Technological Solutions to Optimize Short-haul Rail Operator Workload

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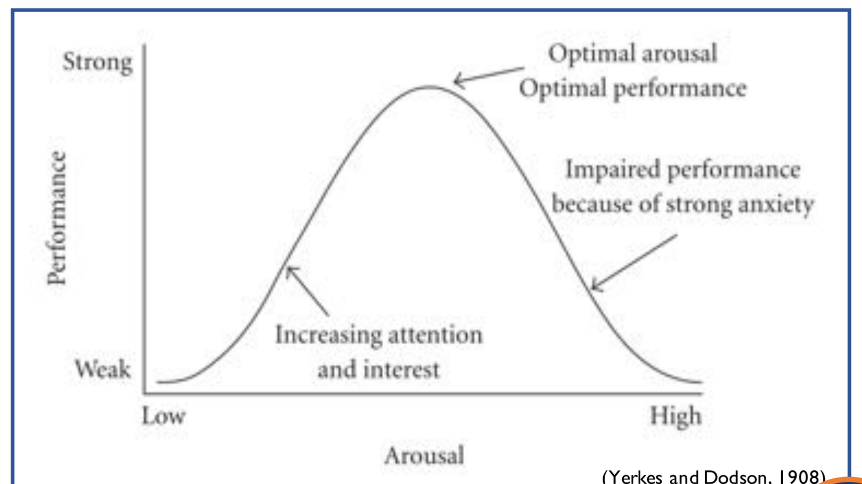
Purpose: Identify potential solutions to moderate cognitive workload of locomotive engineers in short-haul freight rail.

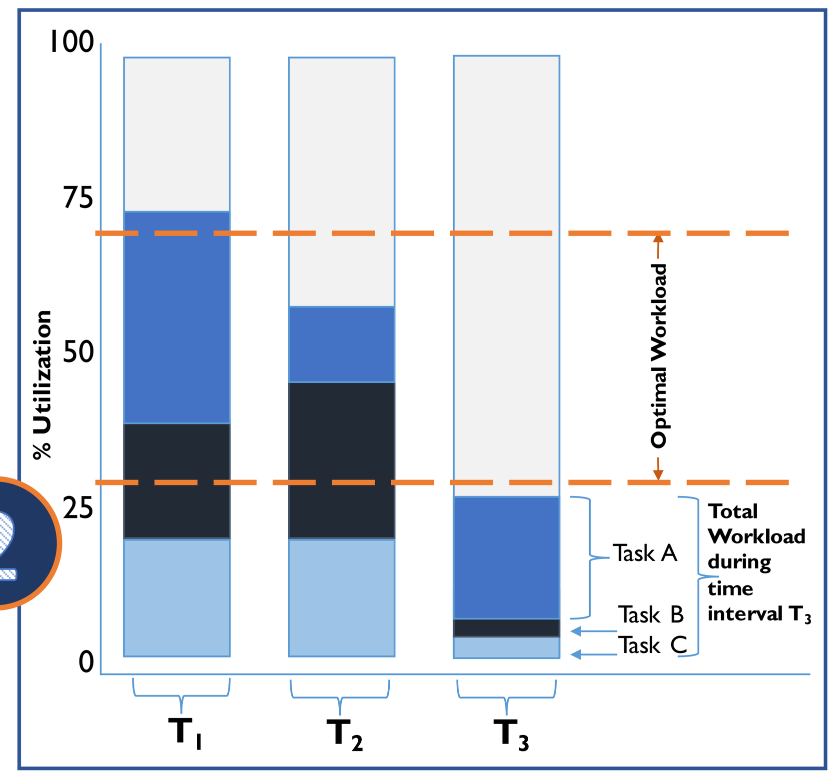
1

We measure cognitive workload with utilization[1]:

$$\frac{\text{Time on Task}}{\text{Interval of Time}}$$

- The maximum utilization is 100%, at which point there are no additional mental resources available for personnel to accomplish more tasks.
- When utilization levels are too high, operators may be too busy to accumulate the information required to maintain situation awareness (SA) for safety. A 70% utilization threshold was selected to indicate an upper bound of optimal task loading[2,3].
- Levels of utilization below 30% have also been associated with poor performance, but due to boredom and distraction[4-6]. When operators are underutilized, they could overlook information from the environment due to complacency and low arousal, leading to low SA.





