Accepted version- To appear in Ergonomics – Accepted 14/6/24

HUMAN PERFORMANCE IN THE RAIL FREIGHT YARD

David Golightly[1*], James Lonergan[2], David Ethell[3]

1 - Future Mobility Group, School of Engineering, Newcastle University, UK

2 - Rail Safety and Standards Board, UK

3 - National Freight Safety Group, UK

* Corresponding author details

David.golightly@newcastle.ac.uk

Rm4.008 Stephenson Building

Claremont Road

Newcastle

NE1 7RD

Abstract

Human performance in the rail freight yard has been identified as a source of risk for rail freight operations. This is both within the yard itself, and also with train preparation issues leading to incidents on the network. The rail freight yard is an area that has received limited research attention. Over 30 hours of observations were conducted at five major freight yards in Great Britain, along with 30 interviews of rail freight ground staff. Task models, human performance factors and potential solutions that were further explored in a workshop with freight personnel. This analysis led to an understanding of freight yard activities, the impact of freight yard design and environment, and the role external pressures on freight yard performance including upstream planning. The implications are discussed for both current freight operations, and for future technology and process change within the rail freight sector.

Practitioner Summary

Human performance in the rail freight yard is critical to safety and performance, but receives little research attention. A structured study included observations in the yard, interviews with ground staff, and a validation workshop. Results include task models, influencing factors, potential solutions and implications for future technology and process change.

1 Introduction

Rail freight is a key function of the economy. Freight moves bulk goods such as aggregates and fuel, intermodal containerised goods, dangerous goods such as nuclear fuel, and provides supplies and train movements for the build and repair of the railways itself. In Great Britain (GB), the total economic and social benefits of freight are valued at £2.5bn annually and removes the equivalent of 7 million heavy good vehicles from the roads (Rail Delivery Group, 2021).

The continued success and growth of rail freight is therefore a cornerstone of transport decarbonisation, nationally and globally (e.g. UNESCAP, 2021). There is an ambition in Great Britain to increase rail freight by 75% by 2050 (UK Gov, 2023), and a desire to move intermodal and more consumer goods onto the railways. Similarly, the EU is looking to massively increase the sector share of rail freight (Islam et al., 2015), and very recently the USA, India, the Middle East and the EU have signed an agreement to develop a pan-continental intermodal freight corridor with rail playing a significant role.

The carriage of freight needs to be safe, ensuring the integrity of the load, and safety of staff and of the public. Accidents both in GB (e.g. RAIB 2022) and beyond (Campbell, 2013) have highlighted the dangers of moving freight by rail. Additionally, there have been other accidents within yards themselves, highlighting the safety risks of freight operations (e.g. RAIB, 2020).

Rail freight also needs to be reliable and cost-effective. Incident-free rail freight is essential to ensure existing freight customer confidence while attracting new customers. Delays to freight trains can be costly, with minor incidents costing thousands of pounds in delay costs, through to accidents that might involve the loss of the freight load, damage to infrastructure or potentially weeks of disruption to both passenger and freight services (BBC, 2020).

In Great Britain, the 2020 Rail Safety and Standards Board (RSSB) Annual Health and Safety Report highlighted that in the previous two years there had been a rise in the number of potentially higher risk train accidents for freight. This is a trend driven by an increase in derailments. Further, over this period, 288 trains were stopped on the network due to issues with vehicles, importing safety risks and delays to the network. The National Freight Safety Group (NFSG) has been set up to address these rail freight risks. NFSG has identified that the condition of vehicles entering the network a priority for the GB freight community, and sponsored a project to understand why freight vehicles may enter the rail network in an unsafe condition.

As part of this work, a structured analysis of rail freight incidents on the network (Golightly et al., 2022) was conducted. The analysis used the GB railway's 10 Incident Factor framework (Gibson et al., 2015) to analyse 31 freight preparation incident and accident reports. 27 incidents were found to be related to human performance issues in the rail freight yard – that is, issues with tasks carried out during train stabling, loading, coupling and uncoupling, shunting moves in the yard, preparation or trains for departure (e.g. checks) and departure. Issues with the performance of these tasks caused or contributed to events linked to inadequate condition of the freight vehicle on the network, or incidents within the freight yard itself. Typical failures involved runaways in or outside of the yard; handbrakes left on wagons or airbrakes left on locomotives that then damage the wagon and rails if the train departs onto the network; or wagons entering the network in an unfit state (e.g. poorly loaded, leading to unstable wagon movement and eventual derailment; damaged wagon parts hanging out of gauge leading to collision with infrastructure or other trains). Slips, lapses and omissions in train preparation were the major human performance issues identified in yard tasks. The analysis also explored potential causal or contributory factors that led to these events. Usability of equipment, yard conditions (lighting, walking routes), wagon condition, time pressure and the organisation of work particularly between third-parties providing services in the freight yard, were all identified as underpinning factors behind these human performance issues.

These initial findings warranted further exploration both to further understand the causal mechanisms, and to identify solutions. However, research on work within rail freight yards is extremely sparse, with very few examples of empirical work. From a human factors perspective, freight functions such as the management of wagons in yards are one of the most under-researched areas of rail operations in comparison to areas such as driving or signalling / infrastructure control (Ryan et al., 2021). Human factors knowledge of tasks, competences, immediate and wider work environment, and pressures due to cultural / commercial / policy constraints is not widely available.

