Future Mining – Thoughts on Mining Trends

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Even though mining for energy resources is likely to decrease, mining activities generally will increase. The demand for metal resources will rise in the next decades. The question is, what will mining look like in the future? Mines have to be dug even deeper and processing has to mill even smaller because ore is getting more complex. One possibility is automation, which may be a solution for mines with certain conditions, e.g. where heat and gas levels (NO_x and CO) are a major concern. However, automating an underground mine is a very complex task. The relevant influencing factors are introduced and discussed in this paper, with brief descriptions of some investigations into different approaches and technologies for handling these situations.

Même si les ressources énergétiques d'origine minière sont appelées à décroître, l'activité minière globale va augmenter. La demande en ressources métalliques va s'accroître au cours des prochaines décades. La question posée est : à quoi va ressembler la mine dans le futur? Les gisements miniers doivent encore être atteints à plus grande profondeur et le traitement par broyage doit être aussi plus fin car la nature du minerai devient plus compliquée. Une possibilité est l'automatisation qui peut être une solution pour des gisements dans certaines conditions, c'est-à-dire lorsque les niveaux de chaleur et de gaz (NO_x et CO) représentent un danger réel. Cependant, automatiser une mine souterraine est un travail très complexe. Les facteurs d'influence significative sont précisés et font l'objet d'un débat dans cet article avec une brève description de certaines recherches concernant les diverses approches et technologies mises en œuvre pour faire face à ces situations.

Si bien es probable que disminuya la extracción de recursos energéticos, las actividades mineras generalmente aumentarán. La demanda de recursos metálicos aumentará en las próximas décadas. La pregunta es, ¿cómo se verá la minería en el futuro? Las minas tienen que cavarse aún más y el procesamiento debe reducirse aún más porque el mineral se vuelve más complejo. Una posibilidad es la automatización, que puede ser una solución para minas que cumplen con ciertas condiciones, por ejemplo donde los niveles de calor y gas (NO_x y CO) son una gran preocupación. Sin embargo, la automatización de una mina subterránea es una tarea muy compleja. Los factores de influencia relevantes se presentan y discuten en este articulo, con breves descripciones de algunas investigaciones sobre diferentes enfoques y tecnologías para manejar estas situaciones.

The most recent *Exploration Review*, edited by Karl and Wilburn (2017) from the U.S. Geological Survey, again shows decreased expenditure for exploration activities in 2016 (***Figure 1***). With this trend present since 2012, it cannot be expected that efforts in mineral extraction will increase in the near future. In general, with rising demands for raw materials on the world market, suppliers of the mining industry are expecting higher sales of their products. However, with today's situation, this scenario is not yet likely. Suppliers should use the time of recession to invest in research and development for new products and new concepts in order to be able to meet future demands in quality. As this task is very complex, companies with different profiles should work together.

What are future demands? What will future products look like and what will concepts be about? To answer these questions, it is important to first discuss expected advancements and to define the parameters of influence. Besides technological aspects, social changes and new ideologies also have to be considered. The world of future mining will be interconnected and operating with more flexible approaches. Relevant influencing factors are discussed in this paper.

Thinking about future technology, automation is of major interest. However, the simple idea of automating a mine comes with a range of demands regarding the mine and the technology itself. Automating a mine means automating the entire mine, requiring a great deal of research and development to be done. Of course, it is possible to copy strategies and technologies of other industries that are at high levels of automation already. However, it is highly questionable whether they will meet mining standards. Sensors, for example, might not be designed for mine environments. If sensors cannot work adequately, they may deliver false data. Analysing false data will lead to wrong conclusions. Will it be possible to solve these problems, for example, with a local remote sensing survey to define the position of each limber of a drilling jumbo, rather than fitting each limber with individual sensors (as in ***Figure 2***)? Also, sensors should be maintenance free and have a lifespan similar to the lifespan of the machine they are surveying. Could drones be an adequate solution? Such technology could be used to survey

