When misperception comes, we should look beyond the negative and be curious about the true sentiment behind the comment/situation. I could have taken it as an offense, when, in fact, he was telling me that I had become his “vitamin person.”
CHAPTER 9

Case Study: Sharing Experiences on Staff Training with Consideration of Language, Culture, Education Background, and Learning Styles in India and Japan

Norie Kobayashi K.

9.1 Introduction

Japan has been influenced by many Indian ideologies since the introduction of Buddhism in the 6th century.

Prince Shotoku’s Seventeen-Article Constitution (regarding bureaucratic and aristocratic morals and disciplines) was established based on Buddhist ideas (AD 604). Since then, Buddhism has been around us, along with Shintoism – an indigenous Japanese religion. In the Japanese language, the phonological table consisting of the vowel “a-i-u-e-o” lines and the “a-ka-sa-ta-na-la-ha-ma-ya-ra-wa” rows is based on the Sanskrit phonological table. The sentence structures of Japanese and Indian languages are also quite similar.

In the present day, there are numerous examples of economic and industrial collaboration between the two countries, of which one is the Mumbai–Ahmedabad High Speed Rail Corridor.

Given the past and the present, the two countries have generally maintained friendly relations and have been able to understand each other quite easily. However, the two countries have different cultures, conventions, ways of thinking, lifestyles, and so on; therefore, by understanding each other more deeply, we should be able to build a smoother cooperative relationship.

In this chapter, I would like to discuss the distinctive features and differences between Japan and India to see what we can learn from each other. The comments below also reflect feedback from Indian graduates who have studied and worked in Japan.

9.2 Language

India is a multiethnic and multilingual society, and while interacting with people in India, it is common to “speak with this person in this language” and “speak with that person in that language.” In many cases, there are “common languages” and “intermediary languages” other than the native language. Hindi is a major language used in North India, but in South India and throughout the country, English is often used. In the office setting to a certain extent, English tends to be used on a daily basis. Depending on the state, school education often provides a three-language system: English; Hindi, local, or native tongue; and a third language. The trend in schools these days is to provide an English-medium education from the beginning along with the study of two other languages.

On the other hand, in the National Education Policy 2020 prepared by the Ministry of Human Resource Development (the current Ministry of Education), “preservation and promotion of Indian languages” as well as “promotion of multilingualism and the power of language in teaching and learning” are emphasized. Along with the use of digital technology, the study materials are or will be
provided in various Indian languages as well as in English with just one click of the chosen language. Such digital education platforms initiated by the Ministry of Education, India, are DIKSHA¹ (for primary and secondary education) and SWAYAM² (for senior secondary and higher education). This is a very positive move toward good balance, the coexistence of “inheritance of own tradition and culture” and “active participation in multicultural and global engagements.” In this respect, I believe India is in a leading position in the world.

In Japan, the proportion of non-Japanese residents is only about 2%; therefore, it is close to a homogeneous country. Japanese is virtually the official language throughout the country, so even though people all learn English at school, their daily conversations are carried out mostly in Japanese. While Japan is gradually adapting to diversity, given their daily usage of Japanese, there tends to be a fixed mindset around only using Japanese. If you live in Japan, speaking Japanese will broaden your network of contacts and work, and will make your life and your family’s life easier, so it is recommended that you learn Japanese.

Generally speaking, understanding concepts in one’s native or first language can be straightforward, precise, and in-depth. Maintaining and promoting one’s own language with a strong foundation is important. On the other hand, the practical use of English is also crucial for smooth communication and operation in the world.

India is a multilingual country, while Japan has been a monolinguistic society. Although the linguistic backgrounds of these two countries are different, in today’s world where information can be shared in a moment or simultaneously, I expect that in Japan also, translations in the digital mode of the school textbooks to English and other languages, especially of mathematics and science, can be easily available to those who need or are interested in such materials.

### 9.3 Eating Habits

About 30% of Indians are vegetarian. In detail, preferences differ based on a person’s family and religion, and dietary choices such as vegan, lacto-ovo vegetarian, pescetarian, and vegetarians who do not eat specific vegetables such as garlic, etc. Some may be vegetarians by tradition, while others choose it for their health, taste, or own beliefs. People’s food preferences and rationales are respected and not interfered with. This may be similar in the United Kingdom and the United States.

