A guide of social management of new technology

Joel Lööw Erik Sundström Lisa Öman Camilla Grane
Lisa Ringblom Jan Johansson Lena Abrahamsson

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Preface

This book is a product of SIMS (Sustainable Intelligent Mining Systems; http://simsmining.eu. So far it is a work in progress.[1] It is a book that intends to give the reader some tools to help them in the social management of new technology. It is aimed chiefly at the mining industry; due to its unique characteristics, much traditional knowledge – or rather, knowledge regarding these issues from other industries – are not readily applicable. Therefore, this book seeks to adapt much of "uncontextualised" knowledge to the mining industry. To do so, we use the technologies of SIMS.

About the project

The vision of SIMS is to create a long lasting impact on the way we test and demonstrate new technology and solutions for the mining industry. With a selected consortium ranging from mining companies, equipment and system suppliers to top-class universities, the SIMS project will boost development and innovation through joint activities aiming at creating Sustainable Intelligent Mining Systems.

About the authors

[1] To a certain extent, it will always be a work in progress; see the later chapters.

1 Introduction

Author One, Auhtor Two, Author Three

This is the introduction.

2 Attracting young people to the mining industry

In most mines the present workforce is ageing and mining companies have difficulties recruiting young talented people. A precondition for being able to recruit the right workforce is that the mining industry can offer workplaces that attract the youths of tomorrow. In order to succeed, the mining companies need to know what in fact constitute attractive jobs and workplaces in mining as well as how they can change their own present operations to align with these requirements. These changes need to be based on current and relevant research on work attractiveness. However, labour supply is determined not only by the work itself and the working environment but just as much of the society and what it can offer its residents. There are a number of factors that have an impact on the attractiveness of society, such as social relations to family, friends and relatives, opportunities regarding work and education, housing and leisure activities. These factors must also be considered when creating the mines of the future.

Unfortunately, there is no single accepted definition of what constitutes an attractive job and current explanations and models differ. While pay and the possibilities of advancement are two general factors, answers have varied in, for example, different time periods and fields of research. It follows that what is attractive also differs between countries, since the general contexts differ, as well as individuals.

A general model for attractive work is presented by Åteg, Hedlund, and Pontén (2004). In this model, three factors, covering 22 dimensions (see table 2.1), interact and contribute to the attractiveness of work. In comparison with previous, similar models Åteg, Hedlund, and Pontén (2004) have added work satisfaction as a factor. This factor is especially important for keeping people at work, Åteg, Hedlund, and Pontén (2004) argue.

Table 2.1: Work attractiveness.

Attractive working conditions	Attractive work content	Work satisfaction

Table 2.1: Work attractiveness.

Adequate equipment and tools	Work pace	Demand, need
Working hours	Familiarity	Recognition
Physical work environment	Physical activity	Status
Leadership	Freedom to act	Stimulation
Loyalty	Practical work	Results
Location	Theoretical work	
Wage	Variation	
Organization		
Relations		
Social contact		

In another model, Hedlund (2007) states that a job is attractive for a person if he/she wants the job and wants to keep it. Thus, an individual can judge the attractiveness both as an applicant (external view) and as an employee (internal view). This means that a job can be described in four different ways: attractive, hidden, idealized and unattractive (see figure 2.1). Accordingly, a job is attractive if it has a high attractiveness from both an internal and an external point of view. A job with high internal attractiveness but low external attractiveness is classified as hidden, while a job with low internal attractiveness but high external attractiveness is regarded as idealized. Finally, a job that has a low attractiveness from both an internal and external view is classified as unattractive.

Thus an individual's relation to work, experience of work and wishes and expectations are important components that form the perception of work attractiveness, i.e. different people have varying opinions of the same job depending on their personal situation and preferences. In essence, it can be said that the relative importance of each dimension in the model by Åteg, Hedlund, and Pontén (2004) depend on the individual. Additionally, we argue that the weight of a dimension may even be negative. This has the effect that an "objectively" attractive job may be perceived as unattractive.

In figure 2.1 we have used Hedlund (2007)'s model to illustrate a plausible present situation for the mining sector. The attractive section is quite small and the view from an internal position is more positive than one from an external position. Thus we argue that the mining industry needs to expand job attractiveness, both for external and internal viewers. As was shown in the above models, this expansion can be achieved in a large number of ways. Essentially, present attractive qualities must be presented and not hidden away from applicants and potential staff. Unattractive or repelling job features must be eliminated or decreased, resulting in a situation close to that in figure 2.2.

The question is how to achieve this expansion of attractiveness. Based on our experiences from the SIMS project and other similar projects, we have summarized our findings in six recommendations for creating attractive workplaces and increasing the visibility of the good parts of mining work:

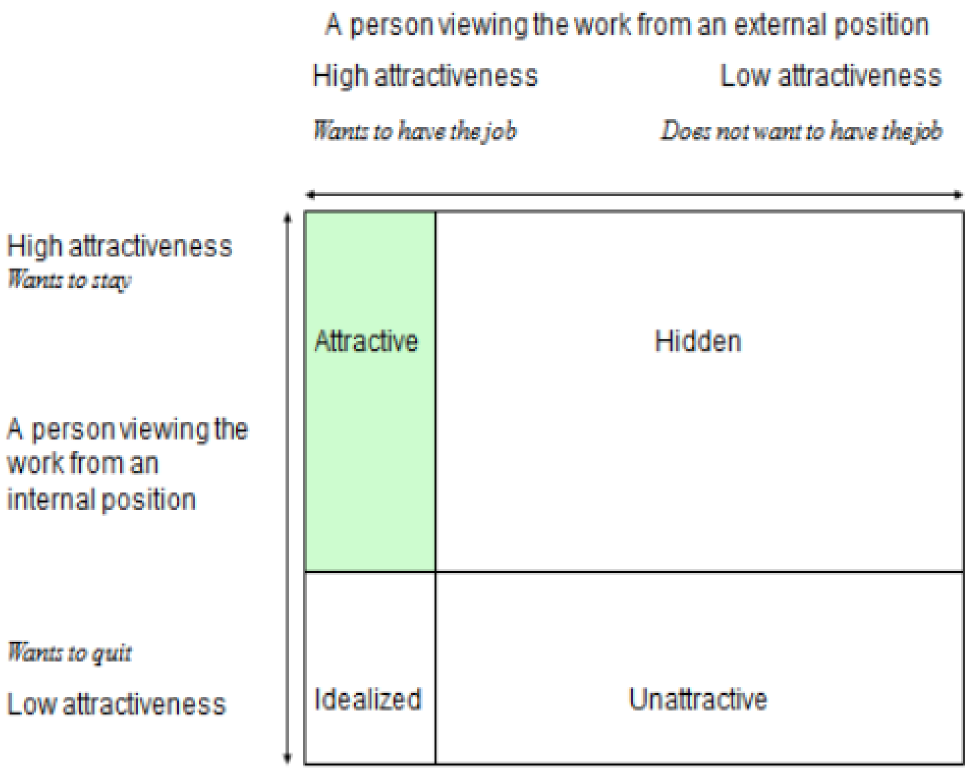

Figure 2.1: The attractiveness of the mining industry illustrated.

