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FUNCTION ALLOCATION AND NEW ROLES FOR HUMANS IN RAIL AUTOMATION

SUMMARY

The purpose of this work was to demonstrate improved system performance on a selected automated system by implementing a function allocation methodology that enables design of a display interface for that system that makes best use of human as well as machine capabilities.

From May 2014 to June 2016, the Federal Railroad Administration (FRA) funded GE Global Research and the Massachusetts Institute of Technology's Man Vehicle Laboratory to provide a methodology that can be used to design and evaluate new operational configurations of human and machine/automation roles constituting human-automation teaming in freight rail systems.

First, attitudes toward and concerns about automated systems were surveyed from the rail industry to bolster previous FRA sponsored cognitive task analyses (CTAs). A CTA is an analysis of human information and decision-making requirements needed to perform a specific job.

Next, this information was used to complete a hierarchical task analysis (HTA) to help define human roles and tasks as well as machine roles and tasks in the operation of a selected system for this study.

FRA also provided a technical report to describe the use and function of CTAs and raise awareness of systems designers of the changing roles and responsibilities of humans when implementing automated systems (Roth, E., Rosenhand, H., & Multer, J., 2013).

Finally, the prototype system, or display was developed and evaluated using human subjects at FRA's Cab Technology Integration Laboratory (CTIL) facility in Cambridge, MA. The metrics for the evaluation were derived from this applied function-allocation approach to the system's design.

BACKGROUND

The introduction of automated systems into the locomotive cab changed the scope and complexity of crew members' work with each other and with these systems (Scerbo, M. W., Freeman, F. G., & Mikulka, P. J., 2003). This research provides a methodology to design and subsequently evaluate new operational configurations (i.e., roles of humans and automation systems) in freight rail systems.

OBJECTIVES

Industry stakeholders provided input on the future of rail operations and automation through a Delphi survey, which is a technique to reach a group consensus through multiple survey questions that were sent to experts in the industry. In parallel, the team reviewed the literature on previous CTAs done in the rail industry, created concept maps to distill the information and understand the system as a whole, and then developed a hierarchical function allocation model. This research allowed the team to select the candidate prototype system to be evaluated in a human subjects' study at the CTIL at the Volpe National Transportation Systems Center (Volpe).

METHODS

The FRA-sponsored CTAs were summarized using concept maps and supplemented with additional research from a literature review. Most of the gaps identified originated from an interaction among three actors in the system (i.e., engineer, conductor, and dispatcher) and in the detailed strategies employed. The concept maps were then used by researchers to conduct a HTA. This analysis and static metrics aided in the creation of the prototype model. The research team validated the model by conducting a human-in-the-loop experiment in the CTIL.

The purpose of conducting a Delphi survey was to reach a group consensus about future implementation of automation in the industry through multiple survey rounds sent to people with expertise in the industry.

Participants with specific views explained their reasoning for consideration by the rest of the participants to spur opinions after several rounds of responses. Numerous fields employ this technique including healthcare, transportation, and energy (Nowack, M., Endrikat, J., & Guenther, E., 2011) (Hasson, F., Keeny, S., McKenna, H., 2000). Figure 1 shows the mean number of years of experience and the range in various crew member positions the non-GE respondents reported from the first round of the survey.

Experience as Crew Member	Mean	Range
Engineer	12.8 years	0–25 years
Conductor	13.8 years	0–31 years
Dispatcher	0 years	0 years
Foreman	8 years	0–18 years

Figure 1. Experience levels of non-GE survey participants

RESULTS

The results from the interviews conducted for the Delphi survey along with the CTAs provided input to create the concept maps used to capture and represent information (see Figure 2).

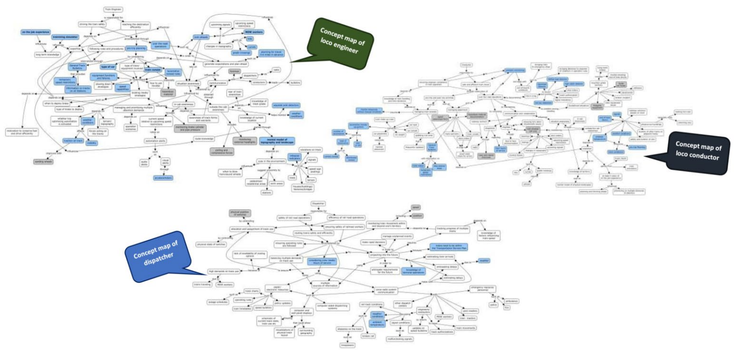

Figure 2. Concept maps for the locomotive engineer, locomotive conductor, and dispatcher

These concept maps aided in the development of a HTA that broke down generalized functions into tasks. This ultimately aided in the development of a new automation model, known as TO+.

Next, the team used the results from the Delphi survey to design the Trip Optimizer Plus (TO+) system shown in Figure 3.

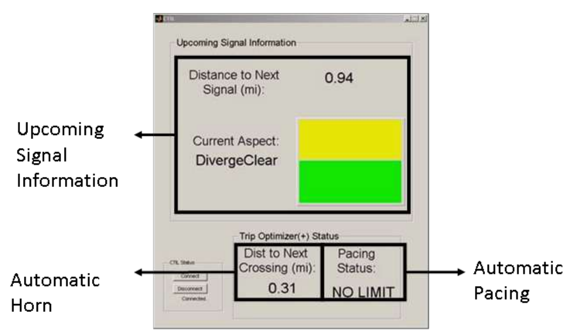

Figure 3. New TO+ operating display

Researchers tested this prototype in the CTIL, which showed how a conductor's workload can be reduced with automation functionality when displaying the signal aspect in-cab signaling (see Figure 4).

TO+ Functionalities	Change in Coherence and Workload Metrics			
	Conductor-Coherence	Engineer-Coherence	Conductor-Workload	Engineer-Workload
In-Cab Signaling (M1)	-17.97%	9.28%	-31.82%	-20.88%
Automatic Pacing (M1)	-39.26%	0.00%	-16.67%	-43.13%
Automatic Horn (M4)	-16.48%	0.00%	-0.00%	-31.16%

Figure 4. Change in static metrics for new automation functionalities (TO+)

CONCLUSIONS

This work demonstrates the importance of the function-allocation process in the design of a human-automation interface that performs best when it takes advantage of both human as well as automation capabilities.

FUTURE ACTION

In addition to the current work, several areas for potentially future work were identified: filling gaps in existing FRA-sponsored CTAs, and computational modeling of task allocation metrics. Future allocations will be determined by using engineering judgment regarding feasibility, input from the railroad Delphi survey results, the work domain model itself, and the function allocation effectiveness measures (e.g., coherency and workload).

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CONTACT

Michael Jones
Engineering Psychologist
Federal Railroad Administration
Office of Research, Development and Technology
1200 New Jersey Avenue, SE
Washington, DC 20590
(202) 493-6106
michael.e.jones@dot.gov

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