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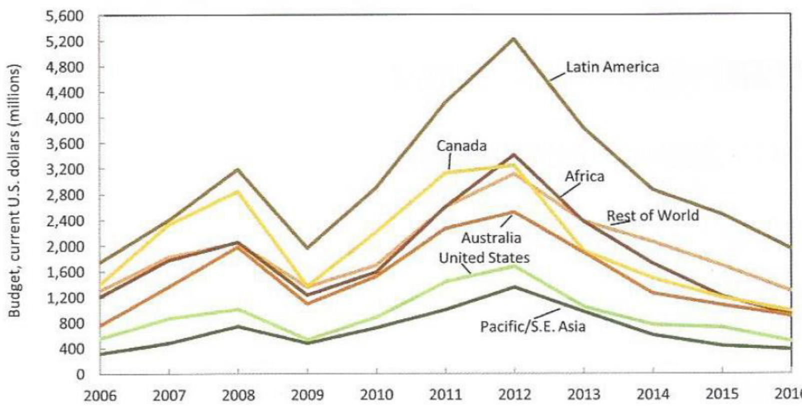

Figure 1: Known investments in exploration by region, 2006 to 2016 (Karl & Wilburn, 2017).

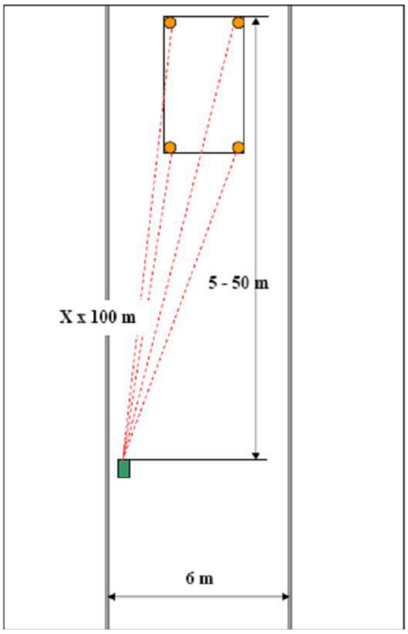

Figure 2: Remote sensing for drilling jumbos (Mining Institute, Clausthal University of Technology, 2009).

large cavities or inaccessible sections. By fitting drones with additional sensors, they could also deliver data that is needed for automation.

The provision of an extensive network is the main basis for any automation process, as information must be exchanged between the sensor and machine. This then requires the installation of a mine-wide communication system (e.g. using fibre optic cables) and information technology. In the first step, data that was collected by the sensors must be reduced to the information that is needed for the process. For solving this 'big data problem', adequate software is required. The data must be saved and guarded by a data protection system. All of these are major tasks to be solved for the mining industry before automation can be implemented.

Besides automation, safety will be a major concern in future mining. "Vision Zero', the aim of achieving a system producing no fatalities or injuries, is no longer a vision, but a goal. Today, the industry is still far from reaching this goal and much is yet to be done. Public opinion of mining reflects this, as the mineral sector is still judged as dangerous, dirty and dark. Improving this image will be a milestone on the way to establishing faith and trust in the mining industry. The most effective approach is by communication and honesty. 'Do good, and spread it into the world' can be seen as a guiding principle. In these terms, it is clear that accident numbers have to be further reduced – worldwide.

One opportunity for advancing safety in underground mines is 'Ventilation on Demand' (VoD) (Clausen & Langefeld, 2013), meaning a controlled and energy-efficient supply of mine areas with the needed amounts of air (***Figure 3***). Generally, with no people in the mines, automation can lead to a significant decrease in accident numbers. Heat and gas levels (NO_x and CO) will not be major concerns. Ventilation would be needed mainly to remove the heat from machinery and to support it with oxygen if it has a combustion engine. In my opinion, these goals can be achieved within the next ten to fifteen years. However, this will require systems that are highly integrated and fitted with adequate communication opportunities. Finally, fully automated mining systems will be a requirement for deep-sea mining and sky mining.

Linking all relevant data and machines is also of high importance for future mines. The comprehensive planning of a mine, respecting a hierarchical and thorough approach, can help to establish an efficient network (Clausen, 2013; ***Figure 4***). Goals must be defined clearly and exactly for machines to understand the tasks. Also, geological and tectonic data of the deposit should be considered. All relevant data, such as amount and quality of conveyed material, must be measured at all tipples or handling points, and must then be compared to expected data from the planning stage. Planned data can then be corrected accordingly, forming an in-time flexible system with self-learning and self-adjusting capabilities.

