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Understanding the human factors contribution to railway accidents and incidents in Australia

Melissa T. Baysari*, Andrew S. McIntosh, John R. Wilson

University of New South Wales, NSW 2052, Australia

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ABSTRACT

Forty rail safety investigation reports were reviewed and a theoretical framework (the Human Factors Analysis and Classification System; HFACS) adopted as a means of identifying errors associated with rail accidents/incidents in Australia. Overall, HFACS proved useful in categorising errors from existing investigation reports and in capturing the full range of relevant rail human factors data. It was revealed that nearly half the incidents resulted from an equipment failure, most of these the product of inadequate maintenance or monitoring programs. In the remaining cases, slips of attention (i.e. skilled-based errors), associated with decreased alertness and physical fatigue, were the most common unsafe acts leading to accidents and incidents. Inadequate equipment design (e.g. driver safety systems) was frequently identified as an organisational influence and possibly contributed to the relatively large number of incidents/accidents resulting from attention failures. Nearly all incidents were associated with at least one organisational influence, suggesting that improvements to resource management, organisational climate and organisational processes are critical for Australian accident and incident reduction. Future work will aim to modify HFACS to generate a rail-specific framework for future error identification, accident analysis and accident investigation.

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1. Introduction

There is little doubt that human error contributes to the majority of incidents and accidents which occur within complex systems, including the railway system (e.g. Atkins, 2003; Gilchrist et al., 1990; Hall, 2003; Krokos and Baker, 2007; O'Hare, 2000; Shappell and Wiegmann, 1997). To prevent and/or reduce the number of accidents and incidents which occur we must work towards reducing human error or making the system/organisation more error tolerant. Human error and accident management involves the prevention of human errors, the recovery from errors, and the containment of the consequences that result from error occurrence (Cacciabue, 2005a). The first step in this process is error identification. Identifying the errors that frequently result in the occurrence of incidents and accidents may allow appropriate prevention and/or mitigation strategies to be developed.

No research to date has systematically examined the human error contribution to rail incidents and accidents in Australia. The predominant means of investigating the causal role of human error in accidents is the analysis of post-accident data (Shappell and Wiegmann, 1997). The primary aim of this study was to conduct an in-depth analysis of Australian rail incident/accident investigation reports for the purpose of identifying human errors. Human error identification (HEI) was achieved via the adoption of a HEI tool or error taxonomy. Taxonomies allow one to build a causal overview across a large number of incidents, enabling identification of dominant, recurring failure factors (Van der Schaaf, 2005), and causal and contributory factors over time (Thomas and Rhind, 2003). This paper represents our first attempt to apply error taxonomy to Australian rail incident and accident data. Human error here refers not only to operator errors, or errors and violations of those at the sharp end of a system, but also to those failures which occur at the blunt end of a system, associated with design, procedures, management and so on. These latter failures, latent failures of the organisation (Reason, 1990), are the product of errors of some individuals somewhere else in the system (e.g. designers, maintenance personnel, supervisors).

In this paper we firstly summarise relevant accident causation research, then outline the error framework selected. We then describe the data set on which the analysis is based, and then reveal the types and frequencies of errors that emerged from the analysis. We discuss the framework's effectiveness in capturing human error

* Corresponding author at: School of Risk and Safety Sciences, University of New South Wales, Sydney, NSW 2052, Australia. Tel.: +61 2 93855976; fax: +61 2 93856190.
E-mail address: m.baysari@unsw.edu.au (M.T. Baysari).

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types and finally we discuss implications for system change following the identification of recurring failures. The paper concludes with an outline of future research.

