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Design and Evaluation Methods for Non-Technical Skills Training for Shinkansen Train Crew

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ABSTRACT

In recent years, several railway accidents and incidents have continued to occur due to human error, indicating that further safety improvements are required even in highly developed railway systems such as the Shinkansen. Analyses of recent incidents at East Japan Railway Company (JR East) have revealed that, in addition to technical skills (TS), non-technical skills (NTS)—particularly situation awareness—play a critical role in accident prevention. However, current training programs mainly focus on procedural compliance and do not sufficiently address individual differences in NTS, nor do they provide objective and consistent evaluation criteria for such skills. This study proposes a methodology for designing NTS-oriented training scenarios tailored to the individual characteristics of Shinkansen crew members and for developing quantitative evaluation indicators for NTS. First, crew members' individual characteristics were classified into three error tendency types—lapse, automatic action errors, and decision errors—based on previous incident analyses and a self-assessment questionnaire. Next, the relationships between these individual characteristics and a JR East–specific NTS framework were systematically organized, and NTS elements requiring reinforcement were identified for each type. Based on this framework, NTS components were embedded into existing simulator-based training scenarios, using a rolling stock failure response by a train driver as an illustrative example. Additional scenario elements were designed to elicit observable NTS behaviors, such as situation awareness, decision making, and communication with dispatchers and conductors. Furthermore, behaviorally anchored, three-level quantitative evaluation indicators ("Adequately Demonstrated," "Partially Demonstrated," and "Not Demonstrated") were developed to reduce subjectivity and inter-instructor variability in NTS assessment. The proposed approach enables the integrated training and evaluation of TS and NTS while accounting for individual differences among crew members. This framework is expected to enhance abnormal situation handling capabilities of Shinkansen crew and to contribute to further improvements in railway safety through more systematic and objective NTS training.

Keywords: Non-technical skills, Railway safety, Simulator-based training, Individual differences, Behavioral evaluation

INTRODUCTION

Since its establishment, East Japan Railway Company (JR East) has positioned "safety" as the highest management priority and has promoted company-wide initiatives to enhance safety levels through the collective efforts of

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all employees. To date, JR East has invested more than approximately 5.5 trillion yen in safety-related measures and has promoted safety initiatives at individual workplaces (East Japan Railway Company, n.d.). As a result of these sustained efforts, railway accidents and incidents within the JR East operating area have shown a downward trend since 1987 (East Japan Railway Company, 2024). Nevertheless, since fiscal year 2019, a number of incidents have continued to occur in which railway workers narrowly avoided being struck by operating trains while working on or near tracks, indicating that the complete elimination of accidents and incidents has yet to be achieved.

With the aim of preventing accidents and incidents caused by human error—not limited to train–worker contact accidents—we conducted a factor analysis of incidents that occurred from fiscal year 2019 onward. The results revealed that, in addition to factors related to technical skills (TS), defined as the knowledge and skills required to reliably execute procedures prescribed in manuals, non-technical skills (NTS), such as situation awareness and communication, also contributed to the occurrence of incidents. In particular, among factors related to NTS, approximately 81% were attributable to errors in situation awareness (Kaneko et al., 2025). This finding suggests that such tendencies are not unique to train–worker contact accidents but are also common to other accidents and incidents caused by human error.

Industries such as aviation, medical, railways, and nuclear power are regarded as socio-technical systems in which safety is established through the interaction of people, technology, and organizations. To improve safety in such systems, research on NTS has been advanced by Flin and other researchers (Flin, O'Connor and Crichton, 2021). Kodate et al. (2012) argue that, in addition to TS, the systematic identification, training, and evaluation of NTS—such as situation awareness, decision-making, communication, and teamwork—are essential.

At JR East, the introduction of NTS into training programs is also being considered to enhance railway transportation safety. However, two major challenges arise when designing training programs that incorporate NTS. The first challenge is that the strengths and weaknesses of NTS vary depending on individual characteristics. Previous studies have addressed training adapted to individual characteristics (Pears et al., 2021; Perera, Myers and Griffiths, 2022), but insufficient attention has been paid to methods for designing or modifying training scenarios themselves in accordance with the characteristics of individual trainees. The second challenge is that NTS consists of many abstract concepts, making it difficult to define clear and objective evaluation indicators. Research on the evaluation of NTS has been conducted in industries (Çeken and Acar, 2025; Pimenta et al., 2025; RSSB, n.d.). However, these studies have also pointed out that NTS evaluation relies heavily on observer subjectivity, making it difficult to ensure consistency in assessment.

