Highlights:

- Systems analysis of factors influencing safety during manual handling tasks
- Various contributing systems factors and relationships were identified
- Policy-orientated countermeasures are required to prevent manual handling injuries
Systems thinking applied to safety during manual handling tasks

RUNNING HEAD: Systems thinking applied to safety during manual handling tasks

Systems thinking applied to safety during manual handling tasks in the transport and storage industry

Dr. Natassia Goode*1,2 (natassiagoode@gmail.com)

Associate Professor Paul M. Salmon¹ (psalmon@usc.edu.au)

Associate Professor Michael G. Lenné² (michael.lenne@monash.edu)

Dr. Peter Hillard² (peter.hillard@monash.edu)

¹University of the Sunshine Coast Accident Research, University of the Sunshine Coast, Locked Bag 4, Maroochydore DC, Queensland, 4558 Australia.

²Monash University Accident Research Centre, Monash Injury Research Institute, Building 70, Monash University, Victoria, 3800, Australia

* Corresponding author.

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Injuries resulting from manual handling tasks represent an on-going problem for the transport and storage industry. This article describes an application of a systems theory-based approach, Rasmussen’s (1997) risk management framework, to the analysis of the factors influencing safety during manual handling activities in a freight handling organisation. Observations of manual handling activities, cognitive decision method interviews with workers (n = 27) and interviews with managers (n = 35) were used to gather information about three manual handling activities. Hierarchical task analysis and thematic analysis were used to identify potential risk factors and performance shaping factors across the levels of Rasmussen’s framework. These different data sources were then integrated using Rasmussen’s Accimap technique to provide an overall analysis of the factors influencing safety during manual handling activities in this context. The findings demonstrate how a systems theory-based approach can be applied to this domain, and suggest that policy-orientated, rather than worker-orientated, changes are required to prevent future manual handling injuries.

**Key words:** workplace safety, manual handling, transport and storage, systems thinking, Accimap
1. Introduction

Injuries resulting from manual handling tasks represent an on-going problem for the transport and storage industry in Australia and worldwide. In Australia the rates of serious claims are the highest of all industries (21.4 compared to 12.6 per 1000 employees) with 42% of claims caused by muscular stress due to manual handling (2009-10 data; Safe Work Australia, 2012a). As a result, transport and storage has been identified as a priority industry in nationally-led government strategies since 2002; however, significant headway in reducing these injuries has not been achieved (Safe Work Australia, 2012b). Internationally, a survey of baggage handlers revealed that 46% had suffered a back injury while at work (Dell, 1998). Two epidemiological studies, each conducted among more than 31,000 American workers in warehouse superstores, show a link between manual handling activities and back pain (Gardner et al., 1999; Kraus et al., 1997). This suggests that the approaches currently employed in this industry are insufficient for understanding and addressing the factors that impact on safety during manual handling tasks. In other safety critical domains the systems approach has been successfully adopted as a way of understanding and enhancing safety and performance. This article describes an application of a systems theory-based approach, Rasmussen’s (1997) risk management framework and associated Accimap technique, to the analysis of the factors influencing safety in a freight handling organisation.

1.1 Rasmussen’s (1997) risk management framework

Rasmussen’s framework is underpinned by the idea that sociotechnical systems comprise various levels; actions and decisions across these levels interact with one another and
contribute to the control of hazardous processes. The system for controlling these processes is described as a hierarchy across multiple levels including:

- a *Government* level at which laws and regulations are developed;
- a *Regulatory* level at which industry standards are developed based on laws and regulations;
- a *Company* level where company policies and procedures based on industry standards govern work processes;
- a *Management* level where company policies and procedures are implemented;
- a *Staff* level representing the activities and characteristics of workers performing the processes; and
- a *Work* level representing the equipment and environment within the work context.

In order to maintain operations within the limits of safe practice, decisions at higher levels (i.e. *Company, Regulatory, Government*) should influence actions at the lower levels, while information about the current state of affairs (i.e. from workers) should transmit up the hierarchy and shape the decisions at the higher levels; a process known as *vertical integration* (Rasmussen, 1997; Svedung & Rasmussen, 2002).

In conjunction with this framework, Rasmussen developed the Accimap technique to graphically represent the conditions that produce accidents (Rasmussen, 1997; Svedung and Rasmussen, 2002). Using Accimap involves constructing a causal diagram of the components, decisions and actions that interact with one another to create the system in which the accident in question occurred, as well as the relationships between them. This technique has been used to represent large-scale organisational accidents in multiple domains (e.g. Branford, 2011; Cassano-Piché et al., 2006; Jenkins et al., 2010; Johnson & de Almeida, 23rd July 2013)
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2008; Salmon et al., 2013; Vincente & Christoffersen, 2006) and to aggregate across situations for a particular hazard domain (Svedung and Rasmussen, 2002) to devise risk management strategies.

Rasmussen’s framework and the Accimap technique were developed to better understand the mechanisms underpinning rare, large scale accidents in high risk industrial settings. The type of accidents considered occurred due to the loss of control of hazardous physical processes that would normally have been isolated from disturbances. In contrast, the current paper is concerned with the frequent, small-scale occupational accidents that occur within repetitive task settings (i.e. occupational accidents; Hovden et al., 2010). The work conditions at the time of the injury are unlikely to be considered abnormal, although they may present a continual risk to the worker. When it comes to injury prevention in such settings, most experts and practitioners tend to focus on the immediate task context.

However, there are a number of reasons why a systems approach (Rasmussen’s in particular) may provide useful insights into the causes of occupational injuries. First and foremost, accident models primarily consist of a set of assumptions about how accidents happen and what the important factors are. Hence, you only find what you look for (Lundberg et al., 2009). The assumption that the causes of injuries resulting from manual handling tasks are constrained to the task setting needs to be tested. Second, although Australian codes of practice (e.g. Safe Work Australia, 2011a; Safe Work Australia, 2011b) recognise that multiple factors (e.g. environmental conditions, workplace layout, nature of objects to be handled, systems of work, psychosocial factors) contribute to workplace accidents, no guidance is provided on how to model this system of factors. Third, typical risk assessment
frameworks for manual tasks (e.g. Safe Work Australia, 2011a) tend to involve the decomposition of tasks into a series of steps to identify potential hazards. While this provides useful insights, the task analyst cannot foresee all the contingencies within the future work context: workers often develop “short cuts” to achieve work goals in response to pressures in the environment. A proactive approach to risk management requires a consideration of the factors that shape decision-making and behaviour in the work context (i.e. performance shaping factors), as well as an understanding of the hazards inherent to the activity (i.e. risk factors) (Rasmussen & Svedung, 2000). Rasmussen’s framework and Accimap technique provide a means by which to integrate these perspectives in order develop an overall picture of the factors influencing the safety of operations.

