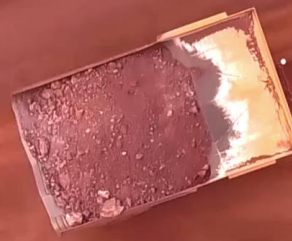
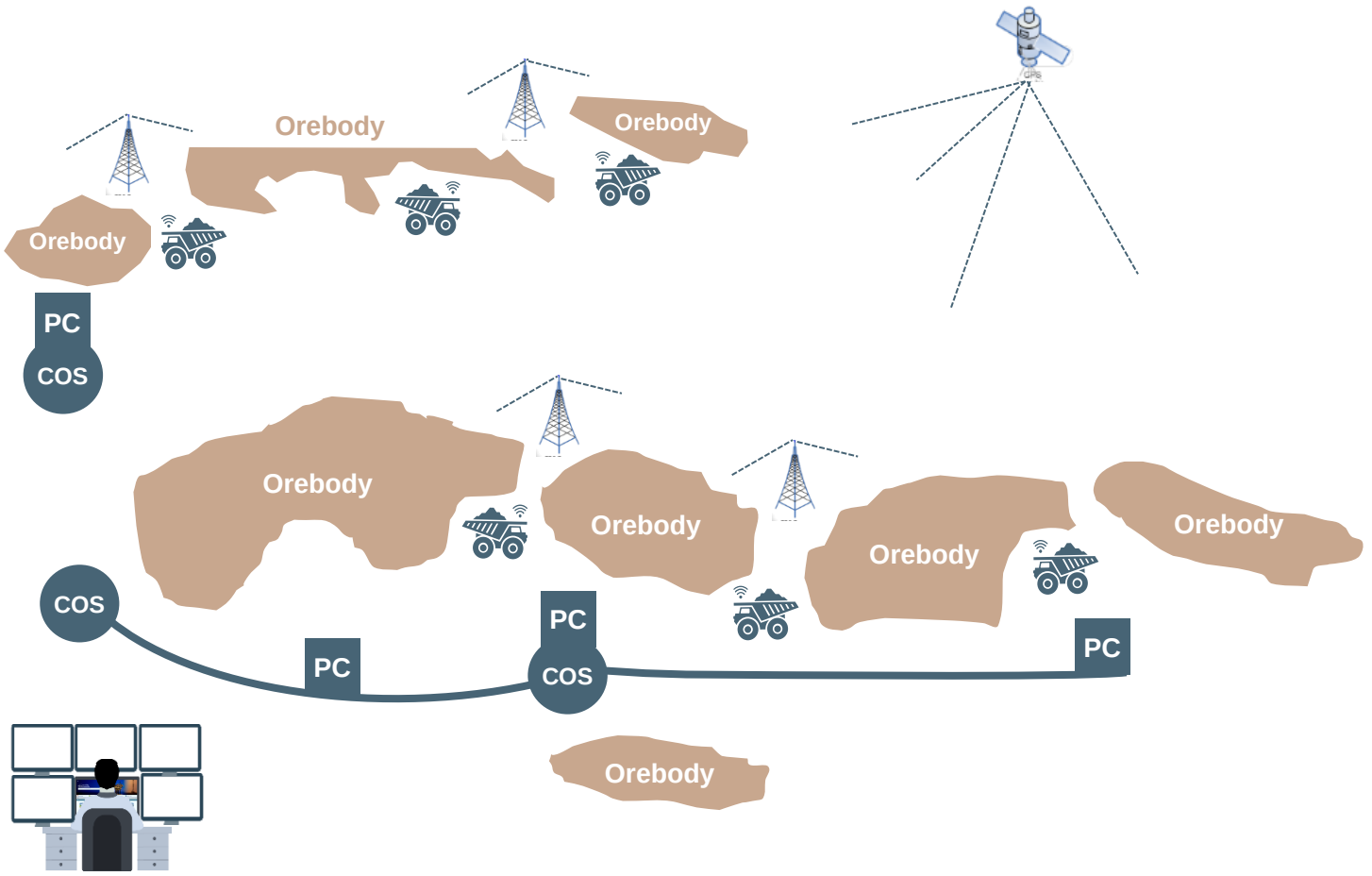
Research results



An evaluation of driverless haul truck incidents on a mine site: a mixed methodology

Todd Pascoe
PhD, Curtin University.

The research site was a WA mining operation



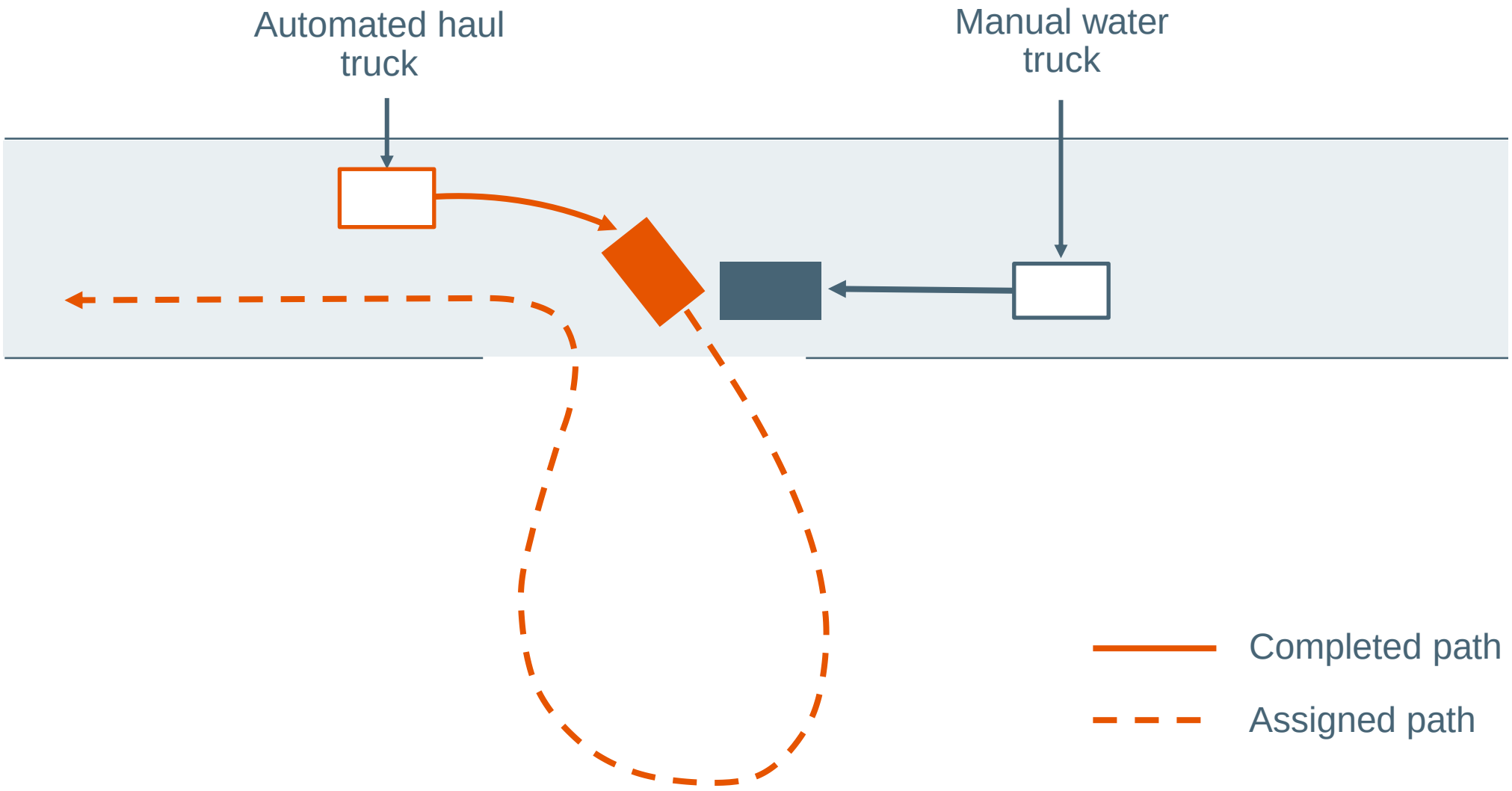
55
Automated haul trucks

~500k
tonnes moved per day

28
Minute cycles

8
Active ore bodies

The industry was surprised by a number of incidents



Regulator soon released guidance note and practices

"The addition of autonomous mobile equipment can introduce hazardous situations not normally encountered on a conventional manned mining operation. It is important that these safety challenges are addressed early in the planning cycle to maximise opportunities for solutions high in the hierarchy of control…"

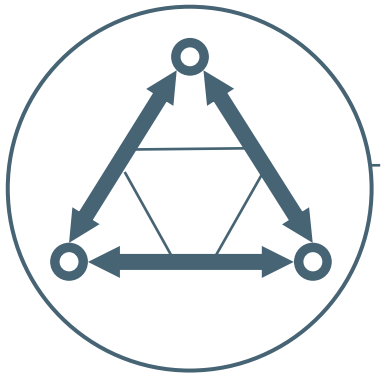
In the Regulator's opinion, autonomous technology introduces hazards beyond those in conventional manned operations.

Evaluating incidents by describing contributing factors

The aim of this research was to evaluate driverless haul truck incidents on a mine site by describing the contributing factors that led to a loss of control

- Describe new hazards and risks that have emerged through automation
- Explain theoretical viewpoints influencing the approach to automation
- Outline the processes designed to support and equip humans to improvise
- Determine the human adaptive performances in non-designed situations
- Provide an in-depth understanding of risk profile changes and strategies

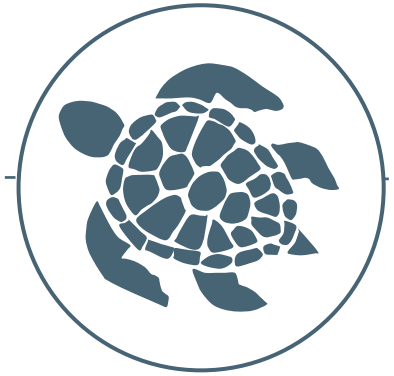
Research overview



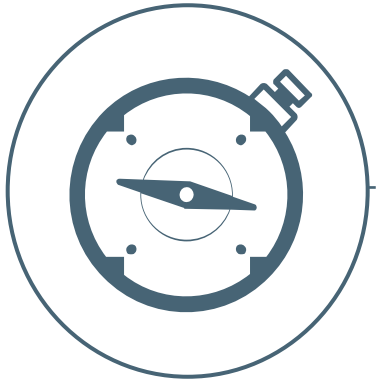
Mixed method

Literature review

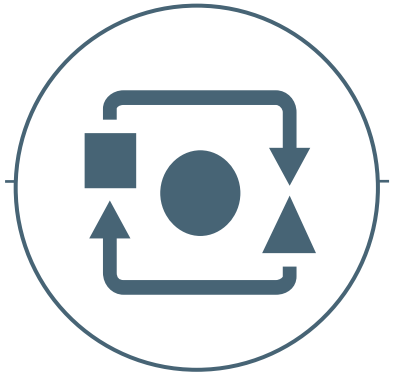
Study 1



Study 2



Recommendations



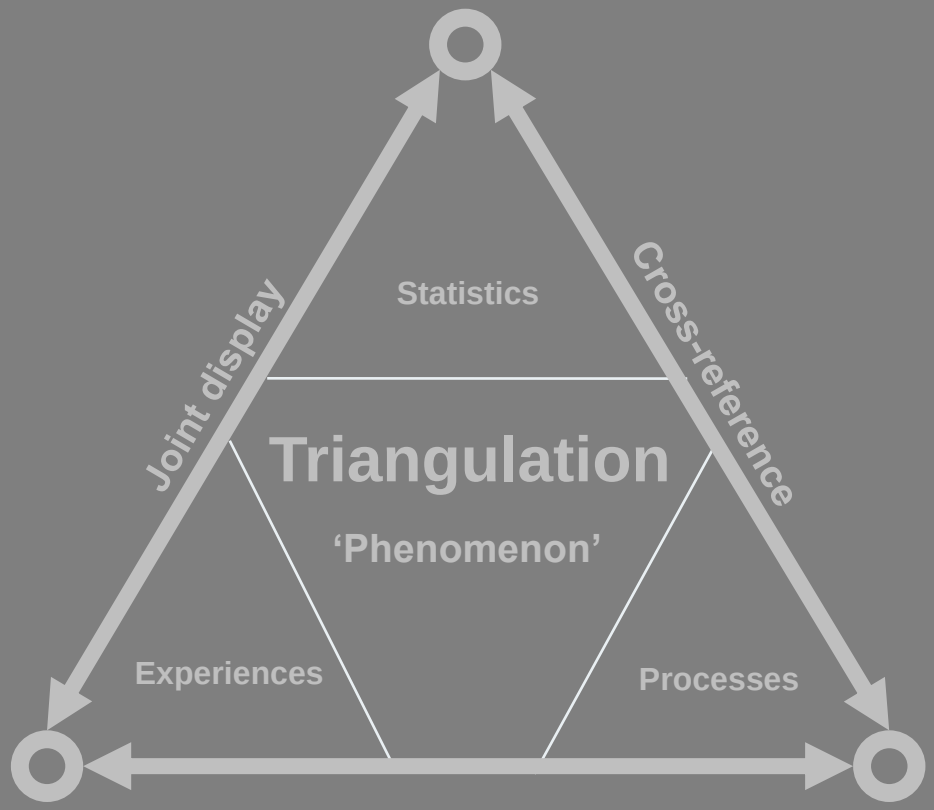
Discussion and Conclusion

Study 4

Study 3

Methodology

A convergent parallel design to develop a comprehensive understanding of predictors and perspectives



