REMOOT

MOBILITY42 OTIV RAIL SYSTEMS ENGINEERING

Ministerie van Infrastructuur en Waterstaat

Gefördert durch:

Bundesministerium für Verkehr

aufgrund eines Beschlusses des Deutschen Bundestages

DLR




# HOF in Remote Train Operation System Development

November 4th, 2026. Geoffroy Sion (OTIV) & Niels Brandenburger (DLR)

**INNOVATE**
RAIL TODAY

# Context

## Why Remote Train Operation (RTO), and Why Now?

Several converging pressures are encouraging rail to automate further. RTO responds to them while keeping a qualified human in the loop and easing the constraint of one driver per cab.

### Workforce shortage

Ageing driver populations and retirements outpace recruitment; operators have cut services for lack of drivers.

### Network capacity

Automation lifts line throughput and punctuality on congested corridors without laying new track.

### Operating leverage

One supervisor oversees a fleet from a centralised desk; cutting cost per train and scaling across regions and entities.

### Tech maturity

Cyber-secure 4G/5G plus on-board edge compute make low-latency remote command viable.

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# Context

## The ATO-Cargo Project*: The RTO & ATO Lighthouse Project for Mainline Operations




### Objectives

1. **Approved prototype for testing**
   Approved prototype for ATO GoA 2 Freight Application + GoA 4 (Vehicle Functions) + Obstacle Detection System + RTO for 1-year pilot operation

2. **Full concept for commercial operations**
   Full concept ATO GoA 2 Freight + GoA 4 (incl. Obstacle Detection) + RTO for approval of commercial operation

### Consortium

DB Cargo, ProRail, OTVV, REMOOT, DLR, HITACHI




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https://railautomation.eu/
https://www.dlr.de/en/ts/research-transfer/projects/ato-cargo



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# Perception systems for assisted, remote and autonomous rail

## Rail-specific perception to unlock rail’s potential

**OTIV.ONE**

### See

Camera and object detection that improve visibility during shunting

**OTIV.TWO**

### Assist

Perception-based driver assistance: an extra set of eyes in complex urban environments

**OTIV.THREE**

### Control

Remote control centre for rail vehicles, with supervision as an added feature

**OTIV.FOUR**

### Drive

Perception for full self-driving, unlocking 24/7 operations

**Working with** RET · CAF · ArcelorMittal · DB Cargo · Rail Logistics Europe · De Lijn

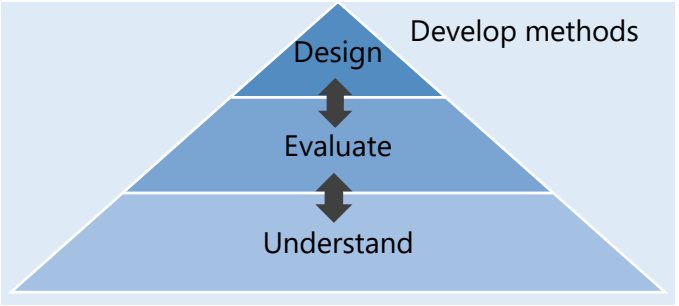
OTIV · Ghent, Belgium · Founded 2020 · otiv.ai

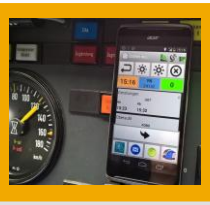
https://otiv.ai/

# Context

German Aerospace Center - Institute for Transportation Systems (DLR-TS)

We investigate human-technology interaction, workplaces and organisational factors in today's and tomorrow's railway system from the human perspective to develop innovative solutions.



## Advisory Systems

We identify acceptance factors, derive requirements, justify driving advice, revise the interface, assess compliance and develop a training concept.

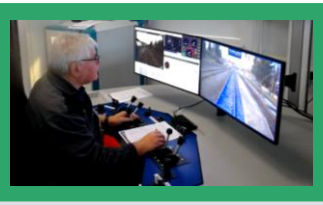
https://www.dlr.de/en/ts/research-transfer/projects/fasan



## ATO over ETCS

We investigate how different automation levels affect train drivers' workload, fatigue, and performance through simulator-based and real world studies.

https://www.era.europa.eu/system/files/2022-10/Automation%20Myth%20Busting%20Paper%20%232_0.pdf?t=1773695923