This study aims to identify the individual characteristics of Shinkansen crew members and to develop a methodology for designing training scenarios tailored to their respective weaknesses. Subsequently, quantitative evaluation indicators for NTS will be developed for the designed training scenarios.

METHODS

Training Scenario Design

In this study, we first organize the relationships between NTS and individual characteristics of Shinkansen crew members, and then develop a methodology for incorporating these elements into existing training scenarios.

Current Shinkansen training primarily focuses on verifying TS. However, the proposed methodology enables the design of training programs that integrate both TS and NTS. Furthermore, by embedding NTS components into existing training scenarios, this approach offers the additional advantage of reducing the workload for training designers while enhancing the educational value of the training.

Definition of the Relationship Between the JR East–Specific NTS Framework and Individual Characteristics

Kaneko et al. organized a JR East–specific NTS framework based on an analysis of 50 high-risk railway events—such as train–worker contact incidents, signal passed at danger, and electric shock accidents—that occurred within JR East between fiscal years 2018 and 2022 (Table 1).

In the present study, we define the relationships between the JR East–specific NTS framework proposed by Kaneko et al. and the individual characteristics of Shinkansen crew members. Based on these definitions, the corresponding NTS elements were incorporated into existing training scenarios.

Yamakawa et al.'s previous research findings were used to identify the individual characteristics of JR East crew members. Yamakawa et al. analyzed events involving train drivers that occurred within the JR East operating area between 2009 and 2011, using the JR East–specific 4M4E analysis method (Chiba et al., 2004; Suzuki et al., 2007). Their analysis revealed that approximately 70% of error types fell into three categories: lapse (forgetfulness), Unconscious (Automatic) Action Errors, and decision errors (formerly referred to as judgment errors). Hereafter, we refer to Unconscious (Automatic) Action Errors as "automatic action errors."

Table 1: JR east–specific non-technical skills framework.

Four Safety Skills	Ten Specific Behavioral Skills
Detecting the pitfalls of the job	Keeping aware of situations occurring for the first time, or that involve a change in protocol, or when returning after a long absence, or other potentially risky situations
	Learning how to behave in unfamiliar situations
	Foreseeing risks on the job
Communicating and listening carefully	Effectively communicating and asking "Why?"
	Communicating according to the other party's point of view
	Avoid guessing, verifying until completely clear
Acting resolutely	Reconfirming regardless of the other party's status
	Reporting without concealing difficult situations
Acting safely in Emergencies	Meet emergencies by first taking a deep breath
	When doubtful in abnormal situations, base decisions on safety

Based on these findings, the JR East Research and Development Center developed a questionnaire designed to help crew members identify their own individual characteristics and to increase their awareness of error prevention (Table 2). By responding to the 12 items in the questionnaire, crew members can identify whether they tend to exhibit characteristics associated with the lapse type, the automatic action error type, or the decision error type.

Table 2: Questionnaire for assessing individual characteristics of crew members.

No.	Survey Questions
1	I intended to send a message via LINE, but forgot to send it.
2	I was going up a staircase with uneven step heights, failed to notice the difference, and stumbled.
3	I intended to send an email to a different person, but accidentally sent it to the person I usually email.
4	I was busy at the time, thought I would make a phone call later, and forgot to do so.
5	I did not notice that the position of chairs or tables was different from usual and ended up colliding with them.
6	While thinking about something else, I forgot an item.
7	I was scheduled to take a train in the opposite direction, but unconsciously boarded the train I usually take.
8	I assumed I would turn at an intersection, turned without checking carefully, and ended up going in the wrong direction.
9	I interpreted the other person's words according to my own assumptions and misunderstood them.
10	I forgot something that someone had asked me to do.
11	I assumed that a TV program had been recorded, but when I tried to watch it, I found that it had not been recorded.
12	I assumed that the information I received through TV or the internet was correct without sufficient verification, discussed it with others, and later regretted it.

