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Authority gradients between team workers in the rail environment: a critical research gap

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ABSTRACT
Communication errors feature prevalently as causal and contributory factors in accident analysis within rail. While matters of phraseology and protocol in communication have been used to categorise communication error, formal inquiries into major rail accidents point to an underlying "authority gradient" as an influencing factor. The aim of this paper was to understand how the influence of authority gradients on communication error has been explored by communities of research and practice in rail. To achieve a holistic understanding and identification of key research gaps, this paper also reviewed prevalent tools and frameworks applied in rail human factors, as well as other sectors impacted by power disparities between teams. The review found that while evidence from industry reports is suggestive of an authority gradient in rail, no research has been conducted to support or refute this conclusion. Moreover, an absence of authority gradients in applied research draws attention to current methodological capabilities vs research foci. The relationship between the authority/power and status/value of core rail operational functions is conceptualised, and application of Hofstede's theory of power distance to rail is considered. A number of research gaps are identified which indicate future research opportunities.

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Railway; safety; power distance; communication error; hierarchical organisation

Relevance statement

Industry reports and Inquiries into major rail accidents draw attention to an underlying "authority gradient" as an influencing factor in communication error, resulting in near misses and fatalities. A number of human factors tools, methodologies and frameworks have been applied in the context of communication error in rail, but there is little to indicate that the influence of authority gradients has been uncovered or has been the focus of research activity to date. Consequently, power disparities between team workers are being addressed using individual-level training approaches, which means the nature of communication error is not being accurately represented. The prevailing theory for authority gradients, Hofstede's power distance dimension of cultural relativity theory, has not been applied to rail previously and is considered in relation to research gaps for understanding

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the authority gradients in rail. This review seeks to promote further growth in the interstices of human factors methodology and substantive theorisation as it relates to revealing the influence and effect of the authority gradient in maintaining the rail system of safe working. Such work will be highly relevant for industry practice.

1. Introduction

The rail environment is a distributed, dynamic, and complex system where teams work interdependently to achieve their goals, and where the working dynamics of any one group can significantly affect the operations and safety of the entire network (Wilson and Norris 2005). In a recent review of 235 incidents on railways in Great Britain, 21% were identified with communication error as a contributing factor (Turner et al. 2017). Understanding how teams communicate with one another and how deficiencies in the relationship may produce errors is therefore crucial for understanding how safety can be effectively enhanced in rail.

Non-compliance with communication protocols and deficiencies in stakeholder communications have been identified as contributing factors in track maintenance rail incidents reported to the Australian Transport Safety Bureau (ATSB). According to a 2017 report, rail network errors frequently occur during important communication exchanges between the network controller and the protection officer[1.] While not specifically labelled as errors in communication, they featured across event categories where the type of protection for track workers was either insufficient (580 out of 700 events), incorrectly positioned (267 out of 700 events), incorrectly removed (219 out of 700 events) or the worksite itself (i.e. location) was incorrectly identified (112 out of 700 events) (Australian Transport Safety Bureau, 2017).

While compliance with communication protocols remain the focus of efforts to circumvent error, Orasanu, Fischer, and Davison (1997, as cited in Hazrati 2015, p. 246) point to the existence of a category of communication where the communication itself is clearly transmitted and the content is understood, but a shared understanding does not form. Gibson et al. (2006) also adopt this view and conclude that communication errors may not only result from the communication process itself.

Early studies within aviation point to accidents involving communication error at rates as high as 70% (Kanki 1995). Errors that occur due to unequal distributions in power are considered using Hofstede's (1983) cultural dimensions theory, specifically in relation to power distance. This is used to understand how power distributions influence behaviours, for instance how an individual's cultural background dictates how comfortable they are in challenging those they perceive to have positions of higher status (Daniels and Greguras 2014). Merritt (2000) used power distance theory to describe the aviation environment as *"hierarchically designed"* with recognisable high-power distance principles, notably the relationship between senior pilots and more junior co-pilots (p. 298). Cookson (2009) observed this as a problem caused by a steep "trans-cockpit authority gradient" (p.22.11) referring to an established and/or perceived command and decision-making power hierarchy within a team, crew or group; thus, authority gradients are observed to have a negative effect on communication and coordination, which in turn can adversely impact safety.

Sasou and Reason (1999) categorise communication errors that occur within teams as Performance Shaping Factors and make reference to the influence of an "authority gradient" (p.4). Errors attributed to an authority gradient are those that occur when power is unequally distributed and where team members are hesitant to challenge a decision or directive from those they perceive to wield more seniority (Dobson, Moors, and Norris 2014). Interaction between team members in an operational context may give rise to an authority gradient, as inequities invariably exist in levels of experience and/or qualification. Authority gradients also exist in multidisciplinary teams between roles, for example in a health context, there is evidence of authority gradients between nursing staff and physicians influencing communication and negatively impacting patient health outcomes (Gordon and O'Connor 2012). Thus the same may be true for multidisciplinary teams in the rail context, where train controllers, train drivers and trackworkers engage in disparate tasks but work towards the same operational objective.

Oborn and Dawson (2010) describe knowledge and power as intrinsically linked and influential in the achievement of status and power, with preference given to the knowledge of some multidisciplinary team members, over others. Formal authority and knowledgeability are anchored within the institutional structure and generate privileged knowledge that serves to reinforce power hierarchies in multidisciplinary teams. In the rail context, network controllers are responsible for their own section of the rail system, monitoring the flow of traffic and managing any emergencies. Siegel and Schraagen describe network controllers as operating at *"the sharp end of the system"* (2016, p182) and having an understanding of system operations beyond their scope of operational control.

While communication errors may potentially arise from interactions between any members of the multidisciplinary rail team, for the network controller, their own privileged knowledge implies that such interactions would be associated with issues of power distance, referring to perceptions of unequal status and/or power distributions, that make it less likely that someone would question someone of higher status or power (Appelbaum et al. 2016, p. 345).

1.1. Hierarchical design within the rail environment

Much like the aviation environment, the rail environment is hierarchically designed and broken up into different sections, each controlled by discrete functional roles. Figure 1 shows an overview of the system and role of the primary actors within the broader Australian context of passenger rail operations, though positions and responsibilities are largely similar in freight. Adapted from Roth, Naweed, and Multer (2020), key frontline workers include the train driver (locomotive engineer, railroad engineer, train operator, engine driver, loco pilot)[2] who operates the train, and the guard (conductor) who is responsible for safe passenger movement and operations associated with platform departures (Dorrian, Baulk, and Dawson 2011). Collectively they comprise train crew. While unconventional in passenger operations, freight operations in countries characterised by long distance rail (e.g. Australia, USA) may also feature a second driver (co-driver, co-loco pilot) who has specific tasks and a share in the driving activities (Naweed, Balakrishnan, and Dorrian 2018). In some rail context, there may not be a train guard.