## Remote Operation

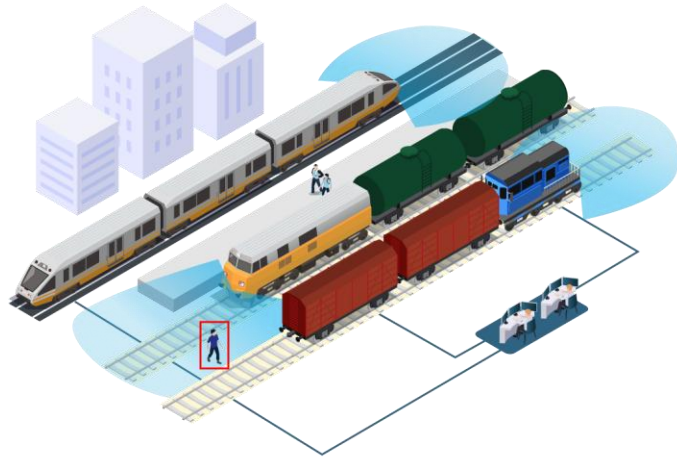
We examine how remote train control impacts performance shaping factors and organisational processes.

https://elib.dlr.de/217599/

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# The RTO System

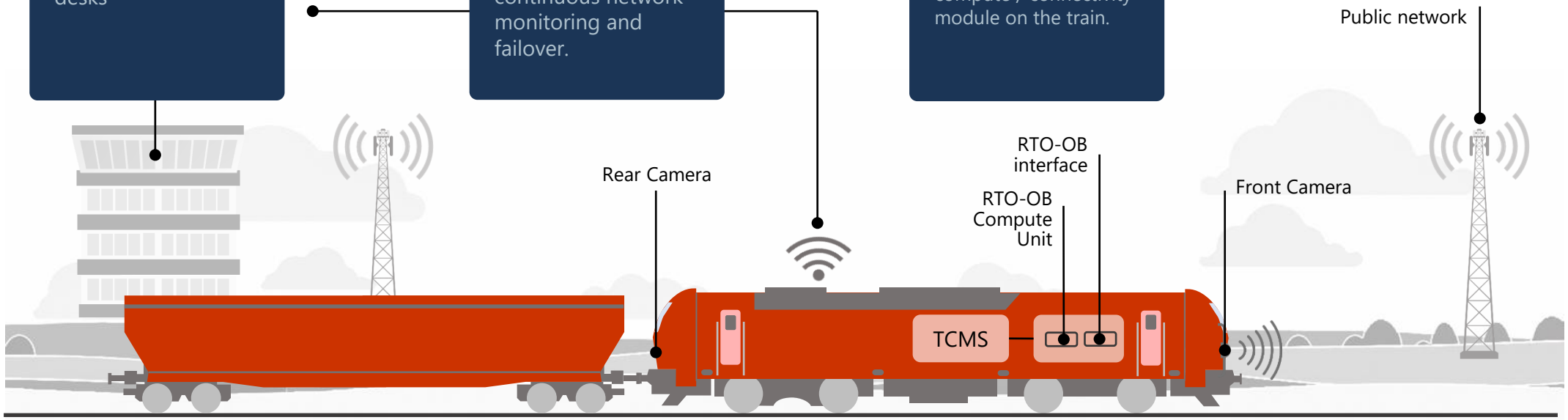
## Remote Supervision & Control (RSC) System: Our RTO-Concept



**Trackside desks (RSC)**
Supervision & control desks

**Connectivity**
Public 4G/5G link with continuous network monitoring and failover.

**On-board sub system**
Sensors, cameras and a compute / connectivity module on the train.



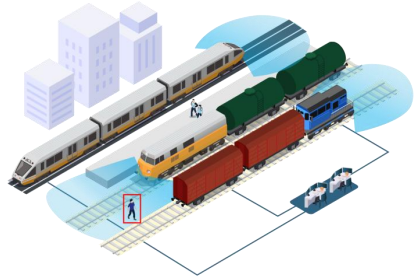

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# RTO center

## Fleet Supervision and Hands-on Control



Oversight and driving are deliberately separated. The supervisor watches the fleet; the operator takes a dedicated control desk to drive a train remotely when needed.