The following section illustrates how the factors identified in previous research in this domain align with Rasmussen’s framework.

1.2 Previous research on manual handling in the transport and storage industry

Relevant research has been conducted in two key contexts in the transport and storage industry: baggage handling in aviation and stock management in warehouses. Studies in these contexts focus on two types of manual handling injuries: accident-related injuries and musculoskeletal disorders related to repeated exposure. Considering the causal factors involved in both types of injuries should provide a holistic picture of the factors impacting on safety during manual handling activities in this domain.

Figure 1 depicts a summary of the system of factors that have been found to influence safety during manual handling activities in these contexts, classified according to Rasmussen’s framework. The majority of the factors identified in the literature can be placed at the Work 23rd July 2013
level, with most studies identifying workspace layout and product-related factors (e.g. item weight, size, type, labels) as potentially hazardous. Fewer studies identified factors at the higher levels. Similarly, the majority of relationships identified represent interactions between the lower levels (i.e. Staff and Work levels). For example, across both contexts, the impact of workspace layout on worker posture was frequently identified as a hazard. Low aircraft ceilings force baggage handlers to squat or kneel (Dell, 1998; Rückert et al., 1992; Stålhammar et al., 1986). Poor shelf design force warehouse workers to adopt awkward postures, increasing their physical workload (Denis et al., 2006; St-Vincent et al., 2005). Other relationships between these levels include: fatigue caused by constant exposure to aircraft noise, and wearing gloves (PPE) that reduce the ability to grip (Tapley & Riley, 2005); equipment incompatibilities increase time pressure and physical effort required by workers (St-Vincent et al., 2005). Only two relationships were identified between factors at the Management and lower levels: poor planning of work activities leads to poor workspace layout and increased time pressure (St-Vincent et al., 2005; Denis et al., 2006).

The lack of factors at the higher levels and few relationships between factors is inconsistent with the view that accidents in sociotechnical systems are caused by a range of interacting human and systemic factors (e.g. Leveson et al., 2009; Rasmussen, 1997; Reason, 1997); suggesting that knowledge of the important factors influencing safety in this domain is incomplete. It is apparent from the literature that the methodologies used to study safety in this domain have been insufficient to support the collection of ‘systems’ data. For example, the majority of studies reviewed employed direct observations of manual handling activities.
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(Denis et al., 2006; Junior, 2012; Keojevic et al., 2007; Korkmaz et al., 2006; St-Vincent et al., 2005; Stålhammar et al., 1986; Tapley & Riley, 2005). As a result, factors at the higher levels were not captured because in most cases they are not directly observable. The review suggests that studies which have employed surveys (e.g. de Koster et al., 2011; Dell, 1998) and/or interviews with workers and managers (e.g. Denis et al., 2006; St-Vincent et al., 2005; Tapley & Riley, 2005) seem better able to capture factors at the higher levels, as they can assess aspects that are not observable or that may only reveal themselves over time. This suggests that a systems perspective on manual handling safety will be best supported through a multi-method approach.

1.3 Transport and storage industry manual handling case study

The aim of this study is to examine the factors influencing safety during manual handling tasks in the transport and storage industry from a systems perspective. The company involved was a major Australian international and domestic air freight handling service. Recognising the limitations of previous research, a multi-method approach, encompassing observations of manual handling activities and interviews with workers and managers, was used to gather information about potential risk factors and performance shaping factors across the levels of Rasmussen’s framework.

2 Methodology

Figure 2 illustrates the overall approach. Data collection was approved by the Monash Human Ethics Committee, and involved direct observation of freight handling activities followed by interviews with freight handlers and managers. Data collection focussed on three manual handling activities (henceforth referred to as target activities) which are undertaken by workers known as “freight handlers”: (1) manually loading/unloading containerised freight; (2) manually loading/unloading aircraft holds; and (3) manually transferring

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containers from trolleys to a mechanised aircraft container loader. These activities were selected because they represent the majority of freight handler’s manual handling activities and the company’s incident data indicated that they were associated with a high risk of injury. Hierarchical task analysis and thematic analysis were then utilised to identify the risk factors (and relationships between them) that could potentially lead to incidents, and performance shaping factors that could potentially influence workers decision-making during the target activities. Finally, this information was represented graphically utilising Rasmussen’s Accimap technique to present an overall picture of the factors influencing safety.

2.1 Sample

Freight handlers and managers from the company’s three largest operational hubs and corporate office were involved in the study. Freight handlers were recruited on a voluntary basis by Human Resources Advisors, and selected to sample equal numbers across each shift. Managers were identified using a critical case sampling approach (Auerbach & Silverstein, 2003) where individuals thought to have the most knowledge about the operation and safety management system were invited to participate by an Environmental Health and Safety Advisor. All participants provided written consent to be involved in the study.

2.2 Procedure

2.2.1 Observational study

Two researchers conducted observational studies of the target activities across relevant shifts at each operational hub over a three week period. This involved direct observations of the target activities and informal discussions with workers regarding work practices. Loading/unloading containerised freight was observed across the day, afternoon and night.

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shifts. Loading/unloading aircraft holds and transferring containers from trolleys to the mechanised container loader were observed during night shifts.

The data collected included a description of the target activities as performed by teams of workers (component task steps e.g. Take package out of cage, load package onto trolley; task goals e.g. Unload cage), transcripts of the communications that occurred between freight handlers and supervisors during the activities observed, the equipment used to aid task performance (e.g. trolleys, rollers), time, and additional notes relating to the activities being performed (e.g. why the activity was being performed, what the outcomes were, what factors influenced performance).

