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HUMAN ERROR ANALYSES ASSOCIATED WITH LOCOMOTIVE CAB AUTOMATION

SUMMARY

From July 15, 2015, to September 4, 2016, the Federal Railroad Administration (FRA) sponsored Alion Science and Technology to conduct a project to examine cab system automation displays and the risk of human error. Figure 1 depicts a typical system display.

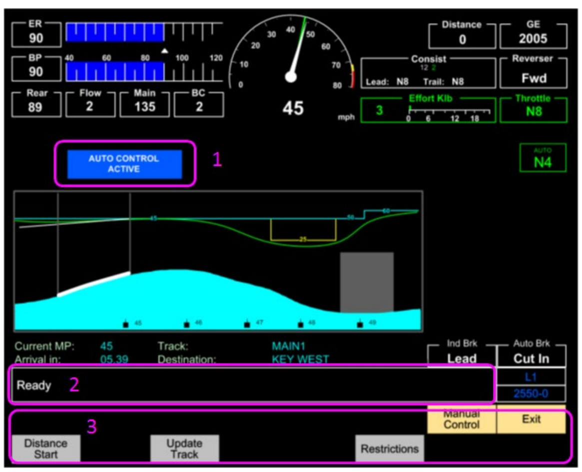

Figure 1. Locomotive Cab Automation

This research addressed the potential for errors that may occur during human-automation interaction with automated systems. Specifically, the engineer and conductor examined the Trip Optimizer (TO) and the Positive Train Control (PTC) systems while in operation. The research team performed four different types of analyses:

- A qualitative assessment based on human-in-the-loop (HITL) performance in scenarios run at FRA's Cab Technology Integration Laboratory (CTIL).
- A model-based workload analysis using the Locomotive Cab Analysis Tool (LOCAT) to predict operator workload (Plott, C., 2011) and human error probabilities (HEPs) associated with individual tasks or task sequences while LOCAT uses a discrete event simulation engine (Law, A. M., 2014) and algorithms (e.g., the Keystroke Level Model technique (Card, S. K., Moran, T. P., & Newell, A., 1980)).
- An attention and noticing model analysis to predict engineer visual scanning behavior and detection of changes in the locomotive cab (Wickens, C. D., 2015).
- A fault tree analysis (FTA) of human errors related to locomotive cab operations and the use of automation (Swain, A. D., & Guttmann, H. E., 1983).

The error analyses provided different, yet converging, perspectives on the possibility for error when operating these systems.

BACKGROUND

To improve railroad safety and efficiency, automation is being introduced into the locomotive cab. While automation can support operators as they perform their tasks, dependent upon system design, it can also create a potential for human error.

The research team based the human error analyses on a set of 10 simulator sessions at the CTIL. In each session, engineers ran a 17-mile section of track. Three professional engineers participated in the sessions: two worked for the same railroad (Railroad 1 [RR1]), and one worked for another railroad (Railroad 2 [RR2]). The engineers were specifically recruited for the sessions based on their experience using TO and PTC systems. The simulator's TO is based on the General Electric TO, while the simulator's

PTC is based on a Wabtec Interoperable Electronic Train Management System (I-ETMS).

The simulator sessions were not strictly controlled experimental sessions, but they primarily served as data gathering sessions. Further, the research team was unable to identify an engineer with extensive experience using both I-ETMS and TO.

OBJECTIVES

The purpose of conducting this research was to qualitatively assess whether there was a potential for human error during train operation using TO and PTC systems. If so, then to define what types of errors may be prominent (see Figure 2).

Error	TO in Use	PTC in Use	Workload
Failure to respond to the automation request	Yes: TO in automated mode	No	High
Failure to stop at a "stop and protect" grade crossing	Available – but set in manual mode	No	High
Large (40%) overspeed	Available – but set in manual mode	No	Low

Figure 2. Characteristics of the Error-Producing Conditions

METHODS

The research team spent 4 days at FRA's CTIL at the Volpe National Transportation Systems Center in Cambridge, MA, developing, testing, and running scenarios.

The development process occurred as follows:

Day 1 – A 17-mile section of track CGI from the CTIL's existing database was selected for use representing an actual rail line in the Midwestern part of the United States. Six events or scenarios were programmed for presentation to participants: permanent speed restriction, quiet zone, prompt for track information, work zone, temporary speed restriction, and stop and protect. Scenarios were designed to be presented in manual operation, simple (low workload), complex (high workload), and complex PTC and TO conditions.

