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DIGITAL MINE: THE IMPACTS ON MINING INDUSTRY, EDUCATION AND COMMUNITY

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Summary Digital technologies are considerablyimpacting modern society in various ways. The mining industry is adopting many of these innovations to reduce costs, increase productivity and improve safety; the Australian mining industry is regarded as world-leading in their development and application. As such, mining education is having to respond to this trend through the use of new technologies both in the classroom and laboratory, and participation in research projects in collaboration with industry and technology providers.

Traditionally, the mining industry provided many well-paid jobs in the regional communities where the mineral deposits are found. However, this is being challenged by newer technologies andmethods – be it through remote operation or fly-in, fly out workforces. This paper considers the impacts of new digital technologies on the mining industry, mining education and mining communities.

Keywords: Mining education, digital mining, community, innovation, autonomoussystems, remote control

ЦИФРОВАЯ ШАХТА: ВОЗДЕЙСТВИЕ НА ГОРНУЮ ПРОМЫШЛЕННОСТЬ, ОБРАЗОВАНИЕ И ОБЩЕСТВО

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Аннотация Цифровые технологии значительно влияют на современное общество. Немало цифровых инноваций внедряетсяв горнодобывающей отрасли для снижения затрат, повышения производительности и безопасности игорная промышленность Австралии считается ведущей в мире по их разработке и применению. Горное образование должно успевать за новыми тенденциями применяя современные методы обучения в классе и лабораториии вести исследовательские проекты в сотрудничестве с поставщиками технологий и промышленностью.

Традиционно в районах месторождений полезных ископаемых горнодобывающая промышленность обеспечивала хорошие заработки и много рабочих мест. Однако в настоящий момент эти новые технологии бросают вызов устоявшейся ситуации- будь то режим работы «прилет-отлет» или дистанционное управление. В данной статье рассматривается воздействие новых цифровых технологий на горную промышленность, горное образование и горные сообщества.

Ключевые слова: горное образование, цифровое горное дело, инновация, автономные системы, дистанционное управление

Introduction. The mining industry has a long history of stimulating invention and adopting innovation. The latest innovation "wave," described as "Industry 4.0" or the "Fourth Industrial Revolution," is already having significant impacts on the mining industry.The Fourth Industrial Revolution refers to the ways of applying digital technologies to society and, as discussed at the World Economic Forum 2016, how these technologies combine physical, digital and biological worlds and how they will impact all disciplines, economies and industriesis challenging the notion of being human (Schwab, 2016).

The disruption of business models through the advancement of digital technology has been a reality for other industries for many years. Global manufacturing industry is expected to grow into a distributed organization of production with products with communication ability in the next decade (Wollschlaeger et al., 2017) and the current trend of automation and data exchange in manufacturing systems is challenging the mining industry to adopt similar business approaches.

The most significant recent development for new commodity markets is in the growth of lithium battery-powered equipment – especially vehicles. The need for greater quantities of high specification materials containing lithium, cobalt, graphite, nickel and copper is changing the focus of many established and emerging mining businesses – often with rapidly growing marketvaluations. Rising commodity prices are also seeing companies bringing closed mines back into production by taking them off care and maintenance or even reopening historical mining operations.

Initial developments in the mining sector were characterised by confidential in-house and external research &development that attempted to secure protection for intellectual property. The concept that technology can secure competitive advantage remains entrenched within the industry; however, a more transparent collaborative ecosystem is growing where small companies andacademic research centres are developing disruptive solutions. Competitive advantage is seen as coming from being an "early adopter" through acting as a trail blazer in the commercialisation process.

Earlier innovative ideas, which focused on improvements in safety and productivity, are now being supported by the development of typically low-cost technology platforms that are necessary to drive further innovation. According to Deloitte Australia, major mining companies have beeninvesting in automation and innovation for some time, however now with the advancement of digital technology and high costs of entry decreasing, the transition of the broader mining industry to a digital future has begun (Deloitte, 2017).In some areas such as drilling, blasting, train and truck drivingthe automation is radically changing the nature of mining operations.