Mixing methods to seek multiple avenues in parallel

1 Quantitative data

2 Qualitative data

"I saw the truck…"

3 Merging data

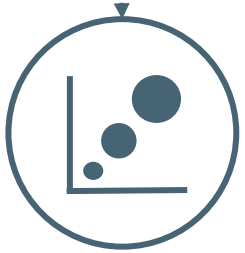
90% of operators were surprised…

Quantitative

(Description, incident details and incident severity)

Analyse

Trend



Plot

Qualitative

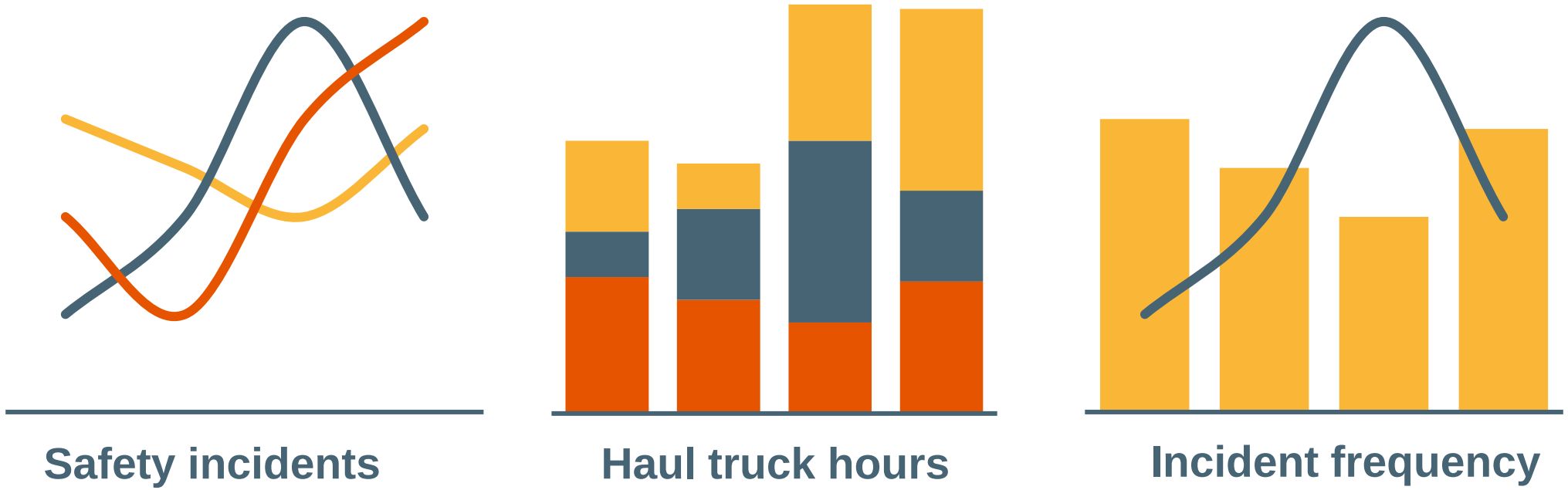
(Systems and procedures, one-on-one interviews, field observations)

Documents

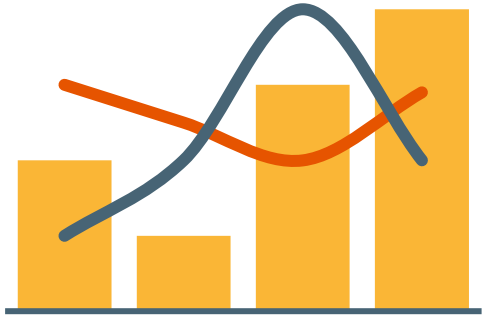
Observation

Interview

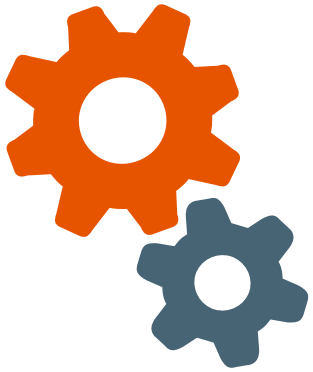
Collecting raw data before, and after automation



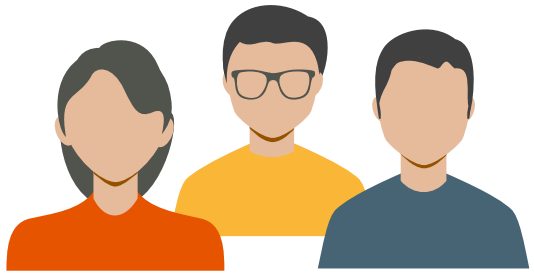
3 Phases: Analysed separately, merged to draw inferences



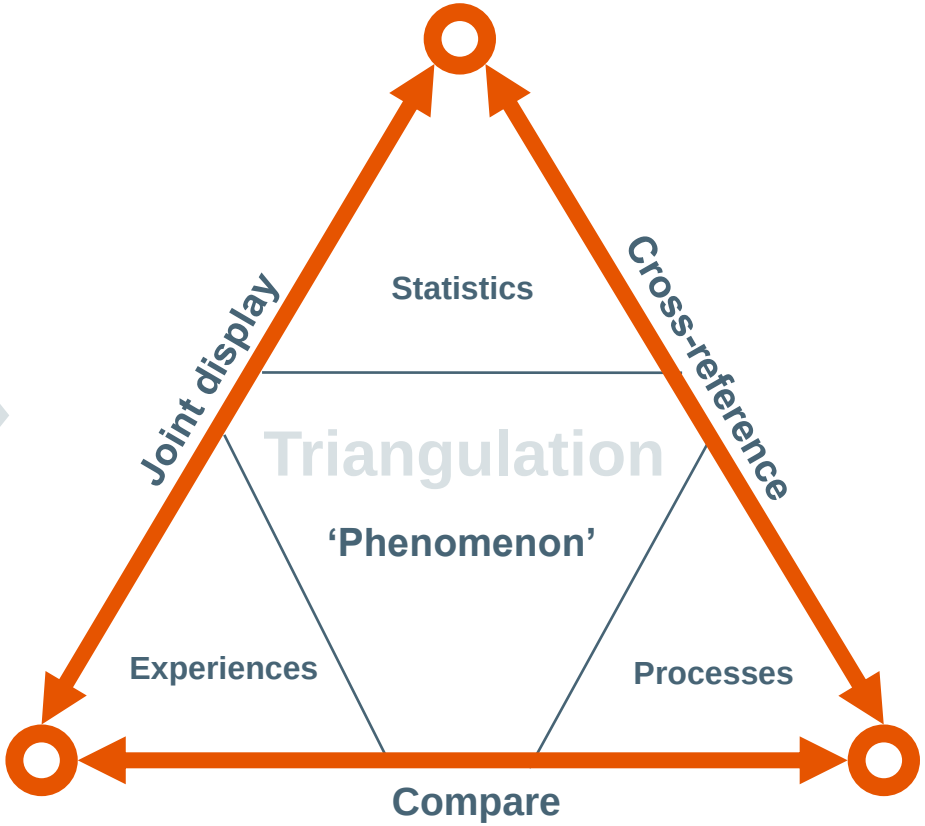
Statistics



Processes



Experiences

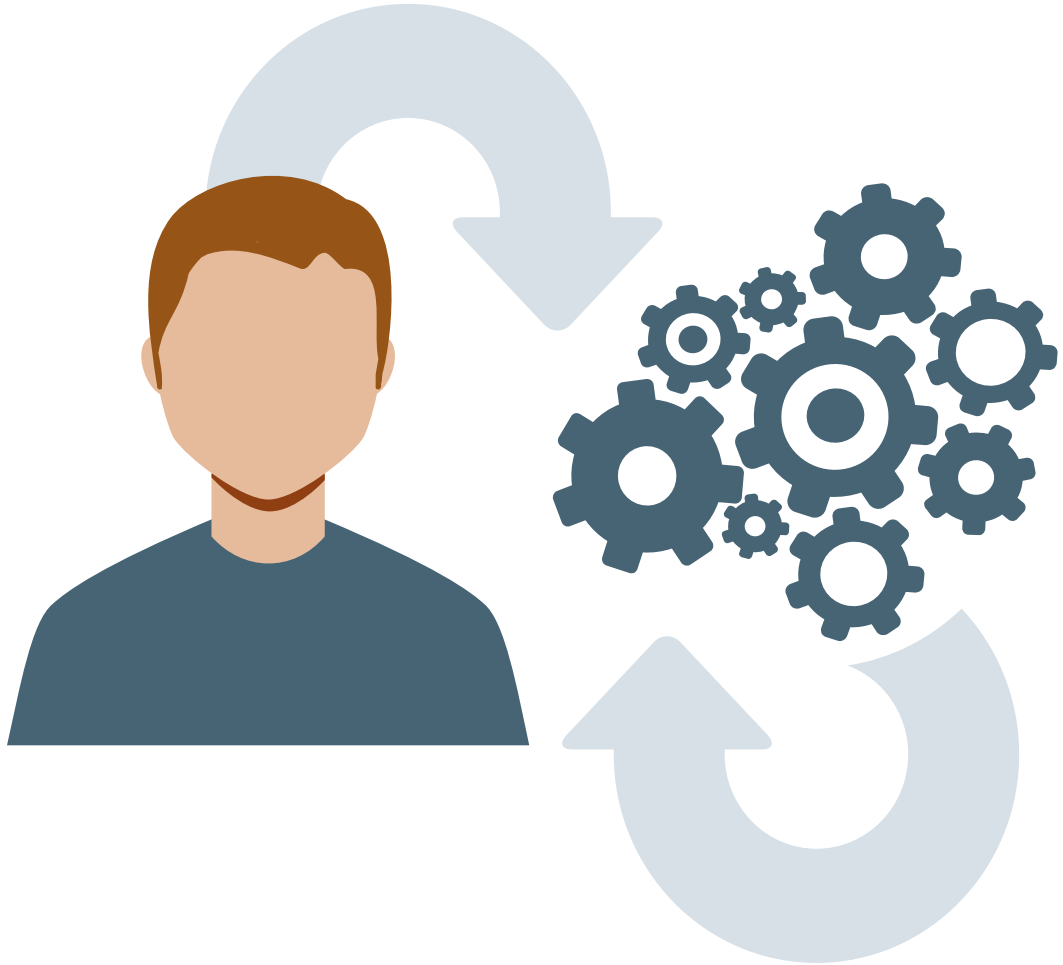


Literature review

A multi-industry analysis of human-machine systems: the connection to truck automation

Pascoe, T., McGough, S. & Jansz, J. (2022). A multi-industry analysis of human-machine systems: the connection to truck automation. World Safety Journal, 31(1), 1-30.
https://worldsafety.org/wp-content/uploads/WSJ-March-2022.pdf