Tasked largely with problem solving and decision making (Farrington-Darby et al. 2006), the network controller (chief dispatcher, rail traffic controller) is responsible for managing and authorising movement for anything using the track (e.g. on-track vehicles, rolling stock). The network controller remotely controls train movement, decides who gets access (and for how long) to particular sections of track (Baldry and Ellison 2006), and balances

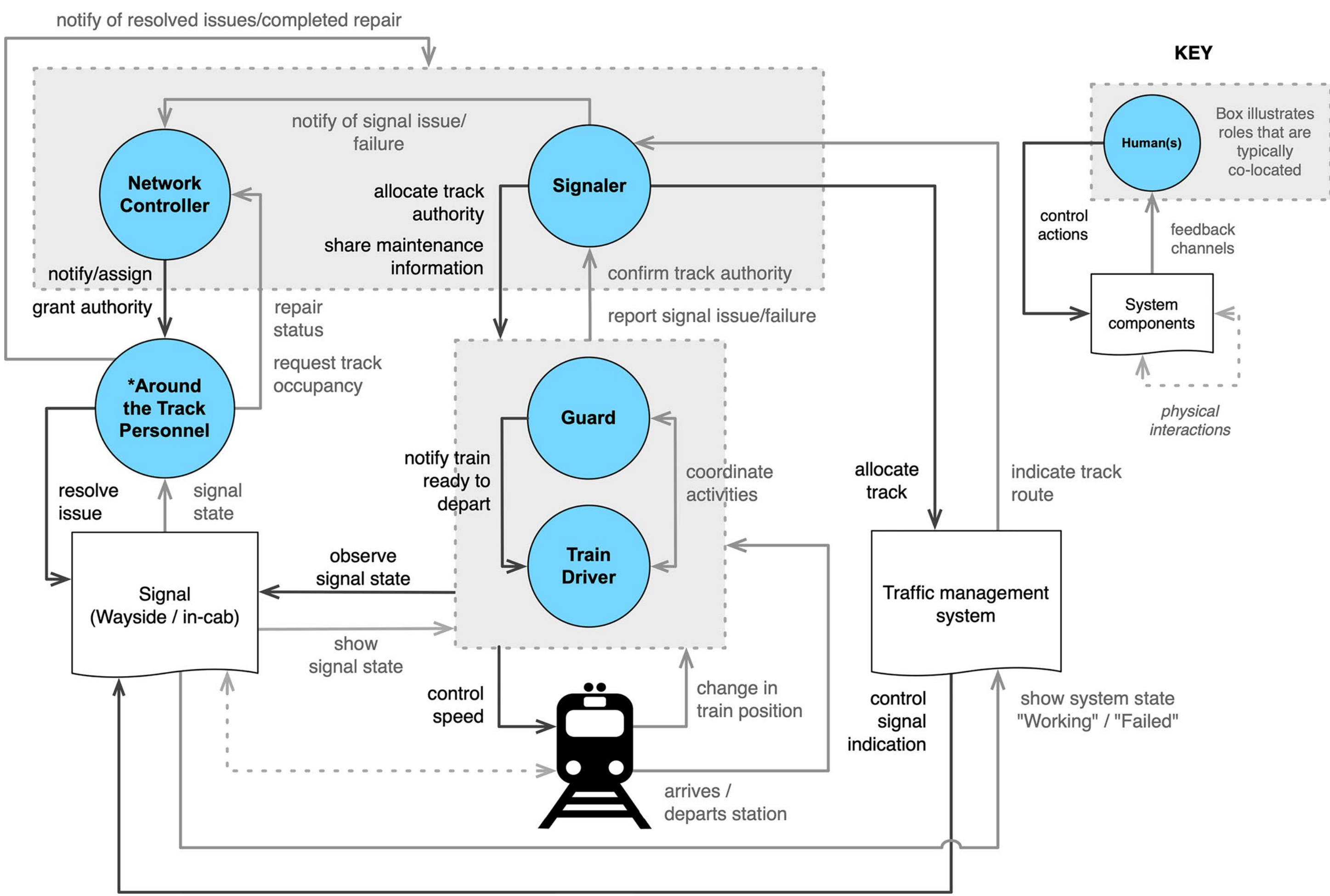

Figure 1. Overview of the primary roles and interactions of frontline workers in passenger rail operations in many Australian settings (adapted from Roth, Naweed, and Multer 2020). *Around the track personnel captures anyone working in and around the track; repair work can also be facilitated by logging jobs to a facilitatory service desk in some contexts.

safety with production targets (Cheng and Tsai 2011). This role is performed independently in some countries (e.g. parts of Australia) and rail contexts (e.g. freight); however, in many settings, a signaller (dispatcher, area controller, block operator) manually controls the signals and switches for a portion of rail territory.

In Figure 1, around the track personnel represent those responsible for repairing and maintaining network infrastructure so that rail vehicles can traverse safely. The latter typically occurs within scheduled shutdowns, where portions of the network are closed to rail movements, but also while trains are still running (Golightly et al. 2013). These comprise track workers, electricians and points maintainers, but also those charged with protecting them, including lookouts, who watch for trains and warn fellow track workers when one approaches their site of work, and the protection officer (controller of site safety, person in charge of possession), who is responsible for negotiating access and the onsite protections of the track work crew (Naweed, Young, and Aitken 2019). While some functions of these work groups may be co-located, the people themselves are physically separated, therefore information is exchanged over the radio or via mobile telephones.

Rail is therefore a transport sector with an established hierarchical structure and, like aviation, has recognisably high-power distance principles underpinning its make-up. This suggests that communication errors also have the potential to be influenced by an authority gradient associated with the power distance, as opposed to matters of phraseology, protocol or procedure. Reviewing protocols and focusing on operational factors, while failing to explore underlying communication influences, may thus be inhibiting action by hindering attempts to understand and prevent communication errors (Roosenboom 2012; Turner et al. 2017).

1.2. Understanding communication error in the rail environment beyond issues of phraseology and language proficiency

In the forgoing discussion, we indicate that categorisation of communication error in accident analysis is broad, and encompasses operational transmission error types (Mathews 2012). Looking at phraseology and language proficiency is important, given so much exchange of information happens remotely, but this has the effect of narrowing focus to the individual level of human error and disregard the broader system.

Wilson and Norris (2005) provided a comprehensive review of human factors-related studies in rail from the 1960s to the early 2000s, during which time the concept of human error concept evolved from being independent and causative to something more systemic and symptomatic (i.e., a contributing factor as opposed to causal factor) (Hollnagel 2012; Reason 2016). Today, understanding human error from this 'systems thinking' perspective has become increasingly relevant for comprehending safety. The sizeable role of communication errors in rail incidents (Australian Transport Safety Bureau 2017; Turner et al. 2017) begs the questions of whether authority gradients are being examined in the literature and in industry-based accident investigations, and if they are not, then why this is the case. Authority gradients and power distance more broadly conform to systems thinking principles in that the concepts innately focus on sociocultural interactions and relationships with other elements of the system.

For the most part, accident investigations across a range of industries already use human factors to explain sociocultural/technical influences on error. The rail industry is no exception and contributory human factors are viewed through the lens of various frameworks, tools and approaches, with many originally developed in other industries and adapted for the rail environment (Morgan et al. 2016). Thus, in conjunction with determining the extent to which authority gradients in rail have been investigated, it is important to examine how various techniques seek to understand how communication errors transpire, whether these methods are effective for identifying power distribution in teams, and the impact this may have.

1.3. Research question & aims

The aim of this paper was to review the literature for evidence of authority gradients impacting communication and working dynamics in the rail environment. A secondary aim was to review the literature for key frameworks/tools that have been applied to communication error in rail. Therefore, the research question(s) guiding this study were:

RQ 1. To what extent has the influence of authority gradients on communication error been explored by communities of research and industry practice in the rail environment?

RQ 2. What indications of an authority gradient are identified in the application of human factors methods in rail?

1.4. Review approach

A narrative review of academic research papers and industry reports was undertaken to identify key themes and research gaps. To meet the primary aim of the review (i.e., evidence of authority gradients impacting communication and working dynamics in rail), a search strategy was undertaken on published scientific (i.e. white) literature, and on literature at the "grey" level (e.g., industry/technical/government reports). The former included searching for relevant papers in national library archives and various databases including *Scopus*, *ScienceDirect*, *Ebscohost*, the UK Rail Industry Safety and Standards Board's (RSSB) *SPARK Rail Knowledge Hub* (www.railknowledgebank.com), and the Australian Road Research Board's (ARRB) *Knowledge Bank* repository (www.railknowledgebank.com). Combinations of keyword search included the terms: *authority gradient*, *rail, communication, power influence*, *power distance*, and *power differential*. Following an initial scan, a snowballing technique was adopted whereby additional literature was identified through citations made in each publication (Wee and Banister 2016). In terms of grey literature, a search of the aforementioned terms was undertaken through the websites of various rail authorities for relevant incident/accident reports/documents using the same search terms. These included the Australian Transport Safety Bureau (https://www.atsb.gov.au/), the Office of the National Rail Safety Regulator (https://www.onrsr.com.au/), the Transport Accident Investigation Commission—New Zealand (https://taic.org.nz/), the NZ Transport Agency (https://www.nzta.govt.nz/) and the Rail Accident Investigation Branch (https://www.gov.uk/raib-reports).[3]

As this review was interested in the power dynamics that may exist within front-line rail operational teams (with immediate impacts to safe working), literature of the broader management hierarchy (e.g., executives, safety managers, shift managers) was not reviewed.

