

Research in-progress

A review of Australian human factors research and stakeholder opinions regarding mines of the future

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Abstract

Background: This paper focuses on human factors in the mining and the minerals industry in Australia. It begins by outlining some of the key aspects of this occupational domain from a user-centred design or human element perspective. Within the industry, significant variation exists in terms of equipment used, mine designs, company policy and equipment procurement and modification procedures. Thus, the scope for human factors and ergonomics (HF/E) extends from physical ergonomics through to cognitive engineering and wider organisational interventions. **Aim:** This paper presents an overview of recent HF/E work in this domain in Australia, and then describes in more depth an ongoing research project. The aim of this research is to identify the emerging trends and HF/E issues associated with automated mining equipment, to obtain interviewee descriptions of their visions for “mines of the future” and gather information relevant to the organisational/social implications of this vision. **Method:** Using a semi-structured interview process, twenty interviews were conducted across a broad range of personnel associated with the implementation of automation into the mining sector. Interview questions were largely structured around asking the interviewee to identify what they believed were the emerging trends and HF/E issues associated with automated mining equipment. **Results and discussion:** For clarity of reading, the results and discussion sections were combined as many of the themes emerging from the interviews require interpretation rather than stand alone reporting. The following broad themes emerged from interviewee perceptions of “mines of the future”: technological implications, the associated skills required to operate the equipment, how the equipment would be maintained and organisational issues, such as the culture and workforce change. The overall results are presented in these broad themes. **Conclusion:** Overall, it is concluded that the minerals industry presents significant challenges and opportunities for HF/E professionals. Issues such as automation, safe design, and workforce skill requirements and organisational issues emerged as key areas of future research and development work.

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Background

The minerals industry is a major contributor to the Australian economy and within the industry significant variation exists in terms of company health and safety policy and procedures, equipment used, mine designs, as well as equipment life cycle issues such as procurement, modification and decommissioning procedures [1]. Thus, the scope for HF/E extends from physical ergonomics, cognitive engineering, through to organisational/social implications [2].

Automation and remote operation technologies continue to be investigated, trialled and implemented by Australian mining companies and research organisations for the purposes of improving production efficiency, safety, working conditions and environmental performance and to address a labour shortage. Automation is largely seen as the pathway to “the mines of the future” [3].

Like other areas of occupational health and safety, HF/E is evolving and becoming more integrated into both initial equipment design and overall work management systems [2]. As more is learned about the complex interaction between organisational, cognitive, environmental and physical factors in the cause of work-related illness and injury the more focus is directed to prevention, or at least toward significant reduction, in these conditions [4].

As such, the scope of HF/E work in this industry is wide. Current research trends in the mining sector include work in the area of physical ergonomics relating to manual tasks and working postures [4, 5,6], vibration [7], workspace layout and equipment design [2], cognitive factors and fatigue [8, 9], control room issues [10,11], incident investigation [12], equipment design and emerging new technologies [13,14], environment aspects, such as examining operator responses to factors such as temperature, dust and lighting in the mining environment [15], and organisational issues such as safety systems in high risk industries, and including human error, system safety team performance, and training [16, 17], and organisational and cultural change [18,19,20].

From such a diverse list of recent research, it is evident that overall the minerals industry presents significant challenges and opportunities for research and development in the areas of HF/E. Issues like automation, safe design, and workforce skill requirements are emerging as key areas of future work [6]. The research example provided below highlights many of these issues with respect to “the mines of the future”. Through this example we have attempted to show the depth of work evolving from the rapid technological advances occurring within the mining industry.

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Aim

With the increasing level of automation being deployed in mining, the aim of this research is to identify the emerging trends and human factors issues associated with automated mining equipment, to obtain interviewee descriptions of their visions for “mines of the future” and gather information relevant to the organisational/social implications of this vision.

The Pathway to “mines of the future”

This research example details the outcomes of interviews conducted with technology developers, mine site and corporate mining personnel, regulators and mining human factors academics and consultants. A wide approach was taken based on a model of the systems of work in the mining industry domain. The ingredients in this model include individual operators, groups/teams, technology /equipment, work organisation and the physical environment [6].