Mining industry and innovation

In Australia where the resources industry accounts for nearly 10% of GDP and over 50% of merchandisable exports (Garnett, 2015), the impacts of innovation and the Fourth Industrial Revolution on mining will be fundamental to the future prosperity of the country. Such impacts include the growth of new commodity market opportunities, new equipment and services. To position the country to make the best of these emerging opportunities, the development of new infrastructure, policy and regulatory changes have become essential requirements.

Mine planning

Until recently, mine planning and scheduling was a very time-consuming activity – often taking many engineers, many months to fully evaluate a single design. Now, new software and cloud computing allow the evaluation of multiple designs in meredays. Optimisation software is emerging for many four or five dimensional challenges, such as positioning, timing and costs of access forshafts or declines.For example, optimal stope designs and scheduling can be calculated to link equipment requirements and utilisation. The availability of geological and metallurgical data is adding further complexity to scheduling, blending and process route optimisation that can add greater value; initially focussed on open pit design where operational options are greater (Hall and Kizil, 2018).

Flexibility and risk reduction are alsoregarded as an integral part of the evolving mine planning and scheduling process. Combined with improved computer models of blasting, fragmentation and downstream processes this is allowing data from whole of operation (holistic) modelling to be conducted of the mine value chain (La Rosa, 2017). Consequently, new roles in mine planning, data processing, systems and process analysis are likely to emerge. Autonomous or remotely driven equipment – either diesel, electric or hybrid-powered – could soon see underground mines with no personnel routinely in the workplace with potentially significant implications for ventilation planning and costs.

Mining surveillance and surveying

As is current practise, information on the integrity of assets and other geospatial information in the mining industry requires regular inspection. Recent innovations have seen the deployment of drone technologies for the rapid collection of data on asset integrity, stockpile positions and volumes, open pit geometries and even underground inspections (including flooded mines).Many of these applications often reduce the cost and speed of data collection and improve safety – leaving the surveyor with greater time for data interpretation and implications.Technology is changing the nature of work and drones are rapidly gaining a presence in mining operations. Consequently, “drone-literate” specialists are likelyto be in high demandin the near future.

Autonomous fleet systems, cost curves and people

New haulage systems have the potential to significantly alter production costs for bulk commodities and the position of mines and companies on the cost curve. Autonomous trains and unloading systems now function commercially in the iron ore operations of the PilbaraRegion in Western Australia..There, GPS-run systems operate with inbuilt navigation and safety controls that are able to detect obstacles in the machine’s way.

In another example, theBulk Ore Shuttle System ore cars (developed by Mineral Resources) will be fully automated and autonomous, and have been purposely designed to allow for continuous movement while loading and discharging (Mineral Resources, 2018).The technology has the potentialto be engaged in the mining of smaller and more remote deposits. Similarly, electric trucks with battery storage have recently been demonstrated in Switzerland (Edumper, 2017). Operating in a quarry high in the Swiss Alps, the truck travels downhill loaded and uphill empty. The batteries are charged during loaded operation andenergy can be used on a time-shifted basis and optimally fed into the grid during peak demand.Thanks to regenerative braking during descent, the “e-dumper” actually generates more electricity than it uses.

A mine haulage system that can make money during operation is not only truly innovative, but commercially motivated. It challenges the position of the Australian operations on global commodity cost curves – the reasons behind this possibly due to the relatively flat Australian terrains, where open pits are inevitably located below ground level and often below the water table.All autonomous machinery does require human operators for a number of tasks:

- monitoring and supervision from a remote centre;
- maintenance and dealing with fleet breakdowns on site;
- mine site security.

While data regarding the necessary operating personnel is insufficient, McNab et al. (2013) suggest that introducing fully autonomous equipment a typical open-cut, iron-ore mine will bring 30-40 per cent reduction in the workforce. Conversely,Cosbeyet al. (2016) regard that there is not enough research into the impacts of automation on the size of the mining workforce to give a reliable number.

At present,the autonomous equipmentin Australia is restricted to the bulk commodities, such asiron ore and coal.Job numbers have not yet dramatically decreased – in fact the opposite: new jobs have been created including in vehicle maintenance and operational control.