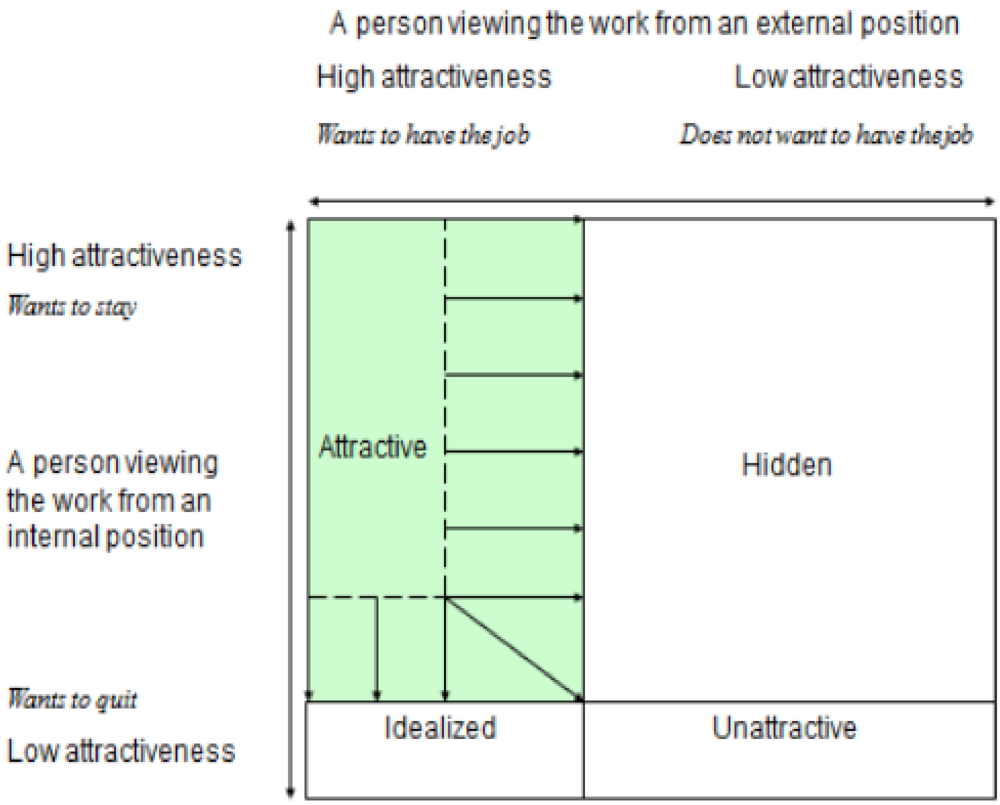

Figure 2.2: How the attractiveness of the mining industry must develop.

- Health and safety at work must have top priority. Mechanization, remote control, and automation are efficient preventive safety measures, but are also appropriate for reducing workload to avoid musculoskeletal injuries and allow for recovery periods. Improved safety is also a matter of a developed safety climate in the form of relevant education, rules and effective leadership where safety clearly is prioritized in the day-to-day-work.
- A work organization based on groups as an operative unit where all employees have control over their own work cycle. This very concrete demand guarantees a variety at work while also providing meaningful autonomy. The demand can also be combined with a Lean approach.
- Competence development, and learning at work are important to guarantee flexibility for the company and development in one's professional role. It is also a question about changing into a workplace culture that follows the developments in the industry, such as new production techniques, new products, and new quality demands.
- Gender equality is essential for the mining industry to being viewed as a modern employer. The industry must break away from its macho-masculine image.
- The mining companies must more actively demonstrate their social responsibility. Employees want to feel proud to work in the company, so issues such as vision, mission and core values are important.
- Focus should be placed on the benefits as well as the potential problems that may come with having a workforce consisting of both in-house personnel and contractors. This includes an emphasis on strengthening both the formal (e.g. implementing joint safety management practices) and informal (e.g. communication and interaction on a workplace level) relations on the emerging multi-employer worksites.

Finally, if the mining industry wants to improve its image and recruit young people in the future, they have to broaden their perspective. New technology is important and can solve many problems, but not all of them. Technology must be complemented with a social perspective that includes attractive and safe workplaces in a social functioning society, sought-after workplaces in a company that people are proud to work for.

See also

Johansson et al. (2018).

3 Fix the problems before they occur

A heavy responsibility for safe mines lays on the mine planners shoulders. They must find solutions that promote high productivity and good economy as well as safety and a healthy work environment. The mine planners will initially shape the general and specific work environment for miners for many years to come. If the planners design a poor solution and it is necessary to redesign it, it will also probably be very expensive to correct after it has been implemented.

Work environment and safety issues are unfortunately often left quite unattended in the early stages of mine planning and design when they instead should be systematically highlighted and developed from the very first planning steps. The best and most efficient way to gain a good safety is through proactive planning instead of reactive corrective actions. It is also the best way to reduce the associated costs for risk elimination and reduction.

The mine planner is however not alone, he or she works in a company context where safety climate and culture, safety policy and safety management have a strong influence on how well the planner can succeed in his work.

The slogan "Safety first" has been heard in the mining business for many decades but is still in many cases not more than a slogan since safety first is not fully practiced, especially if the business has financial problems. It seems however that the times are changing and many mining companies are now making great efforts to improve their safety climate and safety culture. Research on safety has shown that at positive safety climate and well developed safety culture is an important requisite for a healthy and safe work environment, especially in heavy industries.

In order to manage the risks in the business every mining company is also in need of a strategic long-term policy regarding how to deal with safety issues and strive for better work conditions. The safety policy shall direct and establish systematic ways to manage (plan, steer and control) the safety work, also including early planning and design activities.

Because mining is a very risky business it has to follow and obey a lot of directives, laws and provisions. Most of these rules only stipulate minimum demands and the companies are free to exceed them. This is also what mine planners should aim at, exceeding minimum demands. A first step for a mine planner is therefore to get acquainted with the national and international (ie EU regulations) system of rules and basic demands. Many of these demands are provided by the national or EU authorities. This has to be done in a thorough way in each country there are quite a large number of directives, laws and provisions that regulate and give guidelines for health and safety issues in underground mining.

The basis for all activities in systematic health and safety work shall always be an initial thorough risk assessment both of the present state and a future planned state. It is of course easier to assess present or historical risks than future risks, especially if the future holds large changes in technology and or work organization. Still a mine planner needs to assess the risks with different mining concepts that are developed and planned.

Mining might develop in a revolutionary way, but will most probably develop in another way, in an evolutionary way. This means that much can be learned from history and from the present state. Thorough evaluations of present and historic designs have for example systematically been used by the Swedish mining company LKAB in the design of their newest main level at 1365 m below surface. This evaluation has been very important since the time span from the first conceptual designs to the final solutions has stretched over 12 years and a large number of planners.

Risk assessments can be performed in number of ways depending on the situation and circumstances. All risk assessment shall however be based on probability and consequence for unwanted events. A practical tool for this purpose is a risk matrix that eases a systematic and consequent risk assessment (see figure 3.1).

Probability / Consequence	Some discomfort but harmless	Injury but no sick leave	Short sick leave	Long sick leave	Permanent serious injur or death
Very common - 1/week	R3	R4	R5	R5	R5
Common - 1/month	R2	R3	R4	R5	R5
Relatively common - 1/år	R2	R3	R3	R4	R5
Quite unusual - 1/10 år	R1	R2	R3	R3	R4
Not probable - 1/100 år	R1	R1	R2	R2	R3

Figure 3.1: Risk matrix based on probability and consequence.

As can be seen in figure 3.1 probability is expressed as a frequency for a specific event or deviation. The assessed risk level during planning can also be coupled to a specified need for action, (see 3.2).

The risk matrix for risk assessments during planning can also with some modification be used for risk assessments in the operative production stages (see 3.3). The risk matrix has therefore become a quite well known and used tool in the mining companies.

