

Human Centred Design of Equipment: Lessons from the Mining Industry

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Human Centred Design (HCD) has been successfully used in the design of road vehicles, medical equipment and consumer products. It is now beginning to be applied in both the mining and the maritime domains. HCD also closely links with the USA Prevention through Design initiative for ‘designing out’ hazards. This paper will describe an ongoing international collaboration that has the objective of increasing the uptake of HCD in mining. HCD for the mining industry will be defined and key principles, processes and tools outlined. Following this, the benefits of a HCD approach will be outlined, examples of mining HCD successes noted, and barriers towards greater uptake of this approach in mining summarised.

Shipping shares many commonalities with mining terms of large, high-risk, expensive and often legacy equipment that may have new systems added in a piecemeal manner. Both industries are currently experiencing a rapid growth in the deployment of smart devices, tele-operation systems and new equipment. It is therefore particularly important that equipment and new technology are designed to be safe, effective, acceptable and usable by focusing on the end user. This paper will describe the key features of a mining HCD approach and how this might be applicable to the maritime domain.

Keywords: Mining, Human-Centred Design, Equipment, New Technology

1. Background

HCD has been widely used in the design of road vehicles, medical equipment and consumer products (Rouse, 2007). As a general process, it aims to make equipment and systems more usable and acceptable by explicitly focusing on the end-user, their tasks and their work environment/use context (Gulliksen et al, 2003). Equally, it requires that users and other stakeholders are involved throughout the design and development of the equipment or system (Giacomin, 2012).

HCD has not yet been widely applied to the design, development and deployment of equipment or new technology for the mining/minerals industry (Horberry, Burgess-Limerick and Steiner, 2011). Equally, the number of mining HCD professionals around the world is still quite small (Horberry, Burgess-Limerick and Steiner, 2015). Researchers from the National Institute for Occupational Safety and Health, Office of Mines Safety and Health research (NIOSH OMSHR), the University of Queensland and Monash University have been examining the benefits of HCD for mining. Our aim is to encourage the application of HCD-style processes in NIOSH OMSHR-funded projects as well as by Original Equipment Manufacturers, mining technology developers and mine sites.

2. What is mining HCD?

A definition of HCD that is frequently used by the human factors community is:

‘An approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying human factors/ergonomics and usability knowledge and techniques.’ (ISO 9241-210, 2010)

This HCD definition is readily applicable to mining industry equipment and new technologies (Horberry et al, 2015). The key aspects are a continual focus on mine site users, their actual tasks and the mine site environment/use context. For example, focusing on a new technology such as a proximity detection system for a large mining vehicle, the description can be operationally defined as:

‘An approach to proximity detection system design and development for mobile mining equipment that aims to make the system more usable by focusing on the actual mine site use of the proximity detection system and applying human factors/ergonomics and usability knowledge and techniques.’ (Horberry et al, 2015)

For ISO 9241-210 (2010), Gulliksen et al (2003) and Rouse (2007) and Horberry et al (2015), the essential aspects of HCD are:

- The aim is to bring benefits such as improved productivity, user well-being, accessibility, fewer errors and reduced risk of harm.
- The focus is on making systems and equipment more usable, useful and acceptable.
- The vision is for fit for purpose technologies to be well integrated with the demands of the workplace
- This is achieved by early and continual focus on users and their tasks/use environment in an iterative design process. This is often not sufficiently addressed in mining new technology development (Horberry and Lynas, 2012).
- HCD is often now used as an umbrella term, covering other terms such as ‘user-centred design’, ‘interaction design’ or ‘ergonomics design’.

Of course, all of these aspects of HCD are applicable to equipment and new technologies used in the global mining industry as well as to the maritime industry.

3. Key principles, processes and tools in mining HCD

A wide variety of human-centred approaches can be used in mining HCD (Horberry et al, 2011). Building on the ISO HCD standard (ISO 92410-210, 2010, a summary of the essential principles, processes and tools for mining HCD is shown in Table 1.

Table 1. Essential principles, processes and tools for mining HCD, following ISO 9241-210 (2010) and Horberry et al (2015).