Of the work that has been conducted, Zhang et al (2019) carried out a structured human factors analysis of US freight train accidents, and identified the preeminent types of accident were derailment and collision, with a range of human performance factors as primary causes. However, these human factors causes were attributed as a direct, end cause of the accident as it occurred, primarily attributed to the driving role. The analysis did not look back into causal factors, or explore human performance failures that may occur in the yard potentially leading to issues out on the network.

More germane to the current work, Lawton (1998) studied violations in shunting and ground staff tasks in freight yards. The study identified a series of violations (e.g. groundstaff remaining between vehicles while asking a shunting driver to move those vehicles together), before clustering the violations against a set of possible reasons (e.g. time pressure, high work load). These violations were found to be a product of a number of organisational and situational factors, norms and individual differences. While the focus of the work was somewhat different from Golightly et al (2022) (e.g. the work was pre-GB rail privitisation and therefore the organisation of work was different; Golightly et al (2022) found few violations in their dataset), many of the factors influencing work (e.g. time pressure, a lack of understanding of rules) were similar to those in Golightly et al (2022), in particular, to Lawton's concept of 'Situational Factors' – factors such as lack of availability of equipment, working conditions or high workload.

Reinach and Viale (2006a) applied a human error framework to analysing shunt moves in yards in the USA. This study was orientated towards train movements rather than wider preparation tasks, and with a remote control system which is not used in GB. Nonetheless, inadequate lighting, competence and resource staffing also appeared in both their analysis, and Golightly et al (2022). In a related piece of work, Reinach and Viale (2006b) highlighted the importance of the yardmaster's role. In the US this role involves the tactical (ie day to day) planning of movements in the yard and coordination with staff. This role was found to be challenging with significant issues around fatigue, high volumes of communication, training and competence both for the yardmasters themselves and for staff they were supervising, and relations with management.

Bowler and Basicik (2015) studied rail operations at a port, and while their outputs are methodological, they do state the difficulty in understanding work purely from procedures and the importance of observations and interviews to understand risk. Vaghi et al (2018) do not present human factors findings *per se*, but do highlight the importance of understanding human factors as an influencing factor in the deployment of new technology for rail freight. Hricova (2016) gives an example of this, highlighting the benefits of RFID tags on wagons to reduce error in wagon identification.

There was therefore a research gap to fully observe and understand the tasks and task conditions that played a causal or contributory role in the incidents analysed in Golightly et al (2022). Given the significant knowledge gap in how work is performed in the freight yard, particularly in contemporary Great Britain rail operations, the following study aimed to develop knowledge of freight yard practices in order to evolve our understanding of how human factors in freight yard work may contribute to freight train incidents on the network. Specific objectives included (1) capture freight yard tasks and activities; (2) capture the environmental and design aspects of the freight yard; (3) identify specific human performance risks, and (4) identify future steps to address human performance risks.

2 Method

2.1 Observations and interviews

The method built on the groundwork and understanding of the freight yard context in Golightly et al (2022) by using a two stage approach. The first stage involved field work with both observations and unstructured interviews with operational and management staff. Fieldwork was conducted at five different freight yards and constituted over 30 hours of observations as a group or individually. Further information is presented in Table 1. All five sites were major freight yards, managing significant traffic flows. Site 1 was selected as, while fully operational, it was quite quiet in terms of train moves and therefore allowed extended discussion and safe familiarisation with the yard environment. Other sites were selected based on their strategic significance and / or the range of activities covered at the sites. Three of the sites included maintenance and refuelling facilities. Three sites were also adjacent to 'end-user' sites – sites such as ports, or aggregate and bulk goods facilities, and a fourth involved significant wagon loading activities within the yard area.

Observations included supervisory areas in freight yards for operational planning, extensive walk-arounds of the yard involving observations of freight preparation activities, observations of maintenance work, train cab access and opportunities to try out train preparation tasks. This included one observation during the night shift (a time of high workload in that particular yard) to observe conditions at that time of day. Observations also included visits to office areas for freight commercial planning, as this gave important insight into the inputs that shaped work in the freight environment.

During the course of observations, a 'guide' who was an experienced member of staff with knowledge of the site gave instructions, descriptions of tasks and opportunities where safe for observers to attempt tasks. This guide would also ask observers which tasks or aspects of the yard they would like to see. Therefore, while events in the yard were beyond the observers' control, there was an opportunity to be selective and observe a range of tasks, including cab rides to observe movements in the yard from the locomotive. Informal interviews took place with over 30 members of staff on site, across multiple grades and functions. While some lasted only a few minutes, many lasted over an hour.While unstructured, discussions typically covered major activities in the yard, tasks specifically linked to train preparation, challenges and issues that impacted human performance, supervisory arrangements, and training and competence.

Table 1 – Details of observations

	Observers	**Duration and time of observation**	**Tasks observed**	**Approximate interview numbers**
Site 1	DG, JL, DE	6 hours as a group; day time	Rostering, commercial planning; on the day train planning and supervision; train preparation; yard moves	3 including extended tour by one member of ground staff
Site 2	DG, JL, DE	Shift 1 – 8 hours; evening and night Shift 2 – 4 hours as a group + 2 hours split up to observe different tasks; day time	On the day train planning and supervision; train preparation; yard moves; loco and wagon maintenance	10 including extended tour by one member of ground staff
Site 3	DG	4 hours; day time	On the day train planning and supervision; train preparation; yard moves	4 including extended tour by one member of ground staff
Site 4	DG	2 hours; day time	On the day train planning and supervision; train preparation; yard moves	3 including extended tour by one member of ground staff
Site 5	DG, JL, DE	6 hours as a group + 2 hours split up to observe different tasks; day time	On the day train planning and supervision; train preparation; yard moves	10 including extended tour by one member of ground staff

Contemporaneous notes were taken, with a debrief between the authors after each visit. This debrief was particularly valuable given the different perspectives of the observer team, and particularly the experience of DE who had extensive knowledge of groundstaff activities. The observations lead to summary materials including a site complexity risk mapping, task models, and a presentation of key factors shaping safe work in the yard. These materials were then used in a validation workshop.