### Remote Supervision



- Two mode: Fleet overview and train specific view
- Graded, colour-coded alarms (Critical / High / Low)
- Analyze situation with the train's telemetry and the video streams

### Remote Control



- Fixed physical core: traction, brake, dead-man, panto, EB…
- Configurable digital controls: lights, parking brake, circuit breakers…
- Live camera feed, telemetry and alarms

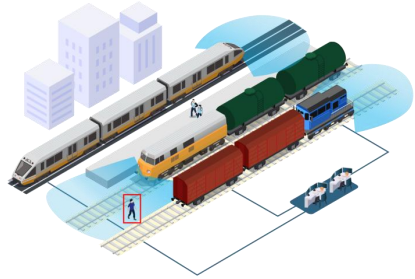
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# Roles by design

## Two Roles, Two Desk, One Clear Handover



### Remote Supervisor

*Oversees a fleet of trains from the supervision desk.*

- Fleet overview, with option to watch any single train
- Monitors alarms, status and is responsible for overall fleet availability
- Decides when to intervene and perform the following when relevant:
    - Contact the dispatcher
    - Assign a control desk
- Needs experience in train operations

### Remote Operator

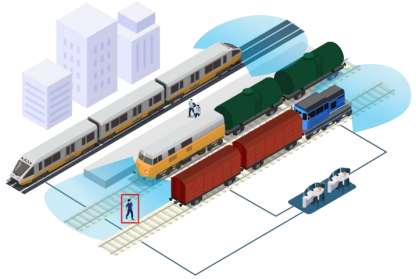
*Hands-on remote driving of one assigned train.*

- Operates a train remotely through:
    - Physical and digital controls
    - Live camera streaming
    - Live alarms and telemetry from the train
- The operator needs to adapt his/her driving style with the unstable-by-nature view of the tracks through live streaming
- Logs events in an integrated digital logbook
- Needs to be a train driver

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# HOF Focus in RTO

## User-centred Design during Development and Trial Operation



### Main Questions

How to ensure adequate performance?

Task Load, Workload, Effort, Fatigue, Situation Awareness*

→ **Performance**

How to ensure user acceptance of RTO roles?

(Perceived) Usefulness, (Perceived) Ease of Use, Trust, Motion Sickness, Feedback on desired future Improvements

→ **User Acceptance**

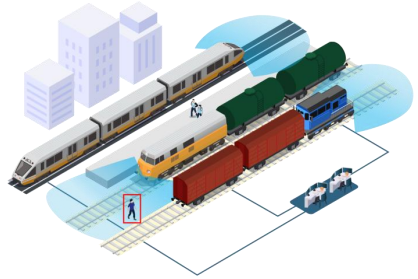



*Brandenburger, Niels (2022) *The Changing Role of Staff in Automated Railway Operation and why Human Cognition is Here to Stay.* ERTMS Conference 2022, 2022-04-26 - 2022-04-28, Valenciennes, France.

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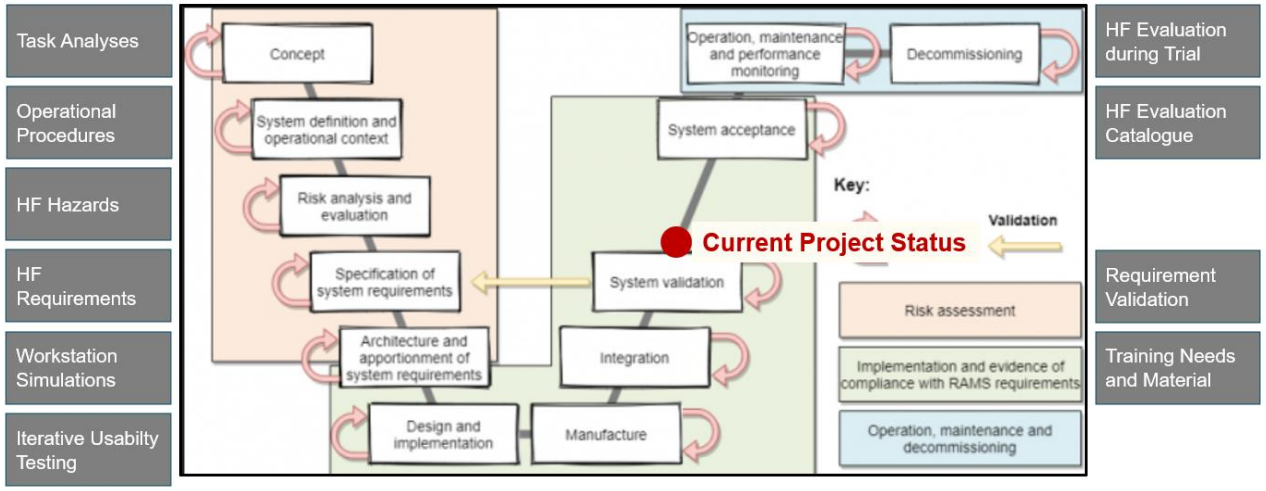
# HOF Focus in RTO

