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.

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.

<table>
<thead>
<tr>
<th>Experience as Crew Member</th>
<th>Mean</th>
<th>Range</th>
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<tbody>
<tr>
<td>Engineer</td>
<td>12.8 years</td>
<td>0–25 years</td>
</tr>
<tr>
<td>Conductor</td>
<td>13.8 years</td>
<td>0–31 years</td>
</tr>
<tr>
<td>Dispatcher</td>
<td>0 years</td>
<td>0 years</td>
</tr>
<tr>
<td>Foreman</td>
<td>8 years</td>
<td>0–18 years</td>
</tr>
</tbody>
</table>

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).

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.

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).

<table>
<thead>
<tr>
<th>TO+ Functionality</th>
<th>Change in Cohesion and Workload Metrics</th>
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<tbody>
<tr>
<td>Change in Cohesion</td>
<td>Engineer</td>
</tr>
<tr>
<td>In-Cab Signaling (M1)</td>
<td>-1.87%</td>
</tr>
<tr>
<td>Automatic Pacing (M1)</td>
<td>-39.26%</td>
</tr>
<tr>
<td>Automatic Horn (M1)</td>
<td>-16.48%</td>
</tr>
</tbody>
</table>

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

Figure 3. New TO+ operating display

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).

REFERENCES


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