2.2 Validation workshop

The validation workshop took place in October 2022 with 13 members of the rail freight community, along with presenters and facilitators. Roles included safety managers and directors, and management level operational roles. While no formal measure of experience was recorded, many of the participants had progressed through a number of different groundstaff grades and therefore had extensive practical experience of the tasks and the rail freight yard environment in general. Two of the guides from the site visits participated in the workshop.

The workshop lasted a full day and began with a summary of the findings from the Golightly et al. (2022) incident analysis and the freight yard observations and interviews. This was followed by structured activities to;

1. Validate task models

Participants were presented with a process map of the tasks completed in the freight yard and supporting office functions (see Figure 1). The objective was to establish if the process map was a true representation of working processes, identify any tasks or details that may have been missed and to generate discussion on how those processes influence train preparation.

2. Confirm key human factors challenges

Participants were asked to identify what human factors challenges were relevant for each task identified in the process map used in task 1. Prior to the activity, participants were given an overview of how the facilitators defined human factors and provided a fictional incident scenario to identify examples of human factors challenges.

For the activity, participants were provided with the GB railway's 10 Incident Factor framework (Gibson et al., 2015) to structure their identification of challenges for each task within the process map. Participants were encouraged to consider each of the incident factors from the framework for each process map task they analysed.

3. Identify potential solutions to freight yard challenges

Participants were asked to identify potential solutions to the challenges identified in task 2. Many of the human factors challenges identified were interconnected and so the activity was structured to focus on 'system' solutions, rather than developing solutions for individual challenges identified.

[Figure 1 about here]

Participants were asked to theme their solutions as either ‘tactical’ or ‘strategic’. ‘Tactical’ were identified as solutions that may apply to a specific freight operator, freight yard or not require inter-organisational commitment in order to deliver. ‘Strategic’ were identified as relevant across freight operators, possibly at a national level, require inter-organisational support and industry level co-ordination.

Notes arising from each activity were analysed and summary conclusions were drawn.

All work was conducted under Newcastle University Ethics 22-030-GOL.

3 Results

3.1 Work in the Yard

The main yard activities include receiving and stabling trains, moving wagons and locomotives, composing new train sets, preparing wagons for the network (e.g. preparing couplings, checking handbrakes), inspecting wagons, and negotiating with either the mainline rail network, or the yard of a receiving customer (e.g. a port) to dispatch a train.

The main roles involved were

- drivers - either mainline drivers, or shunters to execute train movements in the yard;
- supervisors - who planned day to day operations;
- groundstaff - who prepared trains and wagons, amongst a range of other tasks;
- maintenance staff – maintaining wagons and, at larger yards, maintaining locomotives.

The configuration of these roles changed due to local practice, needs and resourcing. In some locations the supervisors were on site and worked closely with the groundstaff to organise tasks for the day. In another the supervisor also conducted groundstaff tasks. One yard involved remote supervision, where groundstaff took plans and communicated with a supervisor in a larger yard several miles away via phone. Also, groundstaff were sent out for ‘remote working’ where groundstaff would travel to a location by road, and prepare one or a small number of trains as needed. Discussion with staff revealed these variations in practice and supervision were common.

Finally, while one yard conducted the actual loading and unloading of wagons, most sites observed did not involve this activity. In practice, this was conducted at an ‘end user’ site, often immediately adjacent to the freight yard, owned and operated either by the end user (e.g. a large manufacturing company that would load individual wagons), or by a third party.

3.2 Freight yard complexity

The yard itself was found to be an environment that was complex, physically and organisationally. Capacity was often limited as 1) specific tracks (or roads) in the yard had designated purposes (e.g. for refuelling) preventing flexible use 2) wagons were stored for maintenance 3) certain trains being prepared or stabled needing to be split to fit within yard constraints. Therefore, yards that seemed large were often very restricted in capacity. Track length is also an issue as this required longer trains to be split for stabling overnight, and then rejoined when being prepared for departure.

The number of movements coming into and out of the yard could be high, with trains arriving every few minutes. These might be trains specifically for processing in that yard, but also when locomotives were needing to find somewhere to stable during mechanical failures, or during rest breaks for drivers. Furthermore, the movement of trains within yards was often high, to construct train consists, move wagons for maintenance and so on. This increased the physical risk associated with moves as well as the number of times handbrakes needed to be applied or released – a key problem when trains with handbrakes still applied went out on the network.

In addition, while some yards had separate inflow and outflow access for trains, others were terminating yards, so terminating locomotives needed to be taken off the front of trains, and run round to form a new service. Yards had different topography and gradients which necessitated different configurations of handbrakes on sets of wagons. In general, each yard had local idiosyncrasies that shaped (and typically increased) the number and complexity of train moves required. Little or no data was available on the number of moves within a yard.

These moves required not only complex communications between the groundstaff and shunting drivers. Workshop participants noted the reliance on communications and the potential for overfamiliarity leading to deviation from appropriate communication. Furthermore, shunting moves that required trains to leave the confines of the yard and to enter mainline network (albeit sometimes for a matter of a few hundred metres before reversing back into the yard on a different line) required communications with the Network Rail signaller, which was also time constrained by requiring a sufficient gap in other services on the network to accommodate the move. This would put further pressure on when and how train preparation moves could be performed.