Aim was to explore the factors across multiple industries

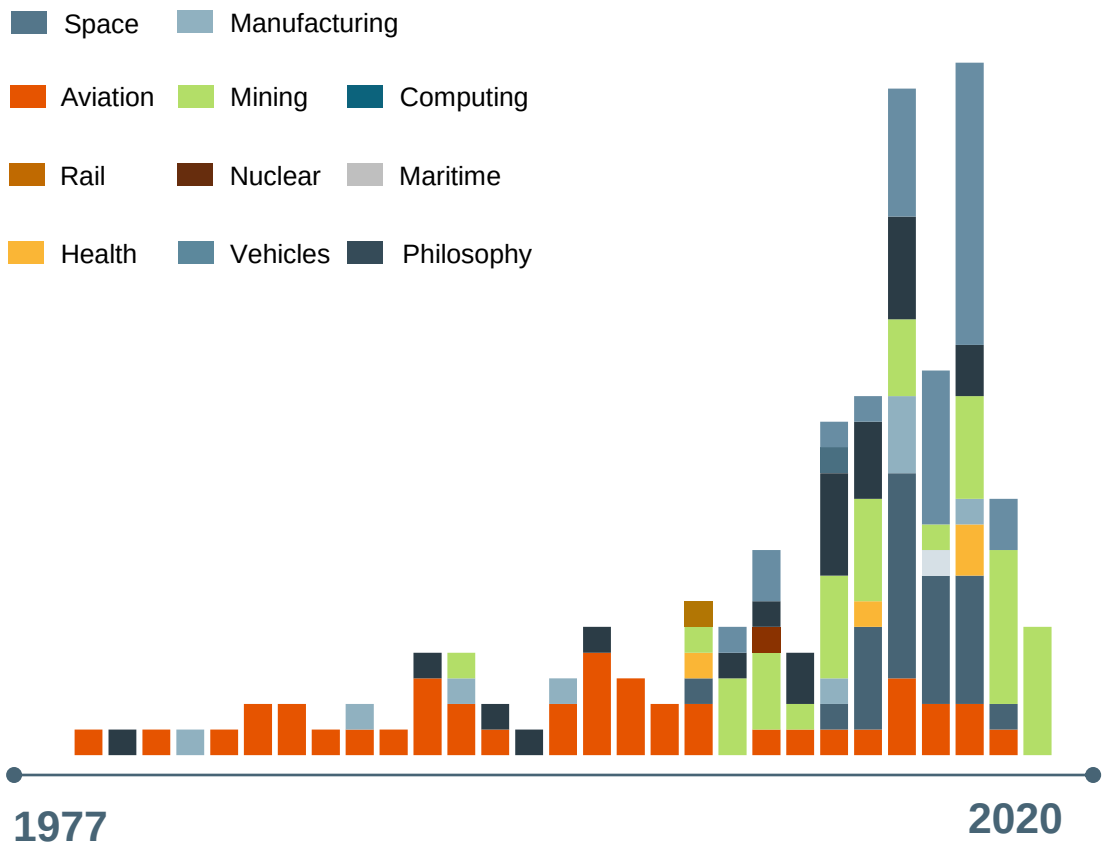


Human-machine relationship

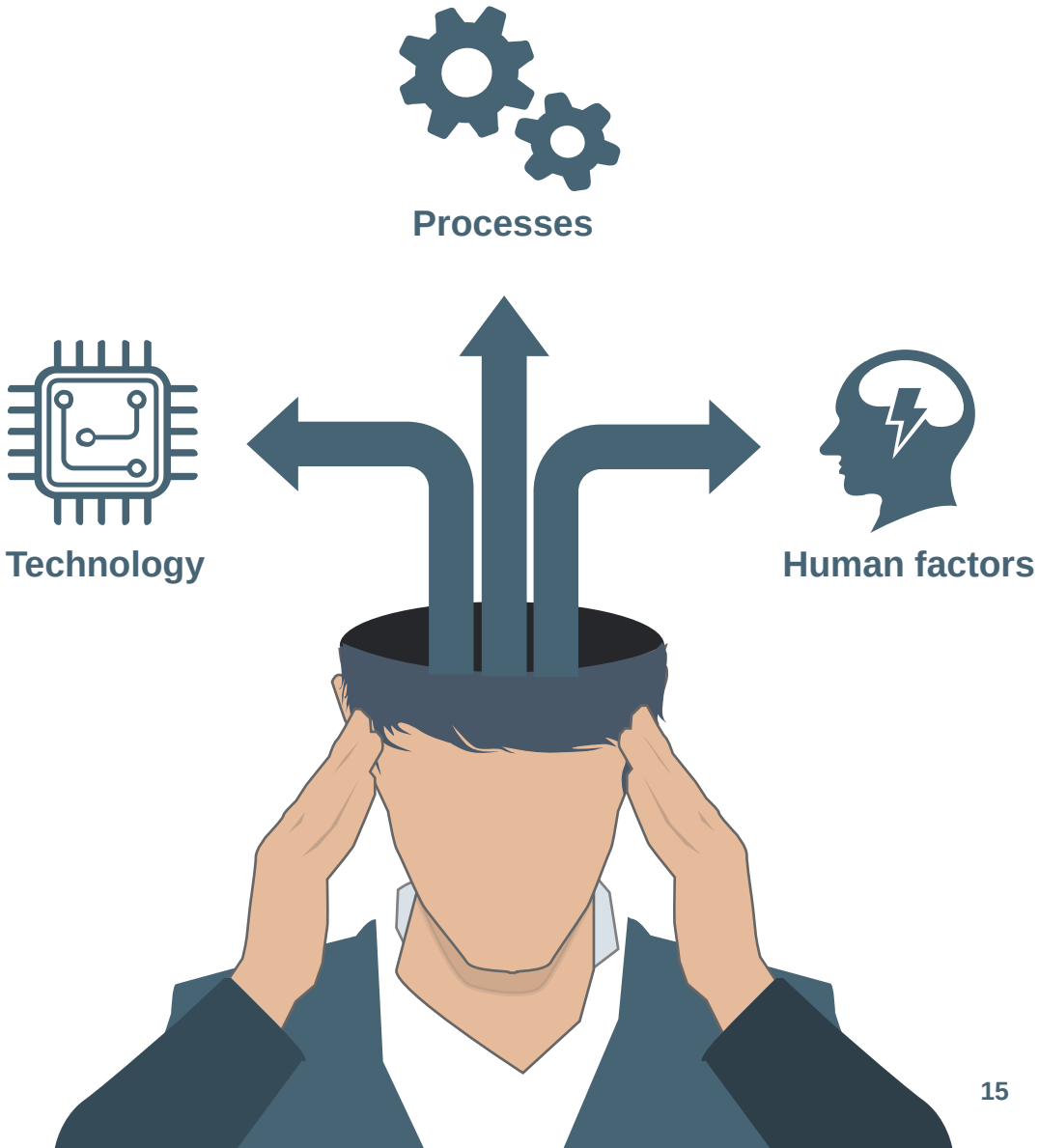
Types of situations that emerge

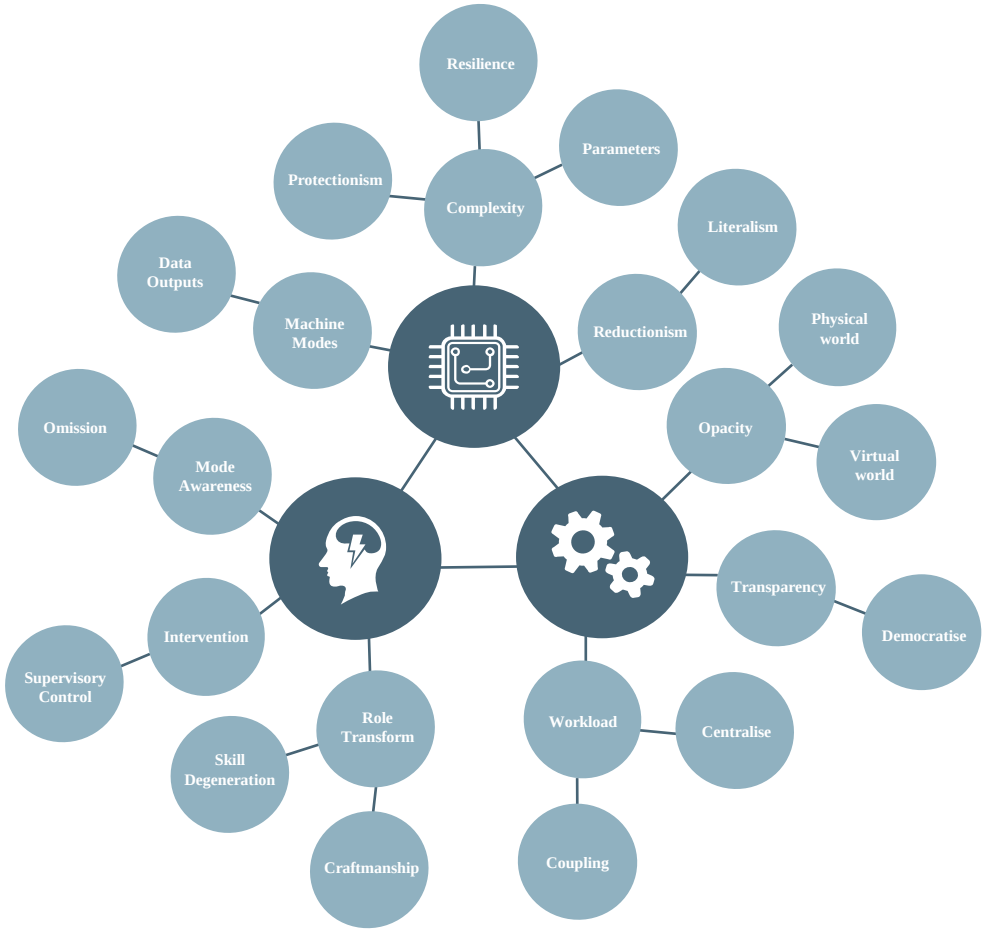
Themes and lessons from the literature

11 different industries, spanning 43 years of learning



Synthesised into 3 main themes, within 23 sub-themes





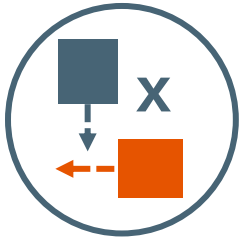
Study 1

From driver awareness to object recognition: a tiger never changes its stripes

Pascoe, T., McGough, S. & Jansz, J. (2022). From driver awareness to object recognition: a tiger next changes its stripes. World Safety Journal, 31(2), 15-28. https://worldsafety.org/wp-content/uploads/WSJ-June-2022.pdf

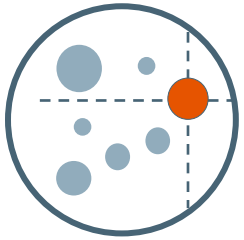
Explored incidents involving driverless haul trucks

Discover why driverless incidents occur



What were the losses of control?

What were the associated hazards?



What occurred to the risk profile?

Evaluated incidents to understand the phenomenon

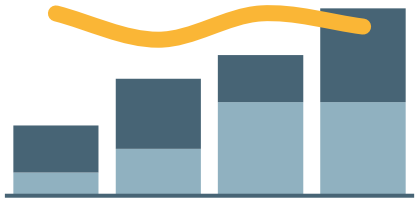
1 Quantitative data

- Incident frequency
- Locations
- Incident types
- Risk rankings

2 Qualitative data

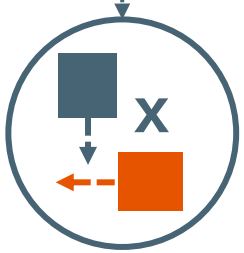
"encountered muddy conditions causing it to briefly lose traction…"

3 Code and trend



Structure

Findings



Circumstance

Frequency

Analysis

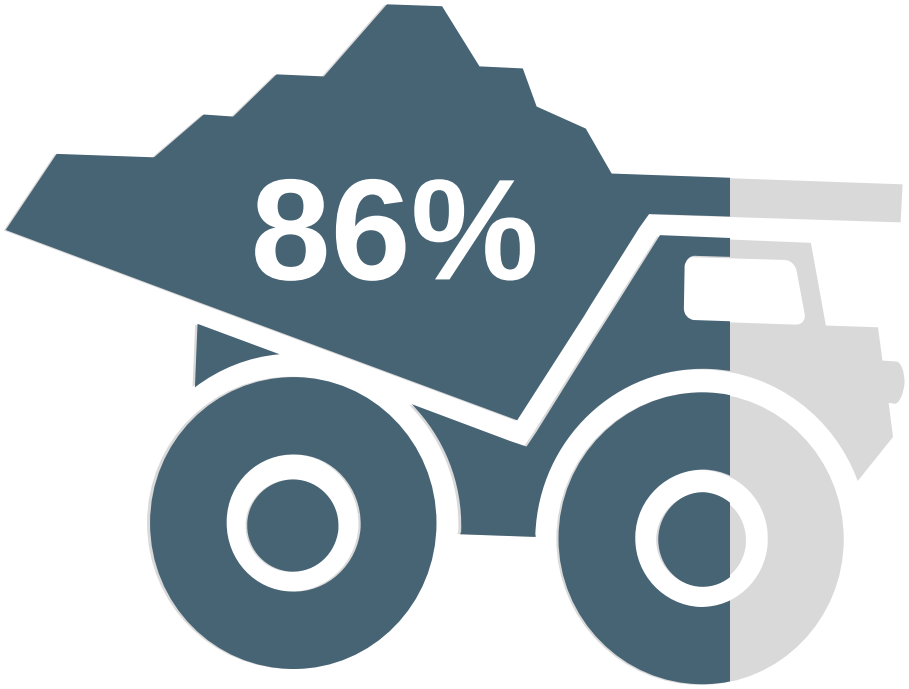
Category

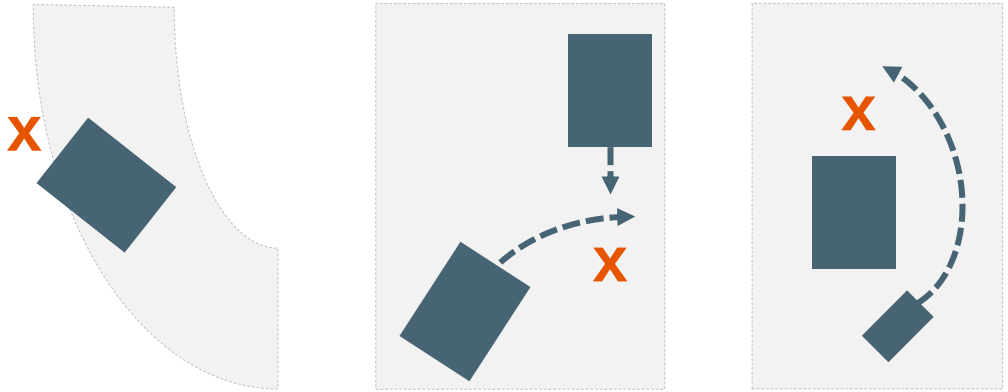
Theme

Represent

This highlighted trends with unconventional pathways

Unconventional truck incidents
(% of incidents not found in manual operation)