Communication error is a human factor in similar, high-risk domains like healthcare and aviation, where frameworks have also been developed to identify contributing factors and develop methods for accident prevention (Morgan et al. 2016). On determination of a paucity of literature relating to the influence of authority gradients or power distance and/or power imbalances within teams in rail, substantive literature from analogous systems mentioned earlier in the paper (e.g., aviation, healthcare) were explored using the same search terms (excluding the term “rail”). Examining the existence of the authority gradient in relevant contexts formed part of the methodology for understanding where the research gaps lie in rail.

Consistent with literature reviews that adopt narrative frameworks to synthesise findings (Ferrari 2015), the foregoing search strategy was used, but the literature arranged into a conceptual frame organised as follows. The first section provides the review findings related to the existence of authority gradients in the rail. We then turn to review findings of key human factors tools and frameworks applied to communication error in rail. The review then examines the theoretical basis for the authority gradient, and consideration of whether it can be applied to rail. The paper concludes with an identification of the key research gaps and suggests where and how further discussion/work might proceed.

2. The authority gradient in the rail environment

Scientific research that focused specifically on authority gradients or power distance in rail was not found in the search, demonstrating a paucity of literature using these terms. However, a search within the government/industry reports did yield findings, though these were by no means prevalent. A single industry-based commissioned review was found to provide some discussion of authority gradients in rail accidents. Undertaken with the aim to inform a separate review of technical standards for interoperability, authority gradients amongst team members were described as a contributing factor in a number of incidents, through an uneven distribution of power (Dobson, Moors, and Norris 2014). The reference within the review was to a single research paper developed by (and for) the United States Department of Transport, concerning power differentials in the cockpit in aviation accidents, and concluded that the greater the difference in ranks of helicopter pilots and co-pilots, the greater the occasion of error (Alkov et al. 1992). Further, the commissioned literature review asserted that authority gradients likely exist between train drivers and network controllers (Dobson, Moors, and Norris 2014).

The way that network controllers relate with train drivers has been referenced by Naweed (2013) in a study investigating train driver distraction. The study found that 26% of distractions were identified as network controller interactions, with indications that these interactions were perceived as a nuisance, unnecessarily intrusive, and overemphasised service delivery requirement in a way that negatively impacted safety. However, the study did not expand on this to directly explore the possibility of a power imbalance influencing the communication relationship. While not the focus of the work, a later study by Rainbird and Naweed (2017) raised the prospect that network controller attitudes to self and the broader operational team were underpinned by a power differential, impacting on the quality of communication. Network controllers were described as *"God"* by train drivers and this was reinforced directly by network controllers from their own perspective in a more recent study (Naweed 2018; 2020, p. 3). Beyond this, very little research appears to have investigated an authority gradient and/or power differential in rail but mention of its existence was found from accident investigation reports within the grey literature.

In the *Special Commission of Inquiry into the Waterfall Rail Accident* undertaken by McInerney (2005), an authority gradient between the train driver and guard was identified as a contributing factor in an accident that killed seven and injured 42 others when their train derailed south of Waterfall railway station in New South Wales, Australia. The train had been traveling at a speed of 117 km/h into a 60 km/h curve, and while a cardiac arrest in the train driver is believed to have precipitated the accident, the *Inquiry* asserted it was necessary to understand *"why the Train Guard failed to take any action when it became apparent G7 was travelling at excessive speed sufficient to alarm the passengers…"* (p. iv). The final report concluded that: *"The [State Rail Authority of New South Wales] and RailCorp failed to ensure that authority gradients did not exist between train drivers and guards, so that train guards were not reluctant to take action to stop a train in an emergency situation."* Further, the commission recommended: *"Train driver and guard training should encourage teamwork and discourage authority gradients"* (p. xxxvi).

The *Rail Safety Investigation Report – Signal Passed at Danger and Opposing Movement Between Two Freight Trains* (Office of Transport Safety Investigations 2012) cited an authority gradient between an experienced train driver and trainee as a factor of a near-collision event between a grain train and a coal train near Gunnedah, New South Wales. In the incident, a train (5424 N) passed a signal at stop at the same time another train (WH191) approached from the opposite direction. A distance of 715 m separated them from a potential collision. The second person (i.e. second driver or co-driver) on 5424 N made several attempts to warn the driver of the approaching stop signal, and while these were acknowledged by the driver, the driver continued. In its narration of the incident, the report states:

> At interview, the second person related: "(I) looked at the driver (and) wondered why we weren't slowing. He was looking straight ahead and had hands on the brake stand (the controls). I (confirmed that the signal was at Stop) again and he replied 'yes, red light'". The train then passed GH26 at Stop at 2227. The second person stated that he stood up and told the driver that he had passed the signal at Stop and that he must stop the train. In the words of the second person, he was "yelling at the driver to stop the train. We passed signal and I stood up and told him". The driver responded 'no we haven't, it's further up'." The second person shouted "stop the train; we have gone past our signal." (p.4)

The report then goes on to say that *"The second person, a trainee driver with limited rail experience, felt reluctant to intervene before this due to both his inexperience of the route and the existence of an authority gradient between an experienced driver and the trainee"* (p. 15).

Multiple authority gradients between several operational staff were considered to contribute to poor management in the derailment of passenger train 602 M, in Sydney (Australian Transport Safety Bureau 2015a). In this long and complex case, Train 602 M maintained station departure and continue its scheduled journey in spite of numerous signals that something was awry and various attempts to stop the train. This included a train crew shift manager (TCSM) who reported a burning smell and smoke to the train crew liaison officer (TCLO), a customer service attendant who made an emergency fire broadcast, and the trainee driver being notified of the fire service en route. In the end, an axle failure, derailment and penetration of rail infrastructure through the floor of an occupied passenger carriage stopped the service. The report findings indicated that *"the incorrect assumption that the problem was caused by sticking brakes appears to have coloured the thinking of the TCLO and through the TCSM to the driver trainer. There was also an authority gradient apparent: from the TCLO through the TCSM to the driving staff and then to the guard"* (p.37). The report concluded that there existed "*inadequacies in a number of areas including communications, training, command and control and culture*" (p.40).

A number of industry reports also described behaviours indicative of an authority gradient, and have referenced the possibility of an authority gradient as an influencing factor. In another report by the Australian Transport Safety Bureau (2015b) into safe working breaches involving Absolute Signal Blocking, an incident occurred in Newcastle, Australia, in 2013 in which the signaller breached procedural requirements for applying this type of blocking. The signaller failed to nominate the signals or points over which the blocking facilities would be applied. According to the report, and in relation to the protection officer (PO), "*this surprised the PO but went unchallenged by him*" (p. 2). The report findings did not identify the PO's failure to challenge the signaller as a contributing factor, rather *"The POs and Signallers did not effectively communicate all information that was critical to the implementation of Absolute Signal Blocking"* (p. 21). Although the behaviour (failing to challenge an erroneous action) is closely associated with authority gradients (Dobson, Moors, and Norris 2014), this was not explicitly acknowledged, rather the error was attributed to a communication failure.