[Figure 2 about here]

Figure 2 gives an example of flows for a generic freight yard. A train arrives off the main network (1), the locomotive decouples from the wagons and takes a subset of wagons to the maintenance area (2), before refuelling (3). The locomotive then travels to the area where wagons are being loaded (4), where the train is prepared and checked, before heading out to the network (5). Even in this very simplified scenario there are a number of points to note. First, supervisors are involved in planning the sequences of these moves based off various documents such as maintenance plans. Second, groundstaff are involved in several of these steps, such as disconnecting the locomotive from incoming wagons, recoupling the locomotive with the next load of wagons, and conducting checks before departure. Third, this is the type of yard with terminating ‘roads’ and therefore any train or locomotive must travel out of the yard, and reverse or ‘propel’ back in. This requires oversight and continuous communications with groundstaff who manage the propelling move. Finally, these moves do not all happen consecutively, but over hours or even days. There may be several other sequences of moves going on with other trains on the same day, and therefore different train moves and train preparation tasks were interleaved for maximum efficiency in the yard.

3.3 Work planning

Figure 1 shows the high level task model and task flows for work. A key finding from observations and discussion was to consider the relevance of office and planning work feeding into the yard. This involved planning the commercial arrangements, planning of paths and rosters. This proved to be a crucial factor in setting up the task loads in the yard. Planning and rostering tasks were reliant on accurate information being provided such as fatigue monitoring and sickness absence for staff and the availability of wagons and locomotives for building the requested train. Combining the available network pathways, staff availability and asset availability into workable plans often led to multiple changes in planning prior to the train build in the yard. It was raised by workshop participants during the validation exercise that whilst the tasks identified in Figure 1 were accurate, the linear model did not reflect the back-and-forth nature of train planning and the complexity of communications and understanding between planning functions and yard functions. Planning and commercial tasks were also subject to their own ergonomics issues in terms of usability of software.

Staffing varied across yards – some being staffed 24/7 while others were staffed on an occasional basis or operated by staff driving to the yard on an as needed basis. Even when yards were staffed, the supervision (the planning and sequencing of work) may be remote. Yards visited noted different peaks of work depending on the type of freight handled (e.g. night shifts at a yard linked to a large manufacturing plant; approaching weekends when preparing infrastructure engineering trains).

The arrangement of assets and wagons in the yard was also complex. Wagons come in many different types and train sets would often require specific combinations, thus increasing the number of shunt moves as a number of wagons would need to be pulled out from within a larger set of wagons. This complex compilation of wagons also applied to wagons being located and moved to maintenance areas, either for repair or regular inspection. Staff highlighted that the number of movements required in conjunction with the complexity of how sites are laid out often meant they felt they had limited time allocated in plans to build trains and complete pre-departure checks.

3.4 Physical workload

In terms of the physical environment, walking conditions, lighting, the exposed nature of the yard (with many activities taking place in the open air) all added to the challenges of the work. Several yards are immediately next to live running mainlines. Yards were often broken into two or more separate areas which required walking and sometimes travel by van. This was also additional time to be factored into tasks.

Also, the tasks in the yard were often physically demanding. Handbrakes required a high degree of torque, particularly if clogged with debris from travel, or stiff after a period of non-use. Handbrakes could be quite low down on the wagon (e.g. around 0.6) metres and require significant stoop for taller members of staff. Other physically demanding tasks involved removal of stanchions, required to hold loads in place, weighing 7 or 8kg but with up to 12 on a wagon this could be a significant task. Other tasks included loosening and tightening of couplings between trains, involving both a physical force to perform the work, and a stoop to get under buffers. All of these tasks took time and increased the physical demands of work in the yard. Other physical tasks involved pulling hand points in the yard, and closing and opening of wagon doors.

3.5 Recommendations

Finally, both the observations generally, and the workshops specifically, identified a range of tactical and strategic solutions to proposed to address human factors issues in the yard. These are listed in Table 2. Already, some steps have taken place to provide better lighting and walkways within yards, and to look more closely to capture data on train preparation activities. However, just as relevant to the proposed recommendations is what they communicate about the issues experienced in the freight yard - for example that better data is required on train movements, that training and processes can be improved, or that all members of staff need a better understanding of work in the yard.

Table 2– tactical and system improvements for rail freight yard operations

Tactical- Unobtrusive monitoring of comms/actions through CCTV, audio recording, body cams etc
Tactical- Better understanding of freight system in training e.g. planners spending more time with groundstaff to see what role is like.
System- Industry take a lead on tools to make process easier e.g. automatic reading of locos and wagons, recognise where they are in the yard (geo-location)
System- Operationalising a fair culture that applies to staff and senior management. Something similar to Network Rail model and freight life saving rules suggested.
System- Better integration of non-technical skills
System- Develop SSOWs with human factors in mind.
System- Standardised training school for staff- drive a common standard throughout the industry.

4 Discussion

When considered in combination, the freight yard reveals a complex picture of fluid cognitive planning and replanning. External to the yard, the commercial considerations of planning, and resourcing, both people and wagons / locomotives, gives a tight set of constraints for operations to take place within. The physically demanding nature of the job, plus the need to work around site capacity restrictions, further influenced the planning and execution of work. In order to manage the external pressures for delivering freight (subject to short-term replanning), supervisors work with groundstaff, and work in the yard requires a high degree of flexibility, tacit knowledge and cooperation. It is notable that that, like Reinach and Viale (2006b), the role of the supervisor (or yardmaster in Reinach and Viale [2006b]) was key to this flexibility. It is also notable that this can be more challenging in situations of remote supervision where plans may not fully reflect constraints in the yard, as observed in Site 4.

