Human-centred design in civil road construction: Methods to inform procurement and improve performance

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Abstract:

Productivity, fatality, injury and health risks are associated with the operation and maintenance of mobile plant in road construction. Unwanted events include: slips, trips and falls from ground or at height; exposure to hazardous manual tasks, pinch points, heat, noxious chemicals and whole body vibration; low levels of distributed situation awareness; fatigue; vehicle roll overs; and collisions. It may be possible to remove or reduce the risk of these events through improved design of the equipment.

The Earth Moving Equipment Safety Round Table (EMERST) -Design Evaluation for Earth Moving Equipment Procurement (EDEEP) method was adapted for road construction equipment. Six field visits were undertaken to review an asphalt job truck. A task-based risk assessment process identified 15 design issues contributing to hazards associated with the equipment. Many of these issues had not previously been captured during routine reporting processes. Design parameters were established to inform procurement regarding preferred specifications for future job truck purchases.

CITE THIS ARTICLE AS

Pazell, A., Burgess-Limerick, R., Horberry, T., Davidson, P., (2016), Human-centred design in civil road construction, J *Health & Safety Research & Practice* 8(1), 3-14.

KEYWORDS

Human-Centred Design, Sociotechnical Systems, Civil Construction

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Introduction

Industry Profile and Injury Trends

The Australian construction industry is the fourth largest contributor to Gross Domestic Product (Australian Bureau of Statistics, 2010), employing 9% of the workforce (Safe Work Australia, 2013[a]). It provides for traditional head-of-household income: full-time (86%) and male workers (89%) (Australian Workforce and Productivity Agency, 2013). In the last 11 years, the number of construction workers has increased by 33% (Safe Work Australia, 2015). In 2012-13, the construction industry had the fourth highest incidence rate of serious claims per 1000 employees and fifth highest rate of fatality per 100,000 workers in 2013-2014 (Safe Work Australia, 2015). Work in this industry in 2012-2013 has given rise to 10% of worker's compensation claims for injuries and diseases involving one or more weeks off work (Safe Work Australia, 2015).

Safe Work Australia (2015) reported that the main cause of the injury claims included body stressing (37%); falls, trips and slips of a person from height or at same level (28%); and being hit by moving objects (14%). Fatalities were constituted by 28% of claims for falls from height and 16% of claims from vehicle incidents.

Across Australia, the occupation groups with the highest serious claim rate include labourers, intermediate transport, and trades workers (Safe Work Australia, 2011); construction includes all three groups.

The construction industry exposes workers to hazardous work conditions with awkward postures, force, exertion, repetition, contact stress, pinch points, vibration, collision risks, chemical exposures, occupational noise exposure, exposure of outdoor work elements, and trip and fall hazards (Boatman et al, 2015; Kramer et al, 2009; Glimskar and Lundberg, 2013; Pazell, 2014[a, b] and Safe Work Australia, 2015). Physical demands are high yet control over product design and material selection has been limited (Kramer et al, 2009). The Australian Work Health and Safety Strategy 2012-2022 (Australian Strategy) has identified the construction industry as a priority for intervention. This is underpinned by the guiding principles that all workers have the right to a healthy, safe environment and that well-designed, healthy, and safe work will permit more productive lives (Safe Work Australia, 2012).

Design as an Intervention

Prevention through Design (PtD) refers to the elimination of hazards through the application of a traditional hierarchy of controls as well as the introduction of novel controls applied throughout the lifecycle of equipment and human-interface design. PtD recognises the increase to business value associated with its practices (NIOSH, 2014). "Healthy and safe by design" is one of seven key action areas of the Australian Work Health and Safety Strategy 2012 – 2022 (Safe Work Australia, 2012). Design includes equipment, task, workstation; environment; work processes; organisation of work and management practice (Creaser, 2008; Driscoll et al, 2008; and NIOSH 2014). The Total Worker Health® initiatives provide that design, and the design process, may integrate protection from work-related safety and health hazards with promotion of injury and illness prevention and advance well-being for workers (NIOSH, 2015). Fundamental influences on employee well-being are rooted in the design of work because design provides for a differentiated, targeted approach to address the most vulnerable issues affecting the workplace: management systems, safety hazards, or productivity hazards (Karanika-Murray and Weyman, 2013).