However, this idea is not a recent one. The German *Ruhrkohle AG* began analysing core drills from general mine surveys in the past (***Figure 5***) (Langefeld *et al.*, 2000; 2001). The ability to analyse the rock can be used for simulating possible shothole spacings and blasting patterns to find an optimum for the downstream haulage and processing system (in terms of chip size, etc.). Especially in cave mining, this can be very important.

Even more sensors will be required to allow an online and real-time analysis, for example sensors that gather information on type of ore, grades and other properties of the rock during transportation (Vraetz *et al.*, 2017) or the drilling process ('measurement while drilling'). Will it be possible to analyse a rock's tectonics from the resistances while percussion drilling? Questions like this express a high and urgent demand for research and development, as only with complete data analysis will automation be successful.

Flexibility in terms of reacting to measured data is another important aim of sensor development and data analysis. As mentioned in the example above, real-time data can be used to improve drilling and blasting operations and thus for optimisation of the mining process. A requirement for this is that reporting and evaluation of measured data must be available immediately. Developing deeper and more complex mines increases the need for available systems. Also, with the present trend on the raw materials supply market, secondary deposits are drawing increased attention. One example is tailing ponds, as focused on in the REWITA project, funded by the German Ministry of Research and Education. Concentrating on evolving strategies for mining and processing, this project uses tailing ponds of an abandoned ore mine in Goslar, Germany. Besides technical questions, social and environmental aspects of utilising secondary deposits also have to be respected.

Furthermore, post-mining is an important aspect. It is more than only securing in terms of subsidence and back stowing.

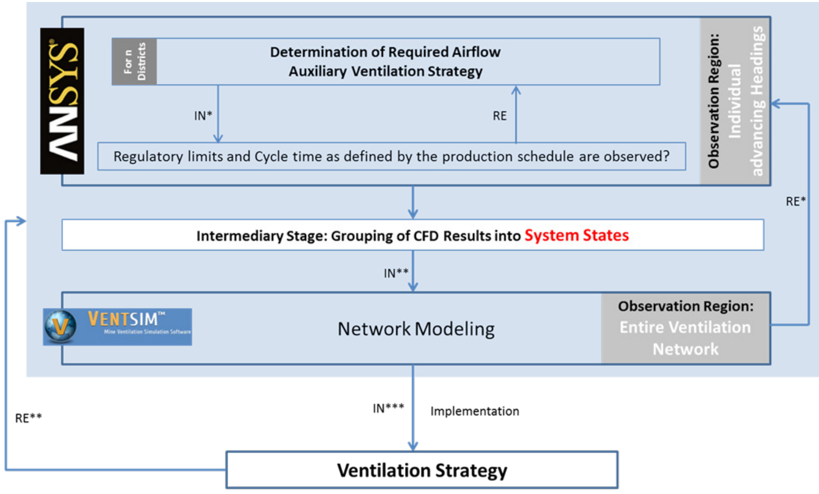

Figure 3: Ventilation on Demand – CFD multiphase and analytical ventilation network, Mining Institute, Clausthal University of Technology (Clausen & Langefeld, 2013).

Developing a concept for using the sites of a mine after the phase of mineral production can be included in the planning even before mining activities start. This guarantees matching mine development regarding the post-mining usage, e.g. energy production. 'Blue Mining' (***Figure* 6**) is a concept being developed at the Clausthal University of Technology since 2013, covering the aspects of post-mining opportunities (Langefeld & Kellner, 2013). From 2008 to 2011, in cooperation with the German Ministry for the Environment and Nuclear Safety, the university also worked out a strategy for using abandoned mines for storing wind power, presented in an 864-page report (Beck & Schmidt, 2011).

In addition, reliability and maintenance are important aspects of automation. Machines that require regular repair and that have inadequate lifespans will not be suitable for automation. Suppliers will have to rethink and focus on quality rather than on spare parts supply. The point of time for replacing spare parts should then be defined by software from information gathered by the fitted sensors. Only then is automation reasonable.