2. Previous research: error and accident causation

Many models of accident causation have acknowledged the contribution of human error in accident occurrence (e.g. Embrey, 1992; Lucas, 1997; O'Hare, 2000; Reason, 1990). The most influential of these is that proposed by Reason (1990). Reason (1990) defined two broad categories of error: active and latent failures. Active errors, whose effects are felt almost immediately, are associated with the front-line operators of the system, while latent errors, whose adverse consequences may lie dormant within the system for a long time, only become evident when they combine with other factors to breach the system's defences (Reason, 1990). In a later version of his model, often referred to as the "Swiss Cheese Model", Reason (1997) included three system levels: unsafe acts, local workplace factors and organisational factors. An accident trajectory passes through the holes (which represent gaps in defences, barriers, safeguards and controls) in successive levels, resulting in an accident (Reason et al., 2006). These holes or weaknesses are caused by errors and violations of front-line operators but also errors of designers, managers, supervisors and maintainers (Reason, 1997).

Identifying what errors (both active and latent) contribute to accident occurrence can be difficult because there is no well defined start of the causal chain of an accident and exactly the same events can lead to widely different consequences (Rasmussen, 1987). It has also been suggested that there is little relationship between the magnitude of an error and the consequence of that error (Singleton, 1972). A variety of HEI tools/techniques have thus been developed to aid in error identification/classification, all comprising of at least one error taxonomy and several also including a human error quantification component (see Kirwan, 1994, 1997a,b for a review). Some of the more well-known techniques include the Technique for Human Error Rate Prediction (THERP), Human Hazard and Operability Study (Human HAZOP), Systematic Human Error Reduction and Prediction Approach (SHEPRA), Cognitive Reliability and Error Analysis Method (CREAM), the Technique for the Retrospective and Predictive Analysis of Cognitive Errors (TRACEr), and the Human Factors Analysis and Classification System (HFACS).

Many studies have identified human errors contributing to incidents and accidents in domains other than rail, like aviation and the chemical industry (e.g. Glendon, 1993; Kirwan, 1997b; Reason, 1990; Shorrock and Kirwan, 1999; Wiegmann and Shappell, 2003), but relatively few published reports have described specific error types associated with accidents and incidents in rail. In the UK, the TRACEr framework, initially developed for air traffic control, was recently modified to become a rail-specific HEI tool for train driving (RSSB, 2005) and is currently being used to identify and classify errors associated with rail incidents and accidents (e.g. Gilroy and Grimes, 2005). Other UK research has identified the types of communication errors involved in railway incident occurrence (Murphy, 2001; Shanahan et al., 2005). There has also been a large quantity of British research describing and classifying the nature of errors associated with one particular type of railway incident: Signals passed at danger (SPADs). SPAD-related errors have been categorised from a range of different perspectives including behavioural (e.g. Dray et al., 1999; Gibson, 1999; Lucas, 1989) and cognitive or information processing (e.g. Wright, 2000).

Analysis of rail incident/accident reports for the purpose of identifying recurring error types has also been conducted in Germany (e.g. Metzger, 2005) and in the US, where the Federal Railroad Administration (FRA) have recently reported that a small number of particular kinds of human errors (e.g. not properly lining switches, failure to lock and latch switches) accounted for an inordinate number of accidents (FRA, 2007).

There have been numerous international studies that have identified error types using an alternative approach to the analysis of incident and accident reports. These studies describe and analyse railway workers' tasks and consequently identify and classify worker errors and factors associated with those errors. The roles/tasks of train drivers (Bott, 1996; Buck, 1963; Cacciabue, 2005a,b; Crick, 2004; Little, 1996; Porter, 1992; Vanderhaegen, 2001), maintenance personnel (Farrington-Darby et al., 2005; Gibson et al., 2005), and signallers (Little, 1996; Sutton, 2003) have been reviewed and frequent error types for each role subsequently identified.

In Australia, no published work has identified or classified the human errors frequently associated with rail accidents and incidents. In the one reported Australian study investigating accident causation, the authors aimed to identify the latent failures (i.e. managerial deficiencies) most likely to be involved in accidents in the Australian public rail authority (Edkins and Pollock, 1996). Focus groups were initially held with drivers and management to identify railway problem factors influencing rail safety. A railway safety checklist, requiring respondents to rate the extent to which each factor had been a problem in carrying out their job, was then constructed and distributed to train drivers. Three factors were identified as the most serious problems, most likely to contribute to Australian rail accident occurrence: Staff attitude, operating equipment and maintenance (Edkins and Pollock, 1996).

