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Human Error Incident Study of Korean High-Speed Train Drivers Using the HEAR Methodology*

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Abstract

Purpose: Apply HEAR to driver-related human-error incidents in Korea—especially high-speed train operations—to identify dominant error–cause–outcome patterns and practical implications. **Research design, data and methodology:** Retrospective review of Korea Railroad Corporation records (2012–2021). We selected driver-related human-error cases and isolated high-speed operations. Errors were classified as execution, decision-making, situational judgment, or information perception; causes and outcomes were standardized. Descriptive statistics and cross-tabulations summarized distributions and frequent combinations. **Results:** By train type, incidents: conventional 45%, urban 39%, high-speed 16%. In the high-speed subset, decision-making errors predominated. Leading causes were improper work methods and negligent equipment handling; leading outcomes were service disruption, then worker injury and emergency stop. About 25% caused actual damage; injuries were approximately 20%. **Conclusions:** Priorities include refined SOPs and dual checks for high-risk tasks, simulator-based repetitive training with real-time risk feedback, improved working conditions (fatigue and cab air quality), and deployment of driver-assistance and automatic safety systems (e.g., ATS). The HEAR-based schema exposes a small set of decision-linked patterns explaining much of the risk in high-speed operations.

Keywords : Train Drivers, High-Speed Trains, Human Error, HEAR Methodology, Railway Safety

JEL Classification Code: J28, L92, R41

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1. Introduction

1.1. Research Background

Railways are a representative mode of mass transportation that move large numbers of people and substantial assets at once; accordingly, safety is a core value of the railway industry and the foundation of public trust. A substantial share of accidents originates in human error by railway personnel—such as train drivers, dispatchers, and track workers—and even minor lapses by drivers (e.g., carelessness, rule violations, judgment errors) can lead to catastrophic outcomes under the high speeds and dense headways characteristic of high-speed rail (HSR) and urban rail systems. Over the past decade, human error has accounted for a non-trivial portion of railway accidents in Korea, with driver-related human error reported to comprise about 18.9% of all cases (Kang & Park, 2024). This underscores that managing and preventing human error is a critical determinant of railway safety.

Korea's KTX high-speed trains, which can carry roughly 1,000 passengers per train and have operated since 2004, have markedly improved mobility for business and leisure. However, the transition from conventional rail to HSR has increased both the risk and scale of accidents commensurate with higher speeds, thereby amplifying the potential impact of incidents attributable to driver human error.

1.2. Problem Statement and Research Objectives

Concerns about the proportion of human error in railway accidents in Korea have been raised consistently in government reports and academic studies. Analyses of recent collisions and derailments indicate frequent cases attributable to train drivers' carelessness, signal misperception, and non-compliance with rules. Building on this problem awareness, the present study pursues four objectives: (1) to present reliable statistics on the actual proportions and counts of railway accidents caused by human error; (2) to elucidate the mechanisms of occurrence by conducting a literature-based, multi-faceted analysis of specific driver factors—fatigue, reduced attentional capacity, information-perception errors, and rule violations; (3) to quantitatively assess changes in accident counts following recent policy measures such as the expansion of simulator training and the introduction of a near-miss reporting system, thereby evaluating their effectiveness; and (4) to integrate three countermeasure tracks—enhanced education and training, the adoption of advanced technologies, and improvements in working conditions—to clarify how they complement one another in reducing human error. The ultimate aim is to derive practical and actionable measures for preventing human-error incidents by high-speed train drivers.

1.3. Scope and Methods

This study conducts a literature-based inquiry into the causes of, and countermeasures for, human error by train drivers. As a conceptual framework, we employ the HEAR (Human Error Analysis and Reduction) methodology to systematically interpret the error types and event progressions embedded in accident cases. Developed for the railway domain by the KAIST Railway Safety Research team and collaborators, HEAR classifies error types—such as execution errors, decision-making errors, and situational-judgment errors—and provides procedures for tracing root causes and formulating recurrence 20prevention measures (Kim et al., 2009). Applying HEAR, we identify incidents involving human error by high-speed train drivers, analyze their underlying causes, and ultimately propose targeted countermeasures for preventing human-error incidents in HSR operations.