Regarding technology in terms of the machinery itself, two aspects are vital. With the ambition of 'zero emission', new methods of engineering will change mining machinery. Electric engines, powered by batteries, are rising in importance. With batteries, new concepts for fire prevention and control will apply that are still in their design phase. But battery powered vehicles change the mining methods and the sequences, e.g. more infrastructure is needed for the battery handling. The other important aspect is the cutting of the rock. Drilling and blasting will be employed in future mining, but cutting holds some advantages. For example, noise emission and vibrations are reduced and no fumes are produced. However, cutting in hard rock is still problematic and should be granted more attention in research. Thus, a new network of researchers is forming these days to solve these problems.

In addition to all of the technological demands of future relevance that I have mentioned, the most important of all is rather a social one, defined by industrial standards, sustainability and communication. The framework conditions are subject to change. Today, stricter pollution levels are forcing the industry to react and introduce cleaner technologies, but it is more than likely that allowed pollutant levels will be further decreased in the future. Today's society is enlightened and aware of environmental and safety hazards. One alteration is that, whereas personal information was strictly kept secret in the past, people

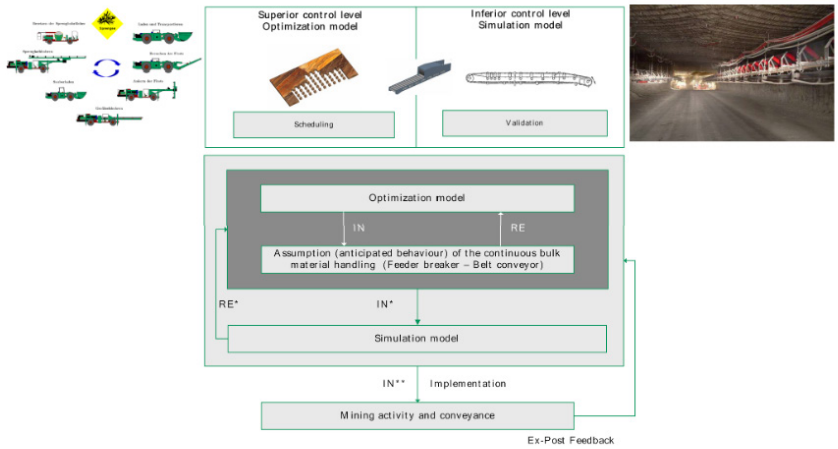

Figure 4: Hierarchy of planning, Mining Institute, Clausthal University of Technology (Vraetz et al., 2017).

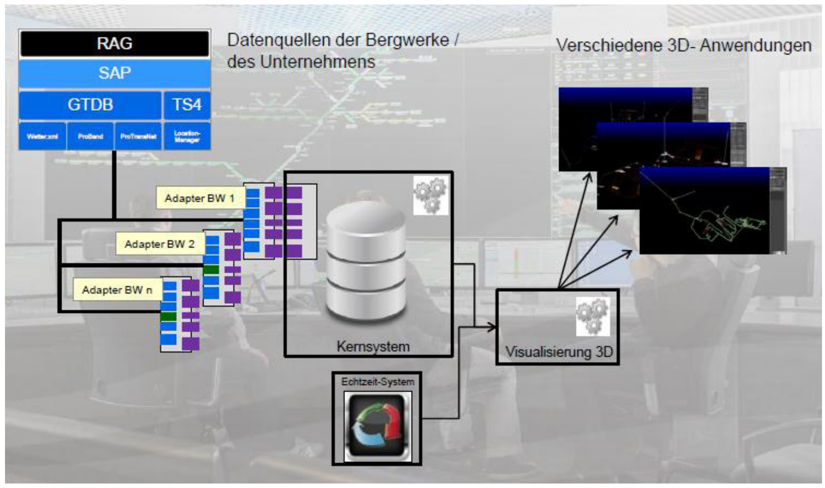

Figure 5: Census of data during the production process (Junker, Martin RAG Mining Solution).

provide it today if they feel they can profit from it. In the 1970s, everyone was afraid of "Big Brother is watching you". Nowadays, a situation in which "everyone is watching you" is no reason to feel uncomfortable and people are willing to impart information for a bonus in a customer loyalty programme or a smartphone app. This shows the importance of passing on information. People need to know how they can benefit from a situation. The mining industry has to involve the public, discuss as equals and provide all relevant information to build up confidence.