The classical tools for the identification of occupational risks in the existing production environments are Safety rounds, Incident and Accident reporting. These tools are however less suitable to identify and assess risks in future work environments. There you need other types of more proactive methods such as:

- Preventive deviation analysis

Risk level	Need for action during planning
R1 Low risk – negligible risk	No need for any redesign of the basic concept
R2 Small risk	A limited redesign of the basic concept might not be needed
R3 Average risk – certain risk	A thorough redesign of the basic concept is recommended for parts related to identified risks
R4 Severe risk	A redesign of major parts of the basic concept is necessary to reach a less than average risk
R5 Very severe risk	Any further development of the design concept is not permitted until the identified risk is reduced to a less than average risk

Figure 3.2: Risk level and need for action during planning

Risk level	Need for action during production
R1 Low risk – negligible risk	No need for action
R2 Small risk	Action might not be needed within months
R3 Average risk – certain risk	Reasonable risk reduction needed within a week
R4 Severe risk	Promt action is necessary within hours
R5 Very severe risk	Work is not permitted until risk is reduced to an acceptable leve

Figure 3.3: Risk matrix based on probability and consequence.

- Preventive energy analysis

A deviation is according to Harms-Ringdahl (2013) defined as an event or condition that deviates from the intended or normal. The purpose of a deviation analysis is to prevent, to predict abnormalities that can cause damage and to develop proposals to improve safety measures. Deviation Analysis is a very useful method since it takes into account the entire system, Human-Technology-Organization. Energy analysis focuses more on technology and might be useful when developing new productions systems. Three main components considered in an energy analysis are:

- Energy that can damage
- Targets that may be harmed
- Barriers to Energy

The energies usually considered are: Gravity, height (including static load); Linear motion; Rotary motion; Stored pressure; Electrical energy; Heating and cooling; Fire and explosion; Chemical effects; Radiation; Miscellaneous (human movement, sharp edges, and points).

There are also many other different risk analysis methods that can be used during the development of new production systems. Besides the methods mentioned above methods like Preventive Work Safety Analysis (PWSA), Failure Mode Effect Analysis (FMEA), Fault Tree Analysis (FTA), Event Tree Analysis (ETA), Work Environment Screening Tool (WEST) etc. are possible to use. The most appropriate tools have to be chosen for every specific analysis task and the users of the tools must also have the necessary competence in order to attain reliable and relevant results. Here the mining business probably can learn much from other industry that has a strong safety culture and long experience of systematic risk management. Especially important will be to learn how to proactively manage risks for fatalities and other severe risks. Here so called leading indicators are preferred instead of lagging indicators

Even if there are many risk evaluation tools available mining industry seem to need new and efficient tools for description, evaluation and design of work environment during early phases of strategic decision making and production system design. The most important decisions regarding work environment and safety are made by top management when mining methods, technology, work organization etc. is decided. Therefore risk analyses regarding these matters should be made as early as possible in the mine design process.

Once a risk analysis is completed it often requires measures which in most situations should be implemented in the following well known order:

1. Prevent already in the planning stage, replace the hazards entirely. For example, through automation to eliminate manual or mechanized underground work.
2. Isolate the individual hazard, risk process. For example, by designing ventilation and layout so that the blasting fumes can't be spread outside the risk zone.
3. Change process technology and behavior. For example, DTH-drilling with water hydraulics rather than pneumatics to reduce dust emissions.

4. Limit the hazard through enclosures, physical protection. For example, build concrete borders and railings at the shaft openings.
5. Isolate personnel from the hazard risk area. For example, by supplying the mining vehicles with safety cabs with good climate control.
6. Risk is reduced by instructions, procedures, training, etc. For example, procedures for safe handling of explosives.
7. Risk is reduced through personal protective equipment. For example, functional working clothes.

Depending on the complexity and severity of problems one may require different combinations of measures as described above. One recommendation is to always try to attack the root causes of the problem first. It tends to result in the most cost efficient and result efficient solutions. This is an important task for mine planners. They have the best opportunity to eliminate a lot of potential health and safety problems when they develop the first conceptual solutions. Planners that don't realize this and neglect these matters can cause great harm for many years to the mining personnel and their company.

4 A vision of "The New Attractive Mine"

The new deep metal mine was a true planning and co-operation success and a huge leap in mining history. A number of leading "European mining companies" had been inspired by a group of "Australian researchers" that had provided a conceptual system for automated and flexible mining, based on drill and blast technology for fragmentation of the actual ore. Continuous mining with road headers was still only used in development works where conventional drilling and blasting was abandoned. The zero entry mine was now almost realised and the large "European manufacturers of advanced mining equipment" had contributed largely to the technological success, which had opened a new global market for them.

The new automated mining method made it possible to almost continuously produce desired ore qualities and quantities on customers demand. This was a big comparative advantage compared to the old traditional bulk production mines that still existed and struggled for their survival. The new mining system dramatically reduced the prevailing and traditional use of expensive storing and stacking of mined ore. With the new way to mine an important first step towards true Lean-mining was taken and gradually one bottle neck after another was discovered and eliminated. Metal recovery was very high and cut-off grades were reduced. It seemed as traditional mining had been a real waste of resources.

Advanced investment analyses had clearly shown that there were great financial benefits with the new automated mining technology. The costs for underground development works were reduced with about 50% compared with traditional mining methods and labour costs were reduced with more than that. This made it possible for the companies to make large investments in new technology and personnel competence and still be highly profitable. If profits for society and individuals also were included in the analysis the total expected financial benefits where overwhelming. Follow up of actual economical results showed even bigger savings than expected.

An unusual feature of the new mine was that open pit mining was avoided although the upper parts of the ore body were close to the surface. A green mining philosophy "In situ mining" was applied and most of the mining activities were invisible for people passing the mine site. Most of the waste material was directly used for backfill after recovering the metal content.

The mining companies had from the start of the project made use of a newly developed iterative planning methodology that reduced common initial design errors when they designed the new mine. Basic guidelines provided very useful demands for the mine designers. During the development works there had for example never been any real ventilation problems, stability problems or water drainage problems. No severe accidents or incidents had occurred so far and all mining activities were systematically risk assessed. The new mine had set a new world standard for results regarding health and safety results. Safety first was not only a simple a slogan, it was a complex and applied reality. In fact no major physical work or main activities were performed unless they had been computer simulated, evaluated and approved. This proactive way to handle production and safety risks had proven its value time after time. The old description of mining work as “Dark, dirty and dangerous” had definitively become out of date and irrelevant. Instead of being almost unpredictable and uncertain mining had become highly predictable. Some of the old miners meant that the original charm of mining was somewhat lost when all worked according to plans, but no one really wanted the old risky ways and days back.

One key to the success was the fact that the mine was already from the start designed for automation and socio technical principles with a work organization based on production teams and broad professional skills among management and miners. One of the mines most impressive features was the information and decision systems based on sensor technology and production analysis in real time. This made it possible for the personnel to actively steer and control the production instead of just passively react on deviations and alarms from an automated production process. This was a major difference and advantage compared with traditional control room work, in for example regular processing plants. Impressive results regarding product quality and production availability and stability had been achieved due to this proactive philosophy. The philosophy also made the miners work interesting and challenging.

The new remote operations control centres (so called ROCs) were designed to promote cooperation and creative problem solving in multi skilled teams. The working teams were mixed regarding age, experience, gender, competence, etc. Diversity had replaced conformity and this had proved to be a good base for creating “production scouts”, miners that were always ready and interested in improving the mining processes. Most of the team members were recruited from national and regional education programs that were specially developed with regards to the new demands that the mining sector had, basically that modern mining was an intellectual analytical work for wise and reliable persons. New education programs on all levels had been started and were recruiting well. Mining work had turned to be attractive, not only because the wages, but also because it was a very interesting work with good possibilities for personal and professional development in a safe and sound working environment.

The total progress had been astonishing although they only have started to utilize parts of the potential that the new technology and organisation offered. Investments in research and development work had paid off quickly and management were convinced that innovative R & D combined with a challenging vision had been and would continue to be the key factor for success.

See also

Johansson and Johansson (2014).