User-centred Design during Development and Trial Operation



## HOF-Approach to Project ATO-Cargo

Alongside the EN50126 V-Cycle




Brandenburger, Petersen & Quante (2025). Human Factors Contributions along System Development Phases. Rail Human Factors Conference, London 2025



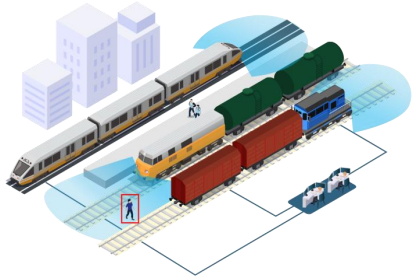

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# HOF Focus in RTO

User-centred Design during Development and Trial Operation



## HOF Evaluation during Real-world Trial Operation

### Challenging Context

**Time & Methodological Aspects**

- Prolonged test duration (1 year)
- Adherence to working-time limits
- Limited sample size (trained personnel n=8)
- Participation in HOF-Assessment is voluntary

**System Aspects**

- Target system is evolving technically
- Physical distances between system components

**Operational Aspects**

- Operational priorities over evaluation (safety, track occupancy)
- Test regime/schedule is changing due to adjacent operations
- Limited access to cab and desks



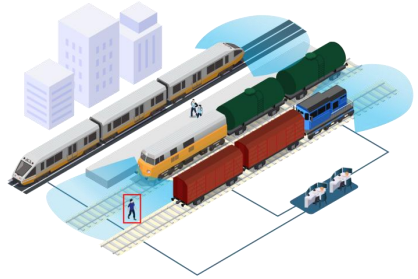

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# HOF Focus in RTO

User-centred Design during Development and Trial Operation



## HOF Evaluation during Real-world Trial Operation

### Approach

A multi-layered data assessment method relying on different assessment categories was developed to cope with these complexities

| Format | Data | Sampling | Duration | Constructs |
|---|---|---|---|---|
| Inherent Assessment | System Logs, Observations | Daily | Ongoing | Performance, Workload, Fatigue |
| Regular self-assessment | Tailored Questions, Questionnaires | Daily | 5 Min | Usability, Situation Awareness |
| Questionnaire Block | Questionnaires | Quarterly | 30 Min | Usability, Trust, User Acceptance |
| In-depth Interview | Semi-structured Interview | Quarterly | 30 Min | All above, Motion Sickness, Qualitative Feedback |




**Lean HOF evaluation requires 1.74% of the available time**

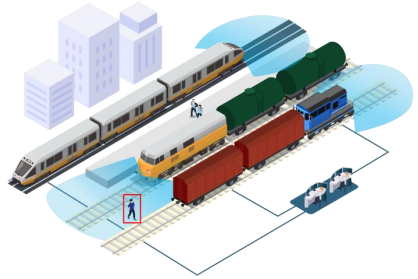
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# HOF Focus in RTO

## HOF Evaluation during Real-world Trial Operation



## In-depth Interviews (first assessment)

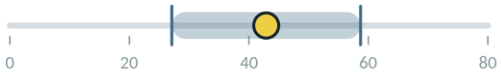
### Sample Descriptives

**Sample size**
N = 7 volunteers



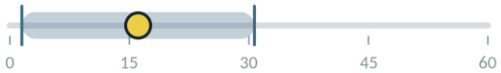
*rather small*

**Age**
(scale: 0 to infinite)
M = 42.9 · SD = 15.8




*representative*

**Occupational Experience**
(scale: 0 to infinite)
M = 16.1 · SD = 14.6




*broad*

**Technological Affinity**
(scale: 1 to 6)
M = 3.98 · SD = 0.75




*slightly elevated*

**Annotations:**

- The assessment took place after approx. four RTO shifts -> *little exposure*
- The target system was still changing significantly -> *fast evolving system*
- Qualitative results only




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# HOF Focus in RTO

Results In-depth Interviews (first assessment)



## How to ensure adequate Performance?

### Task Load:

- **Video latency:** Participants reported temporal delay in visual information compared to direct in-cab perception.
- **Multimodal cues:** Auditory information proved particularly helpful, enabling the recognition of braking events, compressor operation, and wheel slip.
- **Physical train dynamics** subjectively deviated from in-cabin operation and resembled simulator experiences.

### Workload/Effort:

- **Supervision:** Monitoring activities in between control interventions were perceived as effortful
- **Novelty effect:** Initial exposure to the setup increased cognitive load.

### Subjective Performance:

- **Speed estimation:** Biased speed estimation based on video footage caused inaccurate control inputs (braking).
- **Expectations:** Participants assumed that training and experience would greatly improve their estimation of train speed and dynamics.