While the models in Figure 1, and the scenario in Figure 2, appear linear, this is not how work is performed. In order to complete tasks as efficiently as possible, multiple tasks would be combined and conducted in parallel. For example, groundstaff might conduct multiple train preparation tasks, or combine together multiple wagons into a single shunt move to cut down on time and best manage the constraints of the freight yard. Also, these timelines belie how often plans are subject to change. Plans would often have to be adapted within short (less than 24 hour) timeframes. A final comment from workshop participants on the task models was that there was insufficient emphasis on the importance of interactions with 3rd parties such as companies responsible for wagon loading, Network Rail, customers etc.

The work correlates with the limited previous findings so far. First, the understanding of work is difficult through paperwork alone (Bowler and Basicik, 2015) and the difference between work-as-imagined and work-as-done is significant. This is vital looking towards the introduction of European Train Control System or digital coupling (Cantone et al., 2022). Specifically, engineering designs for these technical developments may assume tasks are conducted sequentially, and in isolation. In practice, we may find that tasks are interrupted and combine in a flexible way to make best use of time or to minimise effort. Therefore, processes for utilising technology such as digital coupling must be robust to these kind of procedural changes. While such developments may offer benefits for the freight sector, they cannot be successfully introduced until they fully reflect the complexities of work in the freight yard, and the realities of human factors in the freight environment. In this way, the analysis presented here is a major step towards informing user-centred deployment as advised by Vaghi et al. (2018).

Many of the situational factors such found by Lawton (1998) relevant to the shunting task are found to more widely impact work across the freight yard. Certainly, the degree of (re-)planning and flexibility required sets up the kind of adaptations and, potentially, violations that Lawton observed. What was unexpected was the degree to which back office, planning and commercial processes set the scene and constraints under which freightyard work operates. Participants across all roles commented that customers drove the demands that need to be followed. In this manner, the freight yard provides the resilience in the wider freight system – this is the point in the network that can handle short-term changes, turn trains around quickly, and adapt to changing customer demands. This is only achievable through the commitment to flexibility and adaptability of the workforce. In Woods' (2015) definitions of resilience, this is robustness – an ability to soak up changes and work fluidly, but not necessarily without cost. While the commitment, quality / safety of work and professionalism of on-site staff was evident and paramount, this kind of flexible and adaptive working will inevitably lead to trade-offs identified in Lawton (1998) and the kind of events and incidents found by Golightly et al (2022). Ultimately, it is an example of where working to achieve performance is one side of the same coin that leads to potential performance failure (Hollnagel, 2017).

In this light, one aim of the work was to understand a useful theoretical lens going forward to further understand the work of the freight yard from a Human Factors perspective. As a starting point, Table 3 presents systems aspects of the rail freight yard, following sociotechnical models such as Wilson and Sharples (2015) or a similar structure to Rasmussen (1997). The model sets out factors that influence performance in the freight yard, from the highest societal and cultural factors (a move towards decarbonised transport supporting the market for rail freight; public expectations around the speed with which freight should be delivered, particularly for containerised goods, parcels etc) down through to the physical and cognitive characteristics of operational staff. It would be valuable to further develop the analyses presented here into other forms of structured framework. The early stages of Cognitive Work Analysis (Vicente, 1999) would be useful for fully delineating the relation between the physical characteristics of the yard, and the range of activities where these functions apply. Humans in Safety (HFIS) (Ryan et al., 2021) – a rail orientated systems framework that foregrounds the human contribution to safety - would also be useful in identifying and elaborating on both the tasks of the freight yard, but also how they are performed in a way that manages and mitigates risk.

Table 3 Sociotechnical overview of the freight yard

System Level	**Factors**
Societal and cultural	Demands for decarbonised transport Expectations around delivery time of freight services and products
Governmental and regulatory	Oversight by Office of Road and Rail Standards and regulations by Rail Safety and Standards Board (eg GERT 8000 TW4) Policy and strategy via Department for Transport (eg UK Gov, 2023)
Organisational	Commercial requirements and contractual relation with customers (eg loading agreements with end-user sites) Long-term train planning (train length, frequency, load etc) Planning and execution of resourcing plans (staff, locomotives, and wagons)
Wider work environment	Proximity and interactions with end-user site Supervision (when under remote supervision) Access to and from mainline rail network (either for dispatch / arrival of trains, or for train moves during train preparation) Maintenance access and planning (wagons and locos)
Immediate work environment	Yard condition (e.g. lighting, designated walkways) Yard ‘roads’ availability and capacity On-site supervision IT for accessing, managing, recording train consists Access to welfare facilities
Tasks	Receiving trains, unloading, train decomposition and recomposition, loading, checking, dispatch Loco and wagon moves for maintenance, refuelling, storage Interleaving all of the above for effective use of time Data review and entry
Operator	Formal competency Non-technical skills Experience and knowledge of the railways Physical capability (size, strength, age, fitness)

At a lower, human performance level t is important not to overlook traditional physical ergonomics. For example, REBA analyses (Hignett & McAtamney, 2000) in now underway to quantify typical yard tasks. This will not only quantify areas of risk, but can form an evidence base for task redesign, and ideally equipment redesign. For example, recent work to use composites for lightweighting rail infrastructure components (Grasso et al, 2022) could be considered as a lightweight replacement for steel in wagon stanchions. Walking on ballast is another area that has received some attention (Andres et al., 2005) but does not yet cover the kind of extended walking exposures seen across a typical groundstaff shift. Handbrake wheels can be redesigned with methodology and outputs from similar analyses to understand pump wheel musculoskeletal loading in the processing (Wieszczyk et al., 2009) sector, and methods for assessing physical loads to conventional hand signalling can be applied to ground points found within the yard (Muffet et al., 2014).

