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A Comparative Risk Assessment of Remote Control Locomotive Operations versus Conventional Yard Switching Operations

SUMMARY

This study involved a comparative risk assessment of U.S. remote control locomotive (RCL) and conventional yard switching operations. Figure 1 illustrates the nature of RCL operations. First, a hierarchical task analysis provided a description of yard switching tasks. Based on the task analysis, a preliminary hazard analysis and human reliability assessment were performed. For each method of operation, the preliminary hazard analysis identified a worst credible scenario for 19 potential outcomes. Each scenario was assigned a risk score based on an assessment of the likelihood of occurrence and potential severity. The human reliability assessment consisted of two, complementary techniques: The Human Error Assessment and Reduction Technique (HEART) and Absolute Probability Judgment (APJ). A set of yard operating scenarios was developed to provide the basis for the HEART and APJ assessments. Analysis of preliminary hazard analysis variables indicated that the 19 RCL worst credible scenarios yielded a higher total risk score compared to 19 similar conventional worst credible scenarios. The HEART assessment did not reveal any differences between the two methods of operation in terms of human error probabilities (HEP); however, substantial variability existed in HEP assignments between assessors, suggesting that HEART may be inappropriate as a human reliability assessment technique for the railroad yard-switching environment. The APJ data show a trend toward greater HEP for RCL scenarios, although individual HEP values varied across a large range. The HEART and APJ results should be considered preliminary and interpreted with caution due to their subjective nature and the numerous study limitations and methodological challenges.

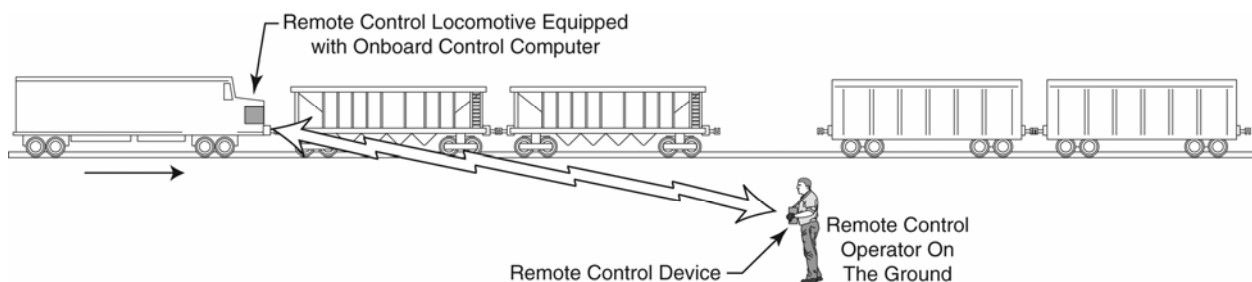


Figure 1. Basic illustration of RCL operation



BACKGROUND

In an effort to reduce operating costs and increase safety, U.S. Class I freight railroads have initiated RCL operations in and around railroad yards. Although the technology has existed for decades, the safety implications of using these devices in the U.S. railroad industry remain unknown. To better understand the safety implications of RCL operations, FRA Office of Research and Development Human Factors Program and FRA Office of Safety initiated several safety studies of RCL operations. This summary presents the results of a comparative risk assessment of RCL and conventional yard switching operations.

OBJECTIVES

The objectives of this research study were to:

- Select one or more operationally relevant and suitable risk assessment technique(s).
- Apply these technique(s) to both RCL operations and conventional yard switching operations.
- Evaluate the relative safety of RCL operations compared to conventional yard switching operations.

METHODS

Risk assessment fundamentally consists of answering the following questions: (1) what can happen (go wrong)? (2) How likely is it that it will happen? And (3) what are the consequences if it does happen? Traditional risk assessment methods have not explicitly accounted for operator behavior. Instead, they have focused on failures of machine parts and components, including mechanical and electrical failures. More recently, human reliability assessment techniques have been developed to provide numeric estimates of human operator reliability within complex systems. These estimates provide a means to assess operator risks within systems and to estimate risks associated with specific tasks.

This study involved a human reliability assessment of potential operator errors and operator reliability associated with RCL and conventional methods of yard switching operations. Any failures associated with RCL equipment, locomotives, cars, or track were assumed in the operator reliability estimates, since yard-switching tasks involve interaction

among yard crews, track, and on-track equipment. The study focused on risks to railroad employees and property.

A multipronged strategy was developed that employed several complementary methods:

1. Conduct of a hierarchical task analysis to delineate the tasks involved in RCL and conventional yard switching operations.
2. Conduct of a preliminary hazard analysis to assess the overall risk of each method of yard switching operation.
3. Conduct of two different human reliability assessments to generate operator reliability estimates associated with each method of operation.

A *hierarchical task analysis* was initially conducted to provide a foundation for the preliminary hazard analysis and human reliability assessment. Naturalistic observations, informal interviews with remote control operators (RCOs) and others familiar with RCL operations, and review of RCL technical and operating practice manuals provided the basis for the hierarchical task analysis. Applicable yard switching tasks involving classifying inbound trains and building new outbound trains were first identified. Then a set of hierarchical tasks and a set of plans that describe the relationships among the tasks were developed. The hierarchical task analysis also included a breakdown of task activity by crewmember.

A *preliminary hazard analysis* was then conducted to assess the overall risk of each method of operation. The preliminary hazard analysis identified 19 potential undesirable outcomes for each method of operation. To assess risk, the study team generated a worst credible scenario for each outcome and assigned potential severity and likelihood of occurrence ratings to each outcome. Risk was determined by multiplying *a priori* values associated with potential severity and likelihood of occurrence ratings. Each scenario received a risk score from 0-24.