Even when I was studying at a college in England about 25 years ago, there was a checkbox on the form for vegetarian or non-vegetarian diet on the first day of enrollment. Since then, all the wait staff I met for the first time knew who was vegetarian and who was non-vegetarian, and each meal was served accordingly. Vegan foods were also available. Vegetarians and non-vegetarians coexisted and understood each other. Many young European and American students were vegetarians.

In India, vegetarian foodstuffs are marked with a green circle, and non-vegetarian foodstuffs with a red circle, which is a very convenient system.

If Japan wants to invite more global talent from India, it would be better if they at least mark vegetarian foods so that vegetarians and people from abroad don’t have to go through the ingredients list of the food packages, which may be difficult to understand.

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¹ See https://diksha.gov.in/.
² See https://swayam.gov.in/about.
9.4 Primary and Secondary Education and Beyond

During the compulsory education period (elementary and junior high school) in Japan, various hands-on skills that help to develop motor skills and basic life skills are acquired and practiced, such as

- cleaning, arrangement, and maintenance of things around us and in the school;
- homemaking, including cooking and stitching;
- arts and crafts, including carpentering and woodblock carving;
- care of plants and some kinds of insects;
- rota system: serving school lunch to classmates and returning the utensils to the kitchen;
- music based on the Western system; and
- various types of sports activities and fitness checks.

I believe that learning these hands-on skills at this stage can also nurture the understanding, quest, and preparation for science and engineering through multifaceted perspectives. I believe this holistic education is the virtue of Japan's compulsory education and focus on developing various life skills. Even though some educational platforms may shift to digital forms, maintaining manual skills will enhance one’s practical capacity.

Another commendable, unique form of education in Japan is the 5-year “KOSEN – National Institute of Technology” education system immediately after the 9-year compulsory education period. KOSEN institutes are located in most prefectures in Japan for high-level engineering education. Students who opt for engineering at an early stage, in the third year of junior high school, which is equivalent to 9th grade, can apply for KOSEN by taking a competitive exam. If selected, their engineering education starts from the age of 15 to acquire vast knowledge and experience in science, engineering, and technology at fully equipped colleges.

Also, there are two national universities of technology—Nagaoka University of Technology and Toyohashi University of Technology—which accommodate the graduates of KOSEN to the third year of their bachelor’s course, which is integrated with their master’s course, to provide leading engineers with practical capacity, academic knowledge, strong research experience, and creativity. Throughout the total of 9+ years of education (with a focus on science and technology), practice, research, and industrial collaboration are given importance. This may be a good example of Japan's strong foundation of “Monozukuri”, a Japanese term for manufacturing and craft, including not only skill, knowledge, creation, and solution but also the spirit and attitude toward the making of things.

9.5 Tertiary Education

In India, students generally study theory in depth as part of their course work (lectures) and focus more on the comprehension of theories than their application, likely due to limited resources. The advantage of studying highly challenging material, like that provided at the Indian Institutes of Technology, is that it provides intellectual stimulation and promotes innovation, which enhances one’s self-development and the ability to work hard. Also, a strong theoretical foundation cultivates problem-solving skills. For these students, the coursework in Japanese universities seems comparatively easy.

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3 See https://www.kosen-k.go.jp/english/.
However, many students also feel that in addition to the theoretical component, greater emphasis should be placed on project-based learning and incorporating new technologies.

As for research, most Indian students who studied in both Indian and Japanese universities were satisfied with the research environment of Japanese universities. In particular, the availability of ample resources, infrastructure, and funding; time-bound research outcomes; precise focus on research; practical training; weekly meetings; and industry–academia collaborations are cited as the most valuable aspects of research at Japanese universities.

### 9.6 Work Environment

Japanese companies tend to have “membership-type employment” by tradition, in which the employees’ sense of belonging to the company is strong, while India tends to have “job-type employment” in which the employees’ appreciation of their own expertise is strong.