3. Selection of an error framework

The type of framework used for error identification in accident analysis or investigation is dependent on the theoretical approach, or perspective, to human error adopted. Common perspectives on human error include cognitive, ergonomic, behavioural, individual, psychosocial, and organisational (see Wiegmann and Shappell, 2003 for a review). It has been shown that these error perspectives may not take into account the full range of errors associated with an incident or accident (Wiegmann and Shappell, 2003).

A framework capable of accounting for the full range of human errors possible in a complex system would be one that identifies all latent and active failures included in Reason's model of human error, as outlined above. The HFACS appears to be one such framework because it encompasses the entire range of system errors, from the sharp end (e.g. operator) to the blunt end (e.g. management). Developed by analysing an extensive set of aviation accident reports, it describes four levels of failure, as shown in Fig. 1: unsafe acts, preconditions for unsafe acts, unsafe supervision, and organisational influences (Shappell and Wiegmann, 2000a, 2003; Wiegmann and Shappell, 2003).

Following its development, HFACS was reportedly successfully applied to a wide range of aviation accidents (Gaur, 2005; Krulak, 2004; Pape et al., 2001; Shappell et al., 2007; Shappell and Wiegmann, 2000b, 2003; Wiegmann and Shappell, 2001). There has also been one published attempt to categorise contributing factors associated with railroad incidents/accidents using HFACS (Reinach and Viale, 2006a,b). The framework was initially modified to be more applicable to rail (HFACS-RR) and then applied to six incident/accident cases in railroad yard switching (Reinach and Viale, 2006a,b). This application however, was to a very specific rail incident type, and the framework is yet to be applied to a more general pool of rail incidents and accidents.

The US FRA has used HFACS-RR to develop a software tool (the Human Error Investigation Software Tool (HEIST)) to help the rail-