In this study, the questionnaire was administered to Shinkansen crew members prior to the start of training in order to identify the individual characteristics of each participant, classified as lapse type, the automatic action errors type, or the decision error type.

Subsequently, this study organized the NTS that should be strengthened according to each type of individual characteristic. First, behavioral tendencies corresponding to each individual characteristic were identified by examining the characteristics defined in the JR East–specific 4M4E analysis framework 11) together with the contents of the JR East–specific NTS framework, which consists of ten specific behavioral skills. The results are summarized in Table 3.

Table 3: Behavioral tendencies corresponding to individual characteristics (partial excerpt).

Ten Specific Behavioral Skills	Lapse	Individual Characteristics Unconscious / Automatic Action Errors	Decision Errors
Keeping aware of situations occurring for the first time, or that involve a change in protocol, or when returning after a long absence, or other potentially risky situations	• Unintentionally forgetting to perform required checks. • Forgetting due to distraction by other tasks	• Habitual actions are carried out automatically, as usual, without conscious awareness.	• Forgetting differences from usual conditions. • Failing to recognize differences.
Learning how to behave in unfamiliar situations	• Dismissing a sense of discrepancy as insignificant and consequently forgetting to perform necessary checks or responses. • Noticing a sense of discrepancy but postponing confirmation due to distraction by other tasks or situational demands, ultimately leading to forgetting.	• Dismissing a sensed discrepancy as insignificant and continuing habitual actions. • Failing to notice an abnormality due to habitual, automatic actions.	• Assuming that the current situation is acceptable and consequently neglecting necessary confirmation. • Making incorrect judgments due to bias from past experience or prior information.
Foreseeing risks on the job	• Being distracted by trouble or situational changes and consequently forgetting to perform necessary checks or actions.	• Performing tasks "as usual" and failing to notice anomalies. • Overlooking changes due to habitual actions.	• Assuming that "everything is fine" and failing to implement necessary countermeasures. • Failing to accurately recognize situational changes and making incorrect judgments.
Effectively communicating and asking "Why?"	• Information communicated without a clear purpose or rationale is postponed and ultimately forgotten.	• Taking incorrect actions habitually due to ambiguous instructions.	• Assuming what the other party "probably means" and consequently misunderstanding the information. • Making incorrect judgments due to failure to understand the background or purpose of the information.

Development of Training Scenarios

Training scenarios were developed based on the simulator training conducted by Shinkansen crew members at the General Training Center. In this study, a scenario in which a train driver responds to a rolling stock failure is presented as a representative example.

Table 4 summarizes the content of the current training scenario as well as the key points that instructors focus on during training. In the existing training scenario, particular emphasis is placed on whether the trainee (1) correctly recognizes phenomena that differ from normal conditions, (2) performs actions in accordance with the prescribed manual, and (3) accurately reports the situation to the dispatcher (train traffic controller) and the conductor.

Accordingly, trainees approach the training with a primary focus on demonstrating TS, specifically executing procedures as specified and reporting their actions correctly. Because the training generally proceeds under the assumption that the dispatcher and conductor with whom the driver communicates do not make errors, deficiencies in NTS tend to be overlooked as long as the correct technical actions are performed.

Furthermore, another limitation of the current approach is that the same training content is uniformly applied to all trainees, without consideration of individual strengths and weaknesses.

Table 4: Current training scenario (train driver response to rolling stock failure).

Scenario Flow	Points Confirmed by the Instructor
During operation, an indicator light showing a vehiclefailure illuminates	Whether the driver correctly noticed the illuminated indicator light
Take action in accordance with the manual	• Whether the correct page of the manual was opened • Whether the correct procedures were carried out in accordance with the manual
Contact the dispatcher	Whether the driver accurately reported the actions taken to the dispatcher
Contact the conductor	Whether the situation was accurately reported to the conductor
End	—

Based on the definitions of the relationships between NTS and individual characteristics presented in Table 3, this study incorporated NTS related elements into the existing training scenarios. As in the previous section, a training scenario involving a train driver's response to a rolling stock failure is used as an illustrative example, and the modified training scenario integrating NTS elements is shown in Table 5. In this section, the scenario was designed specifically for trainees characterized by the "decision error" type of individual characteristic. More specifically, in order to assess the trainee's NTS, two additional scenarios were newly introduced, as described below.