A further instance implicating an authority gradient was reported in an incident investigation by the Australian Transport Safety Bureau (2016) into the wrong running direction involving a passenger train at Mt Druitt, New South Wales in 2015. Mechanical problems with the train meant that the driver, technician and guard had changed ends of the train several times to regain control of the train's systems. When the train was eventually ready to depart, the guard warned the driver that he was at the wrong end of the train for the authorised direction of movement, this was acknowledge by the driver who nevertheless proceeded to depart in the wrong direction. The guard did not take action, either to stop the train or to warn the driver again, when the driver started driving in the wrong running direction. The report acknowledged that the *"the guard was less experienced than the driver"* (p.13) and went on to reference authority gradients in the aviation industry and the Waterfall Special Commission of Inquiry, indirectly linking an authority gradient as a factor in the incident.

3. Tools and analytical frameworks applied to communication error in rail

In the forgoing section, incident investigations openly implicate the existence of authority gradients in rail that have impacted the integrity of the safe-working system. Four of these involved train drivers (Waterfall, Gunnedah, Sydney, Mt Druitt), with three also including train guards and other staff (Waterfall, Sydney, Mt Druitt) and clear indications of power differential based on hierarchical design between roles (e.g. train driver and train guard) as well as level of experience within roles (e.g. train driver and trainee train driver in Gunnedah).

Table 1. Application of methods and frameworks involving communication-based errors in the rail environment.

Tool/Framework	Study	Date	Design*	How communication errors are understood	Effectiveness of identifying power distribution in teams
HFACS	Madigan, Golightly, & Madders	(2016)	U	Errors are not specifically attributed to failures in communication	Crew Resource Management (CRM) identified as being relevant in aviation and medical domains, but discounted from relevance in this study due to "the more solitary nature of the train driver role" (p. 128)
HFACS	Baysari, McIntosh & Wilson	(2008b)	U	Lack of teamwork or poor communication are errors associated with Personnel Factors	CRM identified as a contributing factor, but no specific detail concerning teamwork
HFACS-Railway Accidents	Zhan, Zheng & Zhao	(2017)	A	Communication failure incorporated into main causal factor for an Unsafe Act, i.e., the failure of a station attendant to communicate train network status prior to their collision.	The primary Precondition for the causal Unsafe Act is identified as Substandard conditions of team, i.e. lack of teamwork. No mention of power distribution within teams
TRACEr Rail	Baysari, Caponecchia, McIntosh, & Wilson	(2009)	A	Communication error categorised at a Performance Factor, i.e. a factor that may prevent an error from occurring.	Acknowledgement that organisational factors feature highly in error causation, but TRACEr Rail was not a comprehensive tool for understanding these factors. No mention of power influences
TRACEr-RAV	Baysari, Caponecchia & McIntosh	(2011)	A	Further categories such as 'vigilance' and 'conflicting information' added as participants failed to identify a category for errors related to performance factors. No indication as to how communication is categorised	An Australian-specific version of TRACEr-Rail. Three new categories were introduced as performance factors, including 'errors of other rail personnel', suggestive of thinking that teamwork factors also impacted error
TRACEr	Gibson, Mills & Hasketh	(2012)	U	Communication error identified as breaches in communication protocols. Communication errors related to a task are attributed to the task.	Focus on the context for the error, for understanding error causation. No identification of team work or power influences
Retrospective TRACEr Lite	Baysari, McIntosh & Wilson	(2008a)	A	Communication error not specifically identified in accident causation for drivers	No teamwork factors identified
CREAM	Phillips & Sagberg	(2014)	U	Study into Signal Passed at Danger (SPAD) causation with focus on driver behaviour without Network Controller contribution. No mention of the lack of communication by the Network Controller as a contributing factor in error	Primary focus on driver behaviours, thus no consideration of teamwork aspects of the Network Control and possible influences

(Continued)

Table 1. Continued

R-PSFs	Kyriakidis, Majumdar, & Ochieng	(2015)	A	Of 479 incident reports analysed, no errors associated with the R-PSF categories of 'task instructions', 'relations within teams' and 'communication within organisation', identified	Key acknowledgement that 'communication within organisation' is a difficult contributing factor to identify and is rarely identified in incident reports
Rasch model/ COSMO	Cheng & Tsai	(2011)	U	Communication is an aspect of decision skills and a focus of this study into cognitive activities of the Network Controller	No focus on teamwork aspects of Network Controller competence. Findings that Controllers may underestimate difficulties in dealing with incidents to avoid criticism from superiors
Contributing Factors Framework	Klockner	(2012)	A	Communication is categorised within Individual/Team contributing factors	Suggestion that some accident trends are not picked up by conventional tools, but no elaboration on what these might be
Event Analysis of Systemic Teamwork	Walker, Gibson, Stanton, Neville, Baber, Salmon and Green	(2006)	A	Communication defined as the operational aspects of sending, receiving and acknowledging information	Teamwork is the over-arching concept. Establishes that certain roles have the highest levels of socio metric status and centrality in communication exchanges. Framework appears to be capable of identifying power distribution, though it did not in this study
IFCS	Turner, Townsend, Lowe & Gibson	(2017)	A	Study outcome is to focus on training and development to improve safety critical communications	95 incidents attributed to communication failures were assessed, with no mention of power distribution as a contributing factor

*U = unadapted for rail; A = adapted for rail.

While a subject of research in other settings (Gordon and O'Connor 2012), authority gradients appear to be ostensibly under-researched as a topic in rail. In canonical work, Wiegmann and Shappell (2001) have indicated that some factors (e.g., organisational, supervisory influences) do not feature as highly in accident causation as once believed, or that accident investigation tools are insufficient to identify them. Given the attribution of authority gradients between rail workers in industry, but absence of research focus in the domain some two decades on, this may mean that tools/analytical frameworks applied to communication error in rail are unable to determine the influence of the authority gradient, or that researchers are not looking for it. If it is the latter, then it is important to consider why, but in both cases, it may also be that relevant theory is not being applied.

Table 1 shows studies that have applied frameworks and tools featuring communication error to rail. Some were designed for other environments and applied without being adapted, while others were overtly adapted, meaning that a process was undertaken to consider causal and contributory factors based on unique aspects of the rail domain (e.g. geographically dispersed teamwork). Although they vary, the common aim is to identify and categorise the contributing factors based on prevailing theory. Further to the information presented in Table 1, discussion of key tools and frameworks follow.

The Human Factors Analysis & Classification System (HFACS) is based on Reason's (2016) notion of active failures (acute impact of error), and latent failures (error-producing conditions existing over time). Devised for the military and later applied to commercial aviation (Wiegmann and Shappell 2001), the HFACS taxonomy for defining error contribution has four categories: unsafe acts, preconditions for unsafe acts, unsafe supervision and organizational influences (Cookson 2009; Madigan, Golightly, and Madders 2016). Madigan, Golightly, and Madders (2016) applied HFACS in the UK rail network, examining minor rail safety incidents that occurred between 2012 and 2014; here, *"failure to clarify instructions"* was classified as an unsafe act constituting an exceptional violation by a train driver (p. 126). No exploration of the reason for not clarifying instructions was undertaken or suggested.

Approaching error contribution from different viewpoints may reduce how reliably HFACS is applied, i.e. the pilot to the air traffic controller, or where the error is a result of a perceptual rather than a physical action (Olsen 2011). With this in mind, were the study to delve further and code exactly why the train driver failed to clarify instructions, the error classification may have been somewhat different. HFACs may either not provide a categorisation for examining relationship factors within the organisational hierarchy that may influence communication exchanges (e.g., to explain why a train driver would fail to clarify an instruction), or the study is not looking for it.