Equipment and mobile plant used in heavy industry pose a major occupational hazard, particularly given their use in close proximity to pedestrian workers and other plant. The design is likely to have been focussed on durability and task outcome rather than the optimum interface with operators and maintainers (Horberry, 2011; and Horberry et al, 2011). Participative approaches to design improves work safety and health (Burgess-Limerick, 2010; Burgess-Limerick et al, 2011; Cantley et al, 2014; Grandjean, 1986; Horberry et al, 2011; Horberry et al, 2014; and Karwowski, 2012), reflects positive workplace culture (Lallemand, 2012) and exhibits change-readiness in leadership (Kramer et al, 2009 and Village and Ostry, 2010). Such an approach also enables duty holders to discharge their duty to consult with workers under the Australian work health and safety legislation.

Human-Factors Design Strategies: Design OMAT, EDEEP, and Hazard Patterns

There are a number of human-centred design tools developed for use in the mining sector which may be applicable to road construction equipment. Design for Operability and Maintainability Analysis Technique (OMAT) is a human-centred design approach that is a hierarchical, task-based procedure and focuses on risks for operators and maintainers in relation to the interface between people and equipment (Burgess-Limerick et al, 2012).

Design OMAT is an integral component the Earth Moving Equipment Safety Round Table (EMERST) Design Evaluation for Equipment Procurement (EDEEP) process. The EMERST is a collaboration of multi-national mining companies which formed in 2006. Its purpose is to engage with equipment manufacturers to facilitate design improvements for mining equipment (Burgess-Limerick et al, 2012). The design philosophies include eight key functions associated with human-equipment and system interface: 1) Access and working at heights; 2) Tyres and rims; 3) Exposure to harmful energies; 4) Fire; 5) Machine operation and controls; 6) Health impacting factors; 7) Manual tasks; 8) Confined spaces and restricted work areas.

The design philosophies outline potential unwanted events (PUE's) associated with foreseeable variability in human behaviour and equipment use. These have been grouped to include 20 exposures including: falls; blocked emergency egress; contact incident; caught between moving objects; wheel assembly, rim, or tyre failure or explosion; fire; manual tasks; collision; loss of machine stability; inadvertent or erroneous operation of a control; incorrect interpretation of a display or label; failure to respond to an alarm; extreme temperatures; respirable dust; diesel particulate material or other particulates; noise; whole-body or peripheral vibration; failure of control system; and irrespirable atmosphere in a confined space.

The study of the interrelationship of person, equipment, environment and task in terms of 'hazard patterns' is recognised as a human-factors practice (Burgess-Limerick and Steiner, 2007; Cooke, 2014; and Drury and Brill, 1983). The possibility of extending this layering technique to include design and health considerations linked to a hazard and task pattern was explored in this study.

Objectives of the Study

The aim of this study was to investigate the potential for improvements to vehicle design that may mitigate safety risks and positively affect worker health through the use of a human-centred design approach. An asphalt job truck review was chosen for the investigation.

Methods

An asphalt job truck was chosen for review within a road construction business unit of a multi-national construction firm (Refer to Figure 1). This machine was chosen owing to its routine and regular operation and interface with work crew and mechanics. Supporting material detailing the applications of human-centred design review of mining equipment was provided. A request was made to the regional contracting operations manager to allocate staff time and resource for this review: the manager provided approval and introduced the idea to other relevant managers, including the local assets and maintenance managers, the local safety advisor, and the regional contracts manager. Research gatekeeper approval was obtained as was individual informed consent from work crew and mechanics or representatives involved in the review. Ethics approval was obtained from The University of Queensland.

Figure 1: Asphalt job truck observed during a roadworks project.

