Future Metal Mining

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ABSTRACT: The world's metal mining industry faces a number of challenges, which must be predicted and managed wisely. The prevailing recession will force the industry to further rationalizations that require both new technologies and new organizational forms. The impact of the 2015 Paris Climate Conference (COP21) will increase costs for treating greenhouse gases and acquisition of emission allowances. Ore will be mined from gradually deeper deposits with increased rock stability problems. It will be difficult to recruit skilled workers to the mines often located far from larger communities. This requires an organization of the work that supports both high productivity and good working conditions. Based on an analysis of the conditions for future mining the authors of this article present sixteen predictions for the mining industry of the future. In one or another way the mining industry of today must address them all.

KEYWORDS: Mining, metal mining, future mining, deep mining, lean organization, automation, the 2015 Paris Climate Conference, carbon dioxide, CO_2, safety, work, globalization, skills

1. INTRODUCTION

The world's metal mining industry faces a number of challenges that must be addressed with a socio-technical approach that covers the whole mining and minerals value adding chain including environmental issues. Mining industry need a new mental image of itself based on new technology and a modern work organization that supports both high productivity and good working conditions. There is a need for a new holistic vision for the mine of the future. This article illustrates elements that may be included in such a vision. Before the results are presented some important challenges for the mining industry are introduced.

2. CHALLENGES FOR THE FUTURE MINING

The world's metal mining industry faces a number of challenges that must be managed wisely. The most obvious challenge is the recession that the commodity prices drops dramatically, especially for iron ore. As a result, we can expect a significant structural rationalization, where the strong companies can afford to invest for the future while the weak are drained on their capital. A general effect is that all mining companies are under increased pressure for further rationalization that requires both new technologies and new organizational solutions.

The longer-term challenges also include environmental issues and impacts from the 2015 Paris Climate Conference (COP21). Any future mining must not endanger the health and welfare of local inhabitants and post mining there should be as few traces as possible in nature. The only desirable track is a stable social infrastructure and a flourishing society that continues when mining ceases. A more specific challenge is identified in the Paris Climate Conference regulations of greenhouse gases, especially carbon dioxide. This will require significant investments in acquisition of emission allowances. Another factor to consider is the availability of water, especially clean water, which is a prerequisite and is not an obvious asset in all regions (Hancock & Sinclair 2008, Lane et al. 2008).

An increasing share of the total mining production will be by underground mining where ore will be hoisted from gradually deeper mines. It involves an increase in overburden pressure with subsequent rock stability problems and risks for structural collapses. There is a need for new and safe technologies for deep underground metal mining.

Another challenge is the problem of recruiting skilled workers to the mines often located far from larger communities. A modern mine is so technically advanced that the proportion of unskilled labor will decrease significantly or disappear. There will be fewer workers with higher individual wage costs. Most mining companies want to avoid a "fly-in fly-out" situation, as it could create social instability of societies and cause trouble in the workplace. This requires an organization of the work that supports both high productivity and good working and social conditions.

An important component of good working conditions is a safe environment. In underground mining the basic solution must be to distance the miners from the physical mining front and locate them in a safer environment. Remote control, automation and new mining techniques are major challenges and possibilities, but it is also a matter of relevant education, rules and good practices.

The mining industry is global and the major mining companies operate in many different countries. Here lies a challenge to manage a variety of local cultures which have all their formal and informal rules. It is important for companies to have a good practice and a stainless image if you're going to exploit a country's natural resources (Wibowo & Rosyid 2008).

A further challenge is to break the unequal gender balance that exists in most mines. It is not just about recruiting more women, but rather to challenge the prevailing 'macho culture' in order to create a safer and more productive environment (Abrahamsson & Johansson 2007, 2008a).

To conclude, the mining industry is facing major challenges that require extensive and immediate action. Problems interact with each other in such a way that the solutions require a holistic perspective, where both technical and social factors are taken into consideration.

3. SIXTEEN PREDICTIONS FOR THE FUTURE METAL MINING INDUSTRY

Below sixteen predictions are presented based on an analysis of the conditions for future mining.

1. Future mining will be shaped in a context where it is necessary to produce at costs that are determined in *international competition*. The market sets the prices of metals and minerals but in the long term, there is little doubt that the demand is increasing. Large nations like China, India, Indonesia, Brazil and the whole of Africa will require a larger share of consumption which is leading to the opening of new mines. The difference between these countries' annual – "per capita" – consumption and Western Europe can be more than 10 times. (Hancock & Sinclair 2008)

2. Production conditions will be characterized by the fact that the nearby and easily accessible ores will be mined first. *New ores will also become more distant or found in the depths* (Hancock & Sinclair 2008, Lane et al. 2008). Large ore reserves are located under the sea and there is hardly any doubt that the mining and off-shore companies will develop new technology to extract these (Boughen et al. 2008). In both cases, production costs will increase.

