EUROPEAN UNION AGENCY FOR RAILWAYS

German Centre for Rail Traffic Research at the Federal Railway Authority

AUTOMATION MYTH #5

The freight yard is simple and can be automated without user-centred design.

Automation across cognitive, organisational and physical use cases in the rail freight yard

SUMMARY

Automation and intelligent systems have the potential to make freight work safer, easier, and improve the efficiency of operations. At the same time, it may put new challenges on to the staff who work in the rail freight yard environment. Freight yard automation is often viewed as a simple process that does not need to consider the user. This myth-busting paper looks at importance of considering the ergonomics of the freight yard – the physical, cognitive and organisational nature of the work – to ensure the optimum combination of human skills, knowledge and performance with automation. We look at these ergonomic factors through three relevant automation use cases – planning tools, e-maintenance applications and robotics.

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INTRODUCTION

The rail freight sector across Europe is changing. There is greater need than ever to deliver effective, punctual freight if rail is to offer a viable, low carbon alternative to road traffic, or provide an intermodal link with road, air and maritime freight. This will not only mean more trains running more efficiently; this means longer trains, and more complex loads to meet multiple customer needs.

This change in demand is occurring in parallel with potential for enhanced automation in rail freight and the rail sector generally (Gerken et al, 2022). There are new tools and opportunities to optimise freight train loading and scheduling, new types of traction coming online to provide lower-carbon alternatives, and the introduction of digital coupling. There will also be greater monitoring and sensing of rolling stock and other freight assets, and the potential for train loading and maintenance tasks to include exoskeletons and robotics. Automation in the rail yard offers significant advantages to rail staff reducing the need for physically demanding tasks, reducing the need to be out and around moving wagons and locomotives, supporting better decision, and leading to better performance overall (Pollehn et al., 2021).

However, the assumption, or myth, associated with automation is that the freight yard consists of simple, physical, discrete tasks. New technology can simply be 'dropped in', potentially with some basic training, without any impact. In practice, the freight yard is a complex and agile environment, with demanding activities being implemented in a fluid manner to meet customer needs and operational demands (Golightly et al., 2024). If automation is not designed and deployed in a way that is sensitive to 'work as done' there is a risk that new equipment will introduce its own challenges, leading to reduced performance, rejection by staff or, worst of all, introduce unexpected safety risks into the yard environment (Vaghi et al, 2016).

Central to the successful delivery of operational and technological change is the role of people within the freight yard (Golightly et al., 2024). This includes groundstaff that ensure freight trains are safely stabled, prepared, maintained and checked for entering service. There are also shunters who move wagons within the yard to prepare trains, or move wagons around for maintenance or in and out of storage. Supervisors and planners organise the movements within the yard and planning for staff and resources. Finally, there are those tasked with planning and executing the maintenance of wagons and locomotives.

Despite the crucial importance of the freight yard in rail operations, it is an area that has received very little attention and is often overlooked when considering the impact of change. Automation can have a place in the freight yard, but it must be applied in a way that is sensitive to work demands. We consider this in more detail in terms of physical, cognitive and organisational (IEA, N.D.) aspects of yard work (see Figure 1), with reference to three examples of automation – planning tools, remote condition monitoring, and robotics.