5 Future of metal mining

The world's metal mining industry is rapidly changing and faces a number of challenges which must be addressed with a socio-technical approach that covers the whole mining and minerals value adding chain including environmental issues. We have tried to capture this uncertain future in fourteen predictions presented below:

1. Future mining will be shaped in a context where it is necessary to produce at costs that are determined in *international competition*. The prices of metals and minerals are set by the market 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.

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.* 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. 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. Cutting should also be useful for selective mining of high quality ore in narrow ore bodies. Production drilling and blasting for *controlled fragmentation* are two very crucial operations in the ore mining cycle. Improvements in these operations opens up many possibilities for *automation.*

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 emissions. Today not all nations have joined the Paris Climate Agreement, but in the long term, some form of coordination surely will be established. The cost of emission allowances will be a significant factor to consider.

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. 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. The use of fossil diesel fuel is extensive and

causes environmental burdens. A transition to electric power and battery operation is in progress.

6. The discussion of *waste management* is about to leave as few footprints in nature as possible. We must not leave toxic substances which 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. Such technology is however not without environmental risks and risks for 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. With regard to water in general it is a question about *closing the loops* and re-using the process water as much as possible.

7. The environmental debate also includes a discussion on the mining industry's *social responsibility* for the welfare of the local community. 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.

8. *Health and safety* are very high on the agenda and are also strong driving forces behind the ideas of automation. In the future we will have a production with *zero entry* for employees underground based on automation and remote control

9. A generally good and safe working environment is seen as a prerequisite for the recruitment of skilled workers. The typical underground *work environment* with noise, dust and toxic fumes and gasses will be monitored by using advanced sampling strategies with portable, more accurate and reliable measuring devices and more efficient counter measures can be taken.

10. *Industrie 4.0* is based on implementation of Internet of Things, 5G and Big data where the entire production process is included in internet-based networks that transform the mines to smart mines. We will soon see the outlines for Mining 4.0 where miners equipped with mini cameras can for everyday and emergency situations provide their colleagues and senior management with information that is difficult to convey verbally.

11. *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 opportunities in the system allows for all to optimize the whole chain rather than sub-optimizing parts.

12. *New professional roles* with a higher proportion 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. Their jobs will change 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.

13. New technology create 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. This can challenge the identity of the miners and create a resistance to change.

14. 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. Mining companies will gradually turn to a flat and *lean organization* with multi-skilled workers who can operate in several areas and functions within the company. There is also a discussion about staffing system based on *fly-in fly-out* which is more independent of a local community.

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. 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.

See also

Abrahamsson, Johansson, and Johansson (2009).

6 The Dimensions of Attractive Mining Work

As mentioned in chapter 2, the mining industry has had difficulty with hiring people from younger generations and should as such look for ways to improve the attractiveness of mining workplaces. The 22 dimensions of attractiveness described by Åteg, Hedlund, and Pontén (2004) that were discussed in chapter 2 are presented as more generally applicable aspects of attractive workplaces. In an effort to investigate if and how these aspects of attractive work could be applied to mining workplaces, Lööw et al. (2018) examined the 22 dimensions and their relation to the mining industry. Below is a list describing each of the dimensions which includes descriptions of how they are best fulfilled and how mining workplaces are affected by and can affect the attractiveness of the workplace.

Attractive working conditions

- *Adequate equipment and tools:* Modern equipment capable of providing good results efficiently and safely should be provided. Equipment should be designed to accommodate people of different sizes and with different needs.
  - The equipment in the mining industry has a history of having trouble accommodating the people that use them. With new technologies comes opportunities to design attractive equipment that accommodate both new and existing employees' needs.
- *Leadership:* There should exist proper trust, communication and cooperation between employees and management. Management should feel safe in letting the operators have more control over the planning and execution of work tasks and with letting them partake in decision-making. Employees should feel like they can safely give suggestions and voice concerns, while also trusting that management will take their needs into account when making changes.
- *Location:* It's important that the workplace is located close to home, that there is proper transportation to work and that the surrounding society is developed.
  - Mining companies cannot easily accommodate this aspect due to being bound by mineral deposits' locations. However, providing adequate transportation and housing, and investing in local societies, they can mitigate the negative effects on attractiveness.
  - While bringing in personnel through Fly in/Fly out-methods is an alternative, European mines generally try to avoid relying on them.

- *Loyalty:* Employees should be loyal to and be treated with loyalty from the company, their colleagues and across organisational boundaries by cooperating and making sacrifices for each other.
  - Establishing trust is an important factor for promoting loyalty. Management must ensure that the employees can trust them to make decisions and changes that are designed with their needs in mind.
  - Another important factor is to provide transparency. Management should detail and explain how and why certain decisions are taken, which in turn helps build trust.
- *Organisation:* A successful company can be more attractive, in addition to having low turnover, being in a good economic situation and providing advancement possibilities and benefits. The size of the organisation also affects the attractiveness, where smaller companies tend to be more attractive.
  - In modern mining companies, there is a trend amongst organizations to adapt something called Lean mining. It is meant to help rationalise and make their productions and organisations more effective by implementing Lean philosophies. It entails a focus on quality of infrastructure and safety, production uptime, flexible and multi-skilled workers, and teamwork.
- *Physical work environment:* Attractive locales should have nice appearances and furnishing, pollutant-free air, low sound levels and they should be clean.
  - The move towards control room work helps mitigate negative impacts by removing the operators from the potentially risky mining workplaces for much of the work.
  - Proper ventilation, noise protection and tunnels clear from debris is vital for a good work environment in a mine, even with more remote-controlled work.
- *Relations:* The employees need relations at the workplace that provide support and empathy, with good team spirit, camaraderie, cooperation, honesty and so on.
  - Future mining work provides good opportunities to develop good work relationships with your colleagues if team members work in the same control rooms.
- *Social contact:* The workplace allows for social interactions with other people, such as customers or colleagues.
  - With control room work, people can more easily speak with their colleagues face-to-face.
  - As mining work may sometimes require working alone, proper equipment for communication should be provided to avoid isolating operators.
- *Wage:* It is important that the wage provided is of a sufficient level, that it allows for people to support themselves and that it gradually increases.

  - Wages in mining workplaces are generally higher than average, which could contribute to attractiveness should other factors be addressed.
  - Wages shouldn't be based on produced results, both to provide a stable wage and to promote healthier ways of working. This is due to piece rate wages having been shown to increase the risk for workplace accidents to occur as it leads to safety procedures being neglected to increase production rates.

- *Working hours:* Reasonable working hours that are predetermined and configurable can make a workplace more attractive. The employees should always know when they start and get off work while also being able to influence the scope, distribution over the week and plan vacations.
  - Mining usually relies on around-the-clock working hours. Setting up offices in larger cities that remotely control machines in the mines far away would access a larger employee base, making it easier to find people willing to accommodate these working hours.
  - Working in extended shifts of 10-12 hours is common in the mining industry, but it increases the risk for accidents to occur the longer the shift. As such, it should be avoided in favour of more standard working hours at around 8 hours per shift.

Attractive work content

- *Familiarity:* The employee should know what to do and what to expect in the workplace. This requires proper training, access to work instructions and an incentive to utilize that information.
  - With the implementation of 5G in mines and a digitalization of work, it will become easier to communicate with others and access work instructions whenever needed, even when below ground.

- *Freedom of action:* The employees should be able to organize and control their own and others' work, for instance by influencing the planning and execution of work tasks.
  - Working from control rooms and with digitalized systems could give more opportunities for controlling one's work. For example, operators could more easily swap between and choose which machines in what parts of the mine to operate.
  - Freedom of action could also be provided by placing the smallest planning level on the work group level. Management would no longer need to create individual plans and schedules for each employee. Instead, the work groups would be provided with goals and missions after which they could plan their work accordingly, thus giving the work groups more control over their work.

- *Physical activity:* The workplace should allow and include healthy physical activity and movement to help prevent employees from suffering static work-related injuries or health problems.