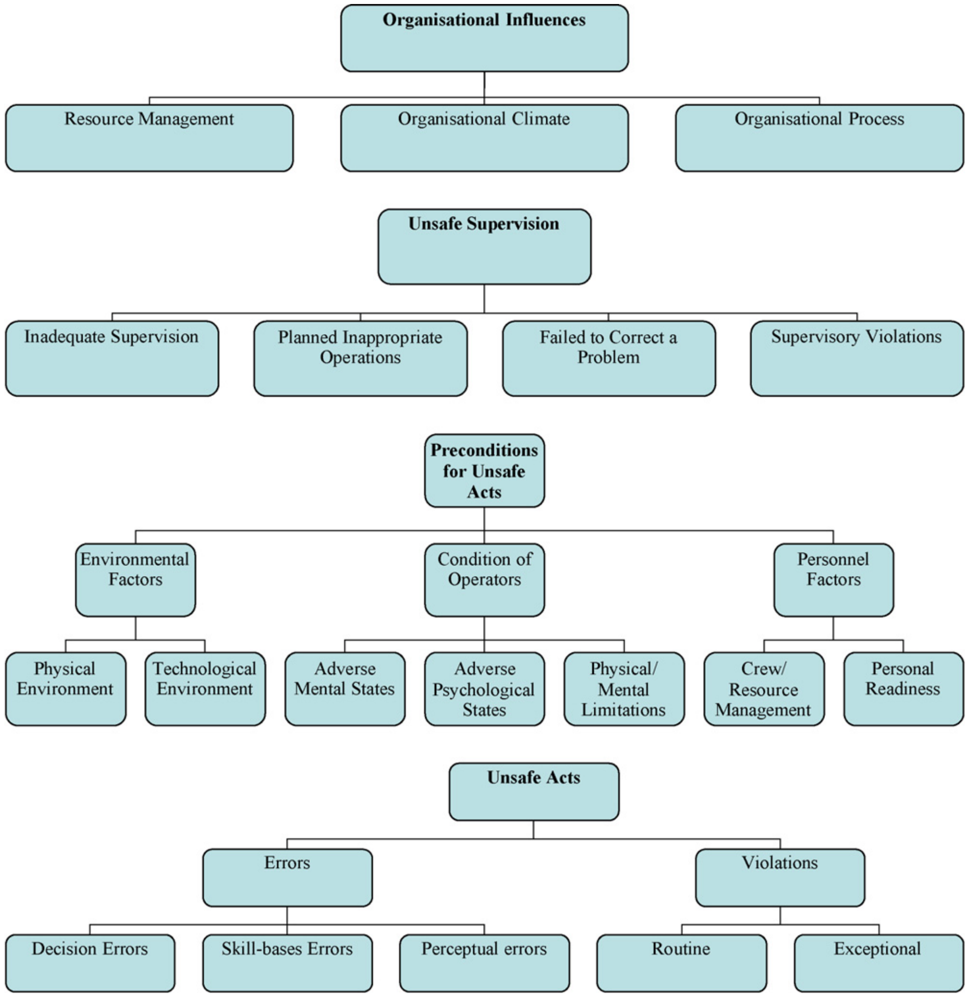

Fig. 1. The HFACS framework (Wiegmann and Shappell, 2003).

road industry consider human factors issues at all levels of the system when investigating the causes and contributing factors of accidents and incidents (Reinach et al., 2007; Viale and Reinach, 2006).

Following these demonstrations of HFACS' potential applicability, and due to the fact that the taxonomy is based on a widely accepted error model that considers all levels of the organisation as a system, HFACS was selected here as an appropriate framework for application to Australian rail incident and accident reports. This study was the first to apply the HFACS framework to rail accidents and incidents (excluding the previous limited application to six railroad yard switching incidents, see Reinach and Viale, 2006a,b). A secondary aim of this study was therefore to ascertain the effectiveness of HFACS to categorise railway errors from existing investigation reports and to determine its usefulness in capturing all relevant rail human factors data.

4. Method

Publicly available railway incident and accident reports spanning the years of 1998–2006 were retrieved from the Australian Transport Safety Bureau (ATSB, 2007), the Office of Transport Safety Investigations (OTSI, 2007), the Victorian Department of Infrastructure (DOI, 2003) and Queensland Transport (QT, 2007). Fifty-three completed reports were available. Of these 53, 12 incidents occurred at level crossings and were thus excluded from the analysis. Although some of these incidents were associated with organisational influences (e.g. poor design of warning signs, limited view of approaching trains), the majority were also associated with errors of car drivers or pedestrians (i.e. individuals other than rail personnel) and consequently, a full HFACS analysis could not be performed. One additional incident was also excluded on the grounds that the investigation report contained insufficient details to allow error identification.

A total of 40 investigation reports were analysed in detail. In this study, HFACS was not adopted as a means of identifying contributing factors, but as a means of identifying the errors associated with each contributing factor. Each report was read in its entirety and then each 'Significant/Causative/Contributing/Safety factor' described in the 'Conclusions' and/or 'Findings' section of each report was mapped to a unique HFACS category using the definitions and tables provided in Wiegmann and Shappell (2003) and the flow-charts included in Viale and Reinach (2006).

4.1. HFACS reliability

To assess inter-rater reliability, three raters, in addition to the first author (all post-graduate students undertaking higher degrees in human factors) were recruited and provided with information on HFACS and its application. Raters received the definitions and tables provided in Wiegmann and Shappell (2003) and the flow-

Table 1
Percentage agreement between raters (based on the number of factors with a common error)

	Rater 1	Rater 2 (%)	Rater 3 (%)	Rater 4 (%)
Rater 1	–	82.5	73.5	60
Rater 2	–	–	72	72
Rater 3	–	–	–	78
Rater 4	–	–	–	–

Table 2
Number of incidents belonging to each occurrence category from 1998 to 2006