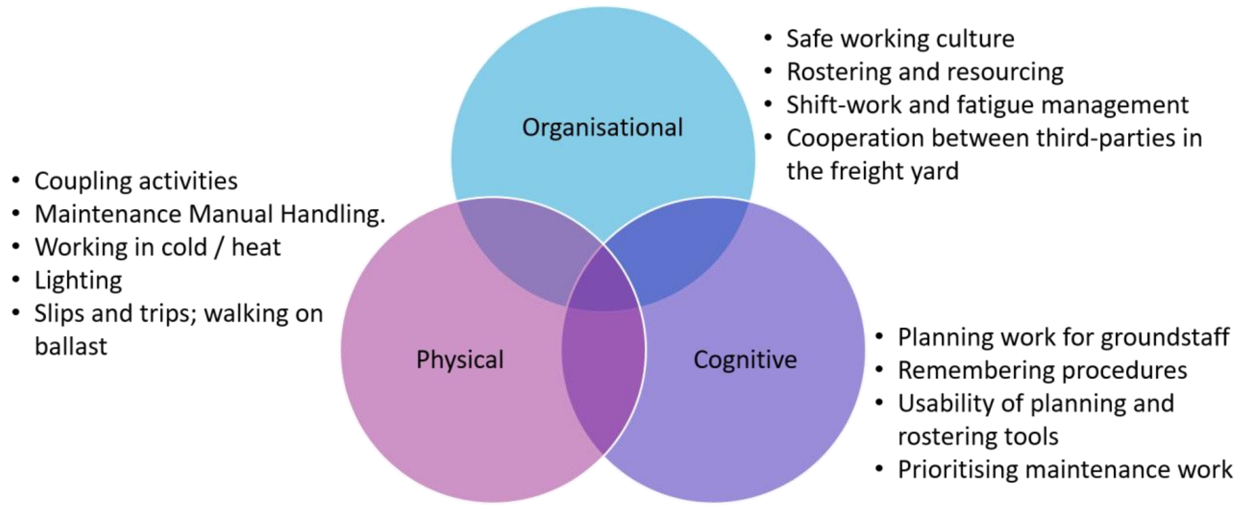

Figure 1 Physical, cognitive and organisational ergonomics with examples found in the freight yard

COGNITIVE FACTORS AND THE CASE OF PLANNING TOOLS

The freight yard is a complex work environment, where plans with multiple constraints (wagon loads, train composition, locomotive resourcing, customer schedule, network availability) must fit around practical considerations such as groundstaff resourcing, or when locomotives and wagons need to be taken out of service for maintenance.

Automated tools can help with the planning of yard operations by helping to predict arrival times (Minbashi et al., 2021), allocate trains to tracks within the yard and plan movements within the yards (eg Wabtec, N. D.), replanning for change (Optiyard [Licciardello et al., 2020]) and to plan resources such as staffing (Preis et al., 2023).

While automated tools can be hugely beneficial, they have to respect the resilient nature of behaviours and activity within the freight yard. Tasks may not be performed in series, but instead are interleaved to maximise the efficiency of groundstaff, and minimise the number of moves with the yard (Golightly et al., 2024). Any optimisation tool must be able to reflect this combination of tasks, either directly in the planned operations, or by giving decision support options allowing flexible, resilient working that also accommodates human resource availability and capability (Preis et al., 2023).

Furthermore, optimisation software should allow manipulation and the easy input of short-term constraints (eg when a track or 'road' in the yard may be out of use), and the operational deployment of tools must be sensitive to short term changes – for example when locomotives are not available at short notice, when trains arrive late and need a rapid turnaround, when only certain ground staff are competent for certain tasks. Ideally, any tool should be facilitate rapid replanning as much as it might deliver an optimal plan in advance of the days operations. The more that a tool can be linked to other systems (eg for wagon asset management, rostering, timetabling), the more operator workload will be reduced, along with opportunity for input error.

All of this points to a fundamentally strong Human-Machine Interface (HMI) for any tool. This includes the basic presentation of information in such a way that it makes sense to the operator, but also flexible (and ideally automated) data input, along with the ability to adapt criteria and constraints within the planning tool. A key element of ensuring trust will be the explainability of the outputs of planning tools – whereby users can understand how decisions have been arrived at; for example by clearly indicating, or allowing the user to interrogate, the reasoning behind a decision. Concepts of Human-Automation Teaming should inform the configuration of optimisation tools to make sure that automation and operators can develop mutual knowledge towards shared goals (AMBP#4). The HMI should also be sharable – one of the biggest challenges with current yard IT is that different people use different software, along with whiteboards and paper. By having a flexible shareable HMI, it will be possible for the supervisor in the yard to share their plans with groundstaff (eg with a tailored HMI for handheld devices) and commercial and managerial level staff (eg via a web dashboard).

ORGANISATIONAL FACTORS AND THE CASE OF E-MAINTENANCE

One of the great opportunities of automation and digitalisation in the freight yard is the case of e-maintenance. E-maintenance involves the capture of data from assets, which can be combined with historical, usage and environmental data, to predict the future state and failure modes of the asset. In its most advanced form, it can predict when maintenance is required and potentially plan a schedule. In the freight yard, this primarily applies to wagons and locomotives, though also can be applied to the yard infrastructure itself (eg the condition of points). Examples relevant to the freight yard include the monitoring and predictive maintenance of locomotives, such as on the Kiruna Iron Ore line in Sweden (H-Nia et al., 2024) and wagon telematics (TIS, 2020).

The human benefits of this kind of automation is that it can reduce the occurrence of unplanned failures that can disrupt operations. Furthermore, it can make sure assets such as wagons remain in optimum condition and therefore are always suitable for preparation. Finally, from a human perspective, this kind of automation can reduce the need for routine, but unnecessary, maintenance, therefore reducing the need for non-essential yard moves, and reducing the need to perform unnecessary physical tasks.

While many of the technical challenges of delivering e-maintenance solutions are now understood, there are still significant human factors considerations to overcome if the technology is to meet its intended needs. This kind of e-maintenance system needs to reflect the general principles of human-centred automation as described above (appropriate user-centred HMI, explainability, tuned to operator decision making needs). Dadashi et al (2023) set out key guiding considerations to enable user-centred design and deployment or remote condition monitoring technologies.