Day 2 – The scenarios were tested and refined.

Day 3 – The first six sessions were conducted with the two engineers from RR1.

Day 4 – The last four sessions were run with the engineer from RR2.

All scenarios ran approximately 25–30 minutes, and engineers were responsible for manually sounding the horn at rail grade crossings.

Figure 3 shows a graphical timeline representation of the simple scenario and the complex scenario.

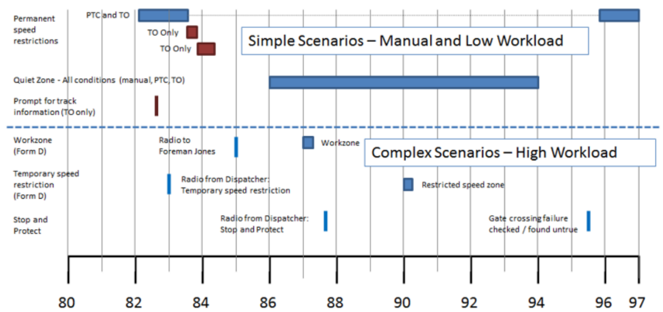

Figure 3. Timeline Representation of the Simulator Scenarios, Including Tasks and Events

RESULTS

During the 10 sessions in the simulator, 3 errors related to train control and automation were observed:

1. Overlooking the TO request for track information, and failure to notice the eventual switch to manual mode which TO implemented
2. Failure to stop the train before the grade crossing at milepost 95.5 (i.e., the stop and protect)
3. Speed restriction violations, one of which can be classified as a major violation

Error	Human Error Probability	Workload	N-SEEV	Fault Tree Analyses	Automation
Failure to respond to the automation request	HEP = 0.011; Confirm automation enabled/disabled)	Yes – high workload due to concurrent communication	Yes	Not evaluated	Automation presented the request, but it can do so in a more salient manner
Failure to stop at a "stop and protect" grade crossing	Not evaluated	No, workload was not high when this error occurred	The information was not presented – thus, it was not salient, and could be missed	P = 0.034	PTC was not engaged, and the TO was not programmed to include this.
Large (40%) overspeed	HEP = 0.010 (Determine and Evaluate Speed)	No	Not salient	P = 0.042	PTC would prevent this if it had been engaged. TO was programmed to include the correct speed, but it was in manual mode. The information could be more salient.

Figure 4. The Prediction of Errors in These Analyses

This research suggests that PTC and TO offer additional opportunities to support freight rail safety and enhance the efficiency of freight rail operations, but there is also potential for new opportunities for error (see Figure 4).

Of the three error types, the first and third (i.e., lack of response to the automation request and large overspeed) are fully consistent with the models that predicted them to be plausible. The ability to predict errors is particularly important, considering the multiple opportunities for the error to occur during all the simulation runs (e.g., multiple TO mode changes, multiple grade crossings, multiple speed restrictions). Thus, there are benefits to using the convergent error prediction techniques.

CONCLUSIONS

Based on the analyses in this research, the team suggested several mitigation strategies, such as including additional methods to check that data has been correctly entered; providing technology that can sense maintenance personnel on the track and the system could inform personnel or equipment on the track; allowing the conductor to make programming changes if information has not been entered into PTC and the TO; encourage the engineer and the conductor to review the train and trip information prior to starting a trip for PTC and TO purposes; increasing the visibility of presented information on the TO; and duplicating the PTC and TO displays at the conductor's workstation.

Researchers found that further training could benefit engineers, conductors, and dispatchers. Training should cover known automation concerns (e.g., the TO switching to manual mode without the engineer being aware of it). The training simulators should include situations where engineers experience automation failures (Sauer, J., Chavaillaz, A., & Wastell, D., 2015) (Wickens, C. D., Clegg, B. A., et al., 2015).

FUTURE ACTION

The research team recommends future investigations into the timing of automation transitions. An examination of possible propagation of errors through the system with increased use of automation should occur. There should be additional investigations on the benefits of a conductor noticing and warning the engineer about potential errors. Future investigators should examine the lack of salience regarding an overspeed indication in the TO when the TO is running in manual. Lastly, there should be an investigation regarding PTC switching off without the engineer's or conductor's awareness; further studies in the CTIL could investigate these issues.

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