Next, the team identified two suitable human reliability assessment methods. The first was HEART. A benefit of HEART is that HEP values are already provided in the methodology so the subject matter expert (SME) assessor (e.g., an RCO) does not have to generate reliability



estimates on his/her own. The second method was APJ. Unlike HEART, APJ relies on SMEs to generate HEP estimates based on personal experiences and expertise. The premise behind APJ is that, absent an objective HEP database, the next best HEP database is the one contained within the minds of SMEs.

Preliminary hazard analysis scenarios associated with the greatest risk provided the basis for the development of the HEART and APJ operating scenarios that were assessed. Eleven sets of scenarios were developed to capture yard switching moves that could be performed under either conventional or RCL operations. For each set, one scenario was developed to be evaluated in the context of a conventional yard switching operation, and a second, almost identical, scenario was developed to be evaluated in the context of an RCL operation. Differences between the two scenarios in each set were due only to operational differences (e.g., the presence of a locomotive engineer for a conventional crew and the absence of one in an RCL crew).

The HEART and APJ exercises were conducted at two locations. One SME participated in the HEART evaluation at each location, and each participant evaluated the RCL and conventional scenarios. For the APJ exercise, two groups of participants (one conventional, one RCL) evaluated scenarios at each location. A total of 14 SMEs participated in the APJ assessment.

RESULTS

The preliminary hazard analysis provided a simple means of evaluating the relative risk of RCL and conventional yard operations by comparing the sum of the risk ratings for the 19 worst credible scenarios associated with each method of operation. The 19 RCL scenarios yielded a total risk score of 197 compared to 143 for the 19 conventional scenarios. Examination of both the average and median values for each method of operation also revealed greater relative risk for RCL operations. The average rating for RCL operations scenarios was 10.4 compared to 7.5 for conventional scenarios. The median RCL scenario value was 12 compared to 6 for conventional scenarios.

Order of magnitude (OOM) was used as a practical measure of agreement or difference in the HEART and APJ assessments. If two HEPs fell within 1 OOM of each other, they were

considered to be roughly equal or in agreement, while HEPs that were more than 1 OOM apart suggest a difference. Data were missing for one scenario for one participant; thus only 10 of the 11 scenarios could be formally assessed using HEART. The HEART assessment revealed no overall difference in HEPs between the two methods of operation. Analysis of the first HEART participant's data (location A) indicated that four conventional scenarios were associated with HEPs that were at least 1 OOM greater than their RCL counterparts, three RCL scenarios were associated with greater HEPs than their conventional counterparts, and three scenarios showed no difference. Analysis of the second HEART participant's data (location B) showed a similar trend: four conventional scenarios were associated with HEPs at least 1 OOM greater than their RCL counterparts, three RCL scenarios were associated with HEPs greater than their conventional counterparts, and four scenarios showed no difference. Thus, HEPs generated by both HEART participants resulted in a nearly equal number of cases where (1) RCL operations were seen to be worse than conventional operations, (2) conventional operations were seen to be worse than RCL operations, and (3) the two types of operation showed no difference.

Additional analyses of the HEART data suggest significant variability between the two participants. It is possible that RCL and conventional operations are both associated with some risks resulting in greater HEP for one type of operation over the other, depending on the scenario. However, the more likely explanation for the HEART results and variability is that the HEART method is insufficient, insensitive, or invalid as a technique for comparing human reliability in railroad yard operations as deployed in this study.

APJ SMEs completed assessments of only 7 of the 11 scenarios developed for the study due to time constraints. Analysis of individual APJ HEP values within each location revealed that, while individual HEP values varied across a large range, the patterns in the data were consistent with a trend toward greater HEP for RCL scenarios than conventional scenarios. Using the 1 OOM criterion for location A data, six RCL scenarios were associated with higher HEPs than their conventional counterparts, while only one conventional scenario was rated higher than its RCL counterpart. For location B data, all seven RCL scenarios were associated with



higher HEPs than their conventional counterparts. A second analysis compared location A conventional operations scenario HEPs to location B RCL operations scenario HEPs. This analysis revealed a similar pattern: six RCL scenarios were associated with greater HEPs than their conventional counterparts and one scenario showed no difference between the two methods of operation. However, when comparing location B conventional operations scenario HEPs with location A RCL operations scenario HEPs, four scenarios showed no difference in HEP ratings.

Though the APJ data support a potential trend toward higher HEPs for RCL scenarios, additional analysis of the HEPs generated for each scenario within each method of operation also showed considerable variability. For a given scenario within a particular method of operation, participants often assigned a range of HEPs, suggesting a considerable degree of variability among APJ participants.

CONCLUSIONS

The preliminary hazard analysis and APJ assessments revealed that, in comparison with conventional yard switching operations, RCL operations were associated with greater risk ratings and HEPs. The HEART data were inconclusive. These results should be considered preliminary due to some significant methodological challenges and limitations, and due to their subjective and comparative nature. Some of these methodological challenges and limitations of the study included:

- Human reliability data for either method of yard switching operations did not exist at the time of the study to support the assessments.
- RCL-related train accident/incident data did not exist at the time of the study to support generation of HEP data.
- Existing human reliability assessment techniques were developed for other-than-railroad industries that lack similarity to the railroad-operating environment. No human reliability assessment techniques had been

developed for the railroad-operating environment at the time of the study.

- The railroad yard is a highly complex, dynamic, and variable operating environment. Consequently, the assessed scenarios represent only a small subset of all possible yard-operating scenarios.

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