2.2.2 Interviews

Interviews were held in a private room at the participant’s workplace, recorded using a Dictaphone and transcribed verbatim post-interview using Microsoft Word. Interviews at the operational hubs were conducted by one researcher; interviews at the corporate office were conducted by two. The two interview strategies are described below.

2.2.2.1 Freight handler interviews

The freight handler interviews involved the use of the Critical Decision Method (CDM; Klein et al., 1989), a semi-structured cognitive task analysis approach for gathering in-depth retrospective accounts of incidents (described in detail in Klein and Armstrong (2004). While this method was developed with complex cognitive tasks in mind, in the current study it is applied to the performance of repetitive manual tasks. From a cognitive psychology perspective it could be argued that such tasks are largely automated and therefore the underlying processes largely inaccessible to the individual (e.g. Anderson, 1995). However, the target activities occur within a dynamic work context (e.g. changing number of workers, 23rd July 2013
deadlines, and workload) in a collaborative team environment. Task performance is therefore unlikely to be automated, and the method was selected in order to elicit a consideration of the factors that shape decision-making and behaviour during task performance.

A disadvantage of the CDM is uncertain reliability due to retrospective accounts (Klein & Armstrong, 2004; Salmon et al., 2011). To overcome this problem, the interviews focussed on the target activities in order to obtain reports of similar types of situations as a way of establishing reliability (Klein & Armstrong, 2004). A set of appropriate CDM probes were derived from the CDM literature (Crandall et al., 2006). The probes relevant to the analysis are presented in Table 1.

At the beginning of the interviews, interviewees were asked whether they had had a recent (< 12 months) injury, property damage or near miss incident involving the target activities. If yes, the interview focused on that incident. Otherwise, interviewees nominated the activity most prevalent in their daily work, and focused on the most recent situation in which they performed that activity. The interviewee was asked to describe in detail the incident or situation and construct a timeline showing the sequence of events. The interviewer then chose a safety-critical decision (i.e. the decision to perform the task in that particular way), and used the probes to interrogate the cognitive processes underlying this decision. Interviews lasted between 40 and 80 min, varying with the length of individual’s explanations.

2.2.2.2 Management interviews

The interview questions reported in this paper were one part of a broader interview on the company’s safety culture. The questions relevant to this study were:

- Why do you think accidents occur during each of the target activities?

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• What do you think are the most influential factors that influence operational staff decision making during the target activities?
• What interventions or changes do you think would prevent operational staff from engaging in risky or unsafe behaviours during the target activities?
• What are the key constraints on implementing and maintaining safety interventions?

The complete interviews lasted between 50 and 150 min, varying with the length of individual’s explanations.

2.3 Data analysis

The interview responses were analysed using a thematic analysis approach (adapted from Braun & Clarke, 2006). This involved descriptively coding responses into themes to develop a coding template. For example, the statement “The conveyer belt is at a weird angle and its not really designed for the aircraft. We just make it work.” was coded as “equipment design”. Often statements were transformed directly into coded themes. For example, “incorrect body motion”, “It’s about correcting technique.” and “I think at times the technique is not followed” were all coded as “incorrect technique”. Relationships between themes were also coded. For example, “every time an international person [i.e. a staff member in the international section] leaves they never get replaced - we just get a casual and they don't know what they are doing” was coded as a relationship between use of temporary workers and staff lack of experience. The resulting codes were reviewed by two researchers to ensure they were distinct from each other, and classified according to Rasmussen’s framework. The data was then re-coded using the final coding template to ensure reliability. Frequency counts of the number of interviewees who articulated each theme in response to each question were performed.

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The freight handler interviews and observational data were used to develop Hierarchical Task Analyses (HTA; Stanton, 2006) for the target activities. HTA is a task analysis method that is used to describe systems in terms of the goals, sub-goals and physical and cognitive operations required to achieve them. In addition, HTA describes the contextual conditions that dictate how and when different tasks are undertaken. The purpose of describing the target activities through HTA was twofold: first, it enabled the analysts to generate an in-depth understanding of the tasks being analysed and second, it enabled the identification of factors that might influence the conduct of component task steps (e.g. over-heavy items) and also of performance shaping factors (e.g. time pressure).

3 Results and discussion

In the following sections, the results from each data source are first described in the context of Rasmussen’s framework. They are then integrated using Accimap to reveal an overall analysis of the factors influencing safety during manual handling activities in this context.

3.1 Participants

Twenty-seven male freight handlers and 35 managers (31 male) were interviewed with an average of 8.35 (SD = 4.52) and 12.91 (SD = 5.11) years of experience at the organisation, respectively. The managers interviewed included: frontline supervisors, managers with safety-specific roles and senior executives.

3.2 Thematic analysis of freight handler’s responses

Sixty-seven percent of freight handlers had been involved in a recent incident during the target activities. No near misses were reported. Of these incidents, 72% were reported, 83% resulted in an injury and 17% resulted in property damage.

3.2.1 Description of target activities

Freight handlers described the target activities as follows:

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Manually loading/unloading containerised freight. Teams of 2 to 10 freight handlers transfer packages or mail bags from trucks, trolleys, conveyer belts or pallets into unit load devices (ULDs), which are large metal containers for shipping freight. Typically, one worker stands inside the ULD to stack the freight while others throw the freight inside. Once the ULD is partially full, all workers stand outside and throw freight inside. Most work with bare hands, some wear gloves. Company regulations state that heavy or awkward items 20kg and above should be labelled, and that a two person lift is required for items over 40kg. Packages and mail bags are often over 20kg, and it is rare to undertake a two person lift with items over 40kg. Packages are usually labelled for weight. Mail bags, loaded with three or four boxes and multiple letters, are never labelled. Each container holds between 1-2 tonne. Workers estimated that they load 6 – 15 tonne per shift.

Manually loading/unloading aircraft holds. One or two freight handlers transfer items from a barrow to a conveyer belt which feeds towards the aircraft hold. The end of the conveyer belt must be positioned so it does not contact the aircraft. Another freight handler sits or kneels in the doorway of the hold dragging items from the conveyer belt inside the hold, then sliding them into the belly of the aircraft. Depending on the type of aircraft, another worker may kneel inside the hold stacking items. The hold is too small to stand upright. Workers wear gloves and knee pads. One to two tonne is loaded into each plane. Workers load 2-3 planes per night.

