論 文 の 内 容 の 要 旨

論文題目　Challenges and Improvement for Safety Management Practices at the Organizational and Institutional levels in Japanese High-Speed Railways
（日本の高速鉄道における安全管理の実践上の組織的及び制度的課題と改善策）

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Safety of Japanese High-Speed Rail (HSR), or *Shinkansen,* is a topic of national and international importance. A series of recent accidents in Japan that could have easily been fatal also warrant attention to the topic of HSR safety in Japan. HSR is a complex socio-technical system comprising of several technical, human, organizational, and institutional system components whose interactions govern the emerging system behavior in the form of Safety. Due to the expected rise in automation, as well as the advancement in technology, the HSR system is expected to become centralized. For such systems, the role of organizational and institutional factors becomes crucial, and hence the current study focuses on studying the organizational and institutional factors for Shinkansen safety management.

Often the concept of Safety Management System (SMS), comprising of safety promotion, safety assurance, safety policy, and Risk Management (RM) strategies are used to manage safety at an organizational level. Using this framework, the study first highlights several relevant academic and practical gaps in the Japanese HSR system. First, the relative importance of the variety of organizational factors has not been examined in the Japanese HSR. Second, at the organizational level, the RM practices of the Japanese HSR operators and at the Institutional level, the risks associated with the current practices of operator-regulator relationships have not been examined. Third, the literature review helps identify a necessity to develop a proactive RM strategy for

Japanese HSR operators. Finally, some of the HSR operators in Japan are facing the issues related to the near-miss reporting behavior of their employees; however, only a handful of the studies comprehensively explore the organizational factors affecting the reporting behavior of employees in Japanese HSR TOCs.

The study, thus, aims to answer the following questions: *How do the organizational (Risk-Management, Feedback) and institutional level (Risk-Management) risks that affect Shinkansen Safety? and How can Shinkansen Safety be improved?* The specific objectives for this study are 1. To clarify challenges in the current safety management practices (Risk-management) at Organizational and Institutional levels in Japanese Shinkansen and identify strategies to improve the practices. 2. To Develop methods necessary for implementing pro-active risk-management strategies at the organizational and institutional levels, and 3. To clarify the factors affecting reporting behavior at the organizational level in Japanese Shinkansen.

The focus of the study then shifts towards *Risk Management* at the organizational and institutional levels. Current RM practices of TOC's are not at par with the state-of-the-art safety theory based on System-control principles, and instead utilize event-chain based accident models, which are shown to be limited in explaining the causes of accidents. Furthermore, the applicability of such models for analysis at the organizational and institutional level has already been challenged in the academic literature. An in-depth analysis of the only "Serious Accident" in Japanese HSR is conducted using System-Theoretic Accident Model and Process (STAMP) analysis based on the system-control safety theory. Information on the serious accident obtained through official accident reports and expert interviews is combined, revealing a new accident archetype at the organizational and institutional level. The archetype demonstrates the common failure causes for the operator and the regulator, thereby making their apparent redundancy ineffective. The archetype demonstrates that the accident can happen when both the operator and the regulator base their decision-making on the same set of faulty information based on unsystematic risk-assessment methods. The archetype is helpful in identifying theoretical improvements in current safety practices, such as independent risk-assessments for both the operator and the regulator, as well as developing leading indicators (indicators that indicate the presence of accident causal factors) for non-technical components. The study thus identifies that, despite having achieved remarkable safety performance, the

Japanese HSR system relies on excessively often-unsystematic risk-assessment methods, making them vulnerable to the systemic factors that could render multiple defenses ineffective simultaneously, under the ever-growing complexity.

Then, the study develops a leading indicator scheme that could be implemented at the organizational and institutional level by considering several modifications from the existing approaches. The most important among these is the identification of a suitable receiver of the warning signals generated upon monitoring the leading indicator. Two new suitability criteria are proposed in and are validated using real accidents. The criteria are that the warning signal generated upon monitoring the leading indicators should a.) Reach to at-least one controller, who can provide actions to the sub-system concerned b.) reach to at least one controller, who can sense the local adaptation by the components under that controller. The approach thus developed is grounded in safety theory, but when applied to a complex system in Japan, i.e., a decentralized wastewater treatment unit provided mixed results. While the approach was more comprehensive in identifying 15 new leading indicators for the wastewater system, the decision on whether to monitor these indicators is dependent on several trade-offs. These trade-offs include the capacity constraints at the regulator level as well as the necessity to strike a balance between the adequate level of control and autonomy.

Finally, a System Dynamics (SD) model representing the dynamics of people, structure, and the management policy within an organization is developed to identify factors and their impact upon the quality of the *Feedback*. The SD model development involves three main steps – a.) development of the causal structure, b.) validation of the model structure, parameter estimation, and behavior validation, and c.) Simulation and policy analysis. While model development and validation, is suitable in identifying the relevant factors, the simulation and policy analysis are suitable to assess their impact on reporting behavior. Cross-industry literature was first reviewed to develop a dynamic hypothesis explaining employee's near-miss reporting behavior. The dynamic hypothesis was then validated within the Japanese HSR context through semi-structured interviews involving senior experts from two different HSR operators in Japan using a disconfirmation approach. The key factors affecting the reporting behavior are workload and fatigue level of employees, incentive structure, and management's commitment to safety in providing feedback to reported incidents. An executable simulation model using the causal factors was then developed and was

calibrated using 3 months of daily safety observation data for a construction company. The same causal structure was also validated through the simulation, revealing a level of generalizability for the proposed model. The simulation results developed resembled the trends observed in the data obtained from the construction company on a total of 5 aspects. Simulations were then carried out for testing several policies revealing the path-dependent nature of the results obtained from a policy to reduce the number of working hours, as well as variation in the effect of similar incentives on different types of incident reports, reports in an HSR operator. The numerically executable SD model thus provides an important policy analysis tool to analyze the organizational factors affecting the quality of the near-miss reports in an organization and are shown to be having implications for the Japanese HSR TOCs.

The study has examined organizational and institutional factors affecting HSR safety performance and makes a case for utilizing the system-control-safety theory for pro-active safety management in the Japanese Shinkansen. Through the archetype, the study identifies the necessity of systematic and independent risk assessment by the regulator using a proactive method such as the leading indicators. While the leading indicator implementation study highlights the trade-offs involved in implementing proactive measures. Further, the SD model reveals the dynamic interdependence among a variety of factors. Considering the key messages from all the sections, the study proposes improvements in the current RM practices in Japanese HSR. The proposal identifies the necessity for first carrying out a detailed risk-assessment followed by the due consideration of the trade-off and the dynamics to set up an adequate level and periodicity of monitoring. Such a solution is deemed a win-win approach that can assure safety by adequately considering the system-specific risks while avoiding the burden of extensive indicator monitoring.

Keywords: Shinkansen Safety, Organizational factors, operator-regulator relationship, systems thinking, leading indicators, system dynamics