In a study of the human factors contribution to rail incidents based on 40 Australian rail safety investigation reports, Baysari, McIntosh, and Wilson (2008b) identified that nearly all categorised errors were associated with organisational errors in some way, increasing the likelihood that communication-related issues, where present, were influenced by hierarchical issues. One conclusion drawn was that resource management should be addressed, however, an authority gradient was not mentioned and reference to the relationship between hierarchical influences on organisation errors were not made. It is however indicated that modification of the HFACS framework would be required to adequately tailor error categorisation for rail, suggesting that without modification, it may not be entirely adequate for understanding contributing factors in rail. Ergai et al. (2016) also identified limitations in using HFACs to code and categorise errors in rail, implying inadequate training and lack of industry knowledge as key influences leading to coding deficiencies and inaccurate classification.

Zhan, Zheng, and Zhao (2017) discussed adaptations of HFACS across a range of industries and a HFACS-Railroad adaptation reportedly introduced a new categorisation of *"Outside Factors"* to better categorise and understand rail specific error (Reinach & Viale, 2006, as cited in Zhan, Zheng, and Zhao 2017, p. 234). This was adapted to a HFACS-Railway Accidents framework, in effort to more accurately fit to occasions of error, however, even with various adaptations, the organisational and communication influences were not categorised in ways permitting easier understanding of authority gradients or power relationship influences on communication within teams.

Use of HFACS to understand communication error related to the authority gradient in rail may be inadequate, beyond broad identification of *"personnel"* errors categorised as *"lack of team work"* or *"poor communication"* (Baysari, McIntosh, and Wilson 2008b). Presently, research using the HFACS framework and its variations do not drill deep enough into teamwork failures (Rail Safety and Standards Board 2008), which would be relevant for understanding power disparities within the team and extent to which this impacts communication.

Reviewing safety critical communications to develop rail industry training protocols, Turner et al. (2017) utilised the Incident Factor Classification System (IFCS) to analyse 95 incident reports attributed to communication failures as part of a broader research project. The ability to *"challenge poor practice"* (p. 140) was identified as a training gap in non-technical skills (NTS). Gordon, Darbyshire, and Baker (2012) describe these as *"cognitive and interpersonal skills"* which influence the ways in which individuals apply professional skills and knowledge (p. 1043). NTS focus on individual skills sets rather than a team-based approach to understanding underlying influences on communication failures, carrying implications of such an approach to understanding the influence of power disparities in team.

Originally developed to understand errors in air traffic control, TRACEr was designed as a retrospective and predictive framework to identify error influence (Shorrock 2006) and adapted for rail application. Renamed TRACEr-Rail, this system was utilised by Baysari, McIntosh, and Wilson (2008a) to examine train driver behaviours in 53 incidents, with perception errors noted as a causal factor for failing to stop and *"not expecting the signal to be displaying a red (i.e. stop) aspect,"* though reasons for encountering unexpected stop signals were not examined (p. 1764). In rail, various controls measures aim to promote an awareness of stop signal approaches (Naweed, Rainbird, and Dance 2015), but where signal change happens unexpectedly, protocol dictates that the network controller warn the driver (Naweed 2020). Both TRACEr and TRACEr-Rail focus heavily on operator error more so than the contribution of other operational personnel (Baysari, Caponecchia, and McIntosh 2011) which does not lend itself easily to identification of authority gradients.

Kyriakidis, Majumdar, and Ochieng (2015) indicated that converting tools developed for other environments was a source of unreliability. Subsequently, they produced a Railway-Performance Shaping Factors (R-PSFs) tool. Based on study of 479 incidents, communication in the R-PSFs was associated with team functionality and error, primarily with network controllers and signallers, while distraction, expectation and perception were primarily associated with train drivers. Much like TRACEr-Rail, application of R-PSFs is limited by a lack of error classification for incidents involving rail personnel other than network controllers/signallers and train drivers. The study also established that a number of human error elements within the framework (teamwork, organisational communication, task instructions) were not identified as error contributions. While this was reported as a weakness of inadequately completed reports used in the study (i.e. by incident investigators), it also illustrated the difficulty in identifying behavioural elements considered non-technical, team-working factors.

Walker et al. (2006) applied EAST as a methodology for analysing scenarios based on rail maintenance work. Concepts relating to team-working, system performance and coordination activities were analysed in the context of teamworking (i.e. giving an instruction to another person). Dimensions relevant to exploring the existence of an authority gradient, such as assertiveness and leadership, were explored and the scenario-based study established that the protection officer and the signaller had the highest levels of sociometric status and centrality, that is, the signaller and protection officer were key agents in tasks associated with communication and coordination of maintenance work. While this methodology appears capable of discerning authority gradients, it does not mention power disparities or authority gradients as a communication influence.

Thus, it appears that the absence of focus on authority gradients in rail-centred research may stem from a combination of potential inadequacies/limitations in methodological capability (i.e. in scalability or design), or that authority gradients have simply not being investigated when examining rail communication error. If it is more so the latter, then this needs consideration as the hierarchical design of rail means it is not immune to issues of power distance.

4. Application of power distance theory

The earlier section highlights a lack of focus on authority gradients in rail research, both in terms of the environment, and through tools/frameworks applied to communication error. However, industry-based incident reports draw attention to its existence. It is possible that in some rail environments and cultures, authority gradients are likely being construed (and therefore potentially misattributed) as communication error or failure. One suggestion for this is that the theory underlying the framework(s) being used to understand communication error in rail is not appropriate, or not being appropriately applied.

When examining power distribution across teams, relationships, communication influences and subsequent error, research in the aviation context has applied Hofstede's theory on cultural relativity and power distance (Hofstede, Hofstede, and Minkov 2010). This theory is used to understand how perceived power differentials influence behaviours, for instance how an individual's cultural background dictates how comfortable they feel in challenging those they perceive to have positions of higher status (Daniels and Greguras 2014). While Hofstede's theory tends to focus on national cultural influences, power distance relationships are also evident in organisations with centralised authority and autocratic leadership (Hofstede 1983).

Orasanu, Fischer, and Davison (1997) examined cross-cultural barriers in communication through power distance theory and cited a number of aviation incidents featuring reluctance to request assistance, and advice rejected from fellow pilots or air traffic controllers. In this study, cultural influences on perceived status and 'politeness' in exchanges between those with lower status versus higher status, was identified as a contributor factor.

Hazrati's (2015) case study of a 1976 Boeing flight 707 that collided with a mountain after taking an incorrect turn exemplifies the safety threat posed by power distance. It was concluded that a large power distance relationship between the air traffic controller and pilot influenced the pilot's feeling of being unable to challenge, or ask for further clarification and guidance from the air traffic controller on instructions concerning a flight procedure. Hazrati hypothesised that the pilot's Korean nationality and associated high power distance inhibited his ability to express concern to the air traffic controller, to whom he felt subordinate. As a result, *"intercultural communicative competence"* was suggested for inclusion in aviation standards for language proficiency (p. 250).

In analysing the 1990 Avianca Flight 052 (AV052) incident in which the aircraft crashed after running out of fuel, Helmreich (1994) identified power distance as a relevant factor. To understand the failures in the crew performance, a set of 52 behavioural markers were used to code crew communications, each marker representing a behaviour positively associated with crew performance. The markers sat within three overarching categories

Table 2. Application of Hofstede's power-distance theory based on industry and context.

Author	Date	Industry	Study Context	Related findings
Appelbaum, Mazmanian, & Appelbaum	(2016)	Health	Power-distance and leader inclusiveness	Power relationships should be viewed as equally organisational and individual
Rieck	(2014)	Health	General Practitioner–Pharmacist relationship	Increased awareness of team roles decreases power-distance
Itoh & Andersen	(2008)	Health	Power-distance influence on safety culture	An increase in power-distance corresponds with a decrease in awareness of the importance of communication and safety
Ruuska, Artto, Aaltonen & Lehtonen	(2009)	Nuclear Power	Cultural influences on operational safety	Regulation and standardisation must be considerate of cultural context
Williams	(2016)	Oil Rig	Intercultural communication and safety	A greater understanding of how risk and safety documentation is interpreted and understood by different work groups is needed
Tharaldsen, Mearns & Knudsen	(2010)	Oil Rig	Safety, trust and group related factors	Important to understand how policies and practices are disseminated to frontline staff, as different work groups can have different interpretations, even if they work in the same environment.