Field Visits and Observations

Six field visits were made (including one visit at the depot) with 49 general activities attributed to this project. Field visits allowed semi-structured and unstructured interviews with work crew, mechanics, team leaders, foremen, and project managers. Naturalistic and simulated task observations were undertaken during day and night shift operation. Five field visits were attended by the local safety advisor and two visits included meetings with field and workshop mechanics at another region. Field visits were coordinated according to crew availability, ease of access, and operational demands that would permit consultation with the investigator. Conversations were conducted as operation demands allowed, except for one structured meeting held with a job truck operator at the depot, and one held with a small group of volunteer maintenance workers (n = 3), including the maintenance manager, in the other region. The activities undertaken included: participatory task analyses (including taking images, video playback, measurements for reaches, exertion requirements, and body mechanics); generation of a job analysis report; hazard identification; task simulation at the depot; field visits as described above; application of a truck design checklist and reporting; dissemination of literature to inform the managers of the process and evidence for practice; coordination and facilitation of a participative design review; participative application of the risk rating tool (e.g. EDEEP); consultation with other business units including transport teams; and internal communication of findings with verbal and written reports. Additional consultation with industry experts and national procurement teams occurred and face to face presentation of findings were made to a regional management team and a national product group within the company using power point media. General findings were shared with the regulator in a transport advocacy group and conversations were held, also, with a representative of the Truck Industry Council as to design improvement methods that may be considered among manufacturers. A representative of the board of the Australian Trucking Association was also informed of the results.

Design-OMAT & EDEEP Application

The Design-OMAT six-step process was undertaken: critical task identification, hierarchical task analysis, hazard identification and risk determination, control strategy development, feedback and action planning, and risk register documentation (Horberry et al, 2011). To mobilise and implement this practice, additional organisational activity was required. Table 1 (adapted from Horberry et al, 2011) provides a description of the Design-OMAT steps and the supplemental, supportive activity undertaken to support the process within an existing management framework. After completing the task analysis, with information provided by the structured interview process and use of the vehicle checklist described below, the EDEEP risk matrix was reviewed and completed during two meetings held with the safety advisor and workshop mechanic. The risk matrixes required identification of hierarchical tasks, potential unwanted events (informed by historical occurrence, near misses, near rights – where workers have had to intervene to assure optimum performance even if the action is contrary to written procedure, and an imagined reality of what may be), the link made to relevant, established design philosophy, and perceived likelihood and consequence of the event. A total inherent risk score is generated by the tool when tasks are considered and risk-rated with regard to framework of the 20 potential unwanted events. The tool requires identification, also, of current control measures, evaluation of these controls, and recommendations for effective control implementation. Periodic checks were made with crew and operations managers to affirm the validity of information recorded and rated.

TABLE 1: WORK FLOW PROCESS

Organisational Support Activity	Design OMAT	Description
a.		*Management consultation to support design trial and for equipment selection*
	1.	Prioritisation of critical tasks
  b. c.	2.	Conducting task analysis: identification of the step-by-step physical, cognitive, or communicative sub-components of the task required within the job role: multiple on-site visits coordinated with work crew *Truck measurements and analysis with worker consultation: multiple visits at depot and/or on site* *Iterative documentation of findings with workers and stakeholders*
 d. e.	3. 4. 5. 6.	Hazard identification, escalation, and risk determination *Participative review of findings and application of EDEEP tool* Control strategy (solution) development Consultation with workers through seeking feedback (occurs throughout the process) Maintenance of a risk register imbedded in project management planning *Presentation to management and procurement for process and design review*

Supplemental Checklist

For the purposes of description and measurement, a checklist of the history of vehicle operation and general features was developed. These included items such as primary vehicle functions; injury or incident history; a discomfort survey; mechanical care requirements; administrative controls advised; and planned procurement schedules. Features were included such as seating systems; general visibility associated with driving or critical tasks; stairwell measures for ingress/egress; grab rail dimensions; hand and foot control types and methods (lay-out, number required to operate, type, shape coding, level length coding, colour coding, functionality or direction, and other comments by workers); alarms, indicators and general noise or haptic alerts; access points to the truck body; pinch points associated with cabinetry or other associated equipment; fixed and portable equipment transported; whole-body vibration exposure measures; steering systems; and proximity sensors. The tools and raw material transported and associated environmental conditions were also considered. This checklist, along with the application of the EDEEP risk management tool, provided for a semi-structured interview process. The EDEEP findings were elaborated using hazard and design layering (Refer to examples provided in Table 2 and 3).