Method

Participants

Twenty interviews were conducted in total in this study. Six interviewees were mine company personnel, including senior executives, mine managers, and equipment end users - both open cut and underground mining, and coal and metalliferous mining; three interviewees were technology developers, including original equipment manufacturers; six interviewees were research scientists/human factors academics, including technology developers and workforce skill experts; three interviewees were government regulators; and two interviewees were independent consultants working in the area. Interviews were conducted over a period of three months. This time frame largely reflected interviewee availability. The participants used were chosen to reflect different stakeholder opinions in an area where automation is still largely technology focussed with a lag in mine site uptake of the developed technology.

Interviews

Using a semi-structured interview process interview questions were largely structured around asking the interviewee to identify what they believed were the emerging trends and human factors issues associated with automated mining equipment, building on the research conducted by Lynas and Horberry [1]. The current work additionally sought to gather interviewee descriptions of their visions for “mines of the future” and gather information relevant to the organisational/social implications of this vision.

Questions were structured so as to gain a level of understanding of interviewee experience, exposure to recent and emerging technologies, their views on key priority areas for automation and remote technologies, and limitations to application and uptake to these technologies with a particular focus on the HF/E aspects. Broadly, the topics focussed on were related to the technologies emerging, operability and maintainability of the equipment and technologies, workforce skills and organisational implications of these changes.

Procedure

Interviews were mostly face-to-face with three interviews conducted as telephone interviews. Each interview was approximately 30 to 60 minutes duration. The interview transcripts were de-identified for the purpose of this work. All interviewees received an information sheet detailing the project objectives and a participant consent form prior to interview (for phone interviewees this information was emailed prior to the telephone call). Interviewee confidentiality was assured and all information was de-identified prior to the production of any reports or publications.

Results and discussion

For clarity of reading, the results and discussion sections have been combined as many of the themes emerging from the interviews require ongoing interpretation rather than stand alone reporting. From the information gathered, the following broad themes emerged from interviewee perceptions of “mines of the future” – technological implications, the associated skills required to operate the equipment, how the equipment would be maintained and organisational issues, such as the culture and workforce change. The results are presented and discussed below in these broad themes.

Pathway and challenges to mines of the future

Interviewee responses were mostly focussed on HF/E implications of how they envisaged automation would be introduced onto mine sites of the future. It was generally agreed among interviewees that automation will be the dominant feature of the “mines of the future”. Those with a more technology focussed background indicated the automation concept is now “too old” and argued that more significantly we need to ask “how will we get there?” Their view was that successful implementation of large scale automation will fail unless change is incremental, flexible and customized to include areas such as mine mapping and planning, and to provide information on productivity issues.

Recently, Cunningham [21] outlined the main challenges he saw to successful implementation of automated equipment in the mining sector in the future, predicting an increased uptake of the currently available technologies and equipment, and more interest from mine management and a change in perception of what might be possible within individual mines. As a negative, he saw the long lead in time to develop and commercialize new equipment influencing the uptake of new technologies. In the mining sector this is often between 7 and 10 years, while many companies have a short-term financial quarter focus, and more often now mines operate for less than 10 years [22].

Technology implications

Many interviewees expressed the opinion that there will be no “people-less mine” in the near future, as currently too much of a technology gap exists to provide optimal efficiency required for this method of operation. Examples of comments included a need to “look outside the box” to include logistics, finance, and tele-collaboration in future planning; a move to a higher level of supervision (less mindless repetitive work, but humans to do what machines

don't do well) involving "keeping humans in the loop"; a gradual shift to virtual apparatus including virtual 3D, and then eventually integration of operation and control, leading to more efficient running with lower environmental impact, but digging more.

A slightly different theme concerning automation technology emerged among some interviewees - that of not having automation as the sole focus, but rather considering it one element of the whole picture with "tele-assistance" or tele-presence a more appropriate consideration in at least the short to medium term. Interview results suggested that the complexity of the equipment involved indicated most likely it would not be "trades people" who were required as technical support; and that a high level of supervisory control (most likely remotely) would be required for remote operation to occur successfully.

At the other end of the spectrum, results from interviewees with highly technical and research backgrounds indicated they considered a quantum leap that provided a greater level of understanding of the physical environment/infrastructure/product was a viable option, given the current level of research and technological advances. Interview comments suggested this could result in invention of new ways of mining/extraction/processing which would lead to changes in mine design and production. Many interviewees envisaged integration of multiple pieces of equipment eventually leading to fully autonomous operation cycles and new automated equipment sourced as a "plug in" to the existing mine operation system.