- After the automation, mechanisation and digitalization of the mining industry, there will still be physical activities available, for example through maintenance work. Having the operators alternate between these tasks and control room work would help vary the otherwise very static workplace.

- *Practical work:* The workplace should include practical and creative work tasks with handheld machines or tools to break from working only with computers or control systems.
  - This aspect can also benefit from including maintenance work to vary the control room work. Furthermore, since the new technologies will likely require adapting into the already complex mining systems of today, there will be opportunities for more creative work through retrofitting.
- *Mental work:* Work tasks or problem solving should include cognitive work in addition to physical work and should be performed cooperatively with colleagues and management. This should include workplace learning, development and training.
  - Control room work in mining industries offer many opportunities for mental work and brings groups of operators together to the same workplace.
  - A more digitalized organisation would enable easier communication and cooperation between groups that would otherwise rarely meet.
- *Variation:* Throughout the day, employees should be provided opportunities for job rotation, development of work tasks and flexibility in ways to perform the tasks. This is to prevent potential ergonomic and mental loads from working with the same tasks repeatedly.
  - While the remote-controlled mining workplaces may allow for rotating between work tasks, there might be less variation between tasks as they would all be controlled through computer systems in control rooms. Including maintenance work tasks could help introduce more variation in work content and working environments, making the job less monotonous.
  - Variation between work tasks require that the employees are trained in how to handle the different tasks.
- *Work pace:* The work pace should include both intensive and calm periods in order to engage people while also providing opportunities for rest and reflection.
  - Since the work pace in mining is continuous around the clock, there are few calm periods outside of assigned breaks. Introducing autonomous or semi-autonomous machines to the mining workplace would allow for more opportunities for calmer periods during the work. As an example, mining vehicles could autonomously drive to their destination, allowing the operator a short break from active work. The operator could then take control during more complicated or critical tasks once the vehicle has arrived.

Work satisfaction

- *A demand for the person:* Workplaces where the employees feel like they are needed and that they perform important work are generally considered to be more attractive.
  -
    - As the mining industry needs more skilful people and people from younger generations, those people may become more interested in the job if that demand can be communicated to them. Potential ways to communicate the demand could include having a presence in mining-related educations to show students that they are in demand.
  - Existing employees could feel more appreciated if the importance of their knowledge and skillsets is made more apparent for them.
- *Recognition:* The employees should themselves feel that they have done a good job, in addition to being provided recognition for their work from management, colleagues or customers. Good performance should be rewarded according to the employee's subjective preference; perhaps through a monetary reward or through more time off.
- *Results:* The employees need to clearly understand what the results of their work is and how it contributes to the workplace.
  - The switch from operating the machines yourself to controlling them from a remote control room could cause some disconnect to their work for the employees.
  - Working from a control room with more digital systems provides a good opportunity to visualise and present the operators with an overview of the entire mine process.
- *Status:* The workplace contributes to and strengthens an employee's sense of pride, success and professional identity. Companies must communicate to their employees the value of their work and their knowledge.
  - The mining industry has had an image of heavy, tough and dirty but profitable work for a long time. The change towards more digital and remote work could impact that image, and in turn impact people's perception of the industry.
  - As many existing employees have established a sense of pride for working in the current mining industry, changing the way mines are operated might negatively affect the attractiveness of the job for them.
  - At the same time, moving towards the implementation of more modern technologies could make the industry more attractive towards younger generations of employees.
  - A more even gender distribution would help improve the status of mining work today, especially amongst younger generations.
- *Stimulation:* The workplace provides an opportunity for the employees to put in effort and use their skills in their work. The work being too difficult can be demoralizing for them, while it being too easy can lower the employees' motivation.

- The mining workplaces of today and of the future both provide opportunities for stimulating work, however they may be stimulating in different ways. A current employee may find future mining workplaces to be unstimulating, while future employees may find it opposite.
- Regardless of what subjective views employees have of the work, they need to be provided with proper training and support if the work is difficult for them.

Even though mining workplaces have the potential to fulfil the dimensions of attractiveness, it could still be difficult to accommodate for each of these aspects at once. However, this doesn't mean that the workplace cannot be attractive if it only fulfils most or some aspects. What is important is that the parts of the workplace that negatively affect attractiveness are being compensated for through other positive aspects to ensure that the negative impact is lessened. For example, if heavy and ergonomically unhealthy tasks are unavoidable, supportive equipment and opportunities for rest in between can be used to lessen the negative impact. That way, an image of a safe and accessible workplace can better be conveyed and maintained.

7 Acceptance of new technology

Introducing new technology in the mining industry is the future but will the users accept the new technology? The purpose of this chapter is to give a brief overview of theories/models that are important for understanding which factors affect the acceptance of new technologies.

Organizations in the modern industrialized world face a rapidly evolving environment that requires changes to be able to keep up with the requirements, and the mining industry is no exception. First we need to clarify that the human is generally skeptical about change, there is a fear of the unknown. Change can be perceived as stressful which leads to negative emotions and feelings of uncertainty which in turn can affect acceptance. There is of course variation in how well individuals embrace and accept change. Regardless, when introducing new technology there are several aspects that needs to be considered to gain acceptance and succeed with the implementation. We will now give a brief overview of the most prominent theories in this area.

7.1 Theory of planned behavior (TPB)

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7.2 The Technology Acceptance Model (TAM)

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Technology is accepted when it is perceived as useful and easy to use. System design also affects user acceptance. In a study by Davis (1993), perceived usefulness was found 50 % more important for user acceptance than ease of use. That means, it is important to design based on user needs. Davis (exemplifies what is meant by perceived usefulness: the system is perceived to improve quality of work, gives greater control, enables the worker to accomplish tasks faster, supports critical aspects of work (i.e. decision making or monitoring), increases productivity, improves job performance, enhances effectiveness, and makes it easier to do the job. If a technology solution does not clearly show high usefulness by the user the user may be reluctant to use it. A system that is designed to control workers has high usefulness for management personnel but not necessarily for the workers. Highly effective workers may be positive to a control system since they may profit from their effectiveness being measured and observed. A control system may also be perceived as useful if its purpose is related to increased personal safety. Acceptance will be low if the workers do not see any own benefits coming from the system.

7.3 Unified Theory of Acceptance and Use of Technology (UTAUT)

There are many models that attempts to determine what factors that affect information technology acceptance among the users. Based on eight such prominent models, including TPB and TAM, Venkatesh, Morris, Davis and Davis (2003) presents a unified model, called the Unified Theory of Acceptance and Use of Technology (UTAUT). According to UTAUT, four constructs are direct determinants of user acceptance and usage behavior, namely; *performance expectancy, effort expectancy, social influence*, and *facilitating conditions.* Below the four constructs are briefly described.

The construct performance expectancy is defined, by Venkatesh and colleagues, as the degree to which an individual believes that using the system will help him or her to attain gains in job performance. It implies that it is of great importance to make the usefulness of the technology visible for the workers. Something more here?

The second construct, effort expectancy, is defined as the degree of ease associated with the use of the system. It is important to build and design technology on human terms. It may seem obvious that a technology should be useful and be both efficient and effective to use. However, there are often several needs that are missed in the process. Some specific demands for operators in the mining industry that are important to consider when investing in usable technology is presented in Chapter x (Technology on human terms in a mining context).

Third, social influence is defined as the degree to which an individual perceives that important others believe he or she should use the system. In the mining context, it means that the attitude to new technology can be influenced by the attitudes of the colleagues. It's a group process....

The fourth construct, facilitating conditions, are defined as the degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system. Leaders must be positive... Proper training and information...