Table 5: NTS integrated training scenario (train driver response to rolling stock failure).

Scenario Flow	Instructor Verification Points (NTS-related)	Individual Trait Focus	Related NTS (Primary)
During operation, an indicator light signaling a vehicle system failure illuminates			Situation Awareness (perception of abnormal indications)
Take actions in accordance with the operation manual Contact the dispatcher			Decision Making (procedure selection & execution)
Case ① **The dispatcher mistakenly restores the fault**	• **Actions taken in response to an incorrect restoration** × Continued reporting without noticing the incorrect restoration × Failure to notice the incorrect restoration and continuing to report o Whether the driver clearly explains the rationale, including "why," rather than only stating "It is wrong." *(Ex.) "The indicator light for Unit No. X is illuminated, therefore this is a fault of Unit No. X."*	Decision error type (assumes shared understanding; omits verification)	• Effectively communicating and asking "Why?" • Mistakenly assuming the other party will understand • Avoid guessing, verifying until completely clear • Assuming mutual understanding and proceeding based on that assumption • Skipping confirmation and taking action based on a misunderstanding
Contact the conductor			
Case ② **The conductor reported that it was hot inside the train**	• **Content of the information provided to the conductor** × Responding only with "Understood." × Explaining the situation using technical terms not easily understood by the conductor O Whether the current condition of the train (e.g., partial air depletion due to vehicle fault procedures) is communicated using language understandable to the conductor	Decision error type (bases judgment on the assumption that the receiver understood)	• Communicating according to the other party's point of view • Making incorrect judgments based on the assumption that the other party understands
End			

Case ①

In this scenario, the dispatcher who receives a report of a rolling stock failure from the train driver incorrectly repeats back the car number and the type of failure.

The instructor observes how the driver responds to this incorrect readback. If the driver fails to notice the error in the readback, or notices the error but proceeds with reporting without seeking clarification from the dispatcher, the instructor judges that NTS have not been adequately demonstrated.

In contrast, if the driver not only states that the readback is incorrect (e.g., "That is incorrect") but also provides a correction accompanied by a clear rationale (i.e., explaining why it is incorrect), the instructor judges that NTS have been demonstrated. Accordingly, this scenario enables assessment of two NTS elements in the trainee:

(1) clear communication that includes rationale ("why"), and
(2) confirmation without speculation until mutual understanding is achieved.

Case ②

In this scenario, after the driver reports the situation to the conductor, the conductor states that "the passenger cabin is hot."

The instructor evaluates how the driver responds to this report from the conductor. If the driver merely acknowledges the statement (e.g., saying "Understood") without further engagement, or explains the situation using technical terminology that the conductor cannot reasonably understand, the instructor judges that NTS have not been demonstrated.

In contrast, if the driver explains the vehicle condition using language that is understandable to the conductor, the instructor judges that NTS have been demonstrated. This scenario enables assessment of the trainee's NTS related to communication adapted to the other party's level of understanding.

By adding these two scenarios to the existing training program, which primarily focuses on the evaluation of TS, it becomes possible to promote the development of both TS and NTS within simulator-based training.

Development of Quantitative NTS Evaluation Indicators

In the railway domain, training has traditionally been influenced by a strong culture of "experience-based engineering." As a result, evaluations during training tend to rely heavily on instructors' personal experience, leading to considerable variability in evaluation criteria. Furthermore, during post training debriefings, while instruction related to TS is typically provided based on regulations and manuals, instructors often find it difficult to clearly point out the appropriateness or inappropriateness of trainee behaviour with respect to more abstract concepts such as situation awareness, decision making, and communication.

To address these evaluation related challenges, this study developed quantitative evaluation indicators for NTS. In constructing the evaluation indicators, the core NTS components defined by Flin et al.—namely, situation awareness, decision making, communication, and teamwork—were adopted as the conceptual framework 4).