Also, as today's society is characterised by flexibility and individualism, companies will have to react accordingly in their human resource policies. Beyond race, gender and spiritual beliefs, also ideology, lifestyle and workplace morale must be respected, in particular in team work. To further define required action in this field, universities and EIT Raw Materials are currently working on a cooperative project on the topic 'Diversity in the EU's Raw Materials Sector'. With automation in the future, this will remain a relevant topic. Automation will allow fully mechanised processes in extraction and conveying, but other activities, such as in repair shops, will still require personnel. If underground, relevant locations will also need auxiliary ventilation.

With increasing demands for sustainable development, mining companies, suppliers, research institutes and related organisations will have to rethink. Along with the concept of Zero Emission, this also means focusing on renewable energies and reducing waste production.

All aspects, as a foundation for a successful mining economy in the future, must be included in education. Universities that teach mining classes have to arrange their educational principles in a way that all graduates satisfy the high level of demand that is present in any employment. Besides basic technical skills, methodological and soft skills are gaining in importance. A good example of a successful implementation of these requirements in the fields of study is the Master programme "Mining Engineering" offered by the Clausthal University of Technology. Held in English, this programme includes modern teaching and CDIO methodology (see

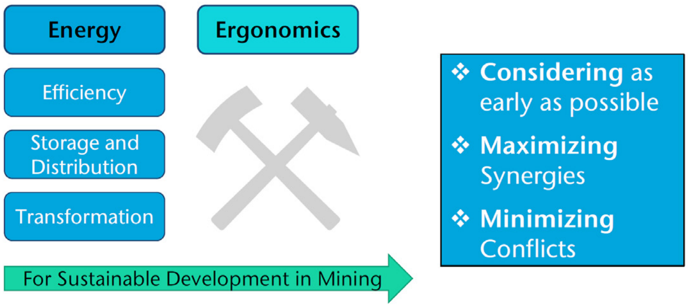

Figure 6: Blue Mining Concept – planning of post-mining use prior to mining (Langefeld & Kellner, 2013).

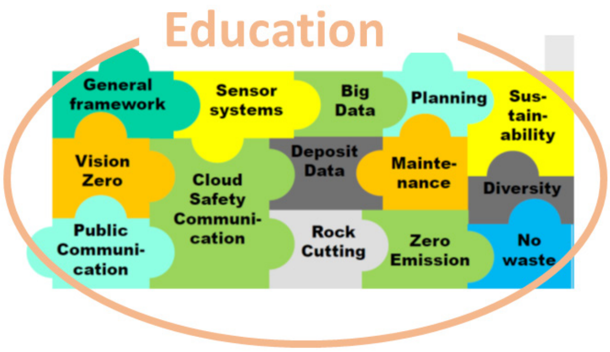

Figure 7: System of connecting disciplines for future mining activities.

http://www.bergbau.tu-clausthal.de/en/studies/study-courses/mining-engineering-master/). CDIO is an initiative for internationally orientated study plans for optimal training of future engineers (for more information, see ***http://www.cdio.org/about***). Currently (as of May 2017), 60 students are registered in the Mining Engineering programme. Some 70% are from non-German-speaking countries, in fact 15 different countries in total, which allows all students to gather cross-cultural experience by learning together and which opens new opportunities for conducting the lectures. In addition to international experience, also the Rammelsberg teaching and research mine in the nearby city of Goslar is part of the study plan. Here, authentic teaching is possible and a range of research opportunities are available for the students (Clausen & Binder, 2017).

With its international composition, the mining study course attracts well educated bachelor-degree holders from foreign countries to Germany and offers a wide range of opportunities for employment on the German market after finishing the course. As many graduates remain in Germany and receive employment there, the study course also supports Germany's national economy. The first contact between students and possible employers is gained during field trips. Here, both German and international students get to know different mining companies and suppliers and may be offered internships or research opportunities.

For the establishment of a successful and socially accepted mining industry in the future, all of the aspects discussed in this paper must be respected. Germany shows high potential to be successful in this progress, as competences are available in the country. However, success is also a question of combining these competences and working together among the variety of disciplines to ensure the best project outcomes. In this, universities are very appropriate partners (***Fig. 7***) in efforts to proactively adapt to trends in the future of mining.

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