At a cognitive level, there are many observed instances of planning and action to achieve adaptive capacity, and many of the kind of behaviours and adaptations observed have similarities to those seen in other environments, particularly recent work to understand capacity generation in areas such as healthcare (Sanford et al., 2022; Saurin et al., 2022). Specific behaviours should be identified as they indicate effective work to balance trade-offs, and also where capacity is brittle and could be expanded by new technology, procedure or business arrangements with other stakeholders. Another aspect that influences planning is the complexity of the yard, and how factors such as length and availability of roads, or need to conduct propelling moves to conduct train preparation can increase the number of tasks steps. A site complexity tool, with 31 site complexity factors, has recently been developed by the authors (Golightly et al., 2024) and is awaiting validation.

There are a number of limitations of the work. First, it is primarily wagon-based and, as noted in the workshop, a different process may be observed for the management of dangerous and tankerised goods, so there is a need for replication of the work in this context. Second, the observations focussed on large yards with on-site or nearby supervision. However, many sites are smaller and operate with remote, mobile working as it is needed. Not only does this work need to be observed, better statistical analysis is required to understand the risk associated with these sites. While they have fewer train movements they may generate disproportionate risk. An analysis is currently underway with Rail Accident Investigation Branch reports to analyse the frequency of freight yard-related events in the reporting data, and to calculate the proportion of smaller yards within that data set. While observers were given an opportunity to see a range of tasks, this was not a ‘controlled’ study. Further work could specifically compare different tasks, different freight operators, different yard environments and environmental conditions (night and day, but also heat and cold). Finally, the analysis is GB-centric, and withthe different operational characteristics in different countries, such as remote shunting operation (Reinach and Viale, 2006a), and therefore caution should be made in extrapolating results. Nonetheless there are commonalities with other countries. In particular, the Federal Railroad Authority in the USA has recently issued a safety advisory relating to train composition (FRA, 2023), and so there may be parallels between the work reported in this paper.

5 Conclusions

Overall, the freight yard has received little research attention, yet is a potential source of risk both to staff working there, and for trains that then head out onto the network. The observational and workshop activities presented in this paper captures the role of people in the freight yard, a unique and challenging environment, highlighting physical risks, but also highly fluid and cognitive planning to achieve success. This work contributes insight to anyone looking at human performance in freight and logistics, and will also be specific relevance to those looking at digital technologies such as ETCS and digital coupling, giving insight into the practicalities of how 'work as done' could impact the acceptability of deployments.

The work has generated a number of of areas for future research and analysis. As a more general point, the paucity of understanding of human factors in the rail yard suggest a range of further activities to not only cover the physical tasks of freight preparation, but to understand cognitive and coordination type activities for creating sufficient capacity within the yard, while ensuring groundstaff have resources to conduct this work safely, both for themselves and to ensure the safe preparation of the train. This will be paramount as the industry looks to increase capacity to enable decarbonised, high performance freight.

Acknowledgements

First author Golightly was funded by Newcastle University QR Policy Support Fund. The authors are grateful for the time, hospitality and insight of rail freight representatives who engaged with this research.

References

Andres, R. O., Holt, K. G., & Kubo, M. (2005). Impact of railroad ballast type on frontal plane ankle kinematics during walking. Applied ergonomics, 36(5), 529-534.

BBC (2020) Llangennech oil spill: Clean-up is 'biggest challenge since the Sea Empress'. Accessed from https://www.bbc.co.uk/news/uk-wales-55893267

Bowler, N & Basicik, D (2015) A human factors review of the rail operation at the port of Felixstowe. Proceedings for 5th International Rail Human Factors Conference, 2015.

Campbell, B. (2013). The Lac-Mégantic Disaster. Canadian Centre for Policy Alternatives, October, 22.

Cantone, L., Durand, T., Ottati, A., Russo, G., & Tione, R. (2022). The Digital Automatic Coupler (DAC): An Effective Way to Sustainably Increase the Efficiency of Freight Transport in Europe. Sustainability, 14(23), 15671.

FRA (2023) Safety Advisory 2023-02; Train Makeup and Operational Safety Concerns. Accessed at https://railroads.dot.gov/elibrary/safety-advisory-2023-02-train-makeup-and-operational-safety-concerns

Grasso, M., Robinson, M., Chaffey, B., Mortimer, P., & Brighton, J. (2023). Innovative Pultruded Composite Mast Design for Railway Overhead Line Structures. Designs, 7(3), 77.

Gibson, W.H., Mills, A., Basacik, D., Harrison, C., (2015) The incident factor classification system and signals passed at danger. In: Proceedings of the 5th Conference of Rail Human Factors, London, UK.

Golightly, D., Lonergan, J., Ethell, D., Gibson, H., & Hill, D. (2022). A structured incident analysis of human performance in freight train preparation. Proceedings of International Rail Safety Council.Seville, Spain, 2022.