Interviewees were consistent in their opinions that unless HF/E are deliberately part of the technology then the technology will fail. Particularly, technology developers expressed the opinion that there was a significant need to look at cognitive aspects and devise programs/equipment that will support not hinder operation. Constructing the human/machines interfaces so they were suitable for the human capability and physical behaviour and designing the technology to suit the individual, and not the other way around, was again seen as essential, particularly by both designers and users.

It appears from the interviews conducted that there are significant challenges to the pathway to automation. A significant concern expressed was that *"too much automation would mean humans would lose their capability to deal with the environment"* (for example, understanding the precise operating mode in an automated process). Discussion around the demands of automation highlighted the probability that the intellectual capacity and concentration required may in turn may induce mental fatigue or impose other cognitive limitations.

Skills implications

Educational issues for automation technologists were seen as one of the major concerns with new emergent technologies. Results suggested that currently a significant gap exists between technology and users. Several issues were raised by interviewees including skill levels, for example interviewees indicated that technicians can be trained for specific technology applications, however engineers will still be needed to interact with the technicians.

Interviewees indicated that with new automated equipment the associated technologies would require different operator skills and different ways of working compared to current and past practices. It was seen that training for new equipment would be challenging as there was uncertainty around the type of equipment that would be used and, therefore, uncertainty around the knowledge and cognitive skills that would be required to undertake problem solving, such as fault diagnosis or the correct response, in an emergency situation. Common interviewee responses were that training needs to be right, as there will be more complex work and the correct people will be needed to support the systems. It seemed operators would need training in computer software use, before being comfortable with new technologies, otherwise this may lead to a reluctance to work in a computer environment, where it may be considered that there was too much information to process and lead to mental overload.

Generally interviewees expressed the opinion that many mine employees want to live in remote communities, so there is potential for huge impact on individual town structures with a critical mass of people not required, but those who are required needing different experience levels. This in turn raises the issue of technical and educational level gaps becoming evident between those who are currently employed remotely and the levels of skill and education required for on-site maintenance and management of automated equipment located in remote areas. Many interviewees thought that those staying on site will be the interface between the mine and remote operation centre, therefore it is envisaged they will have a much more strategic role, and more likely not to be lower skilled workers, but people who are key to keep the mine running (however we should expect different activities at different mines - depending on the kind of mine operation). The general opinion of interviewees was that changes won't happen quickly, but work will be done differently - it will become more technical and most likely performed in a different location and even in a different time zone.

McAree [3] reinforces this trend in thinking. When presenting the current CRC Mining Automation Program, he indicated four gap areas needing bridging for successful automation uptake within the context of "mines of the future". While these strategies included equipment design features and technologies to effectively integrate automated machinery into mine systems, he stressed that workforce skills must be enhanced to support deployment of high-end automation technologies. In a recent article on the top ten business risks, skills shortage was ranked as the second biggest risk for mining and metals for this year and the next [22]. According to the report *Skills Australia* [23], the Australian minerals industry will need an additional 86,000 workers over the next 10 years just to maintain its current international market share.

Maintenance issues

Maintenance was seen by all interviewees as a difficult problem to solve. Many interviewees indicated the probability of the maintenance workforce being located initially at the mine site with gradual changes towards achieving a situation of most staff located remotely.

Maintenance issues provided a significant area of concern for all interviewees with almost all interviewees citing rapidly changing technologies, creating uncertainty around what equipment will be in operation, both from a systems and technology perspective. Typically, it was thought maintenance operators would most likely be younger workers, with inherently more knowledge of technology/computer use and mechanical knowledge – some interviewees thought possibly fitters and turners with real time off site “smart” assistance technology available to them. This opinion is in contrast to that of other interviewees who considered “tradies” to not have the skill level required for most of the tasks associated with maintenance of automated equipment. Multi-tasking was considered as becoming more common with the introduction of new technologies and equipment maintenance – a typical interviewee response was that particularly maintenance staff would be required to take on different roles as needed (some expressing the need for with linkages between key people becoming essential for this to work successfully). Again interviewees expressed the opinion that the equipment is very complex – and so it is most likely not tradespersons who will be required, but those with experience in artificial intelligence/technologies who will hold key responsibilities.