Manually transferring containers from trolleys to a mechanised aircraft container loader. A driver positions the trolley loaded with the ULD as near as possible to the mechanised aircraft container loader. One or two workers tug at the straps attached to the ULD to guide it onto the loader. Most work with bare hands. Occasionally the ULD may become stuck on the trolley, in which case workers will stand on the trolley and push from 23rd July 2013
behind. Once in position, the loader pulls the ULD forward, while the workers push it along the conveyer belt from behind. Each container holds between 1 and 2 tonne.

3.2.2 Perceptions of risk factors and relationships between them

The risk factors identified from freight handler’s descriptions of the target activities, and the percentage of participants who articulated each factor, are shown in Table 1 (Probe 1). The factors were classified primarily at the Staff and Work levels of Rasmussen’s framework. A number of relationships between these factors were also identified from the descriptions. Low staff levels had a negative impact on supervision (7%), manual handling practices (7%), morale (4%), time pressure (7%), working alone (15%) and the use of temporary workers (7%). The use of temporary workers was associated with staff lack of experience (4%). Working alone increased routine violations (4%). Absenteeism decreased morale (4%). Customer factors were associated with packages over load limits (11%) and increased time pressure (11%). Repetitive work had a negative impact on the physical condition of worker (4%) and uncomfortable personal protective equipment (7%). Non-organisational employees (7%) and equipment design (4%) and time pressure (11%) were all associated with routine violations. Confined space lead to poor physical posture (22%); poor workspace layout was associated with increased horizontal and vertical reaching distances (4%); and poor visibility was associated with unsafe acts (4%).

Insert Table 1 about here

3.2.3 Perceptions of performance shaping factors

The performance shaping factors identified from freight handler’s responses to the CDM probes, and the percentage of participants who articulated each factor in response to each
probe, are shown in Table 1 (Probes 2 – 6). The factors identified were classified at the Company, Management, Staff and Work levels of Rasmussen’s framework. While many common factors were identified across probes (e.g. staff levels, package features and equipment), responses to individual probes reveal critical information concerning work practices and conditions. Responses to Probe 2 indicate that few workers pay attention to other team members during the target tasks, indicating low levels of collaboration. Most workers are exclusively focussed on the features of each package (e.g. weight, size, condition) to determine whether it is safe to lift. However, only 26% of freight handlers indicated that package weight information was actually available to them at the time of making their decision (Probe 4). The lack of labelling on mail bags was identified as a particular issue.

Responses to Probe 3 indicate that although the target activities are highly repetitive, the way they are performed changes dynamically in response to a number of variables. A high proportion of freight handlers indicated that their course of action was determined by the number of staff allocated to the shift. Only two freight handlers indicated that their course of action was guided by previous experience with performing the task in the same manner.

Responses to Probe 6 reinforce that the number of workers is perceived as a critical issue; “more staff” was the most frequently proposed intervention. However, some of the interventions proposed were inconsistent with the issues identified in previous responses. For example, although package weight was identified as a key factor, only one freight handler indicated that changes to load limits were required. Similarly, many freight handlers indicated that more equipment was required, although lack of equipment was not frequently identified.
as a factor in earlier responses. Potentially responses to Probe 6 are impacted by freight handler’s perceptions of factors that can and cannot be easily changed. For example, mail bags weights are determined by the organisations biggest client; freight handlers may perceive that requests to change load limits may negatively impact on this relationship.

3.3 The thematic analysis of manager’s responses

3.3.1 Perceptions of risk factors and relationships between them

The risk factors identified from manager’s understanding of why accidents occur during the target activities, and the percentage of participants who articulated each factor, is shown in Table 2 (Probe 1). The factors span the Company, Management, Staff and Work levels of Rasmussen’s framework. Manager’s also reported perceptions of a number of relationships between these factors. Lack of monitoring systems was associated with poor supervision (6%), rushing (3%) and unsafe acts (9%). Low staff levels was associated with poor housekeeping (3%), low morale (3%), poor rotation through tasks (3%), reluctance to use equipment (6%), routine violations (11%), rushing (3%) and time pressure (6%). The poor quality of training systems was associated with incorrect manual handling techniques (26%), lack of staff (3%) and reluctance to use equipment (6%). Conflicts between safety and operational goals (9%) and work scheduling (9%) were associated with increased time pressure. Ageing workforce was associated with poor rotation through tasks (6%). Carelessness was associated with rushing (3%) and unsafe acts (3%). Absenteeism was associated with increased fatigue (3%) and lack of staff (3%). Equipment design was associated with poor physical posture (14%) and routine violations (3%). Lack of equipment was associated with poor rotation through tasks (3%). Time pressure was associated with increased rushing (3%). Confined space led to poor physical posture (3%). Poor visibility was associated with unsafe acts (3%).

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3.3.2 Perceptions of performance shaping factors

The performance shaping factors identified from manager’s responses to the interview probes, and the percentage of participants who articulated each factor in response to each probe, are shown in Table 2 (Probes 2 – 4). The factors spanned all levels of Rasmussen’s framework. Supervision and time pressure were perceived to be key influences on staff decision making during the target activities. Consistent with this response, more policing of Standard Operating Procedures (SOPs) was frequently proposed as a required intervention. Many managers also perceived that faster responses to incident and hazard reporting system were required. However, a high degree of resistance to change within the organisation was evident; manager’s reported that the organisation had a poor record of maintaining safety initiatives, and that freight handlers employed for a long period of time were unwilling to change.

3.4 HTAs of target activities

A number of unique issues were identified through the construction of the HTAs, including: workers in close proximity with mobile plant equipment due to violations of the traffic management plan; freight handlers using equipment incorrectly (e.g. standing on barrows to reach packages); poor communication between workers during tasks; wet/slippery floors; and high levels of noise in the work environment. There were also a number issues in common with the interview data, including: traffic congestion in the warehouse; poor physical posture due to work environment; inadequate personnel available to perform the target activities; packages over allowed weight limit; lack of task rotation (e.g. task repetition for freight

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handlers); lack of PPE; poor equipment design; time pressure; workers with pre-existing injuries; number, size and weight of packages; poor work scheduling; and inclement weather.