TABLE 2: HAZARD TO DESIGN LAYERING: INGRESS AND EGRESS

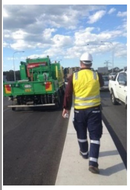
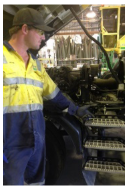
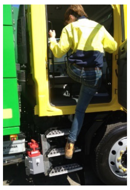
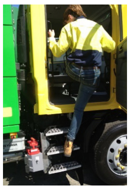
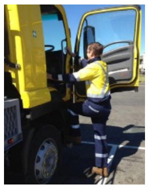
	Hazard to Human-Centred Design: Layers: Ingress/Egress						
Item	1	2	3	4	5	6	7
Equipment	Asphalt Job Truck	Asphalt Job Truck	Asphalt Job Truck	Asphalt Job Truck	Asphalt Job Truck	Asphalt Job Truck	Asphalt Job Truck
Location		Rear of Dual Cab: Steps	Rear of Dual Cab: Steps	Rear of Dual Cab: Steps	Rear of Dual Cab: Steps	Rear of Dual Cab: Steps	Rear of Dual Cab: Steps
Task			Ingres / Egress	Ingres / Egress	Ingres / Egress	Ingres / Egress	Ingres / Egress
Mechanism				Slip/Trip/Fall	Slip/Trip/Fall	Slip/Trip/Fall	Slip/Trip/Fall
Behavioural Risk (Tactics inconsistent with written proceedure)					Forward facing egress; jump versus step out	Forward facing egress; jump versus step out	Forward facing egress; jump versus step out
Design Philosophy						Night Visibility; Cascade Steps; Neutral Alignment (truck body and steps); Initial Step < 500mm; <= 5mm differential among risings; Reaches and heights vast anthropometric range; non-slip grip; Ease in rail reach 90 – 110% of stature of broad population range; clearance of rear steps and engine components; fold-down tiered stairwell where possible	Night Visibility; Cascade Steps; Neutral Alignment (truck body and steps); Initial Step < 500mm; <= 5mm differential among risings; Reaches and heights vast anthropometric range; non-slip grip; Ease in rail reach 90 – 110% of stature of broad population range; clearance of rear steps and engine components; fold-down tiered stairwell where possible
Health Opportunity							Involve Workers in Re-Design; Physical conditioning with safe step up/down; more gender inclusive design strategy
Image(s)						 FRP grating high slip-resistance material	

TABLE 3: HAZARD TO DESIGN LAYERING: DIESEL BATH BUCKET

	Hazard to Human-Centred Design: Layers: Diesel Batch Bucket						
Item	1	2	3	4	5	6	7
Equipment	Diesel Bath Bucket	Diesel Bath Bucket	Diesel Bath Bucket	Diesel Bath Bucket	Diesel Bath Bucket	Diesel Bath Bucket	Diesel Bath Bucket
Location		Transported from truck body to screed arm lug attachments	Transported from truck body to screed arm lug attachments	Transported from truck body to screed arm lug attachments	Transported from truck body to screed arm lug attachments	Transported from truck body to screed arm lug attachments	Transported from truck body to screed arm lug attachments
Task			Used to carry and contain diesel to clean tools. Physical demands: Lift, lower, 2-person carry, adhere and attach	Lift, lower, 2-person carry, adhere and attach	Lift, lower, 2-person carry, adhere and attach	Lift, lower, 2-person carry, adhere and attach	Lift, lower, 2-person carry, adhere and attach
Mechanism				Sprain/Strain; Compression Injury (pinch-point)	Sprain/Strain; Compression Injury (pinch-point)	Sprain/Strain; Compression Injury (pinch-point)	Sprain/Strain; Compression Injury (pinch-point)
Behavioural Risk (Tactics inconsistent with written proceedure)					Drop one end; over-exertion; place on screed walkway versus side arm	Drop one end and fail to communicate in 2-person lift; over-exertion; place on screed walkway versus side arm	Drop one end and fail to communicate in 2-person lift; over-exertion; place on screed walkway versus side arm
Design Philosophy						Reduce 55kg to <20kg; transit option via paver not job truck; improved grip handles; sump plug drainage; review environmental concerns and use of non-diesel release product	
Health Opportunity							Involve Workers in Re-Design; Physical conditioning in safe manoeuvres; less time required; more gender inclusive design strategy
Image(s)							

