Railway automation: promises and problems

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1

Background

- There is a rapid growth in the use of automation technology in railways across Europe:
  - ATO and driverless operation are common on metro; such systems are soon expected to be controlling mainline trains
  - Jones (2017) suggests up to 30% of mainline traffic could be semi-automated in 3-4 years, while large scale driverless operation is realistic some time between 2030 and 2040
- Automation can bring many benefits in terms of safety and performance
- However, experience and human factors research in other domains shows that automation does not always deliver the expected benefits – and sometimes causes new problems

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Jones, B. (2017). Automated operation is approaching… . Rail, 883, 58-59.

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What is automation?

- Automation has been defined as any situation where a machine (usually a computer) executes a function that was previously carried out by a human (Parasuraman & Riley, 1997)
- This definition is quite wide, and encompasses systems that automate the three stages of human information processing:
  - Perception (eg AWS, TOWS)
  - Cognition (eg ETCS, ARS)
  - Control (eg ATP, ARS)
- From this perspective, automation does not necessarily replace a human operator – it can just take over part of the task

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Parasuraman, R. & Riley, V. (1997). Humans and automation: Use, misuse, disuse, abuse. Human Factors, 39(2), 230-253.

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Levels of automation

- There are several levels of authority at which automation can operate, from fully manual to fully automated
- IEC 62267 defines Grades of Automation (GOA) for driverless train operation:
  - Grade 0: On-sight train operation (ie no protection)
  - Grade 1: Non-automated train operation (but with ATP)
  - Grade 2: Semi-automated train operation (eg LU Central line)
  - Grade 3: Driverless train operation (eg DLR)
  - Grade 4: Unattended train operation

4

4

Levels of automation (continued)

- The key distinction between the levels is when the automation becomes the main controller (ie, from ATO Grade 1 to Grade 2)
  - Rather than the human with some automation support, it becomes an automated system with a human supervisor
- With present levels of technology, there are few systems that truly reach 'full automation'
  - Many systems automate as far as possible, but stop short of 'full automation' due to technological limitations
- This means that a human is still expected to play some part in monitoring the system, or taking over manual control if necessary in emergency or degraded situations
- *However, humans are badly suited to carrying out such monitoring tasks*

5

5

Advantages of automation

- From an engineering perspective, the advantages of automation are often described in terms of safety and performance:
- Safety (removes 'error')
  - Train Protection and Warning Systems (TPWS) have been successful in reducing much of the risk of signals passed at danger (SPADs)
- Performance
  - Automatic Train Operation (ATO) can run with reduced headway – and, therefore, higher train frequency – than a human driver

6

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Disadvantages of automation

- From a human perspective, automation can cause problems largely (though not exclusively) associated with the need to retain a person as a monitor or 'fall-back' for the system
- This is a result of technological or other constraints that prevent implementation of a fully automated system
- Furthermore, although automation is often implemented to reduce human error, designers of automated systems are also human and can make errors – but their errors will affect everyone using the system (cf. Bainbridge, 1983)

7

Bainbridge, L. (1983). Ironies of automation. Automatica, 19(6), 775-779.

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Disadvantages of automation (continued)

- Skill degradation
  - Because the human is only monitoring the task and not actually performing it, they miss the opportunity to practice the task and so their skills can fade
  - Automation can therefore result in a need for increased training for operators in order to maintain their skills
- Vigilance
  - Monitoring tasks are susceptible to degradations in vigilance (ie, the ability to detect a problem) after only 20-30 minutes (note that this is a separate phenomenon to underload)
- Information conflicts
  - During the transitional period towards automation, there may be occasions when the automation provides information that is in conflict with 'traditional' information in the outside world (eg, ETCS display vs lineside signals)

8

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Example – Llanbadarn, 19 June 2011

- Train ran on to level crossing with the barriers raised
- Driver did not notice the signal that the crossing was open
- Driver was distracted by focusing on the DMI (departed previous station in SR mode, leading to higher workload and concentrating attention on the in-cab interface)
- The Level 2 ERTMS in use on this line was not interfaced with the crossing

9

9

Disadvantages of automation (continued)

- Situation awareness
  - There are many examples of automated systems that provide little feedback to human operators about what the system is doing – this can cause confusion which, in turn, can affect decisions and actions when working with automation
- Workload
  - Automation can cause problems of 'underload' – ie, the monitoring task is not demanding enough, which can affect performance if the human is suddenly required to take over control
  - Automation can also cause problems of overload – too much workload if the person is trying to maintain awareness of what the system is doing
- Trust
  - Depending on the reliability of the automation, a human might develop a level of mistrust in the system, and consequently fail to notice if a problem develops

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Example - Notting Hill Gate, 31 January 2018