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(Above): Yerkes-Dodson Inverted-U curve of operator workload impact on performance. *(Rightward):* Representation of workload from utilization data collected during operator shifts. *(Below):* Generalized functions adapted from Subrahmaniyan et al.[7]

Locomotive Engineer Task	Description
Motion Planning	Performing tasks necessary to operate the train during transit
Monitoring Inside	Attending to displays and other personnel
Monitoring Outside	Attending to environmental signals
Communication and Coordination	Comprehending and responding to coworkers
Paperwork Handling/ Recordkeeping	Logging trip data, checking lists, recording train performance
Exception and Emergency Handling	Responding to unexpected events, testing emergency mechanisms

We extended time on task workload modeling, developed primarily in aviation settings, to rail operations. A model engineer workload under nominal and contingency operating conditions in a 5-hour trip was developed using objective task time data collected during two short-haul freight rail ride-alongs and analytical data from interviews with subject matter experts (SMEs). The nominal condition represented routine operating conditions, assuming the operators and other crew in traffic, perform tasks without error or technical failures. The contingency condition, designed with the help of SMEs who developed training simulation environments, included situations when multiple components of the human-system network malfunctioned and caused delays, requiring exception-handling from the engineer.

3

Condition	Utilization			Time in High Workload	Time in Low Workload
	Min	Max	Avg		
Nominal	18%	78%	37%	7%	27%
Contingency	19%	99%	67%	60%	3%

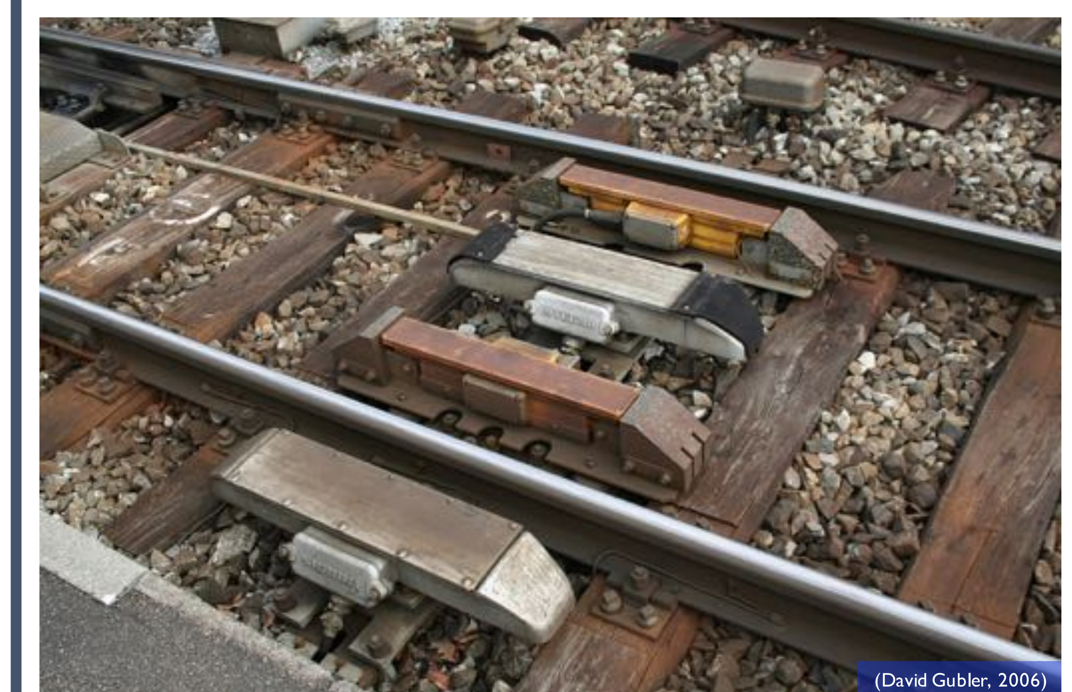
The engineer spends 1/3 of time in low workload during nominal condition and a majority of time in a high workload state during the contingency condition.

According to the model, the engineer spends the final 20 minutes during nominal conditions in high workload, where motion planning and monitoring outside tasks make the contribute most to utilization. If portions of these functions (e.g., responding to signals) were allocated to automation, the engineer's workload could remain at moderate levels, preserving additional cognitive resources to respond to exceptional events that may occur. Similar strategies could be employed under contingency conditions, allocating motion planning or monitoring outside tasks onto automation to maintain workload in optimal levels.