An Appreciative Approach

Appreciative Inquiry was engaged by the investigator during worker and manager consultation to elicit contributions to the design strategy (e.g. Cooperrider and McQuaid, 2012). This method provided for unstructured interviews to complement the semi-structured interviews when referring to checklists. To prompt change ideas, the investigator used provocative language and employed guiding principles of anticipation and positivity. A line of questions involved acknowledgment and appreciation of what was working well (rather than only perceived hazards), collaborative idea-sharing, best-practice examples from other industries, and the consideration of a possible shared destiny rather than any established, predictable, prescribed deliverables or assumed outcome (e.g. Bushe and R-Kassam, 2005; and Johnson and Leavitt, 2001). For example:

> We have the chance to investigate this truck. This is an experiment. What would you like the business to know?
>
> What is the best aspect of operating (or repairing) this truck and what can you dream would make it even more enjoyable?
>
> If your transport division changed the material of their fleet step well from those with metal, bull guards, and plastic to a FRP/GRP fibreglass grid high-degree slip resistance material. Would that improve your step well?
>
> The organisation's job safety analysis advises 3 points of contact and cab facing ingress/egress. However, at least 30% of the time I have observed front-facing egress among the crew. Can you tell me about why they may feel more comfortable facing front?
>
> If funding support were unrestricted, what could improve efficiency of your work with this machine today?

This appreciative approach was engaged during interactions with managers, team leaders, capital expenditure coordinators, a supply chain representative, other business units, and finance teams. Questions were posed to prime these representatives to consider that a new predictive design approach may be possible, finance and process approvals need not be cumbersome, and that it could be freeing to discard old procedures and systems.

Results & Discussion

Design-OMAT and EDEEP Findings

Findings from the Design-OMAT job truck review revealed 3 serious or major risks (fatality or severe to moderate disability) and 4 moderate risks (potential injury relating to musculoskeletal disorder) as shown in Table 4. Overall, 15 hazards were identified and strategies for design improvement were provided. The organisation prepared for some changes to be made by workshop mechanics but, ultimately, favoured the development of procurement specifications that would shift the responsibility of design improvement to the truck body build supplier

TABLE 4: TOP 7 ISSUES RAISED: EDEEP TOOL AND DESIGN CONSIDERATIONS

No	Consequence	Likelihood	Description	Design Considerations: Preliminary
1.	Major	Unlikely	Crane lift failure risk for loss of machine stability or hitting object or person	Capacity routinely engineering rated; training to workers; escalate for review with management as to cost-benefit; assess rural versus metro use
2.	Serious	Possible	Retrieval of diesel bath bucket: Manual task exposure with risk for sprain/strain	Referral for further ergonomic risk assessment; re-design diesel bath bucket, paver lug attachment, storage and transportation strategy
3.	Serious	Possible	Retrieval of vibe-plate and jackhammer: manual task exposure - sprain/strain risk	Independent quick-activation control for hydraulics of lift platform or cradle release with hydraulic or air ram to lower items to ground
4.	Medium	Possible	Access to battery behind electrical housing: manual task exposure – sprain/strain risk	Specify clear access to battery housing for ease in replacement in depot and in the field.
5.	Medium	Possible	Rear cab egress: fall from height	Redesign stepwell for uniform step height, swing away access (for mechanics) and improved visibility and access; add night-time lighting; add coated safety high-vis yellow tread.
6.	Medium	Possible	Front cab ingress/egress: fall from height and sprain/strain	Replace plastic top tread with metal step and add coated safety high-vis yellow tread to steps; design for even risings $\leq$ 5mm variation; add focal lighting and strip lighting; design for visibility day and night.
7.	Medium	Possible	Hard edge and heavy weight cabinet lids: pinch point risk	Use foam insert and install gas struts to prevent hand injuries from pinch point risks