Occurrence category	Number of cases
Collision	10
Derailment	21
Safe working irregularity/breach	6
Shunting accident	3
Total	40

charts included in Viale and Reinach (2006) and were given a brief overview of HFACS by the author. The additional raters were then assigned three rail safety reports (two of which were identical for all three raters) and instructed to independently classify all contributory factors using the framework. Comparison of the sample revealed a large difference in the number of errors identified by each rater, with two of the additional raters (Raters 2 and 3) identifying 33 and 49% more errors than the author (Rater 1). Percentage agreement, based on the number of factors where raters identified a common error, varied between raters from 40 to 75%. Raters were required to make a selection from over 100 errors so an additional comparison was made examining the consistency among raters in selecting the more general error category (i.e. the operator suffered from an 'Adverse mental state', rather than from 'Divided attention'). This comparison resulted in moderate agreements between raters, as shown in Table 1. Factors likely to have contributed to the inconsistency among raters are discussed in Section 6.2 of Section 6. The results presented here are only those of the author, Rater 1, because this individual possessed more expertise in human error and accident analysis, and was highly familiar with the format and content of Australian rail investigation reports.

5. Results

Table 2 summarises the distribution of occurrence types undergoing analysis that took place in Australia over the period of 1998–2006. Three hundred and thirty contributing factors emerged out of the 40 investigation reports, resulting in 360 errors being identified. All but five contributing factors where classified using HFACS. Table 3 lists the report elements that did not correspond to a HFACS category. Although these factors appeared to be 'Preconditions for unsafe acts' they did not fall into the categories of 'Condition of the operator', 'Personnel factors' or 'Environmental factors'.

Table 3
Report elements that did not correspond to a HFACS category

1. Train movements on the track were infrequent and irregular, increasing the potential for error
2. The incident occurred 10 min after a crew change, when the new crew were still adjusting to handling characteristics of the train
3. Initially the misalignment was not of sufficient magnitude to immediately derail the train, however, the misalignment caused severe lateral movement of vehicles which further increased misalignment until wagons derailed (×2)

An equipment failure was identified as the primary cause of 17 incidents (43%). Table 4 shows the number of each error type found and the number of incidents (out of the possible 17) in which each error type occurred. These incidents are described separately here to incidents associated with sharp-end failures because very few unsafe acts, preconditions for unsafe acts or supervisory factors were associated with these events, as shown in Table 4. The most common non-organisational influence to contribute to these incidents was that of the physical environment, with high ambient temperature proving to be the most widespread problem. Interestingly, all incidents triggered by an equipment failure were derailments and all were associated with inadequate equipment or equipment in poor condition. In all but four incidents, an organisational oversight was identified, that of inadequate monitoring or checking of equipment/resources. Although in some cases an

Table 4
Number of errors identified and the number of incidents (out of a possible 17) in which error was identified in "equipment failure" investigation reports from 1998 to 2006

Error type	Number	Number of incidents
Unsafe acts		
Errors		
Skill based	0	0
Decision	4	4
Perception	1	1
Violations		
Routine	4	3
Exceptional	0	0
Total unsafe acts	9	
Preconditions for unsafe acts		
Condition of operators		
Adverse mental states	1	1
Adverse physiological states	0	0
Physical/mental limitation	0	0
Personnel factors		
Crew resource management	1	1
Personal readiness	0	0
Environmental factors		
Physical environment	11	8
Technological environment	2	2
Total preconditions	15	
Unsafe supervision		
Inadequate supervision	0	0
Planned inappropriate operations	0	0
Failed to correct a known problem	1	1
Supervisory violations	0	0
Total unsafe supervision	1	
Organisational influences		
Resource management		
Human resources	2	1
Monetary/budget resources	1	1
Equipment/facility resources	51	17
Organisational climate		
Structure	5	4
Policies	4	3
Culture	2	2
Organisational process		
Operations	1	1
Procedures	14	9
Oversight	40	13
Total organisational	120	
Total	145	

Table 5
Number of errors identified and the number of incidents (out of a possible 23) in which error was identified in "human failure" investigation reports from 1998 to 2006