3.5 Accimap of factors influencing safety during the target activities

Each analysis described above is useful in isolation; however, the aim of this study was to undertake a systems analysis of the factors influencing safety in the transport and storage domain. For this purpose, the outputs were integrated to produce an overall Accimap of the factors influencing safety, shown in Figure 3. The construction of the Accimap involved in the following steps: (1) a list of the factors and relationships identified from all data sources was constructed; (2) where possible factors were combined into broader categories to simplify the presentation of the data (e.g. morale, bad habits, careless and complacency were combined into the factor “worker attitudes”); (3) references to each factor in the interview data were summed to create scores for freight handlers and managers (e.g. “package number, size or weight” was mentioned 54 times by freight handlers and 9 times by managers). The resulting scores reflect the relative importance of each factor to the different samples; (4) the factors, relationships, and scores were then graphically depicted on Rasmussen’s framework using Microsoft Visio software; (6) the factors identified in the literature review (Section 1.2) were integrated in Figure 3 to aid comparisons between this study and previous research.

First and foremost the analysis presented in Figure 3 confirms the notion that freight handling safety is a systems phenomenon, and that a systems approach is required for studying and enhancing performance and safety in this domain. Specifically, the analysis shows that factors across all levels of the system have an influence on safety during manual handling activities; from WHS legislation through to union power to inadequate policies and procedures through to low staff levels and finally unsafe acts. This is consistent with 23rd July 2013
Rasmussen’s assertion that safety is an emergent property of complex socio-technical systems and is impacted by the decisions and actions of those across all levels of the system, not just front line workers.

A strength of the analysis is that it clearly highlights the areas of convergence and divergence amongst the different data sources. On the one hand, staff levels, worker’s physical condition, workspace layout and time pressure were identified across all data sources. The majority of themes (61%) were identified in at least two sources. From the perspective of the company involved in the study, this adds credibility to the findings, and could be used as an argument to counter the resistance to implementing safety changes identified in the interviews with managers (Section 3.3.2). On the other hand, Figure 3 also highlights some striking inconsistencies between the views of different stakeholders within the organisation. Freight handlers perceived that were fundamental issues related to company regulations (e.g. package weight, number, size, labelling) and work conditions (e.g. equipment design) impacting on safety during the activities. Managers perceived that safety problems were largely due to incorrect manual handling practices and worker attitudes; which implies they believed workplace conditions were acceptable. These findings indicate a lack of vertical integration: information about hazardous work conditions were not filtering through to management. This conclusion is supported by freight handler’s perception that management were slow to react to hazard and incident reports. These findings may also explain why the countermeasures favoured by the organisation largely focussed on the individual (e.g. retraining the offending worker on SOPs combined with team meetings to raise awareness of the potential for injury) because managers believed that worker behaviour is primarily the cause of injuries.

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The relationships between the factors illustrate how problems propagate throughout the system. During the development of countermeasures, knowledge of these relationships should be used to identify potential impacts on other activities or unintended side-effects (Leveson et al., 2009; Lundberg et al., 2009). For example, low staff levels make it difficult for supervisors to adequately rotate workers through tasks or supervise workers, and impacts on housekeeping and manual handling practices (e.g. at times only one worker is available to perform lifting tasks requiring two workers). It also increases time pressure, again increasing the likelihood of unsafe acts and violations. However, the link between “low staff levels” and “poor/lack of training system” suggests that simply increasing the number of staff will not suffice. Manager’s reported that the number of fully trained staff was a significant problem. Casual staff members do not receive the same training as permanent workers, are usually unable to operate machinery or work on ramp and require constant supervision. This places additional requirements on experienced, permanent, workers. This suggests that a revision to casual staff training procedures is required to better integrate casual workers into normal work tasks, and alleviate the pressure on experienced staff members.

The factor scores illustrate the relative importance as perceived by managers and freight handlers. On one hand, the low scores for factors at the Government and Regulatory levels, and a lack of relationships between these levels and those below, potentially indicates a lack of vertical integration in relation to WHS law. Australian WHS law has changed considerably in the past few years. For example, corporate officers (i.e. directors and executives) now have a legal responsibility to keep informed about health and safety matters, and act immediately on any risks that brought to their attention (Safe Work Australia, 2012). The clear division between safety and operational staff roles, lack of safety-related KPIs for 23rd July 2013
operational managers and the poor maintenance of safety initiatives indicates that a culture of shared responsibility for safety was not yet established within the organisation. On the other hand, the low factor scores at these levels may also reflect the questions that were included in the interview, as managers were not directly asked whether regulation and government policies impacted on safety within the organisation; a potential limitation.

Finally, Figure 3 illustrates how the findings support and extend on previous research. Almost all the factors found in the studies included in the literature were identified, with the exception of safety consciousness and transformational safety leadership (de Koster et al., 2011). This may be because these factors are positive influences on safety, while the questions utilised in the present study focussed on negative impacts on safety; a potential limitation. Nevertheless, many of the factors at the upper levels of the system represent newly identified challenges for this domain.

3.6 Implications for improving safety in the transport and storage domain

Although the analysis presented reflects employee perceptions and analyst observations only, it does provide pointers to important safety interventions. The following discussion describes some of the implications for improving safety, however, before such interventions are developed it is recommended that further study be undertaken to confirm the present analysis findings. One approach for example would be to use an improved accident/incident reporting system to collect data on the system wide contributory factors involved in manual handling.

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injuries. Whilst consistent with a systems approach to safety this would also provide validation evidence for the current analysis.

Whilst the systems thinking philosophy has its own implications for how to improve safety in work systems, the analysis presented does have some implications for improving performance and safety, both in the organisation examined and the transport and storage domain generally. In line with the systems approach, it is important that the likely temptation to focus on component fixes is resisted, and that interventions are aimed at improving the overall system and interactions between components rather than merely improving components themselves. Reason (2008) points out that safe, reliable organisations work on the assumption that seemingly isolated failures or errors actually come from the interaction of various upstream contributing factors (i.e. at the higher levels of the system). Therefore, instead of applying local repairs, they strive for system reforms.