51%

Lane Breach

(wet roads, obstacles and communication loss)

33%

Proximity Detection

(driver awareness, low feedback on displays)

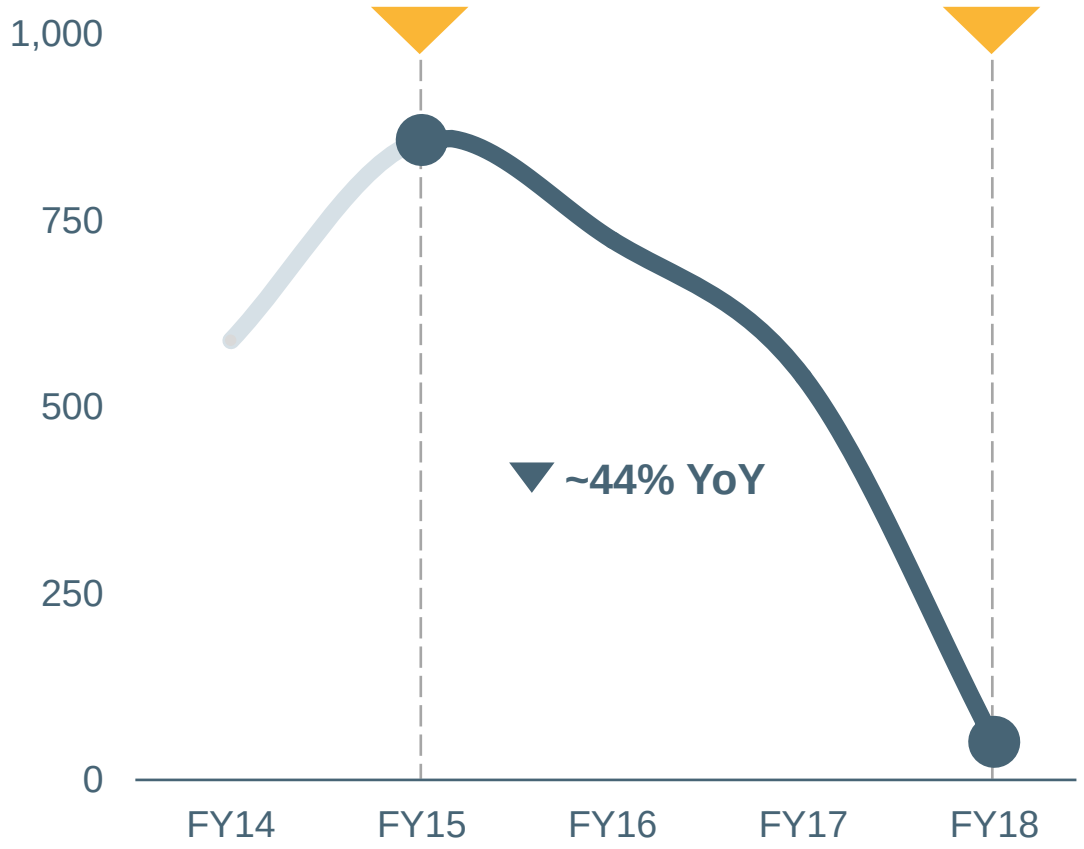
8%

Process Breach

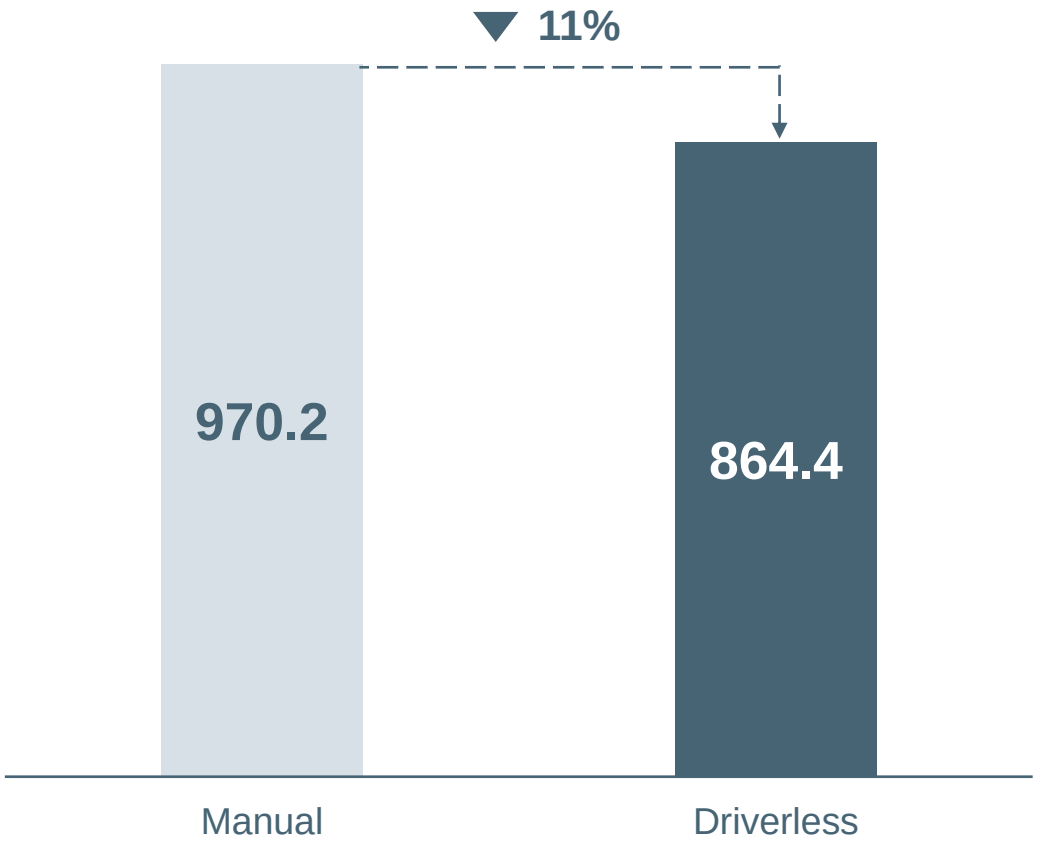
(Communication, process understanding)

Even though there was a reduction in site frequency

Site truck incident frequency
(# of incidents per million production hours)

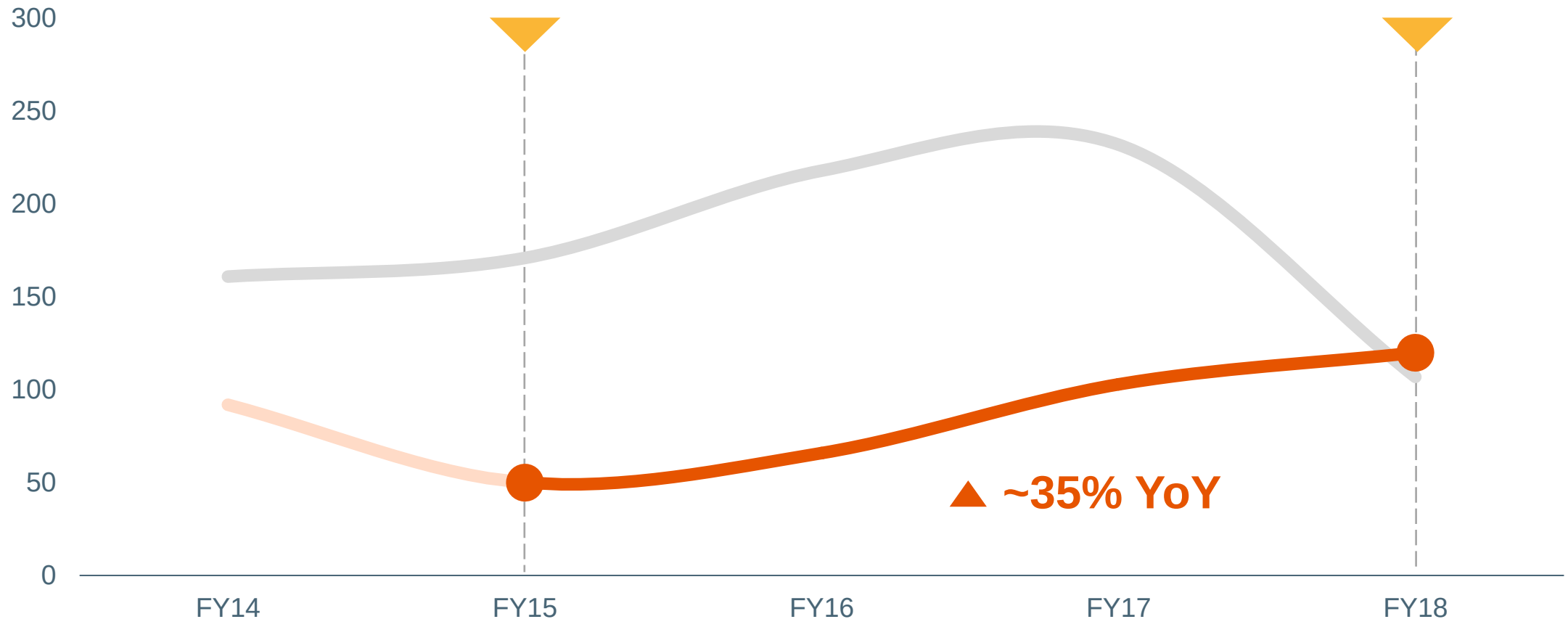


Incident frequency by truck type
(# of incidents per million production hours, FY14–18)



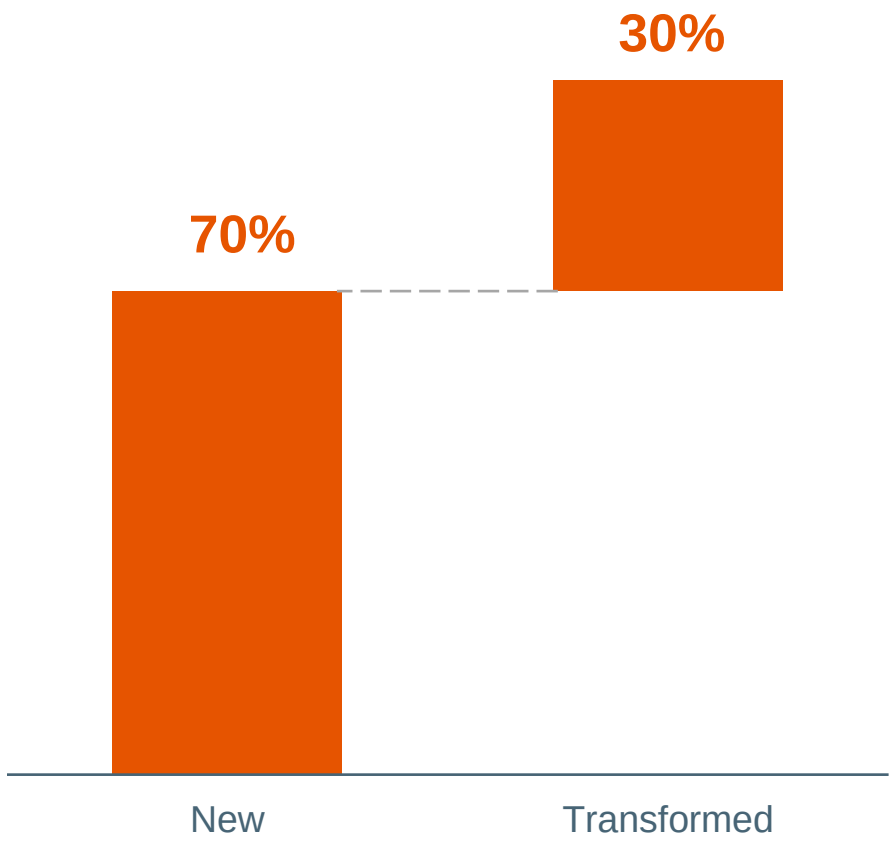
Unconventional incidents involving trucks had emerged