3. Mining depths increase, and it brings new stability problems. The role of rock mechanics in the design of layouts, cutting sequences, strata stabilization, roof bolting etc. must be a central issue for the future. *Full face drilling and cutting* should be interesting from a safety perspective, both directly in safer drifting operations and also in that it can create more stable galleries due to reduced or no blasting damages (Weiner 2008). Cutting should also be useful for selective mining of high quality ore in narrow ore bodies. In the EU-funded project I^2mine we are developing production cutting for hard rocks (Hejny 2010). Production drilling and blasting for *controlled fragmentation* are two very crucial operations in the ore mining cycle (Lane et al. 2008). Improvements in these operations can create significant positive impact on the there after following operations.

4. *The environmental requirements* affect both energy consumption and management of ore tailings. The discussion of energy consumption is largely linked to global warming and carbon oxide emissions. Today we can not fully foresee the results of the Paris agreement, but in the long term, some form of global coordination surely will be established, including large developing countries like India and China which previously stood outside the Kyoto Protocol. The cost of emission allowances will be a significant factor to consider, especially for the production located in the more developed countries (Hancock & Sinclair 2008).

5. The mining industry is an *energy-intensive industry* with high CO_2 emission. Improvement of energy efficiency will increase the economic profitability as well as reducing environmental impact. In order to succeed, the entire system to be optimized

and an appropriate technology is process integration (Nordgren et al. 2007). There are many components that affect the total energy consumption; one often discussed is underground pre-concentration (in situ). It affects directly the energy consuming hoisting and milling (Bamber et al. 2007). Another driving force is that the costs for environmental impacts are externalized by increased energy taxes (Damigos 2007). The use of fossil diesel fuel is extensive and causes environmental burdens, e.g. CO_2 -emissions. A conversion to *bio-diesel* might be a strong alternative for the mining business since there are only minor technical problems with a change and many environmental and economical benefits. Large full scale tests in Germany have indicated the potential for bio-diesel but more research and international collaboration are needed (Drebenstedt & Jauer, 2007).

6. The discussion of *waste management* is about to leave as few footprints in nature as possible. We must not leave toxic substances that leak out into nature and the landscape should be restored as far as possible. One solution discussed is *in situ mining* where as much as possible of the production and processing will take place underground (Lane et al. 2008). We are currently developing underground sorting in the I^2mine project (Hejny 2010). Such technology is however not without environmental risks and risks for health and safety. The mining companies have to establish a good control of the major water flows in the surrounding rock masses (Przhedetsky & Roshal 2008) to avoid unwanted leaching and jeopardizing the miners' health and safety. Pollution of mine water is the single most important environmental issue for the mining sector and consequently also effective mine water treatment. New efficient methods and technology needs to be developed as well as relevant guidance for mining in different situations, e.g. climatic conditions, different regulatory and socioeconomic settings (Jarvis et al. 2007). With regard to water in general it is a question about *closing the loop*s and re-using the process water as much as possible. Here purification in the mine should not be greater than necessary to become fuller before the water is returned to nature (Madin 2008).

7. The environmental debate also includes a discussion on the mining industry's *social responsibility* for the welfare of the local community (Abrahamsson et al. 2014). In addition to preserving the environment they are supposed to build a strong technical and social infrastructure that ensures survival of society after mining has ceased (Ail & Baafi 2007, Wibowo & Rosyid 2008).

8. *Health and safety* are very high on the agenda and are also strong driving forces behind the ideas of automation (Burger & Cook 2008, Johansson & Abrahamsson 2009, Revuelta et al. 2008, Widzyk-Capehart & Duff 2007). Safety issues primarily concern underground work and the prescribed solutions are wise and conscious choices of different levels of automation and remote control (Kizil 2008). A concept that already is partly realized (in Swedish mines and elsewhere) are Noort's and McCarthy's (2008) proposal for three consecutive phases to ensure *safe underground mining*. The first phase means that all work is done from vehicles that have safety cabins that prevent

injuries from falling rock, but which may also be provided with substantial comfort. The second phase means that staff is moved to secure control rooms where they are remote monitoring and controlling the different operations. In the third phase, we have a production with *zero entry* for employees based on comprehensive automated systems.

9. A generally good and safe working environment is seen as a prerequisite for the recruitment of skilled workers to remote mines (Noort & McCarthy 2008). The typical under ground *work environment* with noise, dust, poor illumination, explosive and toxic fumes and gasses etc. is very important to control in order to avoid diseases, injuries and fatalities (Shooks et al. 2014). By using advanced sampling strategies (based on statistics and science) with portable, more accurate and reliable measuring devices better control can be achieved and more efficient counter measures can be taken (Iramina et al. 2007).