The assessments included day and night time observations to capture naturalistic study when and where the equipment may be operated or accessed. This contributed to the breadth and scope of hazard identification. .

Short-, mid-, and long-term recommendations for redesign or improvement to the procurement specifications were prepared. Several short-term design improvements were authorised in-house and included redesign of the diesel bath bucket to reduce its carrying weight and provide ease for attachment on the paver side arm (Refer to Table 2: Hazard and Design Layering: Diesel Bath Bucket).

In one vehicle, mechanics installed lighting to the vehicle door strips to improve night visibility. Gas struts were added to tool box lids with foam inserts to help address pinch-point hazards. Another short-term intervention identified by mechanics and crew was their perceived need for training by the truck body-build supplier for the crane operations. Metropolitan crew could not identify a need for the truck crane while regional teams stated that they used the equipment at least once a quarter. This suggested that task-specific work requirements may differ in different regions and equipment needs may vary accordingly. Savings could be found if the crane was not required in metropolitan area trucks. Similarly, reports that the overhead hang and shade cloth on the truck body was never used suggest potential savings.

The work crew and mechanics reported issues such as:

> "(Our) head hits the rear overhead hang when we climb the stairwell to the body of the truck".
>
> "The guys do not use the lift platform to retrieve the whacker packer vibe plate (up to 80kg) or the jack hammer (40kg) if the truck is not already operating; it takes too long to wait for the hydraulics to kick-in".
>
> "Workers typically exit the rear of the dual cab forward-facing as the design of the steps (are not conducive) to cab facing exit (egress) (difficult to see, flush with the body, require legs to cross midline)".

Impact on Hazard Reporting Process

The findings were significant given that workers had not previously reported hazards related to the job truck. Further, multiple site visits and conversations were required to elicit content reporting. Initially, work teams were reserved and made statements such as, "*This is just how the machine is delivered to us. This is construction and heavy industry – nothing is designed for comfort*".

The only previous hazard report on file related to the findings of this experiment was with the difficult access, carrying effort, and tactics required to attach the diesel bath bucket to the paver side arm (Refer to Table 2). However, crew reported that this hazard report had been made over a year prior with an external investigation authorised, however no change in equipment or task method had occurred. When asked why there were no previous reports of the other hazard issues or potential cost savings with equipment that was not required, the workers ascribed this to not believing that there was potential to affect change in large machinery and equipment design and they had never been asked. Workers uniformly reported that they appreciated being asked their opinion about their interface with the equipment, even if some did not believe that the organisation would do anything with the findings.

Hazard reporting methods engaged routinely in the past included the development of a job safety analysis of equipment or work methods completed by a corporate safety advisor. The recommendations predominantly constituted behavioural recommendations and did not address design. For example, slips/trips/fall hazards were addressed with the recommendation of "cab facing egress and maintain 3 points of contact" and "operators should be aware of their surroundings". This study showed that the design of the rear cab steps was not conducive to use in this way (Refer to Table 1). Hazards were otherwise reported during tool box meetings with team leader facilitation encouraged during conversations and observations with supervisors (key performance indicators required supervisors to hold these regularly with work crew), and permitted spontaneously.