Generally speaking, in Japanese companies, the labor law is well-observed and safety is prioritized; discipline is valued and there is a strong sense of responsibility; and the effort made in the process is appreciated, as well as the result. Japanese companies give importance to progress management, processes and deadlines, as well as efforts to reduce waste and improve efficiency. They tend to take time to build a robust prototype. Quality takes precedence over quantity.

Their process in decision-making is often a bottom–up type in which the opinions of employees can be reflected by a request-for-approval system called *Ringi–sho*. Also, it is not uncommon to have a consensus-building called *Nemawashi* before decision-making, but it tends to take time to make a final decision.

On the other hand, due to the seniority system and conservative attitude of upper-level management, there may be a tendency for it to be difficult for younger employees to demonstrate their abilities. It has also been pointed out that the implementation of an electronic approval system has been slow.

In Japan, English is not commonly used; so, in order to work smoothly in Japan, Japanese proficiency of about N2 in the JLPT (Japanese Language Proficiency Test) may be required.

Indian companies tend to have a top–down decision-making process, in which the opinions of management are absolute and employees follow them, and the decisions are often relayed after they have been finalized. Therefore, decision-making can be quite swift.

Time management is generally more flexible, and deadlines might be missed. Also, the “completion” and “profit outcome” of the project tend to be emphasized, rather than the process—which requires effort. Quantity tends to take precedence over quality.

India tends to be more proactive in taking great risks to deliver exceptionally good results, both in research at universities and in business.

### 9.7 Religions and Ways of Thinking

About 80% of Indians are Hindu, about 14% Muslim, about 2% Christian, and the rest Sikh, Jains, Buddhist, or others. There may be traditional hierarchies within these religions. These are very sensitive topics with various aspects, such as historical background, national politics of the time,
regional differences, and the way of thinking of each family or individual. Much of these are not spoken about or interfered with in public.

Since ancient times, there have been many Indians who have had a significant ideological influence on the world. In present-day India as well, there are people who inspire others with their words and actions. Takeaways from these influences are reflected in one's daily life and school education as well.

There are many Indians born and raised in India who are currently at the top of various fields around the world. Many of them were educated in India and reached their current positions in the world despite having no connections or hereditary privileges, and irrespective of nationality, race, ethnicity, and religion. In my view, this may be the result of not only their diligence, outstanding linguistic ability, expertise in mathematics, and foresight, but also the concrete principles of their life and practices, which resonate with people around the world.

9.8 Conclusion

India and Japan can have a productive relationship where they learn ideas and best practices from each other. For example, Japan is reputed for manufacturing technologies, and India for information and communication technology, each of which has its own strengths; therefore, synergistic effects can be expected through collaboration.

Japan has a strong foundation of craftsmanship, transforming raw materials into the highest quality products based on the total production system, including detailed planning, time and process management, quality assurance, etc.

On the other hand, the power of language and its practice, the ability to create from scratch using speedy solutions from limited resources—which may be called *Jugaad* or “frugal innovation”—may be the strong points of India.

Ultimately, I anticipate that not only the synergistic prosperity of Japan and India but also the ideal of the “realization of a sustainable, diverse and inclusive society”—the consensus of the Sustainable Development Goals—can be achieved through the collaborations of both countries.


References


Conclusions and the Way Forward

Nikhil Bugalia, Sudhir Misra, Ashwin Mahalingam, and KE Seetha Ram

10.1 Conclusions

Many of the essential questions on designing and implementing capacity development programs for megaprojects such as high-speed rail (HSR) were raised in the introduction section. The contributions presented in the book have helped address many of the questions raised and thereby provide specific recommendations for policy makers. Nonetheless, a few questions remain unanswered. We summarize how the chapters in this book have addressed the questions raised. The unanswered questions provide direction for future works.

The chapters collectively addressed HSR-specific questions. The discussion on these questions is as follows.

Q1. How different is the HSR technical system compared to the conventional railway system, and what technological advancements need to be transitioned to the HSR system?