Error type	Number	Number of incidents
Unsafe acts		
Errors		
Skill based	20	15
Decision	7	6
Perception	1	1
Violations		
Routine	10	7
Exceptional	2	2
Total unsafe acts	40	
Preconditions for unsafe acts		
Condition of operators		
Adverse mental states	25	16
Adverse physiological states	11	10
Physical/mental limitation	4	4
Personnel factors		
Crew resource management	9	6
Personal readiness	6	6
Environmental factors		
Physical environment	6	6
Technological environment	7	4
Total preconditions	68	
Unsafe supervision		
Inadequate supervision	6	5
Planned inappropriate operations	3	3
Failed to correct a known problem	2	2
Supervisory violations	2	2
Total unsafe supervision	13	
Organisational influences		
Resource management		
Human resources	6	6
Monetary/budget resources	0	0
Equipment/facility resources	32	18
Organisational climate		
Structure	6	5
Policies	6	6
Culture	3	3
Organisational process		
Operations	9	7
Procedures	16	13
Oversight	16	11
Total organisational	94	
Total	215	

unsafe act was identified, the reports stressed that this unsafe act would not have been significant if equipment had been maintained to operational standards.

The remaining 23 incidents were triggered primarily by errors of frontline personnel. Table 5 shows the number of each error type found and the number of incidents (out of the possible 23) in which each error type occurred. The following sections describe in detail the errors associated with these "human failure" incidents.

5.1. Unsafe acts

All 23 "human failure" incidents had at least one unsafe act committed by a driver, signaller, controller shunter or train examiner. More errors ($n = 22$) were committed than violations ($n = 9$). The most common error types were skill-based errors, which occurred in 15/23 incidents. Of these skill-based errors, most were the result of an attention failure (15/20). Seven decision errors also emerged, most (5/7) identified as procedural errors. For example, on several occasions a poor decision was made because the employee possessed inadequate knowledge of the system or operational procedures.

Of the nine violations committed, seven were routine. In these cases, the operator's departure from standard procedure was a regular occurrence, often going unnoticed or even tolerated by authority.

5.2. Preconditions for unsafe acts

The condition of the operator was the most common 'Precondition for unsafe acts' in "human failure" incidents with 63% of preconditions falling into this category. As shown in Table 5, nearly all incidents were associated with an adverse mental state. The most common problem was the formation of an incorrect expectation/assumption. For example, many drivers approached a red signal with the expectation that the signal would be green. Distraction and decreased alertness also proved to be frequent adverse mental states.

Ten "human failure" incidents were associated with an adverse physiological state, the most common state being physical fatigue ($n = 8$). A relatively smaller number of personnel factors were identified, with the most frequent errors found to be lack of teamwork and poor communication. Environmental factors were found to contribute to ten incidents, with vegetation near the track obscuring the sighting of a signal and equipment design identified as the only recurring problems.

5.3. Unsafe supervision

Only 13/215 (6%) of all errors identified in "human failure" incidents were cases of unsafe supervision. The most frequent problem was found to be inadequate supervision, specifically a failure of supervisors to track worker performance ($n = 5$).

5.4. Organisational influences

Organisational influences contributed to all but one "human failure" incident and many incidents were associated with multiple organisational influences. In fact, nearly half of all errors identified (44%) were of this kind. Forty percent (38/94) of organisational influences related to resource management, with equipment/facility resources proving to be the most frequent of all errors at all levels. Within this category, the most common problem was inadequate equipment design, identified as a problem in 18/23 incidents. Inadequate equipment design included problems with driver safety systems (particularly the deadman/pilot-valve system), security and safeworking equipment, train stops, and signal layout. Most of the errors relating to human resources were associated with inadequate training. Organisational climate proved to be the least problematic sub-set of organisational influences with only 15/94 (16%) of organisational influences falling into this category. Of these, the most frequent issue was the use of inappropriate standards of fitness for duty (e.g. medical examinations). Nearly half (41/94) of the organisational influences belonged to the sub-category of 'Organisational process'. Inadequate procedures were identified ($n = 15$), as were problems associated with worker schedule ($n = 5$). Oversight was identified as an error in 11 incidents with the most common problems being inadequate risk management and safety management systems.