Principles (‘why’ and ‘how’)	a. The design is based on an explicit understanding of the user, their tasks and the use context/ environment. b. Users and other stakeholders should be involved throughout design and development. Their needs, wants, and limitations are given attention at each stage of the design process. c. It fits the equipment, system or interface to the user, not vice versa.
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	d. The design is iterative, evolutionary and incremental.
	e. The design is integrated with the wider work system organization.
	f. It is driven by user-centred safety evaluation criteria during the design process and for the end product.
	g. A multidisciplinary design team is used, including HF/usability champions.
	h. The HCD process must be customizable: capable of being adapted to different mine sites conditions.

Processes (‘when’ and ‘where’)	1. Explore/investigate (understand the need and context of use, and specify user requirements).
	2. Produce/create design solutions based on the exploratory/investigation stage.
	3. Evaluate the design (at all development stages).
	4. Manage the process/feedback information to designers for the next iteration.

Tools (‘what’)	i. To investigate/explore (eg observations, ethnographic studies, and task analyses).
	ii. To provide input into stages of the design process (eg anthropometric data sets, participatory design sessions, or human factors guidelines).
	iii. As criteria in the evaluation process of designs (e.g. user acceptability trials, usability audit checklists, or long-term monitoring of the product/system).

4. Benefits and barriers to Mining HCD

4.1 HCD Benefits

As noted by Burgess-Limerick et al (2011), there are likely to be considerable benefits obtained through greater use of HCD in mining. The three summary case studies later will show that successful products can be developed in the minerals industry by using HCD approaches.

Mining has not yet widely used HCD approaches. But in other workplaces that have routinely obtained extensive user involvement during design (eg aviation, medicine and defence) the following benefits can be obtained (ISO 9241-210, 2010; Howard, 2008; Gulliksen et al, 2003):

- Increased user productivity/fewer errors
- Decreased training costs
- More accurate end-user requirements and better system usability
- Decreased user support
- Avoiding costly system features that are unwanted or irrelevant
- Improved operator acceptance and system understanding

As part of recent collaborative work between USA and Australian researchers, a database of new mining technologies was created building on previous work by Horberry and Lynas (2012). One clear issue from the database was the lack of operator focus: only about 1/3 of the entries explicitly mention how the technologies might impact upon the operator (Horberry et al, 2015). It is likely that little use has been made of HCD methods for the majority of the technologies.

Experience from other industries has shown that unless such human element issues are considered then the technology is likely to either fail or at least not work optimally (Burgess-Limerick et al, 2011). So, the widespread adoption of HCD processes and involving operators at all stages of mining technology development and deployment are key issues. This is equally applicable to the maritime industry.

4.2 HCD Barriers

Part of the reason for the current lack of HCD in mining might be due to the barriers or obstacles with deploying HCD (Horberry et al, 2011). As seen in table 2, the recent USA and Australian collaboration identified four classes of HCD barriers.

Table 2. Four classes of mining HCD barriers from Horberry et al (2015).

Barrier Category	Examples
1. The Nature of Mining	Technology-centred design currently dominates.
	A conservative & risk averse industry. Mine sites do not want to be first to deploy unproven technology. Mining customers not asking for HCD during equipment/technology procurement.
	Technology is often slow to be developed, sometimes longer than working life of the mine.
2. The Nature of Humans	Wide variety of user populations being designed for - often very different from the designer's own.
	A diverse range of stakeholders - not just the end-user, but also maintenance staff, supervisors etc.
3. Design practice	Mine site access difficulties for designers.
	Designers unwilling to change - HCD not part of their core training - use their intuition instead.
	Other competing priorities (eg cost). Especially for smaller OEMs/developers.
	Technology approval process and mandates often result in little time being available for Human Centred Design processes.
4. Selling HCD	Few case studies of HCD to 'sell the HCD vision' and few cost benefit analyses.
	Lack of accessible HCD guidance except ISO 9241-210 and Horberry, Burgess-Limerick & Steiner book.
	Lack of understanding of (or even resistance to) HCD, usability or HF by mining customers.
	Lack of early involvement- HCD/HF often only brought in when the design is largely fixed.