Golightly, D., Ethell, D., Lonergan, J. (2024) Tool for Estimating Rail Freight Yard Complexity and impact on human performance. Accepted as a poster to Ergonomics and Human Factors 2024 Conference, Warwick, UK, April 22-24, 2024.

Hignett, S., & McAtamney, L. (2000). Rapid entire body assessment (REBA). Applied ergonomics, 31(2), 201-205.

Hollnagel, E. (2017). The ETTO principle: efficiency-thoroughness trade-off: why things that go right sometimes go wrong. CRC press.

Hricová, R. (2016). RFID as a Tool of Competitiveness Increase of Rail Freight. International Scientific Journal about Technologies, 2(1), 11-14.

Islam, D. M. Z., Jackson, R., Zunder, T. H., & Burgess, A. (2015). Assessing the impact of the 2011 EU Transport White Paper-a rail freight demand forecast up to 2050 for the EU27. European Transport Research Review, 7(3), 1-9.

Lawton, R. (1998). Not working to rule: understanding procedural violations at work. Safety science, 28(2), 77-95. Muffett, B., Wilson, J. R., Clarke, T., Coplestone, A., Lowe, E., Robinson, J., & Smith, S. (2014). Management of personal safety risk for lever operation in mechanical railway signal boxes. Applied ergonomics, 45(2), 221-233.

Rail Delivery Group (2021) Assessing the Value of Rail Freight. Accessed from https://www.raildeliverygroup.com/about-us/publications/12839-2021-04-assessing-the-value-of-rail-freight/file.html

Rail Accident Investigation Branch (RAIB) (2020) Runaway and derailment of a wagon at Clitheroe, Lancashire, 9 March 2020. Accessed from https://assets.publishing.service.gov.uk/media/5fe1c4d28fa8f56aeee281e4/R162020_201223_Clitheroe.pdf

Rail Accident Investigation Branch (RAIB) (2022) Derailment and fire involving a tanker train at Llangennech, Carmarthenshire 26 August 2020. Accessed from https://www.gov.uk/government/news/report-012022-derailment-and-fire-involvinga-tankertrain-at-llangennech-carmarthenshire

Rasmussen, J. (1997). Risk management in a dynamic society: a modelling problem. Safety science, 27(2-3), 183-213.

Reinach, S., & Viale, A. (2006a). Application of a human error framework to conduct train accident/incident investigations. Accident Analysis & Prevention, 38(2), 396-406.

Reinach, S. J., & Viale, A. F. (2006b). An Examination of the Yardmaster's Role in Railroad Yard Safety. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 50, No. 22, pp. 2429-2432). Sage CA: Los Angeles, CA: SAGE Publications.

Ryan, B., Golightly, D., Pickup, L., Reinartz, S., Atkinson, S., & Dadashi, N. (2021). Human functions in safety-developing a framework of goals, human functions and safety relevant activities for railway socio-technical systems. Safety science, 140, 105279.

Sanford, N., Lavelle, M., Markiewicz, O., Reedy, G., Rafferty, A. M., Darzi, A., & Anderson, J. E. (2022). Capturing challenges and trade-offs in healthcare work using the pressures diagram: An ethnographic study. Applied Ergonomics, 101, 103688.

Saurin, T. A., Wachs, P., Bueno, W. P., de Souza Kuchenbecker, R., Boniatti, M. M., Zani, C. M., & Clay-Williams, R. (2022). Coping with complexity in the COVID pandemic: An exploratory study of intensive care units. Human Factors and Ergonomics in Manufacturing & Service Industries, 32(3), 301-318.

UK Gov (2023) Rail freight growth target. Accessed from

https://www.gov.uk/government/publications/rail-freight-growth-target/rail-freight-growth-target

UNESCAP (2021) Enhancing shift towards Sustainable Freight Transport in Asia and the Pacific Opportunities through railway decarbonisation Accessed from https://www.unescap.org/kp/2021/enhancingshift-towards-sustainable-freighttransport-asia-and-pacific-opportunities

Vaghi, C., Wheat, P., Österle, I., Milottia, A., & Nellthorp, J. (2016). The role of human factors in rail freight innovation. Towards Innovative Freight and Logistics, 2, 245-258.

Wieszczyk, S. M., Marklin, R. W., & Sánchez, H. J. (2009). Height of industrial hand wheel valves affects torque exertion. Human factors, 51(4), 487-496.

Wilson JR, Sharples SC (2015) Methods in the understanding of human factors. In: Wilson JR, Sharples S (eds) Evaluation of human work, 4th edn. CRC Press, Boca Raton, pp 1–32

Woods, D. D. (2015). Four concepts for resilience and the implications for the future of resilience engineering. Reliability Engineering & System Safety, 141, 5-9.

Zhang, Z., Turla, T., & Liu, X. (2021). Analysis of human-factor-caused freight train accidents in the United States. Journal of Transportation Safety & Security, 13(10), 1157-1186.