6. Discussion

6.1. HFACS applicability

The HFACS framework was found to accommodate 326 of the 330 contributing factors listed in the 40 investigation reports. The four remaining contributing factors, although of the 'Preconditions for unsafe acts' kind, did not strictly fall into the categories of 'Condition of the operator', 'Personnel factors' or 'Environmental factors', and would fit better into an additional category describing the conditions relating to the task being completed when the error occurred. Although analysis of a much larger number of incidents is required, this initial work suggests that the addition of an extra 'Precondition for unsafe acts' is needed, that of 'Task factors'.

All error types within the HFACS taxonomy were observed in the investigation reports. This finding, in addition to the framework's ability to accommodate the majority of contributing factors, suggests that the error categories, although initially developed for aviation, are applicable to railway incidents and accidents in Australia. More importantly, the HFACS framework appears to be a useful tool for capturing all relevant rail human factors data. Failures were identified at all levels of framework, providing strong support for a systems approach to accident contribution and Reason's (1990, 1997) model of accident causation.

6.2. HFACS reliability

Although the HFACS framework appeared to be simple and straightforward to use, the independent raters reported that they could not confidently classify every error using the taxonomy. This indicates that a thorough and detailed formal training program (including examples of factors and errors) is required in order to ensure raters' confidence in applying the framework. Clearer and more independent definitions of each HFACS category are also needed as it became apparent that several of the error types were frequently confused with others. For example, what one rater would classify as 'Equipment design', an organisational influence falling under 'Resource management', another would classify as 'Equipment design', an environmental 'Precondition for unsafe acts'. Similarly, 'Staff shortages' as part of 'Planned inappropriate operations' at the level of 'Unsafe supervision' was confused with 'Staffing/manning' as an organisational factor falling under 'Resource management'.

It also became evident that interpretation of each safety report varied considerably between raters. Discussions with raters post-analysis revealed that each rater viewed different factors as having the greatest influence on the occurrence of an incident. While classifying errors, raters appeared to consistently focus on one factor (e.g. training), possibly influenced by his/her experience in human factors. The assessors also reported that the safety reports were confusing and unclear, preventing classification of errors to be based on a complete understanding of each incident. This may be a limitation of the safety reports themselves, being poorly structured, too complex or containing insufficient information for failure analysis to be carried out, but may also be associated with each rater's familiarity/knowledge of the Australian railway system.

6.3. HFACS analysis

The analysis revealed that nearly half Australian incidents and accidents were the result of an equipment failure and that, on the whole, these equipment failures were the result of inadequate maintenance or monitoring programs. In many cases, inspection of equipment was not performed, and in the cases where it had been conducted, inspections failed to detect long-standing equipment defects. The most common sequence observed was that of inadequate inspections resulting in misaligned or unstable track going unnoticed, resulting in derailment. This finding is consistent with that which emerged from the Australian checklist study (Edkins and Pollock, 1996, see Section 2) and suggests that an improvement to Australian maintenance procedures is necessary to bring about a reduction in incidents and accidents, in particular, a reduction in the number of derailments.

The analysis of "human failure" investigation reports revealed that skill-based errors were the most common errors leading to Australian railway accidents and incidents. This result is consistent with that observed in the aviation industry (e.g. Shappell and Wiegmann, 2003; Wiegmann and Shappell, 2001). Interestingly, the majority of skill-based errors were the result of slips in attention, many apparently resulting from the preconditions of decreased alertness and fatigue. Common methods used to combat skill-based errors include increased warning systems and design changes that produce a more error tolerant system or warn the operator when an action becomes unsafe (Shappell and Wiegmann, 1997). The significant contribution of attention failure to incidents and accidents may therefore be linked to the large number of cases of inadequate equipment design observed. This finding is consistent with that found in the aviation and nuclear industries, where it has been shown that design contributes to approximately 50% of accidents and incidents (Kinnersley and Roelen, 2007). The largest unique single category observed here was 'Equipment/facility resources', a factor associated with 32 contributing factors across 18 "human failure" incidents. In many cases, the driver safety system (deadman pedal or vigilance device) was found to be ineffective in detecting reduced levels of alertness. This result suggests that adjustments/improvements to the current driver safety systems are critical for Australian accident and incident reduction. This result also has implications for prospective equipment design in that it demonstrates a need for more effective warning systems.

