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Human Factors Challenges of Automation in Railway Control

Michael Carey C.ErgHF FIEHF
Head of Ergonomics, Network Rail, UK

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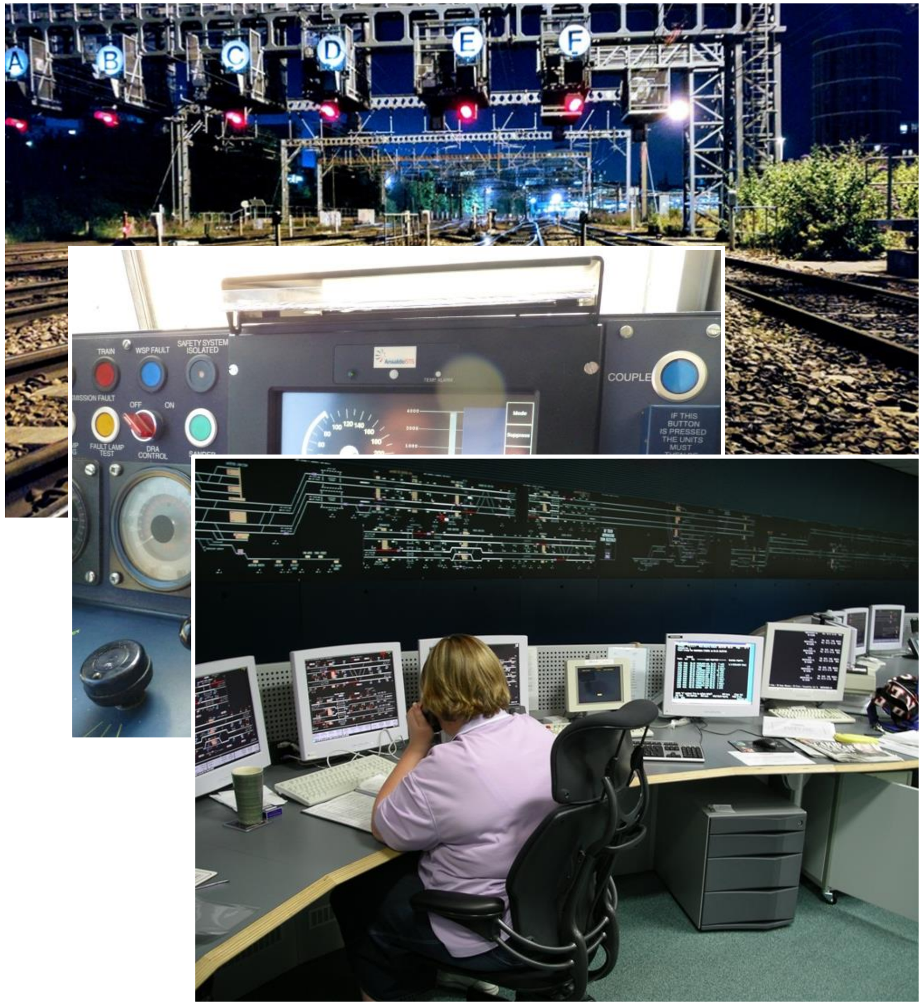
Network Rail and Railway Traffic Control



GB national mainline rail infrastructure operator and maintainer

Control of network is managed from:

- Signalling centres
- Integrated control centres

The rail network is already congested and use is forecast to continue to grow

Digital Railway programme is aiming to introduce:

- ETCS
  - Automatic train operation
- Traffic Management systems

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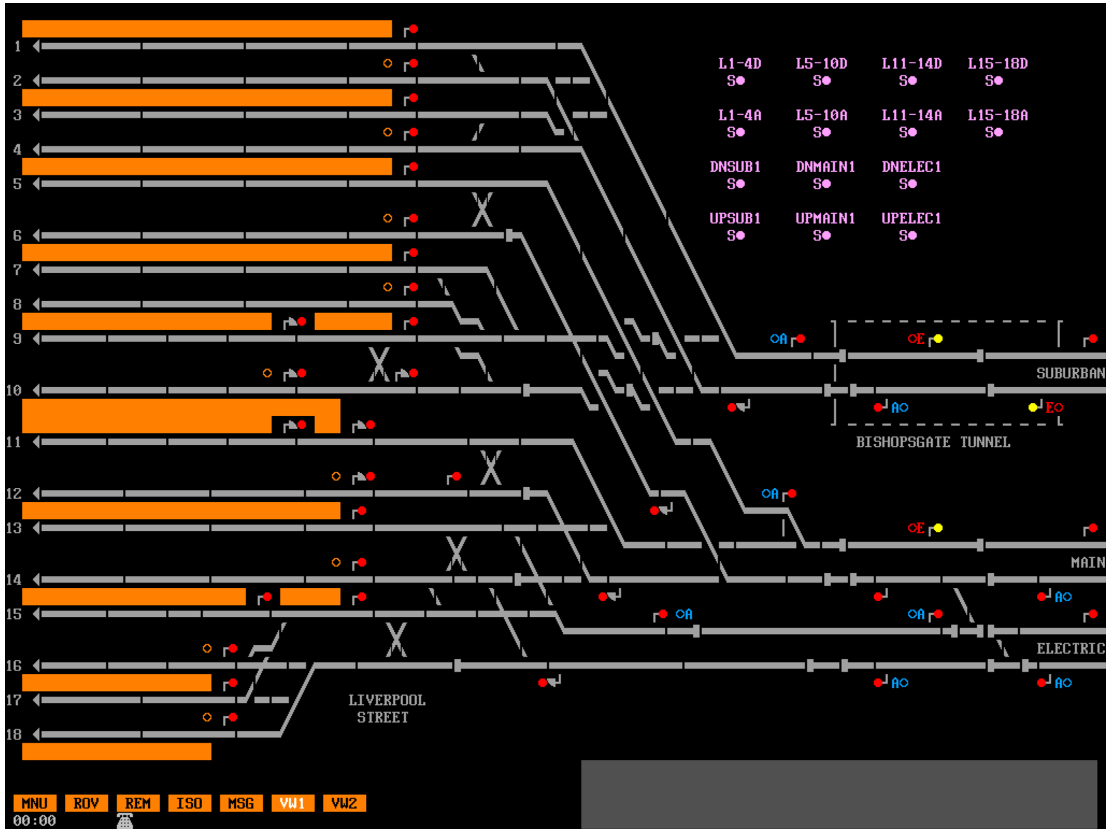
Automation on GB Mainline Railways



1989 – Standard electronic signalling control system first incorporated Automatic Route Setting (ARS)

- Sets routes using data from timetable download
- Where pair of trains found to conflict, works out which to signal first based on least delay calculation
- Routes are called at last possible moment
- In use at 11 signalling centres

2008 – ARS specification published to open up market

- Significant expansion in use of ARS has followed

2009 - Development of Traffic Management systems commenced

c2012 - Development of Automatic Train Operation (ATO) commenced

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Automatic Route Setting (ARS)

Highly successful, used for over 25 years, but system still has limitations:

- Decision making not visible and sometimes surprising
  - Signaller has to predict and anticipate routing/regulating behaviour
  - Signaller considers wider operational picture, including multiple trains, so decisions not always optimal
  - Challenges in providing timetable data at the level of quality to suit ARS
  - Tools to interrogate ARS are ineffective (as decides at last possible moment)
- Tools to control and direct automation are limited
  - Signaller can only turn off ARS in large areas
  - Signallers often use safety controls to constrain what ARS does
- The automation does not cover everything, leaving some tasks for the signaller to carry out
  - For example, shunt moves, including signalling trains into an occupied section, left to signaller
- Where timetabled operation disrupted, then task can fall back to signaller
  - Depends on area of control and where disruption has occurred – it can help, or create problems
  - ARS can be least effective when task is most disrupted

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Principles of Automation applied to ARS (Balfe 2010)

Reliable	Functions consistently
Competent	Perform tasks correctly given input information
Visible	All information used should also be visible to the operator
Observable	Must give effective and immediate feedback of its state
Understandable	Decisions should be understandable
Directable	Operator can direct automation easily & efficiently
Robust	Performs under both normal and abnormal conditions
Accountable	Operator remains in charge of automation and its decisions
Error Resistant	Should make it difficult for operator to make an error
Error Tolerant	Should be able to mitigate effects of operator error
Proactive Control	Operator supported in predicting ahead rather than controlling reactively
Skill Degradation	Implemented in manner that prevents operator skill fade

Emerging Workload Challenge with ARS

A benefit of ARS is to allow a signaller to supervise a larger control area

It is proving challenging to predict workload when using ARS, to feed into control centre design

Residual workload arises from complex and uncertain factors:

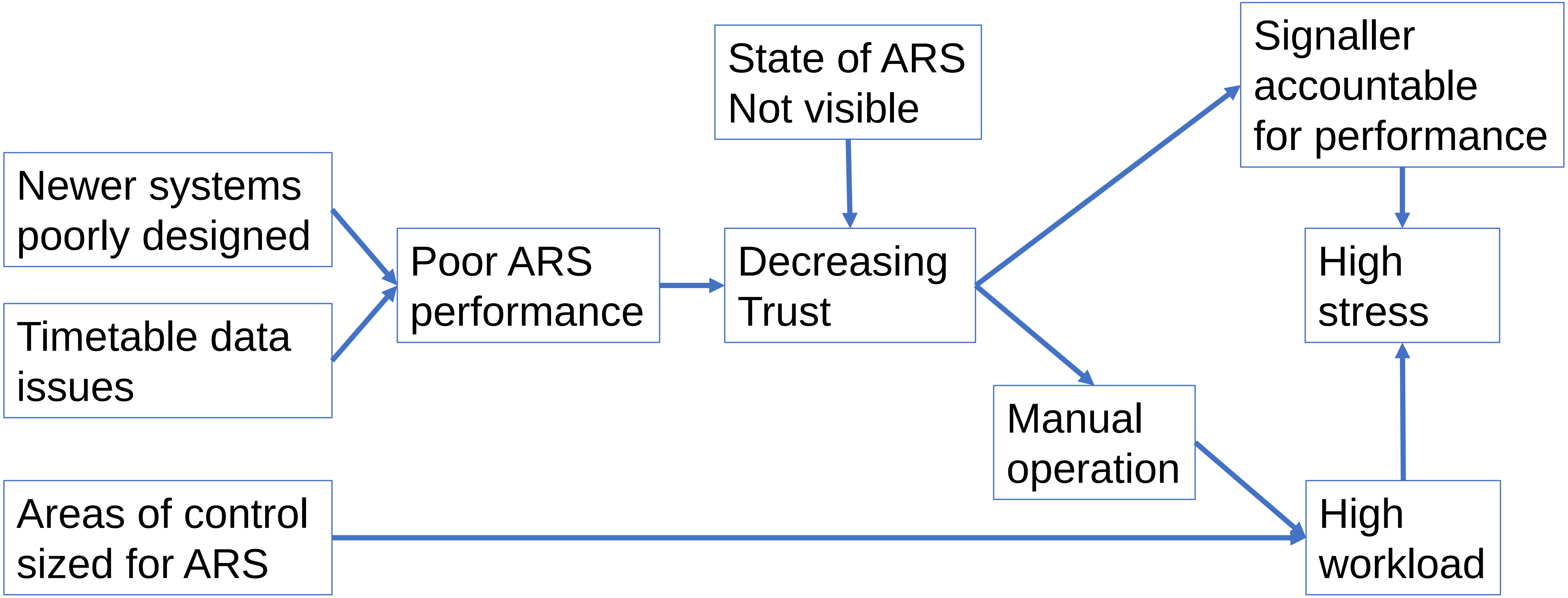
- Quality of timetable data
- Volume of late changes and disruptions to timetabled working
- Routes that will not be managed by automation
- Non-timetabled routing when an incident occurs

Contingency being built in to areas of control to allow for uncertainties

Tools being investigated to increase reliability of predictions

Design process also needs to recognise what needs to be provided in the signalling design to support automation

Risks with current generation ARS



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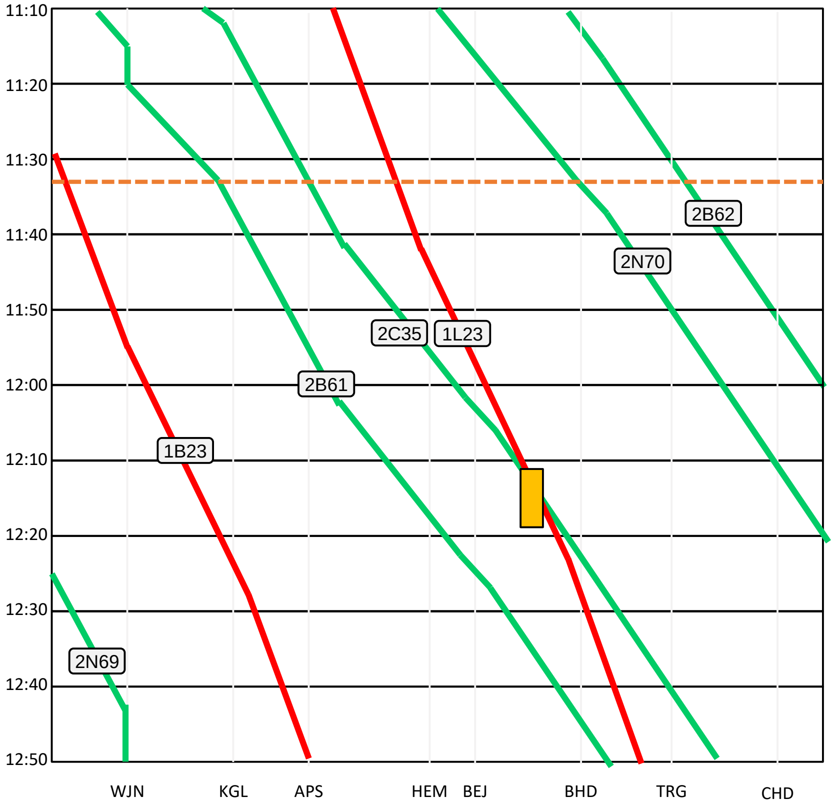
Traffic Management (TM)