Many interviewees expressed concern regarding the level of basic and additional skilling operators and, in particular, maintainers required when considering the uncertainty of the type of equipment of the future automated/teleremote mine. They noted that while up-skilling will be required to manage remote/automated mining there will still be the need to be able to drive the machine, if needed (expert skills/diagnostics). A particular area of concern for most was the method of delivery of training (e.g. on-the-job or virtual reality simulation) and the ongoing maintenance of training levels, given the anticipation of the rapidly changing nature of the technologies that will be employed.

Organisational factors

During the interviews it appeared that most believed there would be some change in the dynamics of regional communities, however most interviewees saw positive impacts arising. Largely, cultural change was viewed as a positive opportunity with many envisaging greater gender equality in mining (e.g. more females employed which will lead to better treatment of mining equipment). Interviewee comment was made on the need for sensitivity and consideration of cultural heritage in some remote areas (similar to those that have arisen in Canada). Concerns were raised about the future of remote communities, where most anticipated there will not necessarily be a decrease in jobs, but certainly a change in job roles available. Overall, results seemed to indicate that automation would lead to a different make up of the community with regard to skill levels but probably not a decrease in population size.

Adjustment issues surrounding job security and fears that automation will replace jobs and changes in job role were issues raised by many interviewees. Additionally, interviewees consistently agreed that a top down management approach was needed. Interviewees commented that by nature mining was a conservative industry with the benefits of being the

‘first to market’ often not a compelling argument to adopt new technologies, that is, companies often not wanting to be first but regarding second place as good technology uptake positioning.

Differences of opinion between the different stakeholders interviewed

Largely, the interview results showed agreement between interviewees on the technological challenges and implications of future large scale automation in the mining sector; however, within the group of research scientists/human factors academics, including technology developers and workforce skill experts, opinion differed between those who believed a “people-less mine” was technologically currently available and waiting for uptake by the mining sector and those who believed there would be no “people-less” mine in the near future, rather different roles and more complex technologies. Results indicated that, while most interviewees had given considerable thought to the organisational and social implications of the emerging technologies on the communities in which they would operate, a small number of those interviewed were more focussed on the technological advantages of the equipment they were involved in developing and less on the organisational/community aspects associated with automation. Some differences in opinion within senior mine company personnel regarding the level and speed of automation intervention was noted, and in general they saw the key driver as providing a more consistent operation, while end users responses indicated they were more uncertain of the long term impact of new technologies on job roles. Consultants interviewed appeared to demonstrate a greater focus on the physical and cognitive implications of new technologies than the technology developers. Regulators were generally in agreement that automation is not fail safe and that redundancy measures need to be in place. Key priority areas seen as essential for use of automated equipment were quite specific – i.e. (i) geographic – underground coal as is a more hazardous environment (gases); and (ii) truck/excavators with focus on health and safety issues, such as vibration and dust.

Conclusion

There is a relatively consistent view within the domains of the technology developers, regulators, and company directors, mine managers and site personnel that automation is the pathway to mines of the future. How that will be achieved creates a spectrum of views ranging from the ideal “people-less” mine to a more gradual uptake of complex technologies that may be managed tele-remotely and in some instances fully remotely. Complex technologies mean advanced skilling of some parts of a future workforce, but this in some ways is hampered by the difficulty in knowing exactly what technologies will be deployed, even in the short term of five years or so into the future. Whether or not operation will be conducted remotely raises issues around not only equipment maintenance but where the workforce will be located. The impact of technological change and workforce location in turn raises significant organisational and psychosocial issues for human factor researchers.

Based on the current findings, the following trends are likely to have more research in coming years: automation; safe and inclusive design of mining equipment; working hours; macro-ergonomics; and organisational and psychosocial implications looking at the impact associated with technological change; and the changing requirements and opportunities for the remote communities impacted upon by these technological advances.

Human factors in mining is about designing to accommodate human abilities, limitations, and variability to improve safety, maintainability and productivity [6]. Research is always constrained by funding issues, but the mining sector presents interesting challenges for those working in the HF/E domain. Ideally, the creation of strong industry partnerships to assist with research funding would greatly support the ability of researchers to move forward in this area.

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