10. Many interesting ideas for automation have been presented in recent years (Bäckblom et al. 2010; Fisher et al. 2012; Grehl 2015; Ruiz-del-Solar 2015). One interesting thing is the idea of *reversing the design process*, i.e. that one should start from the requirements for the automated mine and then design layouts and operations to suit automation and not as today try to automate conventional designs and operations (Kizil & Hancock 2008). It would be interesting to see what experts on industrial automation, with a developed systems thinking, would propose in terms of requirements and solutions for automated underground metal mining. The integrated mine and "Internet of things" are visions with such an approach that discussed in the mining companies today (Larsson & Johansson 2015; Kent & Eisner 2015).

11. Significant efforts to develop *communications systems for increased security* have been made (Gürtunca 2008). Communication systems should also have positive effects on productivity, quality of work, cooperation, etc. Primarily it is a system for verbal communication, but it would be interesting to see if the system also can supports image information and communication. Miners equipped with mini cameras could for everyday and emergency situations provide their colleagues and senior management with information that is difficult to convey verbally. Portable video communication systems are today developed in the German coal mines (Skirde & Schmid 2008). Different types of *machine-machine communication* will grow in use.

12. Virtual Reality (VR) technologies as design and production tools have great potential, especially the use of VR in real time to visualize and control the production processes. *The extended business* and *open collaboration* are two concepts where VR technology can be used to link production functions such as planning, mining, maintenance, logistics, purchasing and for coordination of external contractors, suppliers, customers, etc. all connected to a production flow, a value adding chain, where all share the same goal and everyone sees the same whole. Common visualization of problems and op-

portunities in the system allows for all to optimize the whole chain rather than sub-optimizing parts (Bassan et al. 2008).

13. Production centers are creating *new professional roles*. Bassan et al. (2008) predicts an increasing degree of remote control from production centers and *collaborative visualization rooms*, perhaps located in nearby communities, or further away (other continents), where the operators have monitoring and coordinating activities across the value chain (Bäckblom et al. 2010). The operators are supported by intelligent and automated decision systems and use web 2.0-system of global communication, information and learning. Their jobs have changed character towards service work and the new tasks require different kinds of skills. In addition to deal with advanced information technology the miners have to interact with different specialist team located all over the world.

14. The modern technology has created a new type of work – new in terms of *competencies and knowledge* as well as workload. There is an emerging, and in many aspects already evident, knowledge transformation – from the old and obsolete physical and tacit knowledge and skills (for example the ability to 'read the rock') to something new which can be described as abstract knowledge. But the old culture still provides an important context for workplace learning and the construction of *identity and gender*. This is associated with a degree of 'worker identity lag' and to difficulties in adapting attitudes and norms to the demands and structures that result from the new technology and the new work tasks. The new forms of work in the mine have less need for the traditional mining competencies, attitudes and ideals. Also the traditional workplace culture and 'macho style' have been challenged. Workers have to find new ways to learn and to develop a workplace culture more attuned to a new type of worker identity and masculinity (Abrahamsson & Johansson 2008b).

15. The mines of the future will have a smaller staffing and it is also clear that they will meet a different kind of *model for work organization* than today. We have previous mentioned it is expected that automation provides improvements in terms of work environment and job safety. It is considered important to create attractive and safe jobs. Bassan et al. (2008) predicted that the mining companies gradually will turn to a flat and *lean organization* with multi-skilled workers who can operate in several areas and functions within the company (Lööw 2015, Lööw & Johansson 2015a, 2015b). There is also a discussion about staffing system based on *fly-in fly-out* which is more independent of a local community.

16. It should also be interesting and mutually beneficial if the mining industry should expand its *cooperation with other sectors* (space, aviation, military etc.) to learn from what they have developed (Schmitt 2008). Cooperation and partnership in the industry are increasingly important as development projects are large, expensive and complex and therefore difficult or impossible to manage for a single company.

There are of course other important areas of development, but the above discussed are expressed as the most important from a long-term strategic and sustainable view.

4. CONCLUSIONS

A major conclusion is that the challenges and the changes are so large and numerous that a comprehensive international cooperation is needed both within and outside the industry in order to succeed. Working separately would lead to a far to slow development, something that is undesirable for both the companies and the miners. Another conclusion is that a successful mining industry must work simultaneously with all the problems mentioned above. There is a need for a new and modern vision for the whole industry based on a socio-technical approach that covers the whole mining and minerals value adding chain including environmental issues.

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