For both the mining and maritime industries it is argued here that the largest immediate impact may result from the category of 'selling HCD'. More accessible HCD methods may help. Case studies of successful HCD initiatives and forming an educational strategy for the industry can also be useful.

5. Mining HCD success stories

Three short examples of HCD successes in mining are given in table 3 below. They show that HCD can be applied to different design phases – for example, revising an existing product or helping to create a new technology. Also, the examples reveal that a wide range of methods can be used: including task analysis and user tests. One implication is that it is never too late to integrate human centred design processes with mining equipment and technologies; however, the further into the design process it is implemented, the more costly it becomes to provide effective HCD.

Table 3. Mining HCD successes

Case study example	The issue examined	What was done?	What was achieved?	Conclusion
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Evaluating Underground Roof Bolter Controls by Steiner (2014).	Injuries from roof bolters can be due to design deficiencies with the bolter's controls.	Began by reviewing injury narratives, then conducted tests with roof bolter control design to help limit future injuries.	Designing equipment controls to maintain compatible directional control-response relationships can reduce errors. Operator visual feedback critical.	Assessing incidents then testing alternatives shows that bolter controls can be re-designed to be better suited to human use.
Shovel technology by Cloete & Horberry (2014).	Examined two prototype shovel technologies: load assistance & collision avoidance.	Did task analysis of shovel operation, then a human reliability technique used to see where shovel operation task could fail, so where there was most need for this support technology.	Found that the key Error Producing Conditions could be removed with the two technologies together. So the systems addressed the most error-prone aspects of shovel operation.	HCD can work well even after an early systems have been designed. Understanding user needs was highly beneficial.
Adequate Underground Mine Lighting by Sammarco et al, (2011).	Adequate lighting underground to work safely difficult due to dust, confined spaces, older miners etc.	New LED cap lamps developed: enhancing the color and distribution of light to make hazards more visible.	Better hazard detection and generally better illumination for older miners compared to current LED cap lamps.	Improved cap lamps can be developed based on end user & task focus, iterative design & testing.

6. Can the Mining HCD approach be applicable to the Maritime Industry?

The maritime industry has much in common with the mining domain: both regularly use large, expensive and legacy equipment (Grech, Horberry and Koester, 2008). For new technologies, in both domains they are mainly developed from a technology-centred perspective and they are often added in a piecemeal manner into the vehicle/ship. As a result, issues like operator overload from too many visual warnings, poor operator acceptance of new technologies and a general lack of human system integration can be a significant issue in both industries (Grech et al, 2008, Horberry et al, 2011).

For both of these high-hazard work domains, the earlier-mentioned benefits and barriers for HCD are equally applicable. Although there might be a slightly different regulatory focus and different legislative processes (eg the MINER act and MSHA in US mining versus the International Maritime Authority) both domains employ a wide range of equipment, often have a multinational work force, need to function in harsh environmental conditions and have issues with equipment standardization (Horberry et al, 2015). The key principles, processes and tools for mining HCD outlined in Table 1 are applicable to the maritime industry: a focus on users and their tasks, a consideration of the work environment, using an iterative design process, designing equipment to fit the user and using human-centred evaluation methods (eg user trials) are all of key importance.

In the mining industry, a human centred safe design process called 'SiDE' (Safety in Design Ergonomics) has recently been used to help successfully redesign equipment (Horberry, 2014). This

is a task based, risk assessment and safe redesign process that starts by identifying key tasks (operational and maintenance) with a piece of equipment. In a participatory ergonomics workshop of end users and designers it then breaks these key tasks down into sub-tasks, identifies risks at each stage, and then develops redesign solutions. The use of such a process in the maritime industry is strongly recommended.

7. Conclusions

The three case studies of mining HCD show that it can be a successful and effective process. The key feature that binds all them together is a relentless focus on users and their tasks throughout the iterative design process. For our work in Mining HCD, the next stage of this project will be to help prepare educational campaign and implementation plan material that NIOSH can subsequently use to develop a roadmap for HCD.

Ultimately, HCD should become the way things are done for equipment developed, operated and maintained in both the mining and maritime domains: effective design for human use. HCD is valuable, necessary and timely.

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