Based on the training scenarios developed in the previous section, each of these NTS components was translated into observable and concrete behaviors that can be identified in Shinkansen crew training contexts. Using these behaviorally anchored definitions, evaluation indicators were developed for Scenario ① and Scenario ②, respectively (Tables 6 and 7).

Because the current Shinkansen crew training program employs a three level rating scale for the evaluation of TS, the same three level scale was adopted for NTS assessment. Specifically, the following evaluation categories were defined: "Adequately Demonstrated," "Partially Demonstrated," and "Not Demonstrated." Based on the content of each scenario, concrete behaviors associated with the respective NTS components were organized under these three evaluation levels.

Table 6. Evaluation indicators for Case ①: dispatcher's incorrect readback scenario.

Rating	Evaluation Criterion	Specific Behaviors (Linked to NTS Components)
1: Adequately Demonstrated	Corrective actions are executed and shared clearly, calmly, and explicitly based on sound justification.	• **Situation Awareness:** Correctly interprets discrepancies between the dispatcher's restoration and the driver's own understanding of the system status. • **Decision Making:** Prioritizes accurate information sharing over hierarchical considerations and selects appropriate corrective actions. • **Communication:** Clearly and concisely communicates the correction, including the justification (the "why"), and confirms that the counterpart has correctly understood the revised information after the correction.
2: Partially Demonstrated	Correction is communicated, but there are limitations in the clarity and/or justification provided.	• **Situation Awareness:** Notices that the information provided is incorrect. • **Decision Making:** Attempts to correct the error, but exhibits hesitation influenced by the dispatcher's seniority or authority. • **Communication:** Communicates only factual disagreement (e.g., "That is incorrect; it is unit No. X") but fails to sufficiently convey the underlying rationale (the "why").
3: Not Demonstrated	Fails to recognize or point out the error and accepts incorrect information without correction.	• **Situation Awareness:** Accepts the dispatcher's incorrect information as is and fails to properly interpret the situation. • **Decision Making:** Is unable to clearly identify the problem or execute appropriate corrective actions. • **Communication:** Fails to overcome communication barriers (e.g., hierarchy or assumptions), resulting in uncorrected misunderstanding.

Table 7. Evaluation indicators for Case ②: scenario involving response to a report from the conductor.

Rating	Evaluation Criterion	Specific Behaviors (Linked to NTS Components)
1: Adequately Demonstrated	Demonstrates an understanding of the conductor's role and appropriately shares information necessary for passenger communication.	• **Situation Awareness:** Correctly recognizes that the conductor is directly dealing with passenger complaints and concerns. • **Communication:** Conveys the fact that "air pressure is reduced by half due to power isolation" using clear, plain language, avoiding technical jargon, so that the conductor can directly relay the information to passengers. • **Teamwork:** Shares expectations regarding the resolution of the current situation and the anticipated next steps.
2: Partially Demonstrated	Conveys factual information, but shows insufficient consideration from the conductor's perspective.	• **Situation Awareness:** Understands one's own task status, but insufficiently anticipates the situation faced by the conductor. • **Communication:** Communication remains framed from the driver's perspective (e.g., "power isolation in progress") and lacks consideration of how the conductor should explain the situation to passengers (i.e., limited adaptation to the receiver's understanding). • **Teamwork:** Exchanges information, but the support provided is insufficient to enable the conductor to effectively assist passengers.
3: Not Demonstrated	Information sharing is insufficient, or coordination is unilaterally lacking.	• **Situation Awareness:** Interprets contact from the conductor as an interruption of one's own task and fails to recognize the necessity of sharing situational information. • **Communication:** Provides vague or dismissive responses, or withholds information, thereby missing opportunities to support subsequent actions. **Teamwork:** Misjudges priorities for coordination and makes decisions that undermine team-level safety actions during abnormal situations.

The three level evaluation criteria presented in Table 6 were defined based on the following standards.

"Adequately Demonstrated" refers to a state in which all three elements—recognition, reasoned correction, and verification of mutual understanding—are present. In this state, communication errors are intercepted before propagating, thereby preventing the escalation of incidents. As a result, this level of performance also contributes to earlier resumption of operations.