Based on the analysis, it would appear that the most appropriate starting point would be to introduce a number of system reforms designed to remove or modify some of the influencing factors present at the higher levels of the system, especially those that are heavily linked to factors at the lower levels. The removal of higher level conditions should ease issues at the sharp end of the system. In the present case study this suggests that current policies, procedures and training programs require an overhaul, and that the problems of low staff levels, and conflicts between safety and operational goals, require resolution. Importantly, the organisation should not seek to simply replace, fix, or introduce new components. In the case of training, for example, the systems approach suggests that a holistic approach is more appropriate than merely introducing a new form of training to improve component 23rd July 2013
performance (e.g. training workers to lift objects better). Such an approach might involve first examining how the training program fits in with current practice and then redesigning the entire training system (e.g. programs, delivery, national guidelines). This enables training program flaws to be rectified and also enables the training system to become underpinned by safety and the systems approach. An important part of this is to embed the systems approach within training programs at all levels of the organisation. For example, managerial training programs need to emphasise the role of system wide contributions to injury and accidents at the sharp end. Also, manual handling training programs should communicate how factors such as low staff levels, time pressure etc. can influence manual handling activities and discuss strategies for dealing with them when they arise. This enables multiple contributory factors to be dealt with through training programs as opposed to only addressing lifting techniques.

Other higher level conditions that should be addressed include the organisations approach to incident reporting and the lack of safety-related KPIs. Modifying the current incident reporting system provides another example of how an intervention can be used to embed the systems approach within an organisation. Further, modifying the incident reporting system provides a way for the organisation to gather data regarding the system wide contributory factors involved in manual handling activities, which in turn will provide validation evidence for the current analysis and also clear pointers to required safety interventions. The current incident reporting and investigation system was found to be limited in various ways, but in relation to this article the most important flaw was that it was underpinned by a reductionist, human error, blame oriented approach to understanding incidents. Collective mindfulness (Reason, 2008), whereby organisations strive to extract as much as possible about threats
within the system or work, is required, as is a blame free approach to reporting. Various modifications are thus required. First, the incident reporting system should be designed to collect data on causal factors across the work system and not just on those related to the individual worker. Second, all workers should be trained in the incident reporting system. This enables them to report incidents, but more importantly communicates systems thinking to everybody in the organisation. Exactly what constitutes a reportable incident should also be made explicit, and workers should be commended, even rewarded, for reporting incidents. To further encourage reporting the system should be confidential, anonymous, blame free and non-punishable (where appropriate). Positive outcomes from the reporting system should also be communicated to staff at all levels to further encourage reporting. Once reported, incident investigations should also be underpinned by systems thinking so that investigations consider causal factors across the work system.

3.7 Advantages of Rasmussen’s Approach for reducing manual handling injuries in the transport and storage domain

The analysis presented indicates that Rasmussen’s approach has several advantages for the purposes of devising appropriate strategies to address the risks involved in manual handling in the transport and storage industry. Foremost, the approach is comprehensive as it draws attention to the factors across the work ‘system’ behind the unsafe acts and violations that lead to manual handling injuries. This is important as the worker is no longer seen as the broken component; rather manual handling injury is treated as a systems failure. Whilst this ensures that organisations’ understanding of the causes of manual handling injuries is consistent with contemporary accident causation models, it also ensures that interventions should be appropriate and more effective as the overall system is focussed on rather than the injured worker in isolation. For example, Figure 3 depicts contributing factors stemming from 23rd July 2013
equipment design, time pressure, inadequate policies and procedures, staff levels, non-company employees and worker attitudes. These findings may also explain why training has generally been found to be ineffective in reducing manual handling injuries (e.g. Clemes et al., 2010). The analysis suggests training alone will be ineffective; worker decision-making and behaviour must be considered in the context of many other factors.

The framework also has the capacity to represent factors from within the workplace as well as from other interrelated organisations. For example in Figure 3, the worker’s union and aviation security were perceived as key constraints on implementing and maintaining safety interventions in the workplace. This suggests that the company involved in the study should engage these organisations in the formulation of their countermeasures. The inclusion of these factors is important because in other domains it has been found that it is in these areas of overlapping responsibility that accidents are most likely to occur (Leveson et al., 2009).

Finally, the Accimap technique has the capacity to integrate large quantities of information from different sources into a single, easily understood diagram. This enables the complex problem of manual handling injury to be expressed and communicated simply. As illustrated by the large quantity of qualitative data collected in the course of this study, this is a key issue in workplace safety assessments. By reducing the cognitive demands associated with integrating large amounts of data from disparate sources, potentially this approach could help managers overcome the “silo mentality” that is often adopted when making decisions in complex systems (Goh et al., 2011; Sterman, 2000).

4 Limitations

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Finally, the limitations of the study should be acknowledged. Whilst the methodology adopted represents a novel approach to examining the factors influencing safety during manual handling activities, the use of CDM to study repetitive manual tasks may be disputed: workers are unlikely to be able to provide a complete account of the decision-making processes underlying task performance. Nevertheless, the findings show workers were willing and able to reflect on these processes, and through this process generate valuable insights into the factors impacting on safety. Moreover, the focus of the CDM interview was on systemic and contextual factors influencing decision making, not on the step by step process of decision making. Second, the use of retrospective accounts and personal perspectives will always be associated with some element of bias. In discussing accident causation, freight handlers may have been motivated to “blame management”, and vice versa. Third, the results are partly driven by the choice of questions, and interviewees may have had more to say on government or regulatory issues if they had been directly asked. However, while further probing may have revealed a more complex system of factors, the researchers were wary of provoking unwarranted speculation from participants.

5 Conclusion

This paper utilised Rasmussen’s framework and Accimap technique with the aim of providing greater insight into the complex system of factors impacting on safety during manual handling activities in the transport and storage industry. While the multi-method approach was resource intensive, the findings demonstrate how the systems approach can increase knowledge in this domain, as it has done in others previously. The benefits of the approach included the distillation of a large quantity of information into a single diagram, mapping the potential impacts of countermeasures on other activities and the development of an understanding of the constraints limiting the success of countermeasures. The authors plan

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to undertake further research to determine how this new knowledge is translated into safety measures in practice, and to evaluate the subsequent impact on manual handling injuries.