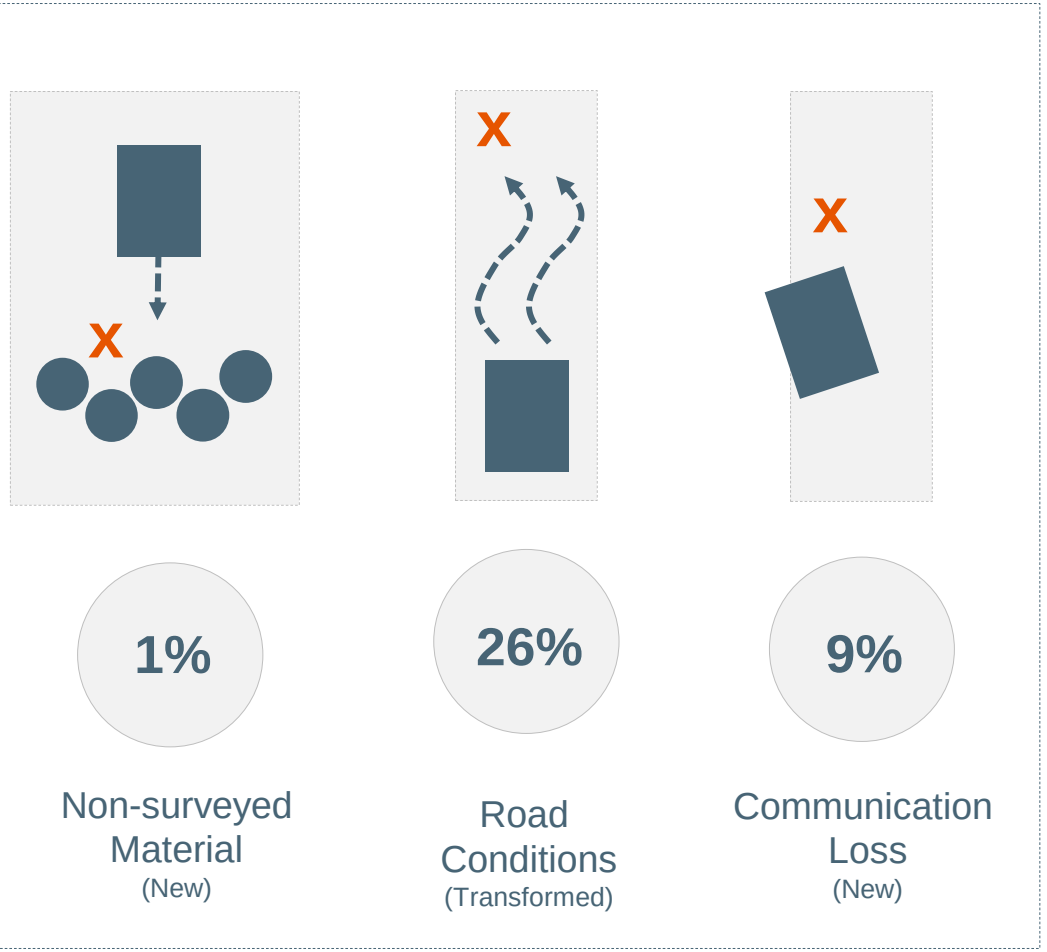
Driverless truck incidents
(# of incidents involving a driverless truck)



Driven by new and transformed truck hazards

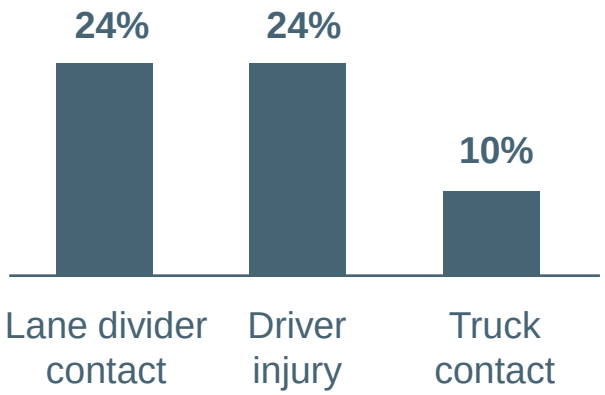
New and transformed hazards
(%)

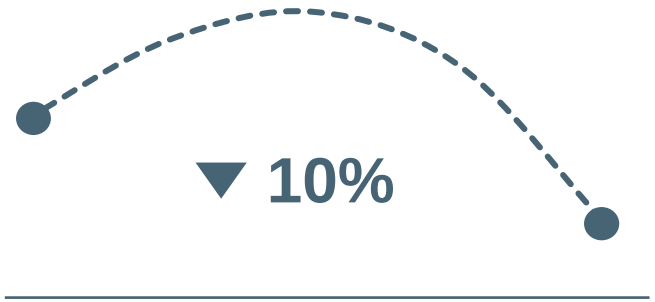




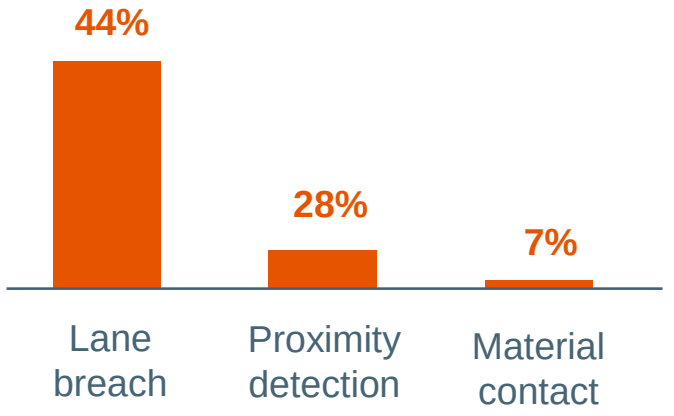
Transforming the mine site's risk profile