## How to ensure User Acceptance?

### Ergonomics and Usability:

- **Workstations** were perceived as intuitive and ergonomically well-designed
- **Alarm philosophy:** Prioritisation and presentation should be improved

### Motion Sickness:

- One participant reported nausea during the first minutes of the shift.

### Trust

- **Close resemblance** of the driver cab was positively evaluated, including standardised functions.
- **Audio communication** with the safety driver / test leader increased system trust.
- **Physical presence** of the safety driver generated a high level of trust.
- **System transparency and reliability** were identified as the primary trust determinants; with a special focus on video latency.

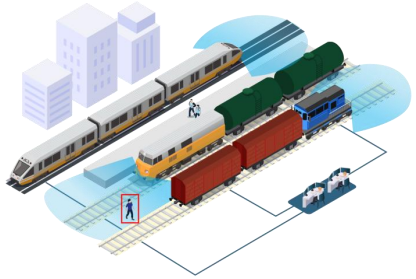
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# HOF Focus in RTO

Results In-depth Interviews (first assessment)



## Out-of-Scope future improvements

**Functionality:**
- The deactivation of the Deadman switch was subjectively perceived as a limitation in trial RTO operation.
- Visual representation of wheel slip (Adhesion)
- A playback function to support localization

**Multimodal extension:**
- Addition of haptic (vibration) and kinesthetic (acceleration) cues to compensate for the limited visual speed estimation.
- Extension with a peripheral panoramic view to prevent motion sickness

**Alarm philosophy:**
- The current alarm density is perceived as overly conservative; a prioritization of alarm levels is required.

**Synchronization:**
- Temporal synchronization of camera footage with the DMIs (ETCS, Diagnostic Interfaces) is a pilar for trust and needs to be ensured.



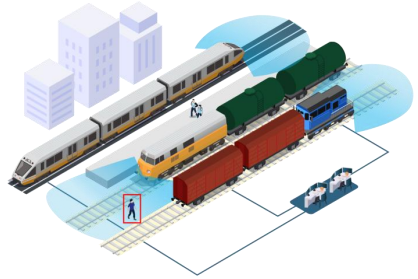

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# Lessons Learnt

## Integrating Human- and Organisational Factors



### Conclusions on the current HOF-Evaluation

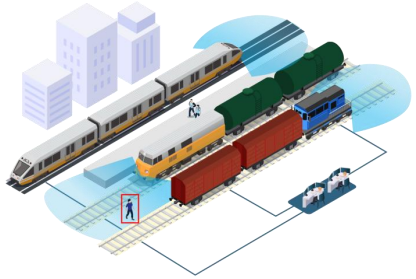
1. **Integrating HOF Activities was a challenge at times**
   - Keep it lean (e.g. 1.74% of the trial time) and communicate the benefits
   - Reference regulatory frameworks supporting HOF early
2. **Reaching a statistically adequate sample size seems close to impossible in real-world assessment**
   - Account for it methodologically
   - Share data and tools across projects and organisations
3. **More data is not necessarily translating into more insights**
   - Choose your sources carefully, trim log data and embrace qualitative data
4. **Stay tuned for further assessments**
   - The full picture is in the complete data set covering all assessment formats (small sample size) over time (evolving target system).




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# Lessons Learnt

## Integrating Human- and Organisational Factors



## Conclusions HOF Integration more General

1. **Define HOF-Integration along system development phases up front**
   - The takeaway is that despite the real-world complexities and compromises of HOF integration, established framework approaches exist to integrate the process.
   - It's a collaborative act between operator, suppliers, HOF-experts and regulatory authorities

2. **Organisational perspective to HOF-Integration**
   - The impact of newly deployed systems on less obvious roles than the train driver (e.g. track workers, maintenance staff) needs to be accounted for as well during HOF-Integration.

3. **HOF-Integration as a facilitator of customer value**
   - By systematically decreasing the gap between "work as imagined vs. work as done" HOF-Activities ensure customer value and a positive business case once the system is deployed.

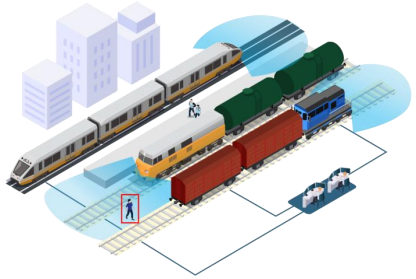
**While there is always room for future enhancement, our continuous HOF process delivered highly actionable results for this first one-year trial.**




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# Lessons Learnt

## System and Process



**Thank you very much for your interest in Project ATO-Cargo!**







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