There are also organisational considerations around how people (and multiple stakeholder) coordinate. For example, there is often an upstream supply chain for any e-maintenance solution – software developers, asset owners, component suppliers, sensor suppliers. The HMI should be designed in such a way as to minimise and when appropriate mask these organisational complexities. Furthermore, it is likely that a maintenance engineer will have multiple suppliers of monitoring solution, and therefore consistency of HMI design is essential so that each HMI doesn't not use different and contradictory terminology, iconography, thresholds and so on (Golightly et al., 2018).

There is also a direct organisational change for maintenance staff, who were previously conducting routine maintenance, but now may be required to carry out work in response to e-maintenance decisioning. This will require changes to shiftworking patterns, and the increase opportunity for remote and on-call working must be managed in a sensitive way. Finally, maintenance and engineering skills must now be matched with digital skills. Appropriate training is required for older staff, though the 'digital wagon' can also be seen as a significant opportunity to attract new staff to the yard who will see it as an advanced workplace.

PHYSICAL FACTORS AND THE CASE OF ROBOTICS

For staff, the freight yard can be a challenging environment. It requires physically demanding tasks to be performed in all weathers, often in 24/7 operations, and performing tasks that have a significant musculo-skeletal risk because of the weights, forces and postures involved. The freight yard involves tasks such as coupling of wagons and locomotives, application and removal of wagon handbrakes, adding and removing stanchions (for loads such as steel or timber), opening and closing of wagon doors, or removing and reloading components during maintenance. These tasks can be physically challenging when repeated many times over the course of a shift, and performance failures can often lead to a safety risk, such as wagon handbrakes left on when a train enters the network (Golightly et al., 2024). Robotics are already being seen in passenger operations (Atherton, 2020) or in environments like ports (Mckinsey, 2016) and there have been exemplars for the introduction of robotics within the yard environment, for example for robotic shunting (Hansen, 2004) or robotic inspection (Anybotics, 2023).

While not all tasks will be immediately appropriate for automation, more routine tasks could benefit from increased automation. Furthermore, the minimisation of physical work can open up the performance of yard activities to a wider range of people, encouraging more women or allowing older workers to remain active in the work place.

The practical challenge is to embed this type of physical automation in a way that is practical is to make it flexible enough for potential users. Unlike the manufacturing environment, or indoor logistics, both the fluidity and environmental conditions of the yard mean that careful task analysis is required to identify those tasks where automation will truly integrate with workers tasks. Also, the range and flexibility of tasks in the freight yard means that user interfaces for robotic integration must be designed in such a way as to support rapid reconfiguration of the robot to meet adapting needs.

Human factors can offer a range of tools to allow us to understand how automation may be designed an implemented in a sympathetic manner. If we take the case of robotics, standards now exist for co-robotic design, allowing workers and automation to safely conduct tasks together (ISO/TS 15066). Research still needs to be conducted to understand how these standards transfer to the most challenging aspects of the freight environment (eg moving around on ballast) but it is possible that tasks in the maintenance area could soon be improved through robotics. Furthermore, Charalambous et al. (2017) offered a process that manages the user-centred design and deployment of robots, from first ideas through to active usage.

Other types of automation such as exoskeletons may also support the conduct of physical tasks. In this case, designer and procurers needs to be cognisant of the flexible nature of work, and of staffing in the freight yard, where multiple operators may need to quickly don and doff the exoskeleton, which also needs to be configured for different user anthropometrics.

HOW TO GET THERE

While we have looked at automation across the cognitive, organisational and physical use cases, there are common threads across all. First, any automation design and deployment must take a user-centred approach, such as that advocated by ISO9241-210. By actively involving users in the design or procurement of products, we can ensure that meet tangible needs in a way that fits with work, and minimises development costs or the risk of expensive, but unused, equipment. This is vital in a sector where margins are low, and investment must be maximised. Furthermore, a user-centred approach ensures the wider buy-in of staff, building their trust, and ensuring their ongoing engagement as part of structured deployment.

While we have focussed on optimisation tools, e-maintenance and robotics, the human challenges physical nature of tasks, the need for resilience and the impact of a challenging environment are just as relevant to other technologies such as digital coupling, and remote or autonomous shunting. User-centred approaches, and principled human-centred automation, should be at the heart of all these complex developments. By understanding the nature of work in the freight yard, and working with end users, we can dispel the myth that technology can be introduced without any impact. The ultimate benefit is a safer, higher performance freight yard, with a valued, skilled, and diverse workforce able to deliver freight into the rest of the 21st Century.

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