Chapter 2 provides an in-depth understanding of rolling-stock technology’s essential differences between an HSR and a conventional railway system. The chapter also illustrates the differences between various global HSR systems (relevant standards, available technology, and their performance). More specific differences in technical components other than the rolling stock have not been directly addressed in the book. However, readers are directed to other published books (Iwasa, Ishido, and Suga 2015). The information in Chapter 2 is an excellent example of the complexity of the HSR system compared to that of the conventional railway system. Therefore, the development and management of such HSR systems require a fundamental shift in the engineering capacity of a country. For example, box case studies discussed in Chapter 5 illustrate how a shift toward a condition-based maintenance strategy is crucial for an HSR system’s efficiency compared to existing time-based maintenance approaches for conventional systems. Furthermore, such transformations are necessary for the technical systems and at all other levels of the system, i.e., human, organization, and regulations.

Q2. What are the most effective strategies for transferring the know-how when importing a technical system such as HSR?

Q3. For the HSR-recipient countries, how should the technical standards and regulations be set considering the long-term (self-reliant development) and short-term implications (successful project implementation)?

The information summarized in Chapter 2 and Chapter 3 helps provide the answers to the questions mentioned above. Given the complexity of modern-day railway systems, a systematic method for in-depth analysis of various performance level requirements is necessary to guide the overall know-how transfer. These chapters emphasize that Reliability, Availability, Maintainability, and Safety (RAMS) is a versatile and widely applicable framework that can enable knowledge transfer. However, RAMS is not the only approach, and different methods of systematic analysis, such as Systems-Theoretic Accident Model and Process (STAMP) and others, can exist. The overview of the RAMS framework presented for successful case studies highlights the importance of the design phase and its influence on the life-cycle outcomes. Hence, a key strategy to successful knowledge transfer is to specify the
system goals and requirements of the country importing HSR technology early in the HSR adoption process. Finally, the importance of continuous risk assessment throughout the life cycle of the system is revealed. No system is risk-free, and risk is dependent on many contextual factors. Hence, new risks can emerge in imported systems that were not present in the system in its origin country. Therefore, the most effective strategies for technology transfer should concentrate on participatory principles, where the existing local experience and expertise are also synthesized and utilized to set up the recipient country’s system-level requirements. Furthermore, capacity building and training efforts are also needed to develop risk-assessment capabilities in the HSR-recipient countries.

Several case studies discussed in Chapters 2 and 3 also provide guidance regarding the selection of technical standards, technologies, and regulations for an HSR-recipient country. A quick comparison of rolling-stock-related standards across different HSR-operating countries reflects that HSR systems in Asia have some of the most demanding standards for ridership comfort, noise reduction, stability, and safety. Such demands are often reflective of cultural preferences and acceptance by the population local to the region. Such standards can then guide the technology developed to satisfy the requirements specified in the standards. Each of the technology-related features can impact the performance of the system such that various demands of sustainability appear difficult to be managed simultaneously. For example, articulated trains can provide better riding comfort; however, this may lead to an increase in life-cycle costs of the HSR systems. Hence, before deciding to identify the best technical standards and regulations, an understanding of the context and demands local to the recipient country must be thoroughly understood to set system-development goals. Further, an assessment of current technology can help identify priority areas in which the existing engineering level for indigenous development can be rapidly increased to pursue strategic self-reliant goals or where important off-the-shelf technology can be leveraged quickly for timely delivery of the new railway system development (see the case of Vande–Bharat Mission in Chapter 3).

Q4. How are training requirements different for an HSR system compared to a conventional railway system?

By tracing the six key areas of technological advancement in the railway system, Chapter 7 has reflected on the role of people (staff, passengers, and the public) in modern railway systems. The chapter highlights that these fundamental issues are being overlooked in pursuit of technological advancement, from the mental health and well-being of frontline workers to the cardiometabolic issues and level of sedentary work faced by train drivers and rail network controllers. Consistent with the systems-thinking principles, the chapter argues that such technological change must also be examined for potential wider reverberations across the whole rail system and nature of work. This has two implications for the training requirements for the technologically advanced railway systems. First, the training requirements must be understood through formalized systems models of the railways that anticipate the role of people. Second, such models must reflect not just idealized work (or “Work as Imagined”), but rather the realities of work and human activity in and around the railways (“Work as Done”). The training programs of the future railways must then consider the understanding of people, their behavior, and support their variability, fragilities, and adaptations so that we design and deploy change that enriches work and enhances the passenger experience, to promote the long-term appeal and prosperity of global rail. The changes in training requirements must also be met with changes in the technical and organizational systems and processes to support human performance.