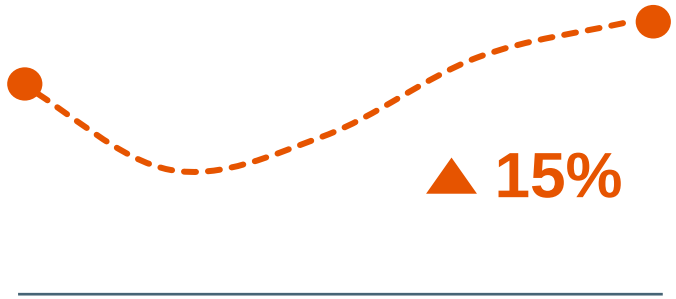
Conventional



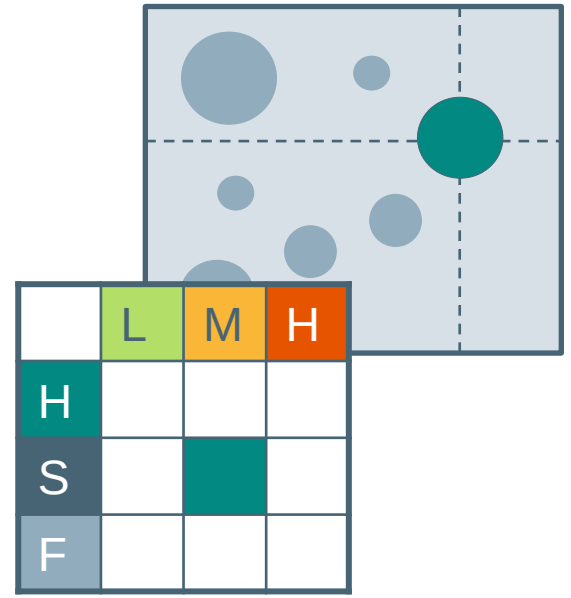


Unconventional

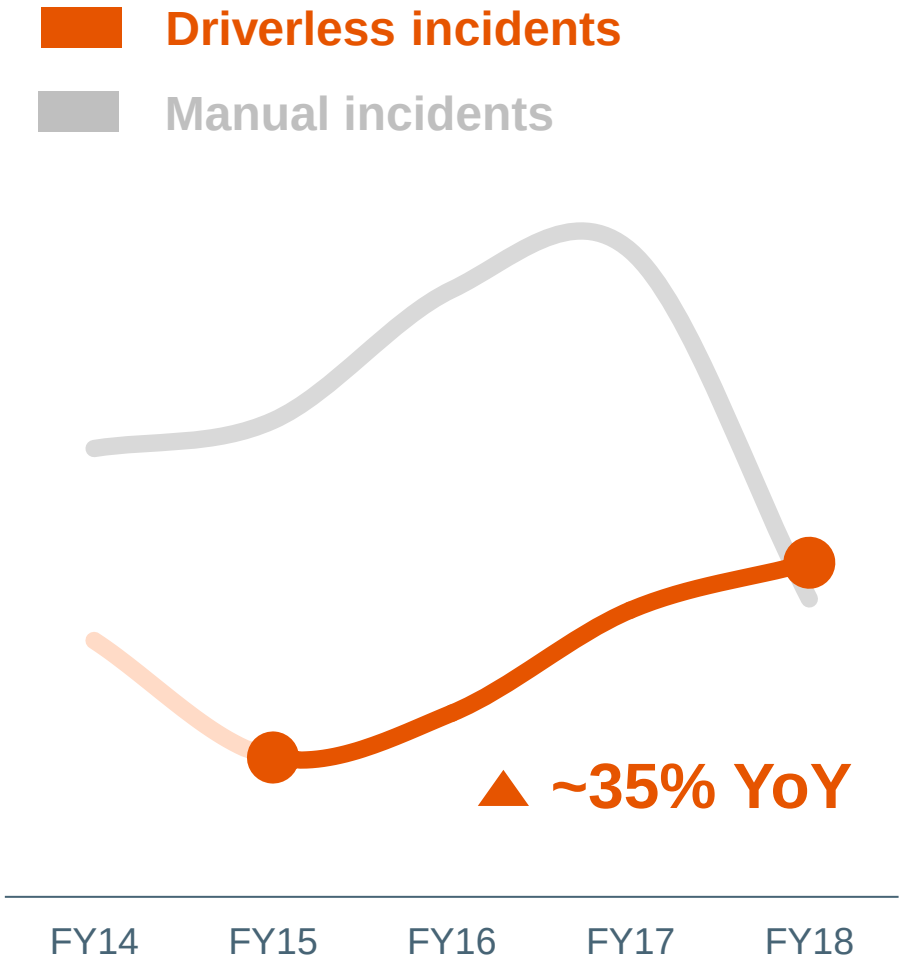


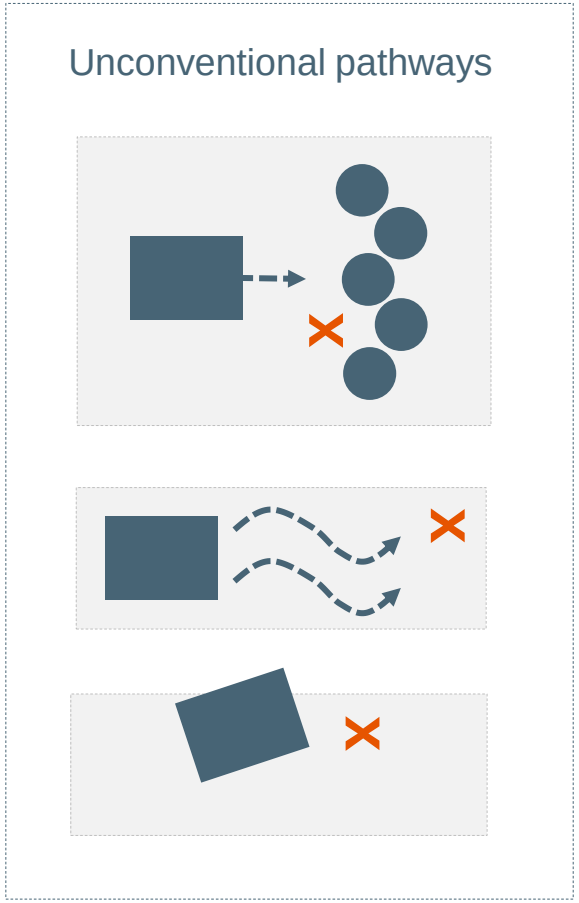


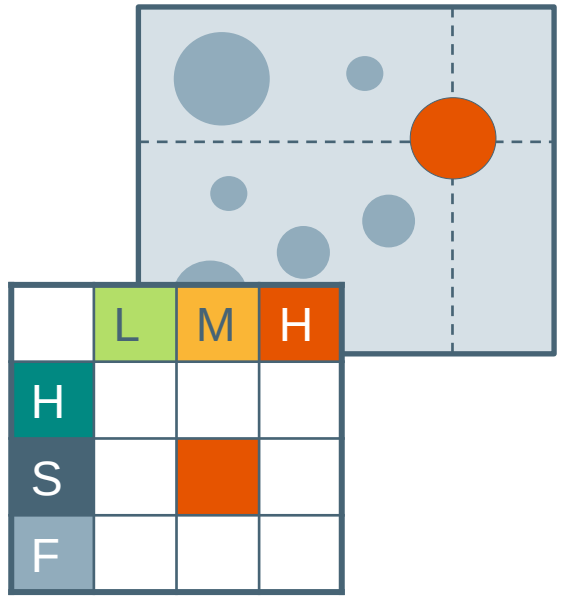
New risk profile



Therefore, automation did not eliminate risk, it changed it



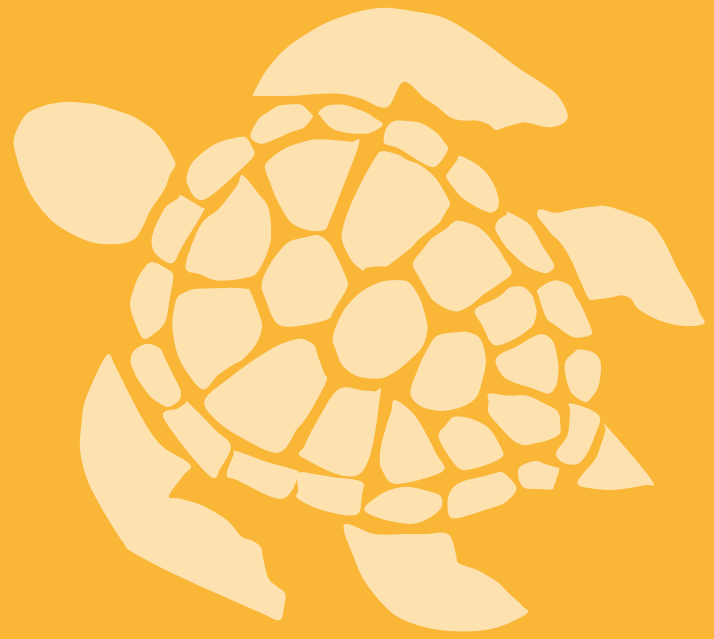




Shifting the risk profile

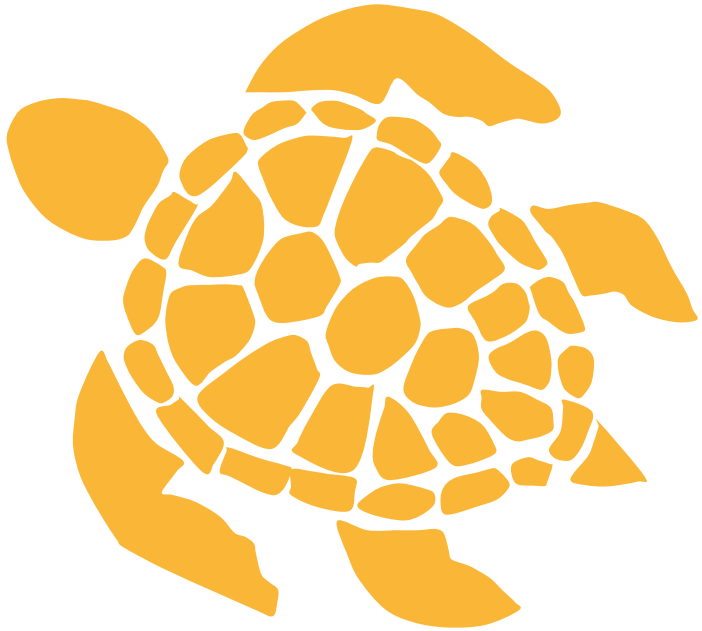
Study 2

Haul truck automation: embody the complexity to avoid seeing turtles as rifles

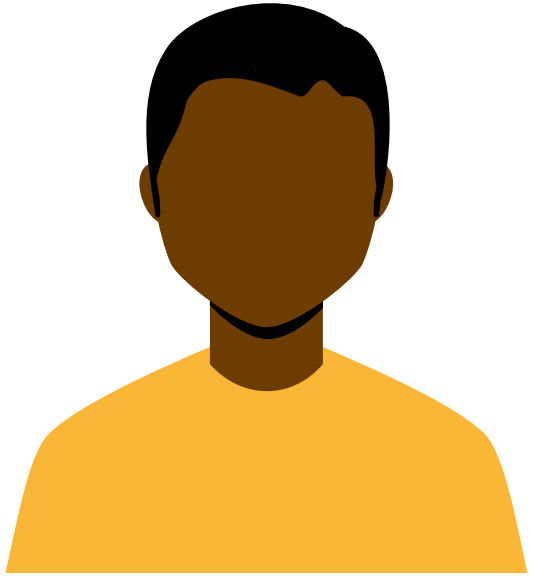


Pascoe, T., McGough, S. & Jansz, J. (2022). Haul truck automation: embody the complexity to avoid seeing turtles as rifles. World Safety Journal, 31(3), 26-38
https://worldsafety.org/wp-content/uploads/WSJ-September-2022.pdf

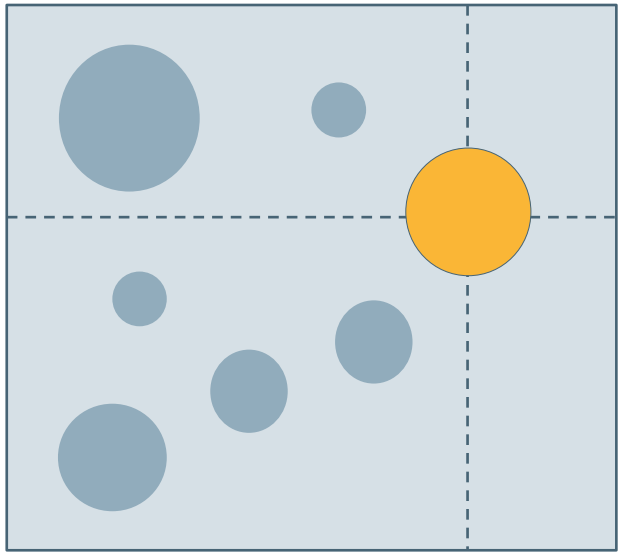
Artificial intelligence has faced practical constraints



Classifying turtles as rifles

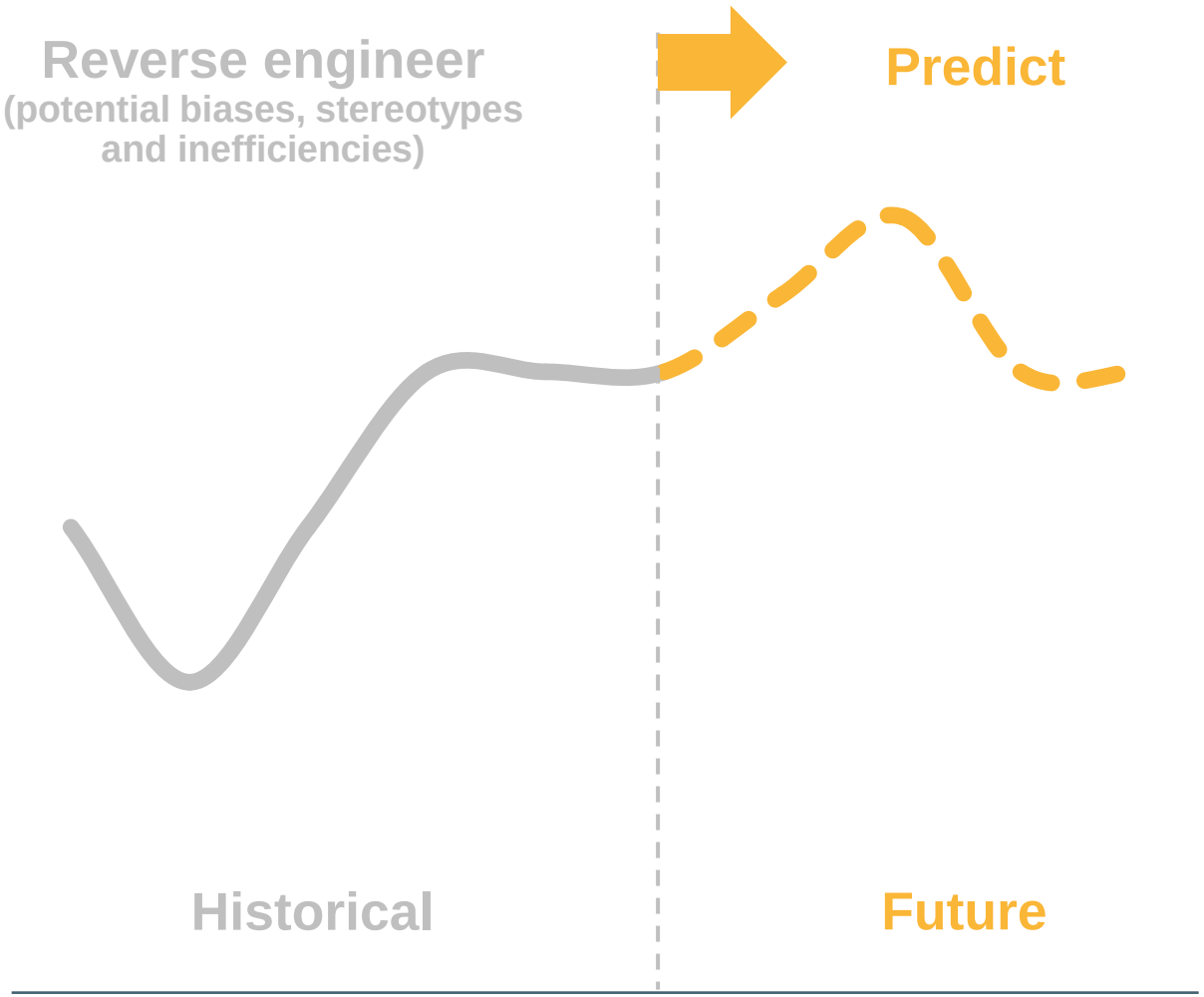


Unable to recognise dark faces



Predicts crime in places already policed

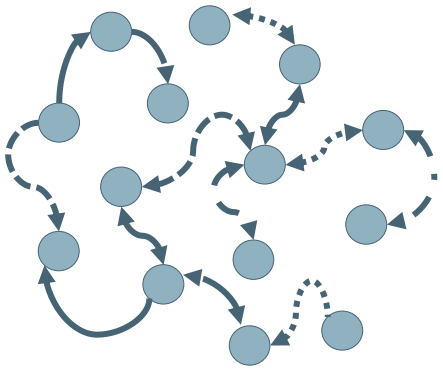
Predictive capacity excludes complexity and diversity