FIGURES

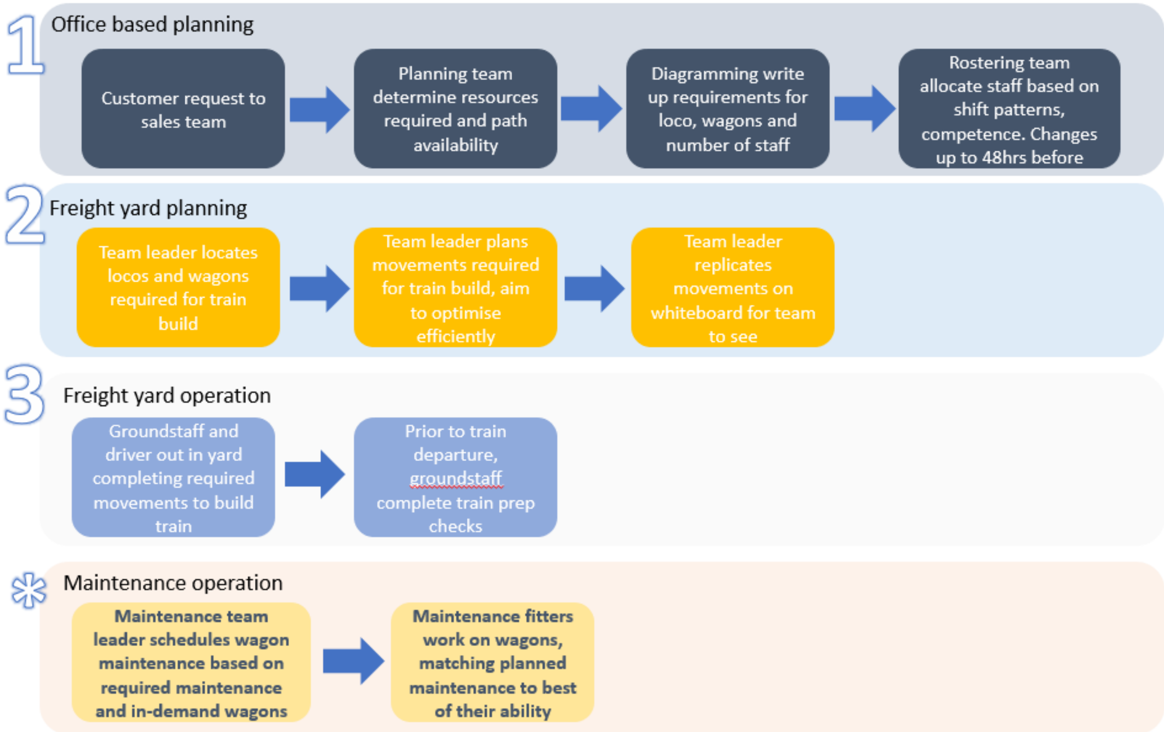

Figure 1. Process map of tasks completed in the freight yard.

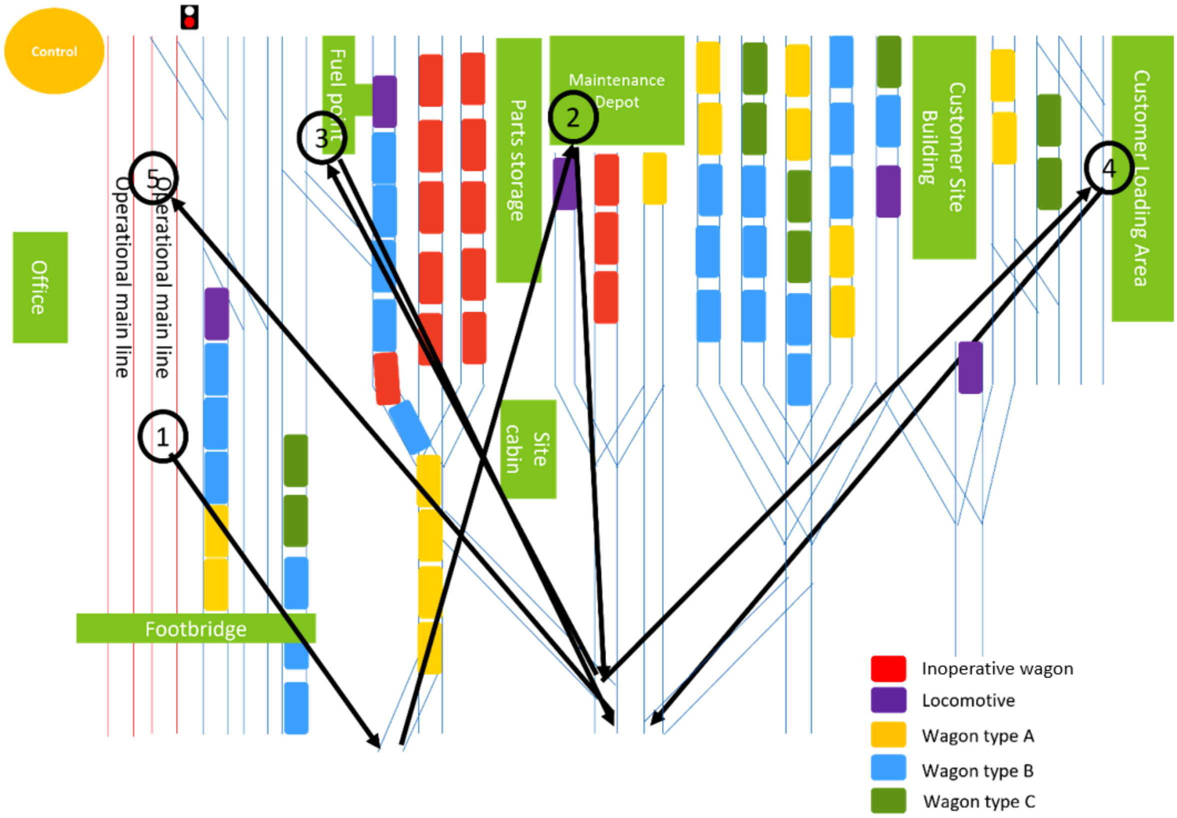

Figure 2. A generic freight yard example and activity sequence.