2. Research Methods and Materials

This study systematically reviewed Korea Railroad Corporation (KORAIL) accident/disruption records for the ten-year period 2012–2021 with the aim of analyzing the characteristics of incidents attributable to train drivers' human error. First, from the full corpus we selected only those cases in which the causal attribution to railway personnel's human factors (e.g., carelessness, rule violation, misjudgment) was explicit. Second, we isolated the subset occurring in high-speed train operations to form the final analytical sample. The sample included all human-error–related events regardless of severity or KORAIL's internal classifications (e.g., hazardous event, accident, disruption), thereby incorporating near misses. This inclusive design follows Heinrich's law, which posits that frequent minor events can foreshadow major accidents, and was adopted to identify underlying causes and recurring patterns.

Operational definitions for the key variable, error type, followed the HEAR (Human Error Analysis and Reduction) framework. Errors were classified into four categories: execution errors (failures during action following a decision), decision-making errors (failure to select an appropriate course of action), situational-judgment errors (inaccurate situational assessment), and information-perception errors (failure to correctly perceive or interpret required information).

The cause taxonomy drew on frequently observed human-error causes in prior research and comprised ten categories (e.g., negligent equipment handling, negligent signal checking, improper driving method), referencing Joo (2014). The outcome taxonomy comprised thirteen categories, including train failure, emergency stop, train collision, and derailment, among others.

Analytically, we employed descriptive statistics. First, we computed counts and shares of driver-related human-error incidents by train category to gauge their frequency in high-speed operations. Second, we presented the distributions and cross-tabulations of error types, causes, and outcomes to identify high-risk combinations. Third, we provided a narrative linkage between frequent error types and salient outcomes in the high-speed context (e.g., collisions/derailments, magnitude of service delay). In sum, by stratifying driver human-error incidents in high-speed operations from a decade of records and applying the HEAR-based classification, we delineated the error–cause–outcome structure to reveal recurring patterns and priority areas for safety management in HSR operations.

3. Results

Over the ten-year period, the distribution of driver-related human-error incidents by rail category was conventional rail (45%), urban rail (39%), and high-speed rail (16%). Within the high-speed subset, decision-making errors accounted for a majority of cases, indicating that correct decision-making under high running speeds is intrinsically difficult and that repetitive training and sustained concentration are required (see Figure 1).

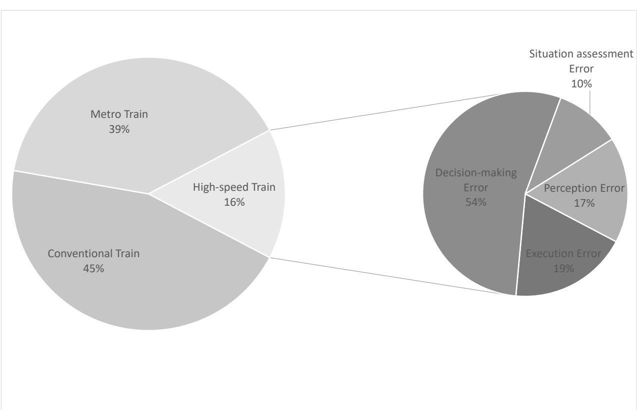

Figure 1: Ratio of incidents by train types & error types

Analyses of causes and outcomes for high-speed cases are summarized as follows. For causes, improper work methods showed the highest frequency, followed by negligent equipment handling, suggesting that non-adherence to procedures, habitual shortcuts, or momentary lapses leading to inadequate equipment handling account for a substantial share of incidents (see Figure 2). For outcomes, service disruption was most frequent, followed by worker injury and emergency stop (see Figure 3). Although only about 25% of the analyzed cases escalated to accidents with actual damage, the approximately 20% share of worker injuries implies that human-error incidents in high-speed contexts can readily lead to high-severity events. Moreover, while emergency stops are classified as near misses when no direct damage ensues, such events—especially near stations or during high-speed running—carry latent risk of secondary harm (e.g., passenger falls or collisions).