(communication, team work and scope of work) separated into activity-based groupings (Federal Aviation Administration 1993).[4] Example behavioural markers include, *"Questions are encouraged and are answered openly and nondefensively"* (Appendix 1, p.2); *"Crewmembers are encouraged to state their own ideas, opinions, and recommendations"* (Appendix 1, p.3); and *"'Tone' in the cockpit is friendly, relaxed and supportive"* (Appendix 1, p.5). In the AV052 accident analysis, a score of "1" was assigned if the marker was present, "-1" if the marker was absent, and "0" if it was not applicable. A score of −38 was found, indicating a significant breakdown in crew performance, cited by Helmreich as being more easily understood when considered in terms of Hofstede's cultural dimensions. Helmreich asserts that while the high power distance experienced by the Colombian crew may not necessarily have prevented the crew from expressing concerns and providing suggestions, it's role could not be dismissed either.

Most incident reports do not provide enough detail to pinpoint performance shaping factors (Sasou and Reason 1999), thus we can only make inferences of the effect of power distance issues on the ability of pilots to challenge. However, Merritt (2000) applied Hofstede's indices of national culture in an aviation setting with hierarchical and multidisciplinary teams, and showed that it was possible to replicate the finding of the original study from a cross-cultural perspective. Table 2 shows where Hofstede's theory on cultural relativity, specifically its power distance dimension, has been applied and includes a range of environments and systems comparable to rail in terms of their highly distributed teams and safety-criticality.

4.1. Hierarchical organisational influence and other key constructions in power distance

Describing power distance in relation to organisational influence, Hofstede, Hofstede, and Minkov (2010) have said:

> In the large power-distance situation, superiors and subordinates consider each other as existentially unequal; the hierarchical system is based on this existential inequality. Organizations centralize power as much as possible in a few hands. Subordinates expect to be told what to do. There is a large number of supervisory personnel, structured into tall hierarchies of people reporting to each other (p. 73).

This assertion means that while employees lower in status experience greater levels of power distance, organisational style also carries influence. Based on attitudes to safety in Norwegian and UK offshore petroleum, Mearns et al. (2004) identified UK organisations as having a *"command and control"* structure and style of engagement between employees and management (p. 546); further, their less consultative style meant that employees had less *"communication and influence"* in their roles (p. 558). In comparison, a more inclusive and consultative organisational style in Norwegian offshore petroleum was conducive to a less self-reliant attitude to safety amongst personnel, and engendered a more team-centric mindset to safe working.

Research conducted by Mearns and Yule (2009) applied Hofstede's cultural dimensions in multinational engineering organisations and established that organisational influences, such as management attitudes to safety and safety procedures, had more impact on safety than the influence of individual nationalistic cultural values. While their study focused primarily on 'culture' in the nationalistic sense, rather than organisational culture, it did identify a future research gap in the investigation of workforce and management cultural values and the influence on employee behaviours in high-risk industry domains. Agreement that culture within organisations determines individual attitudes and behaviours, and support for this in a rail context is also given by Farrington-Darby, Pickup, and Wilson (2005).

To understand organisational culture in rail operations, some consideration must also be given to the features of the distinct functional groups (i.e., train drivers, network controllers, signallers, around the track personnel), and the perennial separation of blue and white collar distinctions within them. For example, Streeck, Seglow, and Wallace (1981) discussed locomotive engine (i.e. train) drivers as having a *"pronounced sense of elitism"* and a *"high prestige"* based on the length of their training, exposure to physical dangers, and responsibility for lives and safety (p. 314). The importance of their skills was described in reference to working class hierarchy and an ostensible membership to an *"aristocracy of labour"* (Hobsbawm, 1968, as cited in Streeck, Seglow, and Wallace 1981, p. 314) entitling them to an elevated status and special rewards. Historically, signal workers (i.e. now evolved into signaller or train controller roles) were paid according to the importance of their signal box and the density of traffic they were responsible for coordinating, and staff were recruited at the most junior levels and trained and promoted through the organisation (Revill 2005).

Hofstede's power distance theory considers social class, education and employment as key constructions and it has also been noted that the cross-cultural findings are relevant within organisational contexts; that is, power distance at an individual level, rather than a societal level (Jiing-Lih, Hackett, and Jian 2007). In Western countries, employees in lower

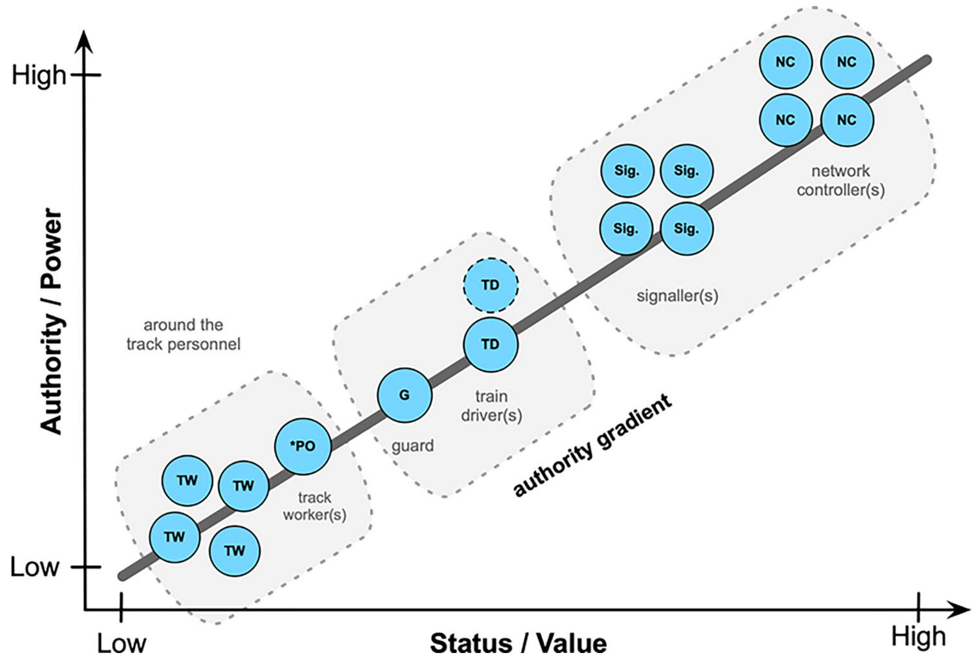

Figure 2. Conceptualisation of the authority gradient showing relationship between authority/power and status/value of the core operational multidisciplinary team functions. *Note: terminology related to Australian settings; box around specific domains is used to indicate that these are typically co-located; *PO = protection officer role in track worker party*.

status roles, with lower levels of education are more likely to be influenced by authoritarian values (Hofstede, Hofstede, and Minkov 2010). Some of the operations in rail attract workers from those of typically lower socio-economic status, i.e. track work undertaken by "gangers" on a low basic wage (Baldry and Ellison 2006). This disparity in education and status, along with the hierarchical organisational structure within the rail industry suggest that status and power are inextricably linked to roles within teams.

4.2. Applying power distance theory to the rail environment

Authority gradients between operational teams have been identified as an influencing factor in rail accidents. Hierarchical organisational structures are known to influence power distance in teams—that is, the measure of accepted distance between those with greatest power and those with least power. Thus, the very nature of the rail environment (see Figure 1) presents the relevant hallmarks and conditions that are ideal to support the existence and influence of an authority gradient. Building on the narrative synthesised in this review thus far, Figure 2 extends Figure 1 by transposing and reconceptualising the authority gradient from a power distance theoretical perspective, visualising the relationship between authority/power and status/value within the *"domains of knowledge"* (Oborn and Dawson 2010, p.1837) of the multidisciplinary teams (as discussed within Section 1.1). While most of these roles are physically separated, some are co-located (e.g., on the same train, in the same

Table 3. Example pf application of CRM principles in industries other than rail.