Q5. What factors affect the sustainability of organizational knowledge and human resource training in an organization, and what are the best strategies to achieve this outcome?

Various contributions of the book can provide a general guideline to answer this question; however, it is an important question that needs to be explored in more detail. The accident in the Chinese
HSR case, as summarized in Chapter 5, shows that several of the contextual factors governing the overall decision-making of the relevant railway organizations can significantly affect organizational knowledge and human resource training. For example, in the Chinese HSR case, a focus on the quick commencement of the railway operations and sustained performance pressure had negatively contributed to organizational efforts to provide training for technologically complex HSR systems. The same phenomenon has also been highlighted in Chapter 6. The organizational focus on financial performance and the belief that complex technology will alleviate system inefficiency often leads to the marginalization of a proportional focus on human factors and training.

On the contrary, the two case studies sharing the experience of knowledge transfer in an intercultural setting often highlight that a systems-thinking-based focus on safety training and organizational knowledge is essential, demanding a closer look at human and organizational factors and safety culture. As training actions concern real working conditions, a bottom-up feedback culture or system is necessary where reports about system improvement are encouraged. Employees’ safe adaptations are also recognized while improving the system to continuously improve human operators’ support. To a certain extent, the long-term employee-employer relationships, such as those prevalent in Japanese HSR organizations, can help enable sustainable organizational knowledge. However, the experience of the organization’s success in sustaining organizational learning without the long-term employee-employer relationships still needs further examination to identify more specific ideas on the theme.

Q6. In terms of interaction with technology and human resources, what are the characteristics of organizations successful in constructing and operating HSR projects?

Various contributions throughout the book have provided ample discussion related to this question. A few salient points have also been discussed via answers to questions 2–5. We provide a summary of the main points for organizations managing the HSR systems.

1. HSR systems are complex socio-technical systems, and various components should evolve synchronously. Hence, organizations should constantly analyze the impact of changes in one part of the system on all other parts and manage performance. The changes in the system (at all levels) could manifest due to intentional decisions in pursuit of system goals or as a response to the socioeconomic contextual factors local to the HSR system.

2. A risk-based perspective for the whole life cycle of HSR is warranted, and organizations should make continuous efforts to identify risks through systematic approaches at all system levels at all stages, with a specific focus on system design.

Q7. How do the regulatory and socioeconomic environments of a country affect the HSR organization’s performance?

As summarized in the case studies for HSR accidents worldwide, a country’s overall regulatory and socioeconomic environment can critically affect an HSR organization’s performance. For example, the accident in the Chinese HSR system highlights that the overall focus on the speed of HSR network development had potentially contributed to reducing the effectiveness of the risk-assessment process. Pursuing various system goals may have marginalized the priority of safety starting at the regulatory level, which subsequently affects the safety performance at the organizational level. The Japanese HSR accidents also highlight that the safety regulatory system based only on an “experience” based risk-management approach, which relies extensively on past events, may not be sufficient to capture the complexity of the modern-day railway systems. The socio-technical context of the HSR system is constantly evolving, leading to the emergence of new risks. Hence, the lack of proactive risk-management approaches at the regulatory level can also jeopardize the overall safety performance of the system.
Q8. How should the regulatory and institutional factors evolve to successfully manage modern-day complex HSR systems?