Additional Unanticipated Findings

News of this job truck review activity and findings was shared among work crew. A spray seal team learned of the activity and took the initiative to convince management to make changes to their tool box struts and foam inserts. They also took whole-body vibration measurements using the WBV iOS application to agitate for replacement of their rear seat upholstery.

The truck review checklist was a useful guide to complement the Design-OMAT process. It aided in conversations held among work crew, safety, operations, engineering, and procurement teams. It ensured, also, a comprehensive review of truck features and aided the investigator to develop a shared understanding of the work crew's language.

The national procurement manager reported that he found the design recommendations to be objective, transferrable and evidence-based. The design process brought together diverse business units which, until that time, had not developed a unified position regarding truck design and body build procurement specifications. There were numerous opportunities for improvement of the equipment, as described in this report, which had not been previously identified through generic and traditional hazard reporting processes.

Challenges Amid Opportunities

EDEEP risk ratings confused some of the team members with regard to the assignment of numeric values and ratings assumptions, but the link to the design philosophy was helpful to inform potential critical control intervention and design strategy. Further, video recording playback was found useful by design review teams, more so than still imagery, of critical work tasks. Overall, this project illustrated the suitability of using the Design-OMAT task-based risk assessment method with the EDEEP risk and design related tool for road construction equipment. Managers reported also, that the hazard and design layering helped illustrate the findings of the project in a comprehensive manner and they appreciated how this added to the weight of design considerations.

The Design-OMAT practice did not occur in isolation from other organisational activity. Significant effort was required to launch and sustain the project and therefore time and resource were consumed. In fact, some managers reported that they thought it a cumbersome process. The 6-step Design-OMAT process, while helpful to outline critical work flow project requirements, did not sufficiently describe the ancillary, inter-related, and supportive functions required to support the project. It did not speak, also, to the need to repeat steps, such as field visits. The use of the Appreciative Inquiry method was critical to the acceptance of the experimental design and encouraged engagement. This method encouraged reporting of a design opportunity.

Conclusions

Human-centred design review of construction equipment within a host organisation may address at least five of the seven national Action Areas of the Australian Work Health and Safety Strategy 2012-2022: healthy and safe by design, supply chains and networks, health and safety capabilities, leadership and culture, and research and evaluation (Safe Work Australia, 2012). To initiate this practice, an organisation may have to take the risk of allocating resources without any expectation of what may be discovered – a phenomenon of predictive design. In this research involving a design review of an asphalt job truck, the findings were extensive, revealing significant design considerations that had not been reported with previous and routine hazard reporting methods. A hierarchical task-based design review process and risk-reporting method, Design-OMAT with the application of the EDEEP tool, provided this rich data.

A semi-structured, task-based method is beneficial in identifying design deficiencies and opportunities for a road construction job truck. The collaboration of road construction operators and maintainers with designers and engineers may be helpful to reduce safety and health risks associated with equipment use. Consultation with workers may provide the most meaningful and relevant findings. The positive feedback from workers suggested that they prized their involvement. The practice of Appreciative Inquiry was useful to engage workers and elicit information: 15 hazards were identified with recommendations for design improvement when only one of these was known to have been previously reported.

There is an emerging trend in Australia for evidence of human-centred design strategies to be demonstrated throughout the supply chain of equipment and service (refer to the Transport Asset Standards Authority of the Department of Transport for New South Wales requirements for Authorised Engineering Organisations: Transport for New South Wales, 2015). The findings in this case review support this initiative: the hazards may have been mitigated if human-centred design had been required of the manufacturer or truck body-build supplier. It may be reasoned that a shared vision in human-centred design with suppliers and manufacturers is required if industry is truly going to develop superior work design for safety, health, and productivity. Further research in human-centred design and sociotechnical systems is recommended as is the sharing of risk management and design innovation across industries.

Paper originally presented at the Safety Institute of Australia: SIA Visions Conference: Queensland, 14–15 July 2016

Acknowledgements

We would like to thank Boral Asphalt Queensland, Boral Construction Materials Pty Ltd, for hosting this project.

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