Author(s)	Date	Industry	Context	Substantive findings
Gordon, Darbyshire & Baker	(2012)	Healthcare	NTS and patient safety	Supports implementation of NTS education inspired by CRM principles
Flin, Patey, Glavin & Maran	(2010)	Healthcare	Anaesthetists' NTS and multidisciplinary teams	Comparison made between ongoing CRM training for pilots and the need for ongoing training in NTS in medicine
Cooper, Endacott, & Cant	(2010)	Healthcare	NTS relevant to emergency care	Enhanced patient safety may be achieved through greater focus on teamwork skills
Gordon & O'Connor	(2012)	Healthcare	Hierarchical culture within the health profession	Comparisons drawn between ongoing CRM training requirements for pilots and a need for this training in healthcare
Griffith, Roberts & Wakeham	(2015)	Emergency Services	CRM training effectiveness	Support for recurrent CRM training in the Fire Service to enhance teamwork
Oberlin	(2018)	Emergency and Disaster Management	Improving decision making in high-stress situations	CRM provides a framework for people to make decisions in high stress situations
Marquardt, Robelski & Jenkins	(2011)	Manufacturing	Training systems to improve awareness of potential errors	CRM training suitable for utilisation outside the aviation context as long as it is tailored to the organisational culture

building, on the same section of track). Team members within roles may physically work closely together (e.g., in the same cab if it is two-driver operations, or the same office if it is the signaller/network controller) but these may also be subject to within-function variations in status/power.

For example, in some rail functions there are senior roles (e.g. *senior* network controller, network control *supervisor*, *senior* train driver) who wield higher status within their respective functional groups. Likewise, around the track personnel may include a range of supervisory roles, but as the person responsible for the safety of track workers and the one communicating directly with network controllers, the protection officer is in charge of track work and responsible for their safety. In this way, the conceptualisation also appeals to the hierarchical design of the rail environment. For instance, it is entirely possible that senior roles within track work have different and higher status/value than fellow track workers. However, unless a track has full occupation for the work, all track workers must cease work temporarily to allow track movement (Naweed, Young, and Aitken 2019). Thus, in this scenario, the train crew (i.e., driver(s) and/or guard) has more authority/power. While functions may have a range of roles that place them at higher or lower status/value, through the theoretical lens of power distance, the hierarchical design of rail suggests that the authority/power dimensions pull it all into a certain alignment and influence authority gradients. Based on this theorisation, network controllers likely exist at the very top of the hierarchy, so even if the status/value of different roles pull them further to the right of Figure 2, the authority/power may not change. Baldry and Ellison (2006) acknowledge that the responsibility for authorising access to the network lies with the network controller, who is able to deny access and designate the amount of time available to track workers. Similarly, the network controller authorises and can override many signaller tasks (in rail environments where the two roles are separated), and ultimately, controls traincrew tasks through authorisation of train movement.

5. Systems used to manage power distance issues in rail and other industries

Having reviewed a range of tools and frameworks that have been applied to investigate communication error in rail research but found little consideration of authority gradients—even though they feature within industry materials—and having reviewed applications of power distance theory in rail and comparable environments, the next section reviews the systems that have been used to *manage* power distance issues. In a bid to further unpack the lack of focus in rail research, consideration is also given to settings other than rail.

As mentioned earlier, research and practice within aviation has long acknowledged power imbalances in operational teams as something that influence safety and ways of work their environment. In 1988, Edwards suggested (as cited in Alkov et al. 1992) that the interactive dynamics between pilots in the cockpit was influenced by differences in rank and teamwork factors. Among the human factors identified in early studies of communication failure was *"Crew resource mismanagement"* (Wiegmann and Shappell 2001, p. 6)—poor decisions made in the cockpit, viewed as failures in the intra-cockpit communication and in communication exchanges with air traffic control or ground staff. These were not viewed as errors in individual competencies, but rather, as team failures that utilised the full range of resources at their disposal (Kanki 1995, p. A23). These failures have since been incorporated into Crew Resource Management (CRM)—training systems for operational staff in areas such as leadership, teamwork, situational awareness and decision making (Cooper, Endacott, and Cant 2010) which represent fundamental skills (Gordon, Darbyshire, and Baker 2012). Early days of CRM training involved specific techniques to enhance flight-deck interactions. Diehl's (1991) example to *"avoid 'excessive professional courtesy': If the captain is two dots low on the glide-slope, tell him so in unequivocal terms. Don't say, 'You're a little low, Sir'"*, reflects attempts to mitigate power disparities (p. 11).

There is little to suggest that a CRM approach has been taken up within rail or applied across the industry, though there are indications of attempts to establish something similar. A Rail Resource Management pilot was initiated by a national rail partnership in Australia, with guidelines and a toolkit launched in 2007 and an operator to pilot the programme. At the last indication, the project continued into 2009 (Klampfer et al. 2012) but little has been released on it since. The vast majority of applications of CRM in industries other than aviation are in the health-related fields, including surgical teams (Savage et al., 2017), intensive care units (Kemper et al. 2017) and flight and critical care paramedics (Ward and Gryniuk 2018). Table 3 reviews where CRM principles and philosophies taken from aviation have been applied in industries other than rail and draws attention to the focus that has been placed on the NTS aspects of the CRM system. As mentioned earlier, Gordon, Darbyshire, and Baker (2012) describe NTS as the cognitive and interpersonal skills which influence the ways individuals apply professional skills and knowledge (p. 1043), though they suggest that what constitutes an NTS is subjective and difficult to define. Cooper, Endacott, and Cant (2010) and others also consider NTS as *"team-work skills"* (p. 14) that enhance an individual's technical skills, encompassing qualities such as leadership, decision making and situational awareness (Cooper, Endacott, and Cant 2010; Flin et al. 2010; Gordon, Darbyshire, and Baker 2012).

In the medical context, NTS for teamwork and leadership are a focus of training programmes designed to teach skills to empower individuals to challenge those in positions of greater status or authority (Gordon, Darbyshire, and Baker 2012). NTS has been applied in rail (Rail Safety and Standards Board 2016) as a counterpart to CRM, with research by Turner et al. (2017) recommending that training be focused on developing communication skills, particularly in relation to working with people and being assertive, challenging, as well as considering others' needs. Turner et al. (2017) discuss organisational culture and communication competence as factors that affect safety critical communications and suggest that focusing on protocols without reviewing the underlying influence of NTS is problematic when attempting to improve communications.

NTS do not feature highly in published research into error causation in a rail context, despite Wilson et al. (2001) indicating that they were central to the development of a methodology for further understanding communication-related errors. An exception to this is recent work by Naweed and Murphy (2019) which used the NTS framework developed by the Rail Safety and Standards Board (2016) to examine the skills most linked with operational risk in Signal Passed at Danger scenarios generated by 20 network controllers across Australia. Ineffective/problematic ways of *"sharing information"* was the most represented category in the area of communication, as was ineffective/problematic ways of *"considering others' needs"*, in the area of cooperation and working with others. As we have postulated, behaviour synonymous with authority gradients are characterized as communication or teamwork errors, rather than specifically identified as an authority gradient. While Naweed and Murphy (2019) work encapsulates these behaviours, the elements of operational risk examined do not explicitly attribute an authority gradient, suggesting that the phenomenon exists and/or is not necessarily lost on researchers in the course of study, but is going unlabelled as authority gradients and instead being represented as an NTS/ training issue.