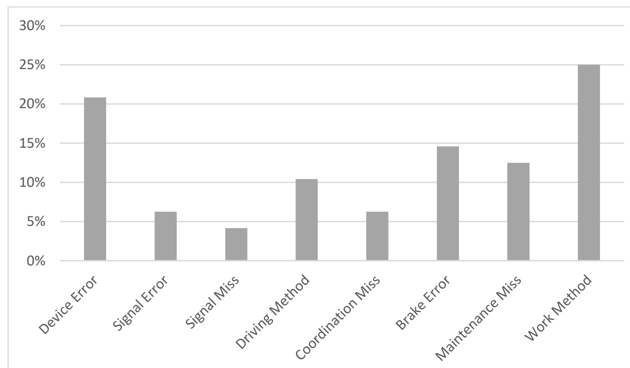

Figure 2: Ratio of incidents by causes

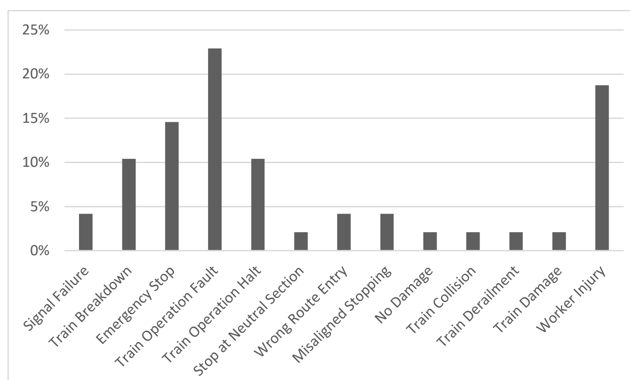

Figure 3: Ratio of incidents by results

To explore underlying causes, we matched error types with causal factors for high-speed driver incidents and summarized the results as incident-type combinations (see Table 1). The most frequent combination was decision-making error × improper work method, followed by decision-making error × improper brake handling. Because high-speed operations require rapid comprehension and judgment over multiple concurrent cues, accumulating driver fatigue can hinder rule-compliant decision-making; when such hindrances compound, they contribute to the genesis of major accidents. Accordingly, reducing human-error incidents in high-speed operations calls for decisionsupport aids and repeated training and education tailored to these high-risk combinations.

Table 1: Ratio of incident types

Type of incidents	Ratio (%)
Improper work method caused by decision error	16.7
Improper brake handling caused by decision error	10.4
Negligent equipment handling caused by decision error	8.3
Negligent equipment handling caused by information perception error	6.3
Negligent maintenance caused by execution error	6.3
Improper driving method caused by decision error	6.3
Improper work method caused by situational judgment error	4.2
Negligent driving coordination caused by information perception error	4.2
Negligent equipment handling caused by execution error	4.2
Negligent signal checking caused by decision error	4.2
Negligent maintenance caused by decision error	4.2
Improper brake handling caused by execution error	4.2
Improper signal handling caused by decision error	4.2
Negligent equipment handling caused by situational judgment error	2.1
Improper driving method caused by situational judgment error	2.1
Negligent driving coordination caused by situational judgment error	2.1
Improper signal handling caused by information perception error	2.1
Negligent maintenance caused by information perception error	2.1
Improper work method caused by information perception error	2.1
Improper driving method caused by execution error	2.1
Improper work method caused by execution error	2.1

4. Discussion

The share of high-speed rail (HSR) within driver-related human-error incidents was relatively lower than that of conventional and urban rail. However, because HSR operates at speeds up to about 300 km/h, incidents attributable to human factors during high-speed running can lead to comparatively greater damage. The 2022 derailment of a high-speed train near the Yeongdong Tunnel resulted not only in train damage but also in damage to rails, sleepers, and catenary, as well as passenger injuries caused by shattered window glass. This underscores the need to secure safety in HSR, which inherently entails higher risk, to prevent such major accidents (ARAIB, 2022).