6 Acknowledgments

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7 References


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Figure Captions

Figure 1 Summary of previous research focussing on manual handling in the transport and storage industry. Figure shows the system of factors reported to influence manual handling activities during baggage handling in aviation and stock management in warehouses.

Figure 2 Overview of the research approach utilised to identify the system of factors influencing safety during manual handling activities in the freight organisation.

Figure 3 Summary of the system of factors identified from interviews with freight handlers, managers and observations. Numbers in brackets () represent frequency of references in freight handler interviews. Numbers in square brackets [] represent frequency of references in manager interviews. Factors identified through HTAs are italicised. * indicate factors identified in previous research illustrated in Figure 1.

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Figure 1

<table>
<thead>
<tr>
<th>Government</th>
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<tbody>
<tr>
<td>Regulatory</td>
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<tr>
<td>Company</td>
</tr>
<tr>
<td>Lack of training (Dell, 1998)</td>
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<tr>
<td>Load limits set by airlines (Tapley &amp; Riley, 2005)</td>
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<tr>
<td>Maturity of hazard management system (de Koster et al., 2011)</td>
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<tr>
<td>Transformational safety leadership (de Koster et al., 2011)</td>
</tr>
<tr>
<td>Management</td>
</tr>
<tr>
<td>Poor planning of work activities (Denis et al., 2006; St-Vincent et al., 2005)</td>
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<tr>
<td>Staff levels (Junior, 2012; Tapley &amp; Riley, 2005)</td>
</tr>
<tr>
<td>Lack of task rotation (Tapley &amp; Riley, 2005)</td>
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<tr>
<td>Management</td>
</tr>
<tr>
<td>Rate of transfer of items (Junior, 2012; Tapley &amp; Riley, 2005)</td>
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<tr>
<td>Handling practices (Korkmaz et al., 2006)</td>
</tr>
<tr>
<td>Customer factors (Junior, 2012)</td>
</tr>
<tr>
<td>Staff</td>
</tr>
<tr>
<td>Worker’s physical posture (Denis et al., 2006; Stalhammaret al., 1986; St-Vincent et al., 2005)</td>
</tr>
<tr>
<td>Level of physical effort required from worker (Denis et al., 2006; Junior, 2012; St-Vincent et al., 2005)</td>
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<tr>
<td>Safety consciousness (de Koster et al., 2011)</td>
</tr>
<tr>
<td>Fatigue (Tapley &amp; Riley, 2005)</td>
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<tr>
<td>Work</td>
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<tr>
<td>Workspace layout (e.g. postural constraints, reaching and lifting distance, carrying distance) (Dell, 1998; Garg, 1986; Junior, 2012; Rücker et al., 1992; St-Vincent et al., 2005; Tapley &amp; Riley, 2005)</td>
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<tr>
<td>Time pressure (St-Vincent et al., 2005; Tapley &amp; Riley, 2005)</td>
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<tr>
<td>Equipment incompatibilities (St-Vincent et al., 2005)</td>
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<tr>
<td>PPE (Tapley &amp; Riley, 2005)</td>
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<td>Exposure to noise (Tapley &amp; Riley, 2005)</td>
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<tr>
<td>Visibility (Tapley &amp; Riley, 2005)</td>
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<tr>
<td>Items over load limit (Dell, 1998)</td>
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<tr>
<td>Number of items (Junior, 2012; Tapley &amp; Riley, 2005)</td>
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<tr>
<td>Lack of equipment (Dell, 1998; Junior, 2012; Tapley &amp; Riley, 2005)</td>
</tr>
<tr>
<td>Equipment maintenance (Dell, 1998; St-Vincent et al., 2005)</td>
</tr>
<tr>
<td>Type of bag/packaging (St-Vincent et al., 2005; Tapley &amp; Riley, 2005)</td>
</tr>
<tr>
<td>Positioning of equipment (Junior, 2012)</td>
</tr>
<tr>
<td>Weight &amp; size of items (Rücker et al., 1992; St-Vincent et al., 2005; Tapley &amp; Riley, 2005)</td>
</tr>
<tr>
<td>Absence of weight labels (Dell, 1998; Korkmaz et al., 2006; Tapley &amp; Riley, 2005)</td>
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</table>
Table 1 Freight handler’s perceptions of risk factors (Probe 1) performance shaping factors (Probe 2-6) associated with target activities classified according to Rasmussen’s framework. Numbers indicate the percentage of freight handlers who articulated each factor in their response to each probe (n = 27).