The UTAUT also consist of four moderating factors which is gender, age, experience and voluntariness of use. However, these moderators are not always applicable to all context because there might not be any variation (Dwivedi, Rana, Jeyaraj, Clement & Williams, 2019). As an example, the organization might have decided that the use of the technology is mandatory, which makes the moderator voluntariness not applicable.

Instead, Dwivedi and colleagues (2019) argues that the UTAUT model is missing out one important aspect, namely the individual perspective. They suggest that attitudes, an individual's positive or negative feelings about performing the target behavior, play an important role in accepting technology.

7.4 Beers theory of organizational change

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7.4.1 Individual factors

7.4.2 Trust

Many barriers for acceptance of change can be structured under *trust*. Trust in management is a good predictor of lower level of resistance to change. If however the organization doesn't have, or has lost, the employees trust, then resistance will be higher and change will be more difficult to achieve.

This section will be expanded. (read Conte & Landy, 2018; Korunka & Hoonakker, 2014)

7.4.3 Perception of fairness

It has been well-established that fairness plays a key role in determining reactions to organizational events such as EPM (electronic performance monitoring). Procedural and interactional justice, will relate to perceptions of fairness.

7.4.4 Technology maturity

8 Positioning technology…

9 Technology on human terms in a mining context

This chapter will exemplify aspects important to consider when investing in new technology that will involve a user. The user is one of the key components for success, hence much is gained when technology is built on human terms. In short this means that the technology should meet and support cognitive demands, personal demands, communicational demands and environmental demands.

Industries are constantly evolving in terms of modernization of technology for production and communication at work. The reason for technology investments are often to increase productivity or safety. If the technology will involve a user it should be usable. According to the definition of usability this means that the technology should be possible to use by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use (ISO 9241-11). So, what does this mean more exactly? The technology should support effectiveness. This means that the users should not misunderstand the technology and end up doing unnecessary errors. The technology should support accuracy and completeness. The technology should also support efficiency, hence it should use as little resources as possible. This means that the user should be able to use the system quickly without spending time on unnecessary steps. It also means that the users should understand the technology, and not end up wondering what to do. As far as possible, technology should be self explanatory. Satisfaction is related to the subjective feeling the user get in relation to the product. The product should not give the users feeling of discomfort. The attitude towards the technology should be good. In this chapter we will mainly focus on aspects that are related to efficiency and effectiveness. User satisfaction in terms of attitude towards technology are more closely addressed in the chapter named Acceptance of technology.

If efficiency, effectiveness and user satisfaction are neglected, the risk is to end up with large investments that are never used, misused or too difficult to use efficiently. The investment may end up in large costs and reduced productivity; the opposite to what was intended.

As long as/whenever a user is included, it is important to build and design technology on human terms. But what is meant by that? It may seem obvious that a technology should be useful and be both efficient and effective to use. However, there are often several needs that are missed in the process. As an organization, you may not design the technology, but you can place demands on the designers and help them understand the specific needs of your personnel. In this chapter we will exemplify some specific demands for operators in the mining industry that are important to consider when investing in usable technology. The examples are built on theory combined with our findings in the SIMS-project and other related projects.

9.1 Cognitive demands

Learning and support

Over stimulation and under stimulation (Yerkes Dodsons Law for complex and simple tasks)

Attention, cognitive load

Stress (special needs during accidents)

Reduced cognitive abilities. Important to use high saliency.

9.2 Personal demands

9.2.1 Age

Age is a large challenge at many workplaces. First we have technology maturity. New generations may be frustrated when technology at work are slow or seem fossil. On the other hand, the workforce that have large experience may lose in speed and efficiency if changes are made frequently.

9.2.2 Gender

The main issues that are related to gender are physical demands. When it comes to investments of new technology it is important to control that small aspects like the size of the handheld device are big or small enough to be easily used by both a large and a small hand. Sometimes it is these small things that make the large investment useless in the end. And if not useless, the product may cause a lot of frustration and demand unnecessary effort if a button or likewise can not be reached easily.

9.2.3 Disabilities

Dyslexia

Color blindness

9.3 Communicational demands

Humans are multimodal. This means, we are able to take in information from several senses. This ability is a powerful gift that is difficult to match with AI. Humans are still a great resource when it comes to noticing differences in an environment, it could be a smell, a noise, vibration or a different color. For example, a human can in a few seconds notice a crack or a leakage on a large area. AI would need cameras, sensors, programming and extensive training for the same task. However, when this type of information are to be shared or saved the communication are often limited to only text or voice messages.

Examples of enriched communication and the gains.

Examples of problems related to communication (filtering)

9.4 Environmental demands

Sound
Vibrations
Dust, steam
Extreme heat or minus degrees. (Mobile phones outdoors during winter in the north)
Clothes
Reduced visibility (smoke during fire)

10 Guidelines for how to do it right - or to understand what went wrong…

This chapter provides guidelines, or statements to consider, when investing in new technology. These questions are meant to aid the organisation in the process towards technology that are effective, efficient and accepted from a user perspective. The guideline can also be used as a diagnostic tool to find out what went wrong if an investment fails to meet its promises.

Although the intention (often) is good when introducing new technology in an organization, there is no guarantee that the intended users will accept and use the technology. Further, even though the technology is “right,” people might not accept it (Zweig and Webster 2002). Hence, the technology must be complemented with human factors/social factors/psychological barriers… The best way to achieve a successful implementation of new technology is of course to proactively avoid making mistakes that can be thought of beforehand.

Based on research introduced in previous chapters (see for example chater x and x) and on our experiences from the SIMS project and other similar projects, we have created a guideline consisting of questions that are good to ask before implementing new technology. The guidelines are based on the models: TAM, UTAUT and Beers theory of organizational change and other relevant research.

10.1 Perceived usefulness (Performance expectancy)

- The technology makes it easier to accomplish tasks more quickly.
- The technology makes it easier to do a good job.
- The technology improves safety at work.
- Overall, the technology is perceived as useful.

10.2 Perceived ease of use (Effort expectancy)

- The technology is easy to learn and remember how to use.
- The technology is easy to understand and interact with.
- The technology is flexible and possible to use for all workers.
- Overall, the technology is perceived as easy to use.

10.3 Inclusiveness

- The technology can be used independent of size and strength
- ...

10.4 Perceived ability (Self-efficacy)

- The users feel confident in how to use the technology.
- The users feel confident in that they will know how to use the technology.

10.5 Perceived justice

- An uneven access to technology and information can be justified.
- The use of information provided by the technology is restricted
- How the information is used is clearly described

10.6 Social influence

- The user groups are positive towards new technology.
- The user groups are positive towards changes at work.

10.7 Voluntariness of use

- *The technology is not compulsory to use, there are other ways.*
- *The technology is compulsory to use.*

10.8 Facilitating conditions

- The users have the competence needed to use the technology
- The users can get appropriate support if they do not know how to use the technology
- The users can get appropriate support if the technology fails to work
- The technology is compatible with other technologies or systems used at the workplace.

10.9 Privacy concerns (Intrusiveness)

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10.10 Perceived need for change

- The pre-existing technology is/was not satisfying.
- The workers were not satisfied with how it was before.
- There was an expressed need of new tools, functions or ways to work that could be met or simplified with the technology.

10.11 The investment process

- Have a clear plan that clarifies who, what, when, where and how the change should take place.
- The plan must be communicated to everybody in the organization.

10.12 Personal demands

10.13 Trust

-

11 Adapting the technology to the miners (Human factors)

Human-centred design, commonly interchanged with the term human factors design, is defined by (Horberry, Burgess-Limerick, and Steiner 2018) as the science of designing equipment, workplaces, tasks and organisations to account for the users' needs and wants. This means that designers need to ensure that they accommodate a wide range of users of different shapes, sizes, gender, age and more. It also entails considering the effect that the design has on other stakeholders, such as the maintenance workers who repair the equipment.