Regarding HSR projects as megaprojects, Chapter 4 of the book provides an overview of activities that should be included in capacity-building programs in addition to traditional elements of technology-related knowledge transfer. The Project Management Paradigm 2.0 requires that for complex projects such as HSR, governance and innovation should focus beyond quality, time, and cost factors to include several dimensions of socioeconomic value that the project is expected to generate. For example, capacity-building programs should also focus on tools for project evaluation beyond the conventional cost-benefit analysis. The 2.0 paradigm also demonstrates that innovation in megaprojects can be achieved by promoting cross-contextual learning from multiple stakeholders’ lenses across different life stages of the project. Hence, the scope of capacity building and training programs should be widened to promote efforts for institutionalizing innovation and governance frameworks. An HSR-specific interpretation of such a framework also requires that countries relying on imported technology develop their indigenous HSR systems to adopt multi-pronged approaches. They need to educate the public at large that all large projects create value and need to remove the perception that such projects create “white elephants” by showing how expectations of a project can change. These countries also need to invest a lot in training. From a policy perspective, such countries can “steal” solutions from economies that have faced such problems. Hence, HSR-importing countries such as India can leapfrog many of the obstacles that advanced economies have faced and develop policies based on the best and latest knowledge and insight.

As summarized in Chapters 1 and 4, the discussion on governance of megaprojects and the experience of HSR accidents, as summarized in Chapter 5, have helped answer the question. Here is a summary of the main points.

1. The scope of system goals that regulatory and institutional structures focus on needs to be broadened from a conventional focus on cost, quality, and speed to include socioeconomic and environmental value maximization for all stakeholders involved.
2. The various functional goals of the systems have inherent trade-offs. Focusing on achieving one practical goal may potentially affect the performance of the other goals. However, considering a systems-thinking perspective throughout the system life cycle (focusing on system design), multiple functional goals can be achieved simultaneously. Hence, regulatory mechanisms and institutional structures should be created to enable systems-thinking-based decision-making at all system levels for complex megaprojects such as HSR.
3. A systems-thinking-based perspective for HSR projects also requires that the regulatory and institutional factors be dynamic and change in sync with the system and its contextual factors. Such dynamism in the regulatory process should be institutionalized through continuous innovation. An innovation forum has enabled all stakeholders (industry, academia, citizen representatives) to engage with the system and guideways to maximize value creation.

10.2 The Way Forward

This book has attempted to address a few critical issues related to HSR projects with a view to assisting countries that are exploring HSR as a part of their infrastructure mix in making informed choices about this technology. We have established the need to view HSR through a “systems thinking” framework due to the complexity of these systems. Specific ideas concerning technology, safety, and organizational performance have also been addressed.
However, this is only the proverbial tip of the iceberg, and several questions remain unanswered and unexplored. For instance, how should an HSR project’s impact be evaluated across different domains, such as the impact on industry ecology, land use, employment, and education? What other technological systems can be explored, and what are their implications? In addition to safety, how do we assess and improve outcomes related to quality and sustainability?

This book is intended as a starting point for practitioners and academics interested in HSR to advance their knowledge in this area. We have collated expertise and have attempted to create a community of HSR practitioners who can share experiences, ask questions, and, through rigorous scientific measures, provide theoretical and practical contributions that can allow us to offer better mobility solutions to citizens all over the world.
Reference

Policy Messages for Planning and Implementing High-Speed Rail in Asia

High-speed rail’s (HSR) capacity to accelerate regional development is driven by non-linear, dynamic technical and social interactions in an HSR system. To enable HSR project growth, policy makers must tackle complex issues, such as stakeholder engagement, safety, and cost and schedule overruns. A robust institutional framework that defines each stakeholder’s role, the standards used, and coordination and conflict resolution mechanisms is critical.

Policy Messages for Planning and Implementing High-Speed Rail in Asia explores policy keys to boosting HSR technology, safety, and organizational governance and culture. Drawing on global case studies and lessons learned, the book showcases successful HSR development experiences and evidence-based recommendations for realizing project breakthroughs. It is an invaluable resource for policy makers, practitioners, and researchers seeking to promote the sector’s growth and sustainable development impacts in the region.

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The Asian Development Bank Institute (ADBI) is the Tokyo-based think tank of the Asian Development Bank (ADB). ADBI is focused on delivering demand-driven policy research, capacity building and training, and outreach to help ADB developing member countries practically address sustainability challenges and accelerate socioeconomic change. ADBI seeks to advance timely, innovative evidence-based development solutions that improve the outlook for growth and prosperity across Asia and the Pacific.