Health and safety

Electric mining equipment for use in open cut and underground operations is becoming increasingly available and affordable. A number of global mining manufacturing companies are offeringbattery powered mining vehicles. For example, Atlas Copco is planning to expand its current portfolio of electric mining equipment including loaders, drill rigs and mine trucks with a focus on zero emissions. The company states that electric and battery-powered vehicles are the future in underground mining (Tunnels & Tunnelling, 2017).

Traditionally, trackless underground mines have relied on diesel engines but are now being challenged by the growing availability of electric and battery-powered machinery (Carter, 2018). In addition to the health and safety of workers in the underground setting, the move to the electric equipment will:

- make extraction cleaner and safer;
- reduce noise dust and heat associated with diesel;
- remove the presence of diesel particulate matter, a known carcinogen and a health hazard;
- create better interfacing with digital technologies.

As alternatives to diesel, electric and battery powered equipment significantly impact the design of the mine ventilation system – diminishing air volume exchange and ventilation requirements.Energy costs associated with ventilation (a sizable mine operating expense) are getting reduced. The subsequenthuge decline in production ofgreenhouse gasesassociated with power generationwill benefit the natural environment.

Communication networks

Complete mining coverage and many specialised tasks are not possible when using two-way LMR based radio systems in many operating underground mines; wireless data communication relies on Wi-Fi network. Cellular LTE (Long Term Evolution) network technology enables many smart mining related tasks not only for open pits but also for undergrounds mines facilitating the processes of digitalisation and automation. Examples include monitoring power networks, security surveillance camera systems, ventilation fans, water levels, gas detection and automated collection of mine slope wall data just to name a few.

The move to a fully-integrated 4G (fourth generation mobile network technology) wireless LTE is happening in some underground mines in Australia. It even makes it possible for miners to use personal devices at speeds high enough to communicate with home and access streaming services after work.

Mining solutions on advanced technology platforms will typically be commercialised in jurisdictions where advanced infrastructure is provided as an enabler.5G for underground mining applications is being developed by Ericsson in collaboration with Boliden in Sweden (Ericsson, 2018). However, it should be noted that 5G technology is only expected to reach Australia in late 2019.

Mining Education

Innovation is becoming more critical to national economic performance, job creation and standards of living. This links to national education policy (Innovation and Science Australia, 2018), where the government can become a catalyst for innovation. Industry and government provide support for both teaching and research through a number of programs that require collaborative initiatives; however, the nexus between quality teaching and research is being tested by many conflicting external factors, including globalisation, diminishing funding and disruptive technologies (Hall, 2016).

Mining Education Australia (MEA) is a joint venture between four Australian mining schools that provide over two-thirds of Australia's mining engineering graduates (Hall, 2016). MEA is reviewing the collaborative curriculum in resource estimation and mine planning; together with its mine design units, MEA is also developing a new shared course in mine automation and data analytics in mining. These include autonomous equipment, remote operation, underground communication, data collection and data analytics.

Data analytics and virtual reality

The future mining graduates need to be equipped with data analytics skills as most current and upcoming mining machines are equipped with hundreds of sensors which constantly produce a large amount of data. If this data is not processed and promptly converted intokey performance indicators, then it becomes "cyber garbage" instead of delivering useful information to benefit production and operations safety. One way of managing the data in real-time would be to use "machine learning" algorithms and technologies.The companies which achieve this quickly and efficiently will have an advantage over the rest.

One of the major challenges during the mine design process is the usage and visualisation of the massive amount of available data. Shared virtual reality is an emerging essential tool that enables team members to communicate geological, technical and financial design interactions. With virtual reality, a number of design options can be evaluated.As a result, flexibility of operations over many years could become the key factor to mitigate against commodity price fluctuations.

Figure 1. Use of virtual reality in mining education.**Source**: Hall and Kizil, 2018

Addressing industry requirements

The introduction of newdigital technologies has created challenges for mine planning engineers, project managers, site operation superintendents and resource and production reconsolidation processes. Ongoing industry requirements for the workforce include:

- much wider professional development;
- recruitment and retaining of workers with generic skills sets;
- interpersonal, creative, problem-solving and entrepreneurial skills of the 21st Century.