The formation of incorrect expectations/assumptions was observed to be the most common precondition for unsafe acts. This finding is consistent with the idea that a driver's route knowledge plays an important role in perception and interpretation of signs and signals (RSSB, 1998). Technological support, via the introduction of some form of driving automation (e.g. in-cab track monitors/preview screens) may increase driver situation awareness and keep operators informed about upcoming events, possibly reducing their need to rely on route knowledge.

Only 13 of the 330 factors identified were associated with unsafe supervision, this level of the system being associated with fewer errors than any other kind. This finding may reflect one or more of the following: (i) a high standard of supervision, (ii) a tendency for accident investigations to focus on the underlying organisational failures associated with each incident, (iii) a smaller role played by supervisors in railway operation compared to front line personnel and/or management, and (iv) a tendency for supervisors, in reporting incidents, to minimize their contribution to accident occurrence. Analysis of a much larger sample of incidents would confirm whether or not unsafe supervision plays only a minor role in incident/accident causation and may also provide some indication of why this may be.

The most surprising result which emerged out of the current analysis of "human failure" incidents was the very large number of organisational influences identified ($n = 94$). In fact, 39 (out of a possible 40) incidents were associated with at least one organisational factor suggesting that on the whole, incidents and accidents in Australia are the result of latent errors, system problems that only become evident when they combine with other factors (like skill-based errors) to breach the system's defences (Reason, 1990).

A reduction in the number of Australian incidents and accidents is therefore dependent on changes to resource management, the organisational climate and organisational processes. This preliminary work identified a need for improvements in equipment design (as outlined above), training, standards (especially medical standards), procedures and risk management. Specifically, it was revealed that workers require more suitable and complete training, and that system standards and procedures (including operating practices, guidelines, and instructions) require revision to be clearer and more straightforward. Safety hazards and risks also frequently went unnoticed by management, highlighting a need for better monitoring of resources, processes and procedures, and ultimately, improved risk management.

7. Future work

The major limitation of the current study was the relatively small number of incidents reviewed. A greater number of reports must be analysed for these preliminary results to be validated. Future work will seek to include a review of confidential rail accident investigation reports. Application of HFACS to a much larger sample size will not only allow trends in error types to be confirmed but also allow identification of any differences in error types and factors across occurrence types. With further analysis, more concrete areas of system improvement can also be recommended. HFACS can then be used to determine the impact of intervention strategies on overall accident rate and on specific types of human error that result in incidents/accidents over time (Wiegmann and Shappell, 2003). Finally, future work will also involve the development of more detailed and independent descriptions of each HFACS category so as to improve the consistency with which the tool is applied.

8. Conclusions

The present review of Australian incident and accident reports revealed that nearly half the cases were associated with an equipment failure, most due to inadequate monitoring or checking of equipment. In incidents triggered by the actions of frontline personnel, the majority of unsafe acts were slips in attention (i.e. skill-based errors) associated with decreased alertness and physical fatigue. Inadequate equipment design (e.g. driver safety systems) was identified as a major problem in these “human failure” cases and possibly contributed to the relatively large number of incident/accidents resulting from attention failures. Nearly all incidents were associated with at least one organisational influence, suggesting that problems with resource management, organisational climate and organisational processes need to be addressed in order for error reduction in the Australian railway system to occur.

Overall, the HFACS framework was effective in categorising errors from existing investigation reports and proved useful in capturing the full range of relevant rail human factors data, although some modification of the category descriptions is required in order to ensure consistency in the framework’s application.

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