<table>
<thead>
<tr>
<th>Interview probe</th>
<th>Company</th>
<th>Management</th>
<th>Staff</th>
<th>Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Describe in detail the incident or situation</td>
<td>7% Use of temporary workers.</td>
<td>37% Low staff levels, 26% Working alone, 15% Failure to learn from incidents, 11% Inadequate supervision, 7% Poor planning.</td>
<td>Workers: 26% Manual handling practices, 26% Poor communication, 19% Physical size of worker, 11% Absenteeism, 11% Staff lack of experience, 11% Decision errors, 11% Routine violations, 4% Physical condition of worker, 4% Fatigue, 4% Morale, 4% Skill-based errors. Customer factors: 7% Non-company employees, 4% Customers.</td>
<td>Products: 44% Packages over load limits, 30% Unlabelled heavy items, 19% Package weight, 4% Package number, 4% Package size, 4% Unsuitable packaging.</td>
</tr>
<tr>
<td>2. What features were you looking for when you formulated your decision?</td>
<td>7% Location of other workers, 7% Availability of other workers, 4% Pressure from management.</td>
<td>Workers: 4% Workers physical condition, 15% Communication with other workers. Customers: 4% Customers.</td>
<td>Products: 37% Package weight, 33% Package size, 22% Heavy stickers, 11% Packaging condition, 4% Package number.</td>
<td></td>
</tr>
<tr>
<td>3. What courses of action were available to you and how/why was the chosen option selected? Why were the other options rejected?</td>
<td>26% Lack of workers, 11% Supervisor/Manager told them to do it that way, 4% No control over how we do the task.</td>
<td>Workers: 7% Previous experience performing the task in this manner, 4% Not thinking, 4% Reducing manual handling.</td>
<td>Products: 4% Package weight. Equipment: 7% Equipment failure, 4% Equipment availability. Tasks: 11% Time pressure. Environment: 19% Only way to do it in the confined space.</td>
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<tr>
<td>4. What factors influenced your decision making at this point?</td>
<td>4% Training.</td>
<td>19% Staff numbers, 4% Management expectations</td>
<td>Workers: 4% Workers physical condition, 4% Communication with other workers</td>
<td>Products: 19% Package weight, 11% Package size, 4% Heavy stickers. Equipment: 11% Equipment availability, 7% Equipment design, 4% Equipment failure. Tasks: 22% Time pressure, 4% Repetitive nature of task. Environment: 7% Weather, 4% Confined space.</td>
</tr>
<tr>
<td>5. What information did you have available to you at the time of the decision?</td>
<td>7% Traffic management plan.</td>
<td>26% Location of other workers, 4% Staff numbers.</td>
<td>Workers: 4% Workers physical condition, 15% Communication with other workers, 4% Staff experience level.</td>
<td>Products: 26% Package weight, 19% Package size, 11% Heavy stickers, 11% Package number. Equipment: 15% Aircraft, 15% Equipment, 1% Weight of container, 7% Equipment failure, 4% Equipment design. Tasks: 7% Repetitive nature of task. Environment: 15% Traffic congestion, 7% Weather, 4% Confined space, 4% Housekeeping.</td>
</tr>
<tr>
<td>6. What interventions do you think would prevent inappropriate</td>
<td>15% Change work procedures, 11% More/better training, Health and fitness programs.</td>
<td>41% More staff, 7% Better job rotation, 4% 4% More attention to</td>
<td>Workers: 7% Better compliance with procedures, 4% Better hazard awareness, 7% More</td>
<td>Products: 11% Improved labelling of heavy items. Equipment: 26% More equipment, 11% Better servicing of equipment, 7% Equipment design.</td>
</tr>
<tr>
<td>Interview probe</td>
<td>Company</td>
<td>Management</td>
<td>Staff</td>
<td>Work</td>
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<tr>
<td>decisions being made during similar incidents in the future?</td>
<td>4% Lighter load limits for mail bags, 4% More staff with complete training.</td>
<td>hazard reports, 4% More supervision.</td>
<td>cooperation between workers, 4% Communication with other workers.</td>
<td></td>
</tr>
</tbody>
</table>

Note: No factors were classified at the Government or Regulatory level of Rasmussen’s framework.
Table 2 Manager’s perceptions of risk factors (Probe 1) and performance shaping factors (Probes 2-4) associated with target activities classified according to Rasmussen’s framework. Numbers reflect the percentage of managers who articulated the factor in their response to each probe (n = 35).

<table>
<thead>
<tr>
<th>Interview probe</th>
<th>Government</th>
<th>Regulatory</th>
<th>Company</th>
<th>Management</th>
<th>Staff</th>
<th>Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Why do you think accidents occur during each of the target activities?</td>
<td>26% Training, 14% Conflicts between safety and operational goals, 11% Lack of monitoring systems.</td>
<td>40% Staff levels, 17% Poor rotation through tasks, 11% Work scheduling, 6% Culture, 3% Working alone.</td>
<td>Workers: 94% Incorrect manual handling practices, 34% Physical size of worker, 23% Ageing workforce, 20% Rushing, 17% Reluctance to use equipment, 14% Violations, 11% Lack of concentration, 9% Carelessness, 9% Not stretching, 6% Bad habits, 6% Physical fitness, 6% Absenteeism, 3% Not asking for help, 3% Not wearing PPE, 3% Skill of workers.</td>
<td>Products: 37% Unlabelled heavies, 20% Heavy items requiring two people, 3% Size of packages, 3% Volume of freight. Equipment: 43% Equipment maintenance 40% Lack of equipment 37% Equipment design. Tasks: 51% Nature of the work, 46% Physical posture, 31% Time pressure, 20% Repetitive work. Environment: 57% Confined space, 6% Visibility, 3% Workspace layout.</td>
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<tr>
<td>2. What do you think are the most influential factors that influence operational staff decision making during the target activities?</td>
<td>3% Work Health and Safety (WHS) law</td>
<td>6% Lack of training, 3% Standard Operating Procedures.</td>
<td>31% Supervision, 20% Staff levels, 17% Culture, 11% Communication from management, 11% Poor management styles, 3% Work schedule.</td>
<td>Workers: 14% Behaviour of other staff, 14% Rushing, 11% Complacency, 9% Fatigue, 9% Lack of experience, 6% Lack of teamwork, 6% Morale, 6% Personal issues, 3% Attitudes, 3% Bad habits, 3% Efficiency.</td>
<td>34% Time pressure, 3% Nature of the job.</td>
<td></td>
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<tr>
<td>3. What interventions or changes do you think would prevent operational staff from engaging in risky or unsafe behaviours during the target activities?</td>
<td>34% Incident/hazard reporting system, 11% Traffic management plans, 14% Training for supervisors, 14% More/better training, 14% Safety KPIs, 6% Revisions to procedures.</td>
<td>23% Policing of SOPs, 17% Consequences for violations, 14% Safety leadership, 9% Fatigue management strategies, 9% More staff, 9% Work schedules, 6% Consultation with workers.</td>
<td>Workers: 9% Morale, 3% workers should pay more attention.</td>
<td>Equipment: 9% Better/more appropriate equipment. Environment: 3% Housekeeping, 3% Bigger workspace.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. What are the key constraints on implementing and maintaining safety interventions?</td>
<td>9% Union power, 3% Aviation security.</td>
<td>31% Financial constraints, 3% WHS advisors working across multiple sites, 3% Divisions between operational and safety staff, 3% Lack of national consistency in policies.</td>
<td>Workers: 23% Staff unwilling to change, 6% Morale, 3% worker’s lack of trust in management. Customers: 3% Pressure from customers.</td>
<td>Environment: 9% Workspace constraints.</td>
<td></td>
<td></td>
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</tbody>
</table>