Sustained high-speed operation in a confined cab can readily induce fatigue and reduced concentration for drivers. In particular, under single-person operation, the driver's burden inevitably increases when complex situations—such as signal issues or rolling-stock failures—arise. These background conditions raise the likelihood of confusion or transient panic at the moment of an incident and ultimately increase the probability of a train accident. The finding that decision-making errors account for the largest share of error types in HSR is consistent with these background factors.

Drivers must rapidly perceive diverse information during operation and make subsequent decisions for the next course of action. Under high-speed conditions, however, the volume and tempo of information increase, and excessive complexity can trigger perceptual mistakes. This pattern appears in our results: one of the most frequent categories involved information-perception errors that led to negligent equipment handling. Errors also arose from negligent driving coordination when the volume and complexity of information contributed to lapses in operational consultation.

To prevent such human errors, education and training should be strengthened. While conventional programs emphasize stable driving techniques, training must expand to human-factor–oriented content to enhance safety awareness and prevention capability. In particular, effective training should provide real-time estimates of incident risk for behaviors or judgments that induce errors during practice, thereby discouraging such actions at an unconscious level. By offering diverse scenarios, drivers can repeatedly rehearse responses to rare or emergency situations, helping ensure that rule-compliant behavior is activated automatically in real operations (Olsson et al., 2023).

Improvements in working conditions and individual health management are also essential. To address fatigue accumulation from long and shift work, adequate rest must be guaranteed and the working environment improved. Notably, increased CO_2 concentration in the cab can induce sleepiness, and exposure to volatile organic compounds and other harmful agents can cause eye irritation and dizziness, adversely affecting drivers' perception and judgment during operation (Barnes et al., 2018). Moreover, prior research indicates that poor sleep quality and experiences of post-traumatic stress are associated with increased human errors, highlighting the need to attend to both physical and mental health (Jeon et al., 2014).

Finally, adopting advanced technologies that reduce driver workload and provide real-time feedback is necessary to prevent safety incidents. For example, radio-controlled shunting systems and automatic train stop (ATS) can mitigate decision errors by drivers and contribute to enhanced operational safety.

5. Conclusions

This study systematically reviewed KORAIL accident and disruption records from 2012–2021, identified incidents attributable to train drivers' human error, and extracted the subset occurring in high-speed rail (HSR) operations. Using the HEAR (Human Error Analysis and Reduction) framework, we standardized each case into error types, causes, and outcomes and analyzed them with descriptive statistics. By including near misses irrespective of internal classifications or severity, the design sought to detect recurring risk patterns in small, repeated events—an approach aligned with Heinrich's law and appropriate for major-accident prevention.

Key findings are as follows. First, the distribution by rail category was conventional 45%, urban 39%, and high-speed 16%. Although the HSR share is relatively small, the potential scale and propagation of damage at high speed requires focused management. Second, within HSR cases, decision-making errors formed the majority, consistent with the cognitive load of rapid, multi-cue judgments under high-speed running and single-person operation with accumulated fatigue. Third, on causes, improper work methods ranked highest, followed by negligent equipment handling; on outcomes, service disruption was most frequent, followed by worker injury and emergency stop. While roughly 25% of cases produced actual damage, the approximately 20% share of injuries underscores the latent severity of human-error events in HSR.

Implications are fourfold. (1) Given operating speeds approaching 300 km/h, severity management is paramount: refine SOPs, strengthen control-center/field communication protocols, and institute dual checks for high-risk tasks (braking and signals). (2) On training, prioritize simulator-based repetitive drills for rare/abnormal scenarios with real-time risk feedback to automate rule-compliant behavior. (3) On working conditions, mitigate fatigue via shift/rest design and improve cab air quality to stabilize perception and judgment under information overload. (4) On technology, deploy driver-assistance and automatic safety systems (e.g., ATS) to create technical defenses against signal misperception and overspeed.

In sum, the study identifies decision-linked patterns and their dominant cause–outcome combinations in HSR and proposes an integrated education–technology–environment strategy. Future work should maintain a consistent classification scheme, institutionalize line/phase-level comparisons and temporal monitoring, and evaluate pre–post changes after interventions. Such stepwise maturation will clarify priority management areas and strengthen the capacity to prevent major accidents in high-speed operations.

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