Neat and controlled

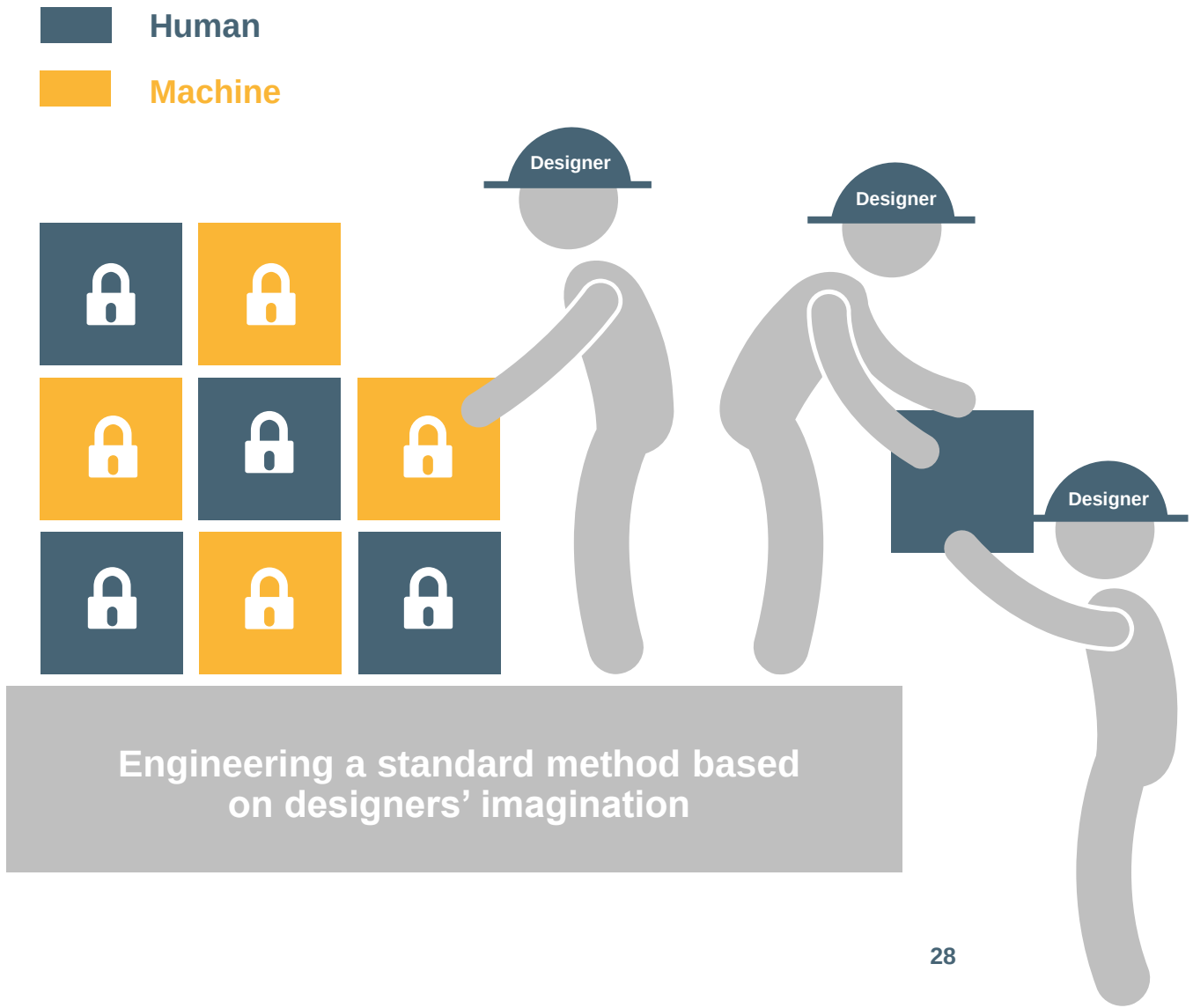
Includes

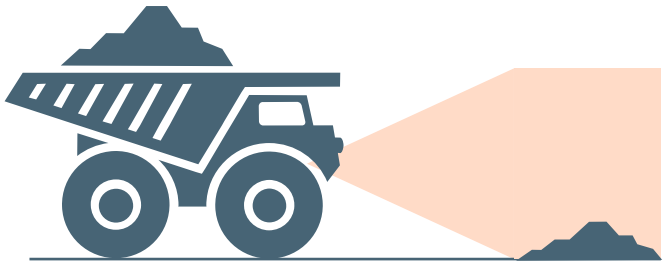
Excludes

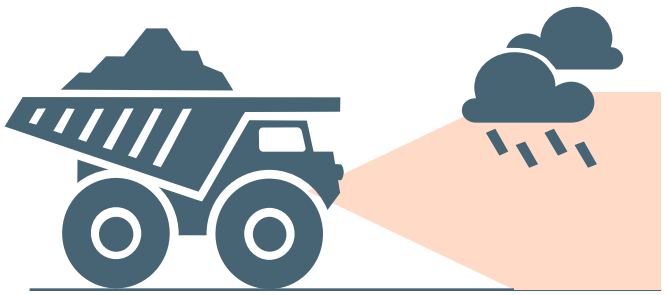


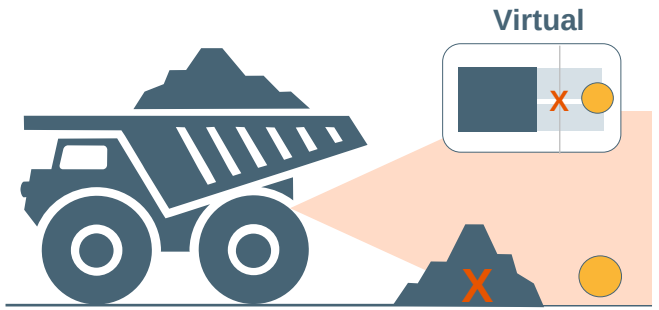
Complex and non-designed

Locks in one best method, yet faces practical constraints




Unable to classify objects


Cannot detect rain

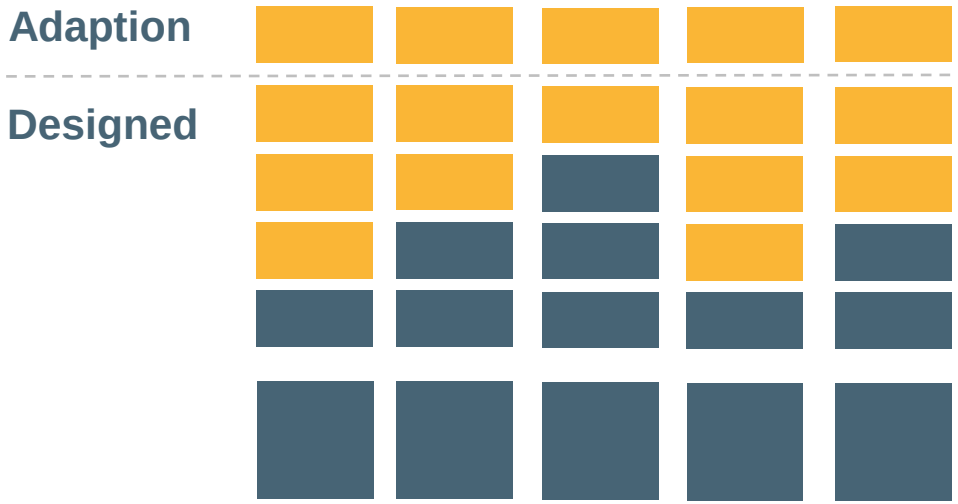


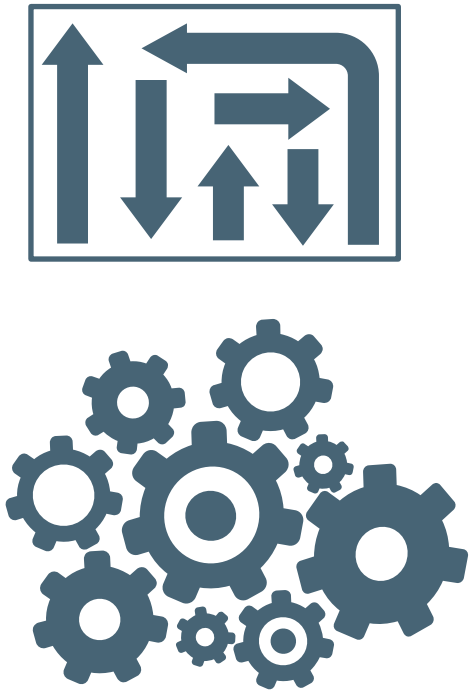
Physical world distinctions

Therefore it needs human adaption to navigate constraints

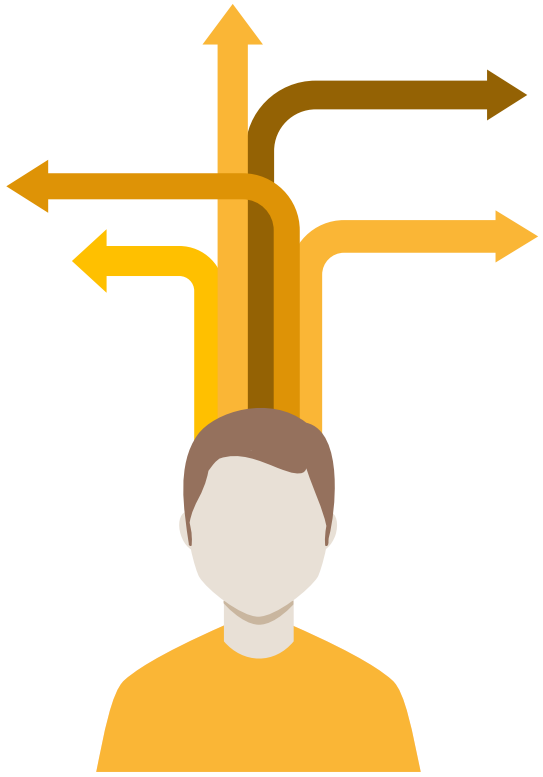
Reverse engineered into machine

Residual human tasks





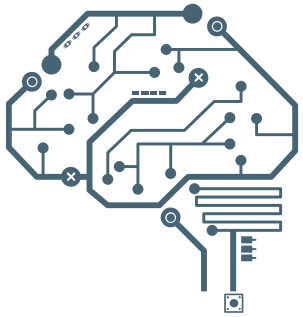
Constrained



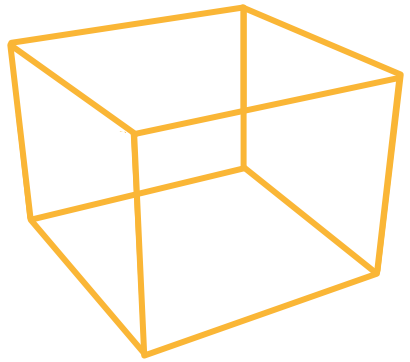
Unconstrained

The box must open, establish diverse methods and ideas

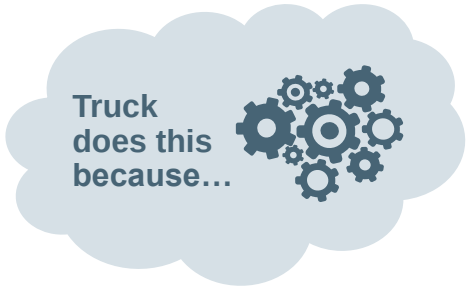
Open sourced to work with other fields

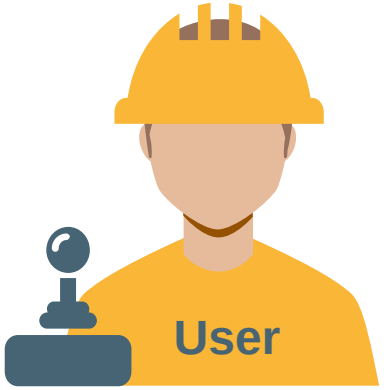


The system will do x, y in this instance



System needs to be transparent and explainable





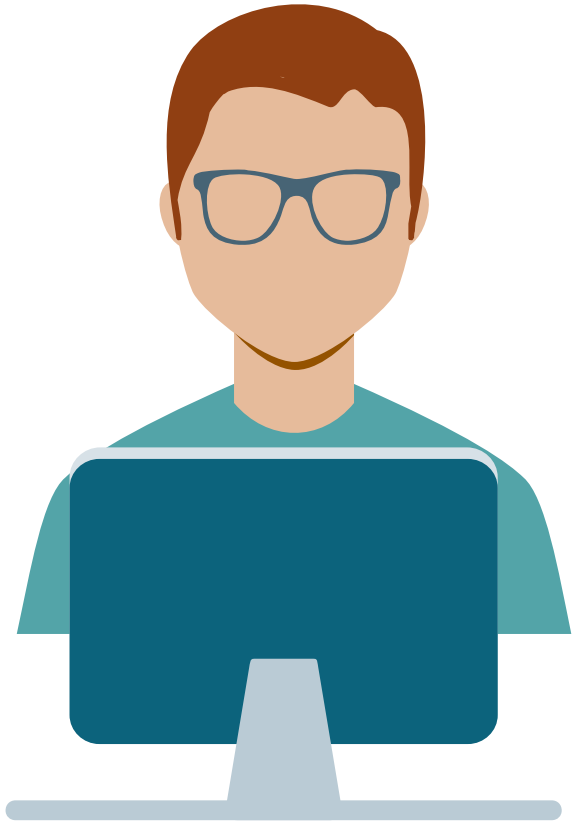
Users know how it works, not just how to work it

Study 3

Mine worker experiences working with driverless trucks: risk, trust and teamwork

Pascoe, T., McGough, S. & Jansz, J. (2022). Mine worker experiences working with driverless trucks: risk, trust and teamwork. World Safety Journal, 31(4), 19-40. https://worldsafety.org/wp-content/uploads/WSJ-December-2022.pdf

Exploring the practical experiences of mine workers



What is it like working with automation?