The goal of human-centred design, or HCD, is to improve work performance and the safety, health and well-being of the workforce (and, if possible, society in large). The key principles for HCD can according to (Horberry, Burgess-Limerick, and Steiner 2018) be summarized as:

1. Adapt the equipment, system or product to the needs and wants of the people who interact with it instead of having them accommodate the system or object. For example, controls and equipment should be designed to be easy to use and perform maintenance on. People shouldn't have to work with the equipment or system in unhealthy or dangerous ways to make it function properly.

2. Designing systems or equipment requires an understanding of the people who will interact with or be affected by it. Questions like what's the context for their interaction, what tasks do they need to perform, in what environment and so forth need to be investigated.

3. The continuous involvement of the users and other stakeholders in the design and development process is important to ensure that the previous principles can be upheld.

4. The design process is iterative to ensure ideas and concepts are reworked until they fulfil established requirements. Amongst these requirements are needs to account for human-centred subjects such as usability, safety and ergonomics.

5. Each stage of the design process of the equipment or system must accommodate the needs and wants of the people who will be interacting with it.

There are several potential benefits with designing in accordance with human factors:

- May allow for solutions or performance improvements not otherwise possible.

- Improves operator performance, efficiency and lowers costs of training.

- Can help avoid additional costs and problems stemming from equipment, workplaces or tasks being badly adapted to the users.

- Demonstrates that the company accommodates their employees' needs and wants. This can improve the attractiveness of the workplace and the products for potential employees and customers.

- Can improve employee acceptance of workplace aspects, changes and tasks.

- Can increase the trust from the people involved with the human factors-designed system.

Human factors are rarely considered when designing mining equipment according to (**???**). Instead, focus often lies on what the technical aspects of the equipment can achieve. The people are often left to perform the tasks that the machines cannot. This doesn't mean that there aren't parts of the mining workplace where human-centred design has already been taken into account. Below are examples of areas of mining workplaces where human-centred design is designed for or should be designed for.

The vehicles and machines used in mining have according to Simpson, Horberry, and Joy (2009) had problems with the visibility from the cabin for a long time. Due to the size and equipment of the vehicles, the drivers' line of sight is often very limited. The risks and potential consequences of this have inspired the implementation or design of several preventative measures. These include added cameras to show the "blind spots" of the driver's line of sight, proximity sensors to notify the driver on how close they are to things in their environment and more.

The interfaces of mining equipment and machines often contain many buttons, levers and other interactable elements. A human-centred design ensures, amongst other things, that:

- No parts of the interface are difficult or unergonomic to reach. The most commonly used levers and buttons are the easiest to access.

- Interactable elements are grouped up on the interface according to function, for example by putting buttons next to the dials and screens that they interact with.

Relating to unergonomic interfaces, foot rests, seats, handles and other physical elements of the machines can easily become uncomfortable or even perilous to use if they aren't designed to accommodate people of different sizes and statures. Tools and equipment can have the same problem, where their weight and size doesn't consider the physical capabilities of different users. To design with a human-centred focus is to ensure that equipment, tools and other elements in the workplace are comfortable and safe to use for more than just the average person. Making the equipment modifiable and adaptable, so that chairs can be adjusted and helmets can fit more people, helps ensure that all employees can safely and effectively use it. It isn't enough, however, to ensure that the equipment is comfortable and safe for the users to work with. The equipment also needs to be designed with maintenance in mind. Maintenance hatches, engine housing and electronics need to be reasonably easy to access to not complicate maintenance work more than necessary. As for future technologies in mining, the batteries of the electrical vehicles that are to be implemented in the mines need to be easily charged and replaced. Designing and creating these future technologies provides an excellent opportunity to create machines, systems and equipment that accommodates the users and the people affected by them.

There are aspects of the future vision for mining workplaces that likens a human-centred design thinking. Mining industries are moving towards utilizing more remote-controlled machines and control room work in mines. The mining operators can thus be removed from potentially dangerous or ergonomically unhealthy work tasks and environments. This reduces their exposure to vibrations, dust, blasting gases and the risks of cave-ins, improving the safety and health conditions of the workplace. With future mining workplaces consisting of more remote-controlled work, however, operators will spend more time doing static work in control rooms. Several researcher warns of the potential health risks such as circulatory problems caused by too much static work (Bohgard et al. 2009). A workplace with a human-centred design should thus provide their employees with work tasks balanced between physical and static work.

12 Iterative design of mining workplaces

When making and implementing changes to mining industries, it's rare to see large extensive changes take place, which is likely due to the complexities of the systems involved in a mine. Instead, changes are often implemented incrementally, with individual implementations coming together as a larger change effort over a longer period of time. The development and implementation of changes and solutions can sometimes take between 7 and 10 years to complete, after which they remain in use for at least just as long. The problem is that the changes may have already become obsolete at the point of their implementation due to this long implementation process. The designers and planners must thus ensure that they don't introduce long-lasting changes that negatively affect the working environment. This can, however, become difficult due to how mining change projects are structured.

According to (**???**), design processes in mining industries are rarely iterative and human-centred processes, instead following more linear processes with a technology-centred perspective. While these processes has been successful at times in the mining industry, there are cases where it's only revealed which issues that are relevant late into the project. A linear process doesn't allow for earlier parts of the process to be easily revisited, which could make necessary adjustments difficult or expensive. With how long the development times can be for mining implementations, this can risk invalidating several years' worth of work. An iterative design process is more suited for adapting to changing goals and requirements, in addition to placing a greater focus on user feedback. This, in turn, provides better opportunities to create results that addresses relevant issues and user needs.

The iterative design process has been described by several different authors as consisting of a varying amounts of steps. The process can be generalized, however, into four steps: planning, diagnosis of the present status, formulating demands, and creation and evaluation of proposals. When working with an iterative process, these four steps are followed in order, with more focus being put on the first steps early in the project. Once all steps have been completed, the process cycles back to the planning phase and work begins again, only this time more emphasis and detail is put on the following steps. Osvalder, Rose, Karlsson, Eklund, & Odenrick (2015) describes this design process using project circle similar to 12.1. During the cycles, several different solutions should be created in order to compare and judge between different alternatives. The solutions that satisfy the demands of the project can then be assessed and combined with other solutions, while the solutions that don't can be removed. This design process continues, with each cycle shifting the work focus more towards the final steps, until a final proposal has been gradually developed and chosen.

To more specifically describe the work that goes into the steps of an iterative work process, Ranhagen (1994) starts with describing how the planning phase can be separated into three parts; formulating the goals in general terms, creating a project organisation, and separating the work into stages. A project organisation can consist of a decision-making body, a health