"Partially Demonstrated" refers to a state in which one or more of the three elements—recognition, reasoned correction, or verification of mutual understanding—is insufficient. In such cases, corrective actions are shared in

an ambiguous manner, which may lead to differences in interpretation among individuals. Consequently, additional confirmation or rework becomes necessary, resulting in reduced efficiency and reliability.

"Not Demonstrated" refers to a state in which recognition is absent or incorrect, and therefore neither reasoned correction nor verification of mutual understanding is performed. In this state, actions may proceed based on an incorrect understanding, raising concerns that errors may propagate and increase the risk of incident escalation.

Furthermore, based on these evaluation criteria, concrete NTS related behaviors associated with situation awareness, decision making, and communication were defined.

The three level evaluation criteria presented in Table 7 were defined based on the following standards.

"Adequately Demonstrated" refers to a state in which all three elements—avoiding the use of technical terminology, communicating the current situation and future outlook, and confirming the other party's understanding—are present. In this state, the conductor is able to provide passenger guidance promptly, accurately, and without hesitation.

"Partially Demonstrated" refers to a state in which one or more of the three elements—avoiding technical terminology, communicating the current situation and future outlook, or confirming the other party's understanding—is insufficient. In this state, the conductor is able to explain the situation to passengers to some extent; however, uncertainty or anxiety may remain.

"Not Demonstrated" refers to a state in which coordination itself is not achieved due to insufficient information, postponement of information sharing, fragmented communication, or lack of response. In this state, the conductor is unable to obtain the information necessary to explain the situation to passengers, raising concerns that team based safety behavior may be weakened during abnormal situations.

Furthermore, based on these evaluation criteria, concrete NTS related behaviors associated with situation awareness, communication, and teamwork were defined.

As illustrated in Tables 6 and 7, explicitly specifying observable behaviors corresponding to each skill makes it possible to reduce inter instructor variability in evaluations during training.

CONCLUSION AND FUTURE WORK

This study focused on Shinkansen crew members and developed a methodology for designing NTS oriented training scenarios based on individual characteristics, as well as quantitative evaluation indicators for NTS.

First, the relationships between the JR East–specific NTS framework and individual characteristics—namely, lapse, automatic action errors, and decision errors—were systematically organized. Based on this classification, the NTS elements that should be strengthened for each individual characteristic were clearly identified. Then, drawing on the behavioral tendencies associated

with each individual characteristic, a design approach was proposed to integrate NTS elements into existing simulator-based training scenarios for responding to rolling stock failures. As a result, a training mechanism was established that enables instructors to observe the demonstration of concrete NTS—such as clear communication and confirmation behaviors that avoid speculation—which are difficult to capture in conventional training that primarily emphasizes procedural compliance. Furthermore, to address the challenge of variability in instructor evaluations, three level quantitative evaluation indicators based on the four core NTS components were developed, providing a foundation for clarifying behavioral criteria and standardizing evaluations.

With respect to future work, several directions can be identified. First, it is necessary to apply the training scenarios and evaluation indicators developed in this study to actual Shinkansen crew training and to verify their validity and effectiveness. In particular, examining whether consistency among instructors' evaluations can be ensured—through assessment of inter rater reliability—is essential for deploying the quantitative evaluation indicators in practical training settings.

Second, it is also necessary to integrate the evaluation indicators developed in this study with routine, regularly conducted training programs at the workplace (approximately 24 hours per year for drivers and around 20 hours per year for conductors). By doing so, individual strengths and weaknesses in NTS can be continuously monitored and reflected in long term training plans. While the simulator-based training examined in this study is conducted once every two years and provides intensive training focused on abnormal situations, applying the NTS evaluation indicators to routine training would enable continuous follow up of issues identified during simulator training and facilitate assessment of long term NTS training effects.

The approach proposed in this study can be positioned as a new framework for comprehensively enhancing the decision-making ability, situation awareness, and communication skills required of Shinkansen crew members during abnormal situations. Through continued practical validation and iterative improvement in operational use, this framework is expected to contribute to further enhancement of railway transportation safety.

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