NTS is now incorporated into standard training packages across UK rail, including worker inductions, professional development and recruitment and selection (Rail Accident Investigation Branch 2017, p. 55). However, an implication raised from this is that NTS is packaged as a training tool rather than as a framework or system for understanding how communication error transpires. NTS incorporate qualities and behaviours that may act to inhibit an authority gradient, but although it is described as a training tool that promotes teamwork skills, as a training tool it also fundamentally concentrates on individual capabilities (e.g., assertiveness, ability to challenge). Thus, it is inherently limited through its reliance on individual motivation and behaviour change, rather than systemic team dynamics.

While their focus did not extend to rail, Sasou and Reason (1999) indicate that performance shaping factors, that include excessive authority gradients, are better considered from the broader team (i.e. system) as opposed to the individual perspective, *"It is thought that there are specific causes in team errors that will not be revealed by an exclusive emphasis upon the errors of individuals"* (p.9). Authority gradients ostensibly serve a better focus as they view working dynamics through a systems lens and the hierarchical structure of system ties with status and power.

Table 4. Summary of research gaps related to investigation of the power-distance issues in rail.

Research gaps	Research Opportunities	Likely Benefits
There is anecdotal evidence of authority gradients in rail, and some dimensions relevant to authority gradients have been researched, but no empirical research has specifically investigated authority gradients within the rail environment	Conduct comprehensive research using suitable methods within, between and across different operational functions	Improved understanding of the overall impact of the authority gradient in heavy rail and its treatment. This may also apply to all areas (e.g. operations, safety, competence management, leadership, risk management)
Incident investigations conducted by industry in Australian rail have drawn overt reference to authority gradients between front-line workers. A small number are selected to support this review but a better understanding of its prevalence within industry is needed	Conduct systematic search of rail incidents attributed to authority gradients as a contributory factor and examine rail incidents linked to communication error for behavioural markers of authority gradients.	Better understanding of authority gradients in incident investigation literature
Building on the previous research gap, this review has only focused on incident investigations from the Australian industry	Conduct systematic search of rail incidents attributed to authority gradients in countries and rail settings outside Australia	More complete understanding of the international rail industry profile on the issue
While it has been applied to many other industries and sectors, the power distance aspects of Hofstede's theory on cultural relativity has not been applied to the rail environment	Conduct comprehensive study based on applications of Hofstede's theory	Greater understanding of team interdependencies and the social factors that serve to enhance or impede communication and safety within the rail context. Potential integration of power-distance theory in mainstream analysis concerning rail accidents and improved understanding of rail human factors more broadly
Building on the previous research gap, Hofstede's power distance theory suggests that network controllers are at the top of the rail operational hierarchy and track maintenance staff are at the bottom but there is no evidence for this other than the hierarchical design of the rail environment	Conduct specific research that examines power/hierarchy and status/value in rail front line staff	Supporting evidence for application of Hofstede's power distance theory to rail
There is a lack of clarity on whether the current tools and frameworks which have been applied to explore communication error in rail are capable of identifying an authority gradient	Explore/empirically evaluate current tools/frameworks to determine whether they are able to identify authority gradients in rail	Better understanding of communication error in rail and its application to teamwork
Industries and sectors other than rail address issues of power distance with a range of tools, including NTS frameworks and CRM systems. More insightful descriptions and in-depth comparisons of where this works well, why, and what the similarities and differences are with rail is needed	Conduct comparative review of systems used to manage power distance issues in similar industry contexts	Determining suitable systems for managing issues of power distance in rail
Related to the above point, CRM is widely applied in other contexts to understand and influence power relationships within teams but does not seem to have transferred adequately to rail	Determine relevance and benefits of a complete training (i.e. CRM System) vs skills analysis (i.e. NTSs) frameworks in rail	More complete understanding of the practical utilities of the different approaches in rail

6. Conclusions

Examining power distance is relevant to understanding how people interact within hierarchical organisations in terms of deference, trust in leadership and decision making (Daniels and Greguras 2014; Schwartz 1999). As power is an aspect of all interpersonal interactions, it affects how communication flows, even when its influence is not immediately obvious (Dunbar 2015). For the rail environment, standardised communication alone does not appear to be the solution for improving communication within the multidisciplinary and distributed teams that exist (Orasanu, Fischer, and Davison 1997). Relying on disciplined adherence to rules and regulations is insufficient for incident prevention as it does not consider the management influences or organisational contexts (Roosenboom 2012). Thus, many studies of rail incidents advocate improved training in systems and process (Turner et al. 2017; Wilson et al. 2001; Wilson and Norris 2005), but tend to ignore the underlying factors influencing team dynamics, behaviours and therefore, communication.

Though categorised as communication errors, this review has found that errors in communication that are not associated with transmission failure, or misunderstandings based on incorrect protocols, or mistakes in the content of the message being relayed, can be attributed to another phenomenon in which a shared understanding is not developed, and industry recognises these failures exist. It is difficult to conclude one way or the other if current tools/frameworks used to investigate communication error in rail are incapable of identifying authority gradients, or whether they are inhibiting identification, awareness and/or contributing to misattribution. While authority gradients have been unearthed as contributing factors within incident reports, empirical research specifically into an authority gradient has not been undertaken. Some empirical work based on attitudes to self and others (particularly in train drivers and network controllers) has alluded to authority gradients, but a paucity of literature in rail supports the view that researchers are not looking for it, or alternatively, assuming there is no substantive research gap.

There is broad agreement that factors such as assertiveness, decision-making, and teamwork comprise NTS (Flin et al. 2010; Rail Safety and Standards Board 2016). The relevance of NTS as a way of managing interpersonal dynamics that fall into the orbit of authority gradients are evidenced (Rail Safety and Standards Board 2010, 2016) but as a training tool rather than a framework or system for understanding communication error. Moreover, NTS is fundamentally about the capability of the individual, not about hierarchical structures or the broader system. Gordon and O'Connor (2012) suggest that even with the implementation of the CRM system, a hierarchy can remain, but that the hierarchy is "flattened" to some degree and corresponding changes in culture may reduce accidents (p. 43). The absence of rail research that views communication error from such a perspective suggests the industry may not yet understand how to "flatten" the gradient in order to improve team working and safety goals.

6.1. Future research directions

From this review, we can surmise that while organisational hierarchical aspects of power distance theory have yet to be applied to rail, the theory offers an appropriate framework for application in this environment. Communication exchanges in the rail environment are highly regulated and rule-based exchanges of safety critical information in the same way that they are in aviation. It is clear however that while acknowledged and studied at length in aviation, study of authority gradients in rail is made conspicuous only through its absence, presenting an opportunity for future research. In Table 4 we integrate and summarises the research gaps which can guide future research in the field. These align with findings presented in earlier sections and detail our assessment of research opportunities and likely benefits.

In rail, an authority is needed, and like other hierarchically designed and operating environments, we may accept that hierarchies are an inescapable part of overall design. But in effective multidisciplinary teams, one person should carry as much validity as another. Greater emphasis of authority gradients as an important area for research focus is needed in rail, particularly as communication and connectedness between teams is a hallmark of future work in the context of ever-increasing levels of automation. By researching the issue more explicitly and establishing a knowledgebase for this industry, we may develop better ways of "flattening" the gradient which do not rely on individual motivation but drive culture change.

Notes

1. The terms "network controller" and "protection officer" are Australian terms for those who respectively manage train movement and are responsible for site safety of trackwork. These terms vary from country to country and place to place. While this paper will adopt Australian terms for the most part, key terms are disambiguated for readability and applicability to other geographical rail contexts.
2. Different terms are used to refer to the same position in different countries. For simplicity, we use the terms train driver, guard, network controller, signaller, protection officer, and track worker in the remainder of this paper. These are commonly used in Australia. Examples of alternative terms used in other countries are indicated in parentheses, with accompanying footnotes for further details where appropriate.
3. Grey-level literature focused on Australasia and the United Kingdom (UK) only
4. Note that these behavioural markers have been provided from the primary source as they are not detailed in Helmreich (1994). The primary source is an appendix to an FAA Advisor Circular 120-51a, *Crew Resource Management*.

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