*Research
Results*

Human Reliability Analysis in Support of Risk Assessment for Positive Train Control

SUMMARY

This report describes an approach to evaluating the reliability of human actions modeled in a probabilistic risk assessment of train control operations. Human reliability analysis was applied to a safety evaluation of the Communications-Based Train Management System (CBTM) being tested by CSX Transportation, Inc.

The study analyzed the probabilities of specific human errors representing potential contributors to the risks being modeled in a risk analysis study of the CBTM system for four train related events: entering a block without authorization, exceeding the track speed limit, entering a preplanned work zone without authorization, and crossing a misaligned switch. Figure 1 shows the two error distributions based upon experience on CBTM territory only and all CSXT territory for trains entering a block without authorization. The distributions were created using a combination of objective and subjective sources.

The report also includes a set of guidelines and recommendations for performing a human reliability analysis to insure that the results will be acceptable to the broad set of stakeholders, meet accepted standards for human reliability analysis, and able to be integrated into probabilistic risk assessments.
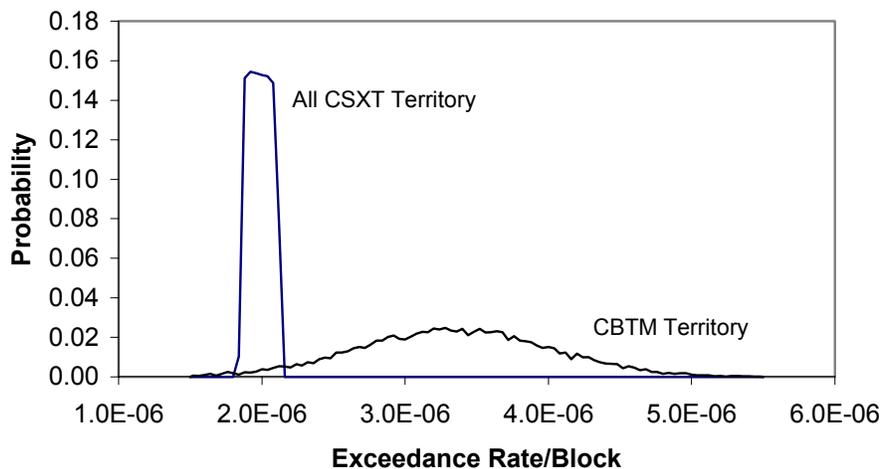
Figure 1. Probability Distributions for Trains Entering a Block Without Authority for CSXT-Wide and CBTM Territory Experience

BACKGROUND

The railroad industry is developing a new generation of processor-based signal and train control systems to improve safety and enhance operations. To meet the challenge of enabling railroads to adopt new signal processor based technology while reducing risk, the Federal Railroad Administration proposed the use of probability-based risk analyses (PRAs) to evaluate the risk associated with the introduction of new systems.

Any meaningful PRA of a complex train control system needs to examine human actions in a way that accounts for what is known about human performance and how human errors can occur. This report describes a methodology for analyzing human performance and estimating the reliability of human actions that can be used in support of PRAs being performed as part of the Product Safety Plan submissions to the FRA. To illustrate the HRA approach, it was applied to the safety evaluation of the Communications-Based Train Management (CBTM) System being tested by CSX Transportation, Inc. (CSXT). The report describes the overall approach to the HRA and its trial application to the CBTM evaluation.

Approach to Human Reliability Analysis

The purpose of human reliability analyses (HRA) is to estimate the likelihood of particular human actions not being taken when needed, or other human actions that may cause hazardous events to occur. Failures to take action to prevent hazardous events, and actions that cause hazardous events, are commonly called "human errors" in HRA.

It is the purpose of the HRA task to estimate the probabilities of human errors that can potentially fail the defenses. However, this estimation needs to take into account the work environment and task conditions under which the work is done, since these can provide an important influence on the likelihood of error. For example, bad weather, long shift times, and high workload all can increase significantly the likelihood of human errors. In turn, work environment and task conditions are often influenced by organizational factors like work rules, duty times, and so on. Therefore, the error estimation

process needs to account for these contributing factors.

There are four main tasks that need to be performed as part of an HRA. These tasks represent the general process by which human reliability analysis supports probabilistic risk assessment tailored to railroad operations. The details of these steps may vary in each application.

- *Qualitative Evaluation of Human Factors Issues*. Analyze the impact of the current work environment and new technology on human performance. This task requires study of operating rules, procedures, available data, as well direct observation of the work environment and interviews of individuals involved in the work.

- *Survey of Databases for HRA Sources*. Identify collections of data that may be relevant to the quantification of errors, problems associated with direct application of that data, and ways in which experts in operations can evaluate and adjust that data to the case at hand.

- *Quantification*. Develop quantitative estimates of the likelihood of the human actions in question. The process for quantification always begins with an evaluation of the relevance of available data to the actions under analysis.

- *Documentation*. To permit review and later understanding of the details of the quantification, all results and processes must be well documented, providing the bases for all estimates.

Application of HRA to prototype train control system

The CSXT CBTM safety case was used to illustrate the methodology. CBTM is a form of train control that provides a warning to the locomotive crew when the train is predicted to exceed the limits of its authority and stops the train if the operator fails to act in time. CBTM is intended for "dark" territories where there are no signal systems.

The HRA process outlined above was used to estimate human reliability values for current

railroad operations in the territory where CBTM was tested and when added to the current method of railroad operation.

The study analyzed the probabilities of specific human errors representing potential contributors to the risks for four train related events:

- Entering a block without authorization
- Exceeding the track speed limit
- Entering a preplanned work zone without authorization
- Crossing a misaligned switch.

Qualitative and quantitative analyses were made to establish the human reliability associated with these four events.

For the qualitative human factors analysis, the authors analyzed the current work environment to understand the types of errors that can arise and the factors that contribute to those errors and examined the proposed CBTM system to assess its potential impact on human performance and human reliability. Two site visits were conducted:

- A visit to the yard in Spartanburg, South Carolina to interview and observe CSXT locomotive engineers and conductors, as well as to ride a locomotive equipped with the CBTM system;

- A visit to the CSXT Dispatch Center in Jacksonville, Florida, to interview and observe dispatchers to understand CSXT dispatch operations and the factors that could contribute to dispatcher errors.

For the quantitative human factors analysis, relevant sources of data were identified, along with their limitations and gaps. Quantitative information included the numbers of events similar to those being modeled, and information about the number of opportunities for such events so that a probability or frequency of the events could be estimated. Two major sources of data were identified in this study: databases maintained by the FRA, and databases maintained by CSXT. Both sources contained information about the frequencies of events and the opportunities for such events. While these databases contained relevant information, they exhibited certain limitations and gaps with regard to the events being analyzed. To compensate for these limitations, the data was filtered and scaled. The authors conducted a

two-day expert elicitation workshop with industry representatives to perform these adjustments. The final probability estimates for the human error events were computed based on the combination of the databases and expert judgments and generally took the form of probability distributions.

Outcome

The HRA methodology was able to generate reasonable results (i.e., acceptable to the workshop participants) despite the fact that there was no directly applicable database. The workshop format permitted experts from many different organizations and backgrounds to work together and reach consensus. Uncertainty was expressed through probability distributions that were accepted by the group. The teams contributing to the HRA and PRA reached agreement that the HRA results were appropriate for use in the PRA.

WANT MORE INFORMATION?

Details on this study can be found in the following FRA report:

Wreathall, J., Roth, E., Bley, D., and Multer, J. (2003). Human Reliability Analysis in Support of Risk Assessment for Positive Train Control. Report No. DOT/FRA/ORD-03/15.

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