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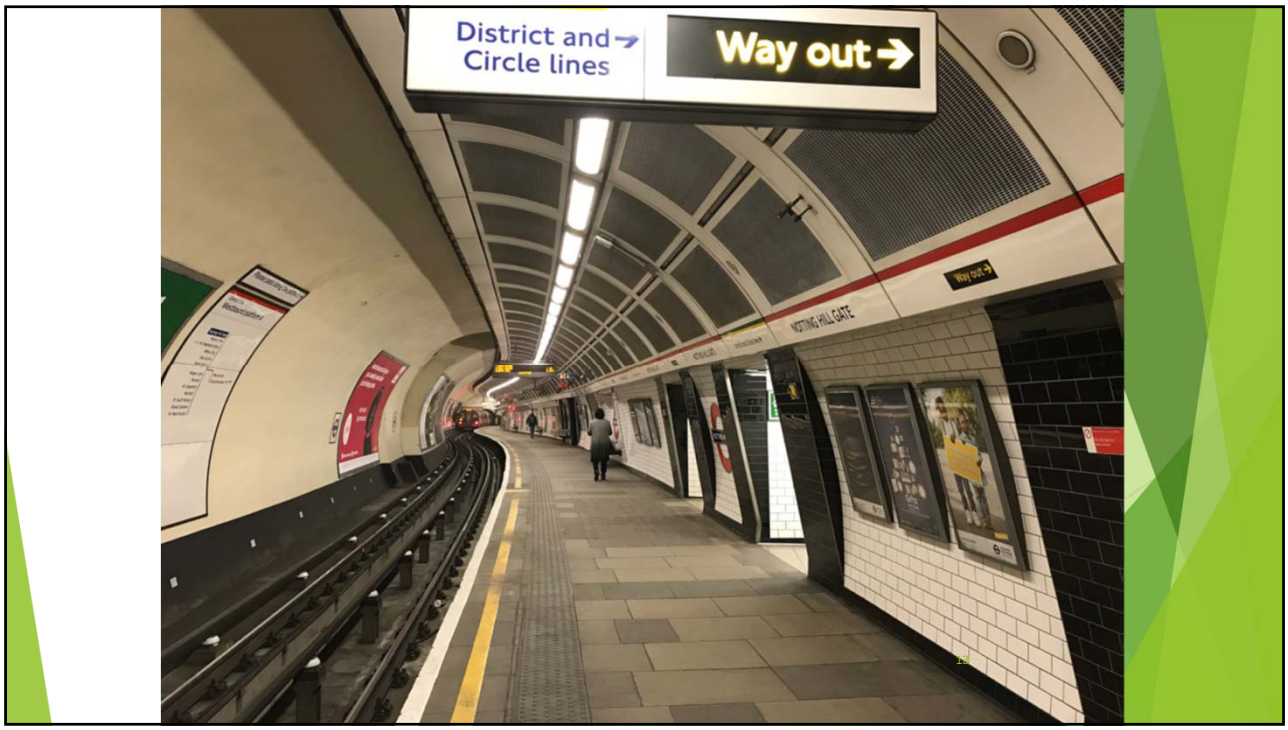
District and
Circle lines
Way out
NOTTING HILL GATE
Way out

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SPEED (KPH)
Saloon doors
End door cut-out
Re-open
Re-open
Saloon doors
2018/05/09

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Passe
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Taking a human-centred approach

- Human-centred automation designs the system around the human user – taking into account their capabilities and limitations from the outset
- It should seek to mitigate all of the issues identified earlier (eg, workload, vigilance, trust, situation awareness, skill degradation)
- Solutions should be design-focused rather than relying on training of the human operator – training only serves to mask a badly designed system!

18

18

Taking a human-centred approach – high-level principles

- Consider whether the automation is 'hard' (ie, has ultimate authority) or 'soft' (ie, human has ultimate authority)
  - Generally speaking, for systems that are 'invisible' (ie, provide a safety or protection system), hard automation is acceptable, but for systems that assume some level of control, a soft automation approach is advisable
- Retain a meaningful role for the human user if they are required as a 'fall-back' option in the system
  - Until reliability of the automation is such that the human can be fully replaced, the human should be an active controller of the system, not just a passive monitor
  - Use the technological capabilities to support the human in the task(s) that they normally do and strengthen the overall performance of the system, rather than try to replace parts of their task in a piecemeal manner
  - This may mean restraining the full potential of the automation until its development reaches a point when it can fully take over the task, without need for monitoring or intervention

19

19

Taking a human-centred approach – high-level principles (continued)

- Consider the automation as another team member and adopt design principles that reflect teamworking principles, such as:
  - Exploit the strengths of each team member (both human and machine) while compensating for their weaknesses
  - Ensure that the automation cooperates and communicates well with the human user (ie, provides adequate and timely feedback via its interface)
  - Ensure that the responsibilities of each team member (human and automation) are clear – in terms of what actions they are reasonably expected to do, which might be different from who is legally responsible

20

20

Conclusions

- Automation undoubtedly has benefits – but it can also have shortcomings if not implemented with due consideration to the human user
- The drawbacks are not just related to safety and performance, but also worker satisfaction if jobs become marginalised
  - For technological and societal reasons, trains are expected to have drivers for many years yet
- Therefore, if the benefits of automation are to be realised fully, then a human-centred approach is essential

21

21

Human-centred automation in rail

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22