Since the end of the commodity boom in Australia, graduate numbers in mining related disciplines have dramatically fallen. While industry is concerned at the quantity of graduates, the quality of their education is also of utmost importance, especially in reference to meeting current and emerging technological needs.

In response to these concerns, both the technical vocational and higher education sectors in Australia are introducing new courses and modes of delivery. With industry support, new programs suitable for jobs of the future are being developed to teach skills and competencies in robotics, data analytics and digital inclusion.

Diverse commodities supply into the emerging “Green Economy” will employ a greater number of mining professionals who require a wide range of skills to best position their companies in a rapidly evolving “periodic table” of mining opportunities(Hall, 2017). Demand for specialist professional development and mining-related educational courses for professionals from other disciplines is growing. Postgraduate studies as conversion courses for geologists and graduates of engineering subjects will be required together withknowledge in mineral economics, geostatistics, geotechnical engineering and mine planning.

It has been observed that countries which renew their mining education systems will reap most benefit with a third wave of mining education from 2020 to 2040(Lynch, 1998).Currently the supply of high-quality graduates in mining geology, mining engineering and extractive metallurgy is limited. The training of such graduates should cover the entire value chain of mineral commodity production, community engagement, entrepreneurship and financial skills.

Communities

The major community concern is often that of the availability of jobs in or around a regional mining centre. Reduction in employment opportunities can include disruption to property valuations and service business viability, with the knock-on effects of depopulation and decreased government services such as transport, health and education. Potential social impacts of large-scale automation can include a dropin economic activitieslocally and in the region triggering a loss of population and services over the longer term.

Preliminary research (Cosbey et al., 2016) has suggested that when disruptive digital technologies are introduced,host countries will be at risk of reduced socioeconomic benefits from mineral extraction. Local employment and tax revenue from personal income taxes will decrease and consequently lead to a fall in local procurement.

The use of remotely operated equipment underground greatly improved mine safety but also reduced the number of mine site workers.The process started withthe operators initially being moved to a line-of-sight position, and later operator control was carried out via camera systems. Now remote operation centres, many hundreds or thousands of kilometres distant can run short-term mine operations to plan a single operator controlling multiple machines. On site backup systems are in place for potential major communication failures;

While employment within the mine sitemay fall, communitiescan still benefitfrom jobs in the supply chain to the mining and processing operations. A fair share of taxes and royalties paid to government by the companies can be returned to the impacted region.Moving to preventative maintenance, improving the quality of mine haul roads and other regular onsite activities should retain job opportunities in the regional mining communities.Potentially returning to regular day shift and week day only employment.Together with the jobs,the associated workplace culture is going to change, though it remains to be seen what the true reality of these changes will be.

Conclusion

Digital technologies introduced and deployed in the mining sector mean that the mines of the future will look much different than they are now. Mines, process plants, rail and port networks are all likely to be controlled from remote locations allowing for more consistent operation and delivery to plan. Deployment of autonomous driverless trucks and trains is continuously increasing, with huge potential for further implementation of automation and artificial intelligence.

With the nature of many mining job being transformed the associated workplace and culture will be different.Soon there will be underground and open cut mines with no workers present, and interactions will occur with roboticrepair and maintenance systems, predominantly without human intervention.

Electric and battery powered equipment and the new digital technologies can reduce production costs and considerably improve health, safety and environmental performance.Most of these technology developments have so far been retrofitted to mines that were built to conventional designs under current regulatory regimes (i.e.ventilation requirements). New designs will require revision of regulations and development of appropriate guidelines, such as those introduced in Western Australia for autonomous vehicles in open pit environments.

Automation will inevitably limit employment within mining operations; however,mining professionals are very much in demand for mining projects.Implications of digital mines for mining communities are complex and depend on many factors, including community structure, history, demographics, degree of reliance on mining, links with the regional economy and economic diversification.

Keeping these rapid changes in mind, mining education providers must ultimately match this pace in the content and method they deliver their materials. The necessity of government and industry to work with such providers is essential to increase graduate numbers and ensure adequately skilled labour that will carry the global mining industry forward.

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