We developed a model of workload, under a 5-hour shift of an engineer under nominal v. contingency conditions. The contingency condition involved 3 unexpected events. Our models were validated by subject matter experts. We present potential technological solutions to reallocate tasks during periods of higher workload to alleviate the locomotive engineer in operational performance.

4

Motion Planning

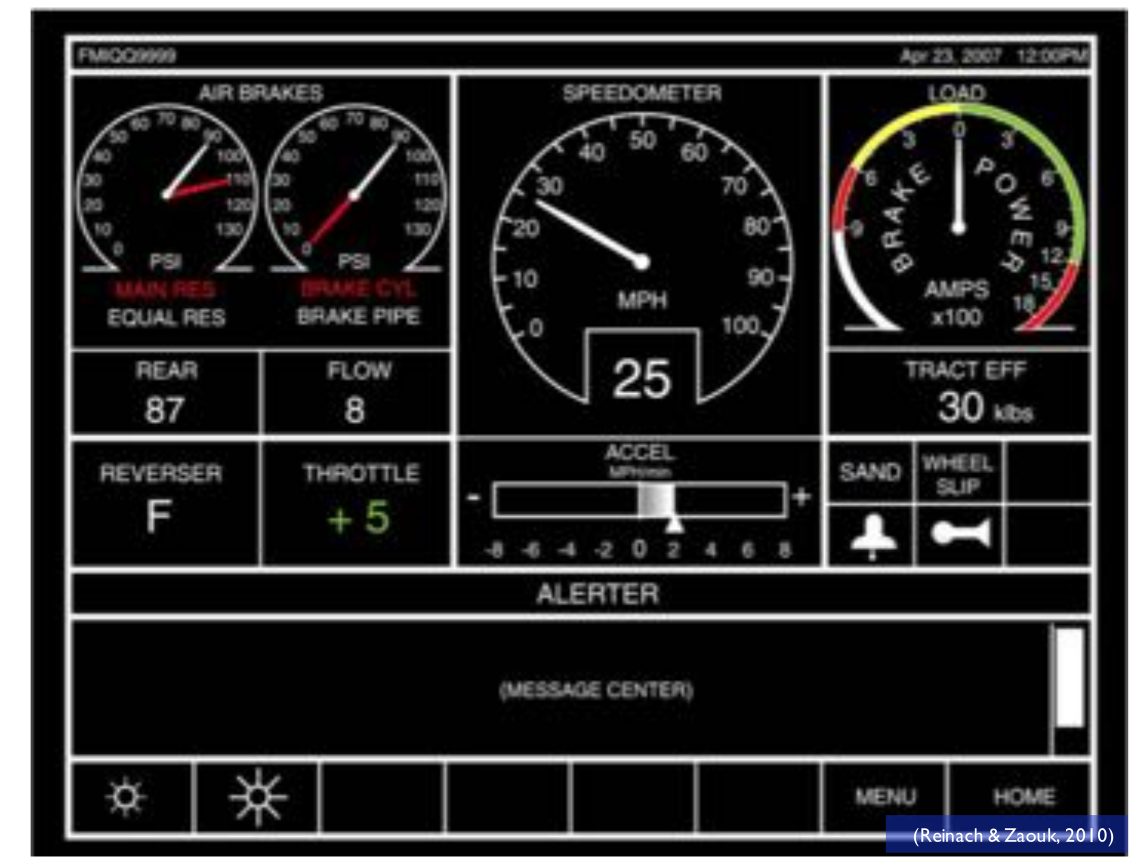


Current Industry Standard: Positive Train Control (PTC), fully implemented by 2018. Intelligent cruise control (i.e. GE's Trip Optimizer).

New Tech: Optimized motion planners (i.e. GE's Movement Planner) and autopilot.

What's Missing: Connected network of rail traffic (i.e. vehicle-to-vehicle communication).