- Hazards and risks
- Trust levels
- Unanticipated situations

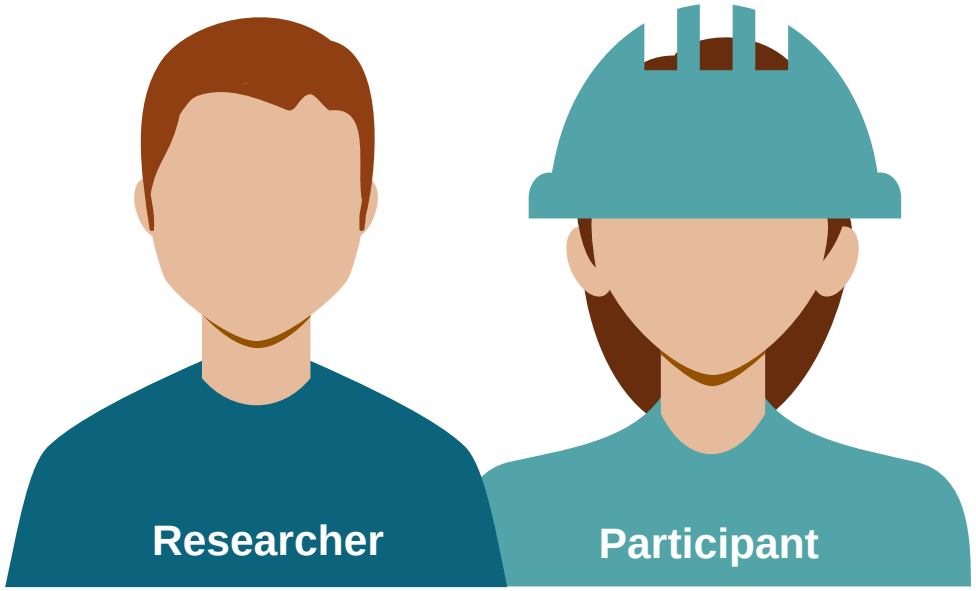
Closed and open questions, merging nodes into themes

Questions

- Semi-structured interviews
- Nine questions
- One-on-one

Responses

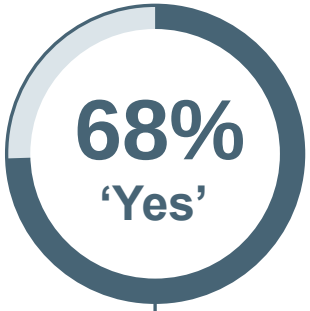
- Qualitative
- Quantitative



‘Yes’

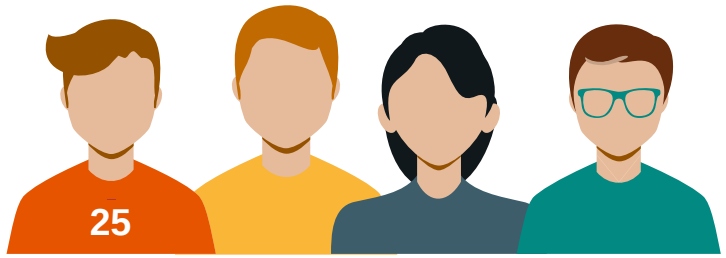
“For me the autonomous side has sort of **taught me you know to like… Techno man**.”

Cross-referenced



“Well, you know in my mining career **I’ve never work with screens before**…”.

“Then you might have four hours flat out then nothing... **So it really does fluctuate a lot.”**



Stratified sample

Hazards introduced, high trust, while trucks play their role

New hazards and risks

68% Believe new hazards and risks have been introduced through automation

> You still have to respect the blue light. They are a big machine, no one in them, could be doing 60 km/h. They are not just going to stop on a dime.

What do you think is contributing to incidents involving driverless haul trucks?

> We (humans) are the ones that slow it down or make it fault.
>
> They're experienced operators, but not all have autonomy experience.
>
> They didn't go into the in-depth detail to look at it a little bit further and actually really check.

High level of trust

9.2 Out of 10 — Median trust level out of ten for the driverless haul trucks

52% Stated that have not observed a truck perform something they did not anticipate

88% Stated that there trust level did not change after incident or an unanticipated situation

9.7 Out of 10 — Confidence level for redirecting or overriding obstacles detected

> A man truck might be spot on after his smoko and his coffee, but 5 hours down the track, he could be thinking about fishing or something like that. An autonomous truck is not thinking about that.

Play role, don't assist others

96% Stated that the system informs them adequately of its mode or function truck is performing

64% Said that they've never instructed a truck to do one thing and it performed something different

> … if you know how to control the options you give it properly, it will play your game. But, if you let it do whatever it wants it to do, it will play its own game and it's a production game.
>
> It's blue, flashing blue, it's in autonomous mode. It's lifting its tray, its dumping, its backing under the digger and it's going to get loaded.

If the driverless trucks were team players, how would you describe them?

> They just do what I asked them to do and they don't talk back.

Despite new hazards and narrow-focus, trust increased

New hazards

- Virtual world distinctions
- Human complacency
- Limited driverless experience

High trust

- Predicted pathway provided
- Never wavered after incidents
- Stopping for small objects

Plays its role

- Role-focused, not team
- Informs others of function
- Performs instructions

Study 4

From truck driver to systems engineer: transforming the miners' contribution

Pascoe, T., McGough, S. & Jansz, J. (2023). From truck driver to systems engineer: transforming the miners' contribution. World Safety Journal, 32(1), 13-42. https://worldsafety.org/wp-content/uploads/WSJ-March-2023.pdf

Understanding the role and skill transformation of miners

From active participant to passive receiver

- Role and skill changes
- Residual workload
- Local adaption

Skills increased, workload varied and adapting to novelties

Role transformation

72% Stated their role changed through introduction of driverless trucks

96% Stated their skills changed through the introduction of automation

> "Definitely, yeah… I was actually physically driving the truck, refuelling… now it's just like sitting behind a computer, more technical based…"

How would you describe your role in the driverless operation?

> "Our current role is all about making sure the virtual mine model that the truck live in, making sure that it matches up to the real world."

Residual workload

62% Stated there are residual tasks due to driverless truck limitations

8.2 Out of 10 Median rating for understanding of modes and features

68% Misinterpreted information given to them by the driverless system

> "So it is busy things and I think of lot of people forget you've taken away the thirty truck drivers and left one person in charge now."

How would you describe the workload of system-based roles?

> "There can be days when they do not do a lot then they are flat out doing dumps and planning stuff."

Local adaptions

68% Were faced with situations that required them to think outside the box

> "Constantly. Our structured processes pretty much only cover a scenario. The mining world is extremely dynamic and fluid."

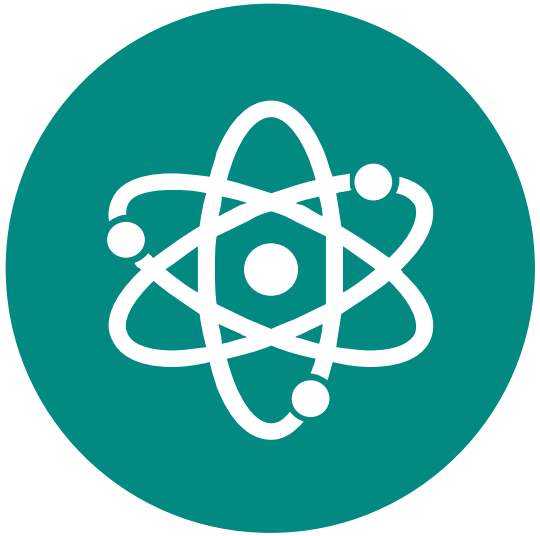
How do you remain in the loop with what is happening in the system?

> "I'm always looking at my tablet to see what is going on… People also tell me what is happening."

How do you determine whether to interview or not when something doesn't seem right?

> "It comes back to experience of feeling when something doesn't seem right."

Skills developed, varied workload with local adaptions



Transformation

- Learned computer systems
- New tasks and interfaces
- Lane colours and alarms

High-low workload

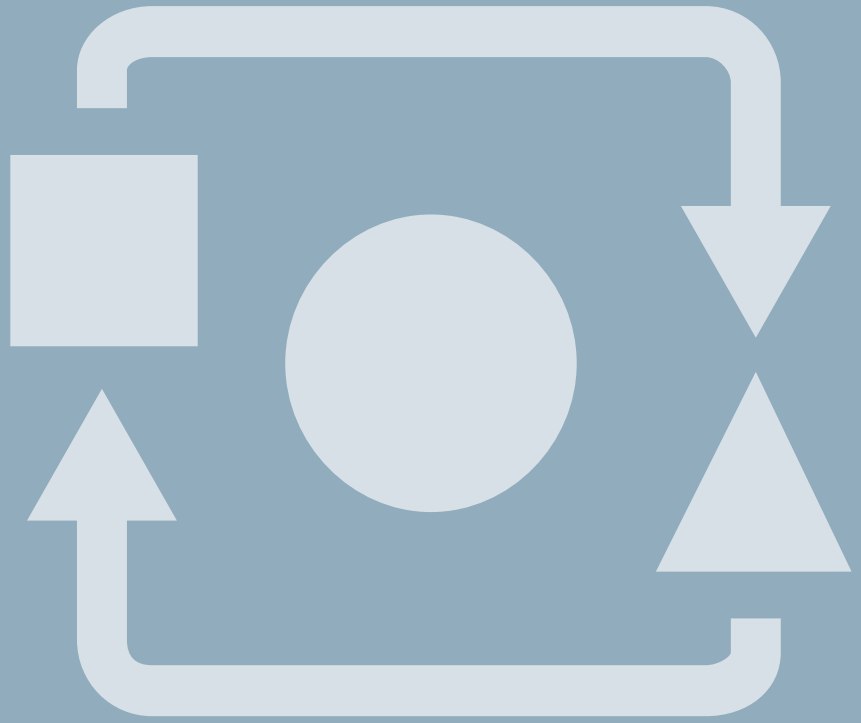
- Up and down workload
- Understand features for role
- Outputs can be cryptic

Adapting locally

- Beyond design thinking
- Clearing objects
- Building mine models

Discussion and Conclusions

Interpretation of the research results



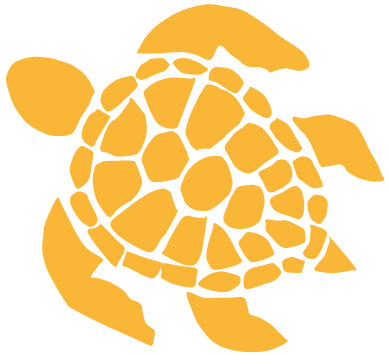
Risk profile changes, reductionism and worker adaptions

Literature review

Highlighted the complexities that emerge between human and machines in joint systems and how they apply to mining.

Study 1

Incident analysis highlighted unconventional incidents and hazards. Demonstrated the risk profile changes through introducing automation.



Study 2

Illustrated how reductionism gives the appearance of being more intelligent; yet faces practical constraints in non-designed situations.

Study 3

Explained worker views that hazards are introduced, high trust was developed, despite system focusing on its own role without helping others.

Study 4

Explored the role skill transformations with new skills developed, residual workload and adapting locally in non-designed situations.

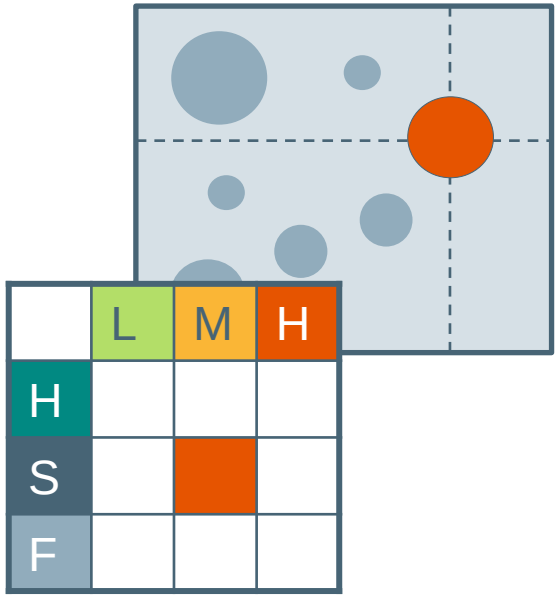
Evaluation of driverless haul truck incidents on a mine site by describing the contributing factors that led to a loss of control

Recommendations

Providing a way forward to avoid driverless haul truck incidents on mine sites

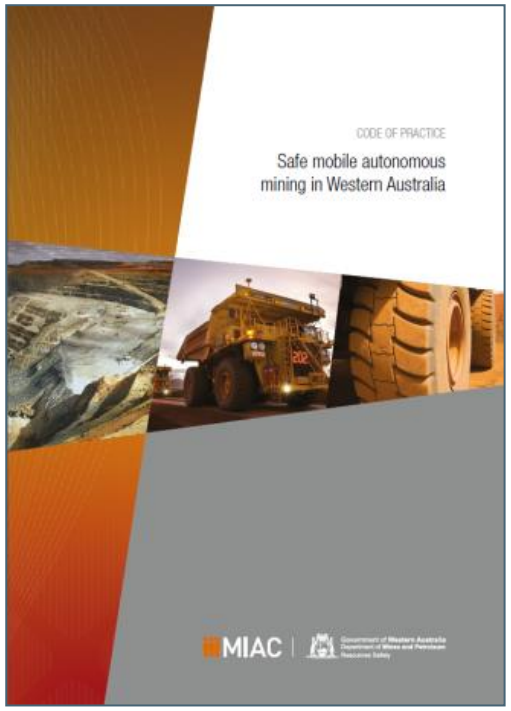
Update risk profiles, safe systems and code of practice

Update risk profiles



Safe systems of work

Update COP



Questions