Changes focus to management of the timetable

Highlights conflicts, giving options for re-planning and then executing the traffic routing requests:

- Manual
- Semi-automatic – options offered
- Automatic – best option implemented

Dynamic train graphs (and other similar graphical displays) are effective "cognitive artefacts"

- Common understanding of plan – distributed cognition
- Simplifies decision making

Main GB use is for planning short term timetable changes and major changes during disruption

The power of this technology lies in its ability to put control of automation in the hands of its users…

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Principles of Automation applied to TM?

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(based on Balfe 2010)

Challenges with Traffic Management

Planners and signallers both can change the plan

Not currently co-located, so need to develop protocols for effective distributed decision making

- Issues of trust may be with colleagues rather than automation!

Automation is simpler and should be more transparent

Yet system implemented on top of ARS generated early surprises!

When deployed on new workstations – will be hard to determine workload demand – how many conflicts will be generated?

Further work is required on detection and resolution of conflicts

- Predict that progress to full automation is likely to be slow, which could be beneficial

Automatic Train Operation (ATO)

Building ATO on top of ETCS cab signalling system

ATO is being added to ETCS specifications

Technology in place and fully tested on Thameslink service under London – staff now being trained

Main purpose to increase reliable capacity

Grades of Automation in ETCS specifications:

- GoA 1 - Manual Train Operation (including C-DAS)
- GoA 2 - Driver-attended Automatic Train Operation
- *[GoA 3 - Driverless Train Operation]*
- *[GoA 4 - Unattended Train Operation]*

Now developing GB specs for future procurement of ATO (at GoA 2)

Potential Challenges of ATO – Initial Thoughts

…there is no human factors to be done, it is all automated…

Will the driver be able or expected:

- To monitor adherence to speed curves?
- To intervene at low adhesion sites?
- To intervene if routed off planned path?
- To respond to line side signage (e.g. whistle boards)?
- To intervene when entering a platform/approaching lineside staff?
- To report trespassers, objects on line or infrastructure failures?
- To identify locations of trains or other issues?

What will be the impact of ATO on vigilance, driving skills and route knowledge?

How will transitions to/from ATO be managed?

What is the residual accountability of the driver?

Power Changeover - Automation Challenges

We need to be clear on the tasks and accountabilities placed on drivers

Trains being purchased that are bi-mode – diesel and electrically powered – for use on routes with partial overhead line equipment

Intention is for power changeover at line speed

Largest risk is when needing to lower pantograph due to an overhead obstruction (e.g. bridge/tunnel portal)

- Primary option – automatic power changeover (APCO), with lineside signage to prompt driver manual intervention if it fails
- Other option – manual power changeover (MPCO), but with system to drop pantograph if manual process fails

Challenge – how reliable can we expect driver to be if automatic system fails? Depends on how often this occurs…

Not very reliable - MPCO may perform better

Highly reliable - manual intervention only needed if APCO isolated

Conclusions

There are significant gains to be made from automation in railway operations

The current focus in GB railway control is using automation to increase reliable capacity & recovery from failure events

The biggest risk lies in mixing together unreliable/opaque automation with unsustainable expectations on the staff that operate it

The technology either has:

- to be designed in a user centred manner, providing the means for the operator to understand and direct the automation, or
- automate the whole task, without significant reliance on supporting operator activities

The key research challenge related to humans working with rail automation is to be able to predict what reliance can be placed on humans when automation is not perfect or when it fails

Robust and transferrable lessons are needed – this is just the start of the journey!