Monitoring Inside

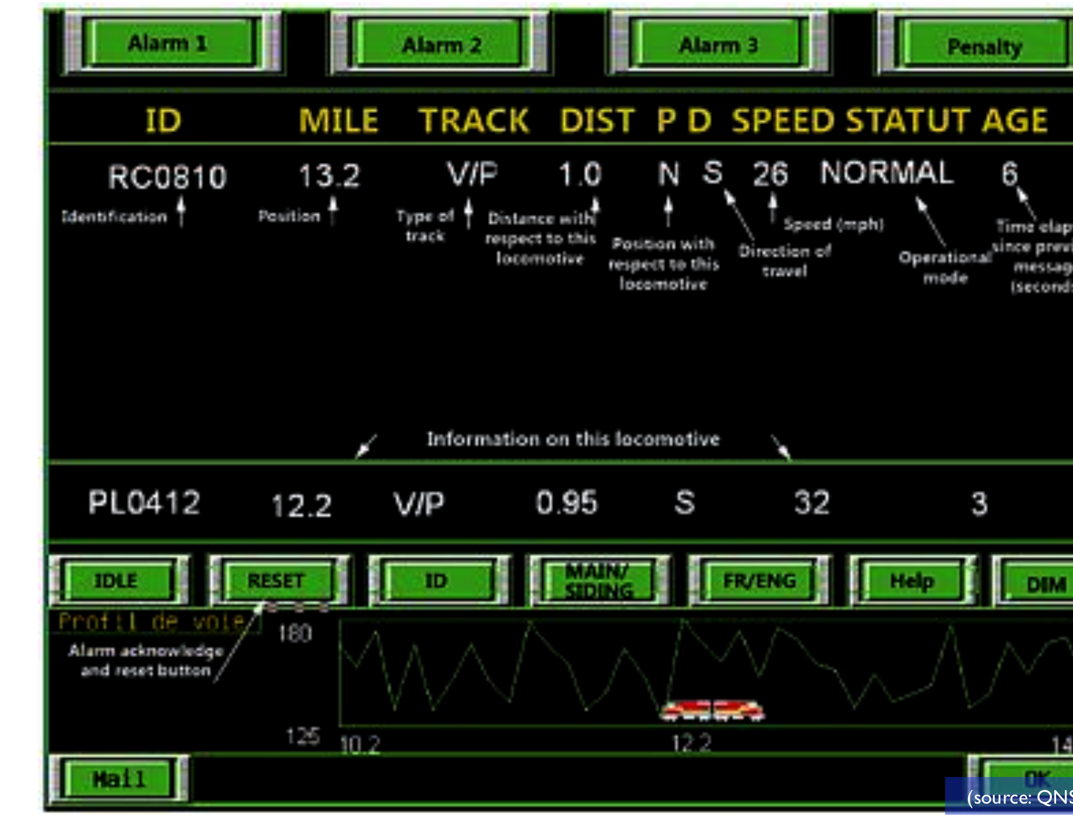


Current Industry Standard: Displays designed from legacy systems, not operator usability.

New Tech: Next Generation Locomotive Cab (NGLC) sponsored by the FRA.

What's Missing: An ergonomic SA interface[8].

Monitoring Outside



Current Industry Standard: Engineer monitors surrounding to line of sight limit via windshield and rear mirror.

New Tech: Proximity Detection Device (PDD), used on a Canadian railroad. Alerts engineer of approaching vehicles on track.

What's Missing: An effective audio alarm[9].

Communication

Current Industry Standard: 2-way radio communication between dispatch and engineer.

New Tech: Inward-facing cameras, outward-facing cameras, and Unified Train Control System (UTCS).

What's Missing: Dispatch capable of monitoring specific train information (GPS location, ETA, speed, live streams) and managing by exception. Motion planning updates pushed to PTC system.

Paperwork

Current Industry Standard: Pre-printed pages to review and revise during shift.

New Tech: Electronic Logging Devices (ELDs) mandated by FMCSA for trucks.

What's Missing: Test in freight rail environment. Predictive text support.

5

Future Work

The results of this research help identify sources of high workload as well as periods of low workload. However, limitations in our approach may affect the generalizability of the models. Additional observation and interviews would allow us to refine and expand the underlying data of the current models. To this effect, we are developing a discrete event simulation to rapidly investigate operator workload under a wider array of conditions to:

- predict impact of new technologies on human operators
- provide railroad stakeholders data to inform system requirements
- ultimately **get freight delivered safely and efficiently**

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