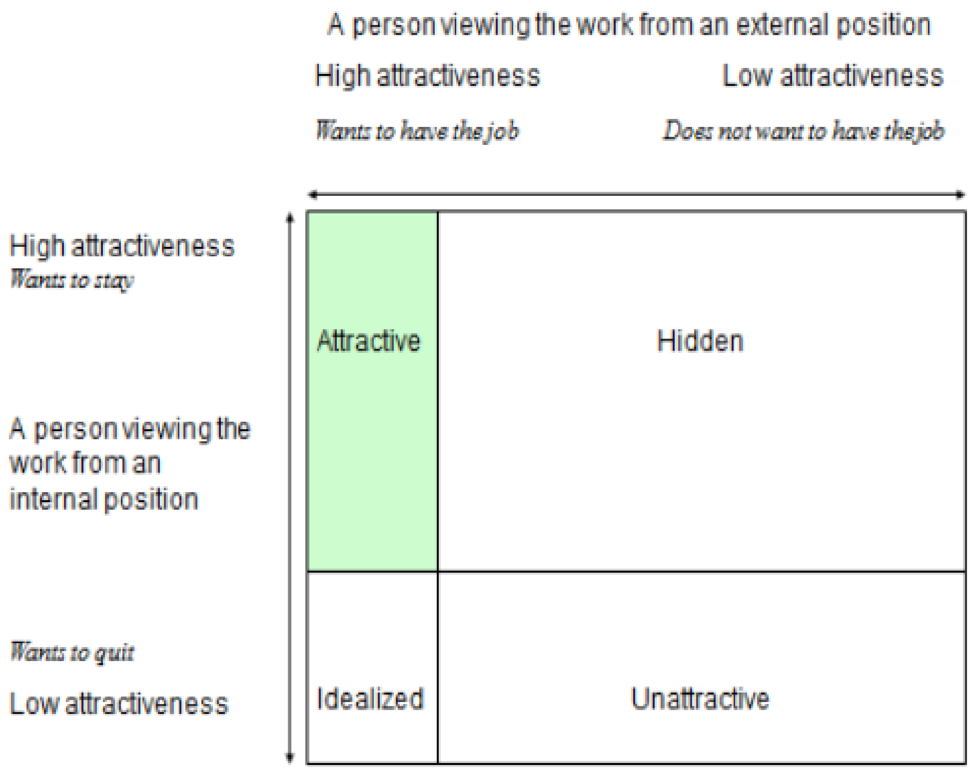

Figure 12.1: An illustration of the project circle describing an iterative design process

and safety reference group and a project group. The important thing here is to include both people with experience in design work and people from the areas of the workplace that will be affected by the changes, like maintenance workers or miners. The second step of the iterative process, the diagnosis step, consists of documenting and investigating the current state of the workplace; what problems exist, how the work is done today, what will be done in the future, and so on. During the third step, functional demands are to be established and developed. These demands help guide the creation of concepts and solutions by serving as objectives that needs to be fulfilled. At the same time, they need to promote creativity by not specifying a certain solution, for example by having a demand for good air quality instead of a demand for extensive ventilation systems. If one demand is more important than another, a weight point can be applied to each demand that signifies its importance. The final fourth step entails using different creative methods to create solutions that can then be evaluated after how well they fulfil the established demands. Here, the weight of the demands can be combined with how well the solution fulfils it in order to create a score system, allowing the designers to see which solution that generally fulfils the demands best. It is important to note, however, that having the highest score doesn't guarantee that the solution is the best choice. Before making a decision, the results should be assessed to see if the solution is sensible, or if another solution is a viable alternative despite not scoring as high.

As mentioned before, the benefits of using iterative design processes in mining industries comes from the flexibility in creating solutions. This flexibility helps make projects less vulnerable to changes in focus, or if a new problem arises midway through. Furthermore, an iterative process offers more opportunities to create attractive workplaces for both new and existing employees by involving them more in the design process. This makes it easier to discover and adapt the solutions to their needs and wants, which helps create workplaces where they want to work.

13 Mine Operator 4.0

Industrie 4.0 is a strategy that was shaped by the German government in 2013. Industry 4.0 is described as the next great industrial revolution. After the steam engine, electricity and electronics, the revolution consists of an implementation of "Internet of Things, Humans and Services" where the entire production process is included in internet-based networks that transform ordinary factories to *smart* factories (Kagermann et al. 2013). Similar concepts have appeared all over the world. The Chinese government promotes a similar idea under the name *Made in China 2025*, the the Japanese government has launched *Society 5.0* and the Swedich government use the term *Smart Industry*.

Meanwhile the German vision paints a bright picture of the future industry in which virtual and physical worlds will be linked into a powerful 'whole' through the integration of software – from product development and production, machines will not just do 'physical work' but also perform calculations. This is described as cyber-physical systems, or even socio-cyber-physical systems: smart ventilation, smart logistics, smart maintenance, smart machines and other smart systems continuously exchange information with themselves and with human workers. The German strategy highlights the potential for skill development and a richer working life with more challenging work tasks.

Industry 4.0 will also come to affect the mining industry. In fact, some mines have taken important steps towards the digitalized mine of the future. Gradually, the mining industry gets closer to the visions of Industry 4.0 and fully automated mines as well as more technologically sophisticated ore processing facilities. Analogous to the application of Industry 4.0 in a mining context, we conceptualize Mining 4.0 as a mining operation where the miner is an expert who ensures that production runs smoothly. A Mining 4.0 operator is not confined to a control room. Instead, real-time process data and the status of machines follow the miner as they move around the mine. The miner solves problems on the spot by remotely interacting with other operators, experts, suppliers and customers in multi-competent teams. Production control could even be done in a digital model (or "digital twin") far away from the factory. In short, Mining 4.0 envisions an augmented miner with senses and memory extended through technology. This technology takes advantage of and supports human skills and increases situational awareness through sensors embedded in the clothes of operator, for example, while keeping an uninterrupted operational vigilance.

Romero et al. (2016) formed a typology of the future Industry 4.0 operator: Operator 4.0. It built on eight characteristics that can be seen as the core of the new technology; we have modified them to relate to the future miner:

- **Strengthened operator** – Powered industrial exoskeletons assists with heavy loads and lifts, while also mitigating vibrations. This helps operators avoid musculoskeletal disorders from unergonomic work. In future mines, while much of the work will be done remotely, exoskeletons can be useful during manual work tasks, such as maintenance work and manual drilling. A common optimistic hope is that this opens up for women. This technology doesn't come without drawbacks, however. Industries could start using exoskeleton technology to mitigate health problems from work tasks rather than addressing and solving the issues that cause the problems in the first place.

- **Augmented operator** – Augmented reality glasses allows for overlaying digital information onto the real world. It has many possible uses in the mining industry that would help provide and translate information for the operators while out working. This includes having work instructions show the operators what they need to interact with and when, navigational aid within mines and displaying machine information such as fuel levels.

- **Virtual operator** – VR technology provides interactive 3D visualizations, for example allowing operators to train and interact with a virtual machine before working with a physical one. In the mining industry, VR technology could simulate sitting inside the cabin of a machine through cameras while the operator would in reality be sitting in a remote control room, allowing for more accurate remote control. It also allows for training simulations to become more realistic or engaging. The combination of VR technology and remote controlled machines could, however, lead to outsourcing parts of production control to low-wage countries becoming a more viable and attractive prospect.

- **Healthy operator** – Tracking of operators' health values and position to notify them of danger, identify injured people and locating them. This can help locate people and provide vital information if an accident, such as a cave-in, were to occur in the mine. The technology can also be used to better monitor and organise the operators in the mine. For example, operators can be guided based on monitoring data to travel through safer paths with less traffic, which will make navigating the mine safer and more efficient. At the same time, one must be aware that these systems are a threat against personal integrity and must be handled with care. The technology could be used to control workers rather than the process. In a safety critical situation this type of human tracking might be welcomed, but the information could also be misused.

- **Smarter operator** – Intelligent Personal Assistants (IPA) will, through voice interaction technology, allow for operator to more easily interface with machines and digital systems. For example, an operator would be able to vocally ask the IPA where certain vehicles are, and the IPA would map out a route. For a mining operator, an IPA could make it easier to access and managing information while out working or performing maintenance. They could also be used to control semi-autonomous machines vocally, for example by asking a drill to drive to a specific part of the mine.

- **Collaborative operator** – Advancements in industrial robot technology would allow for robots more capable of avoiding collision with any nearby people or objects. This would allow operators to work side-by-side with industrial robots and will help make tunnels, where mining vehicles travel, safer for the employees. The optimistic perspective for this technology sees that the robots take over the dangerous, unergonomic and/or tedious work tasks, letting the employees focus on interesting and safe work tasks. In a pessimistic perspective, robots and technology take over all jobs, essentially replacing the people with machines. The fear of this occurring must be taken into account when implementing the technology so as to not cause worry and incite resistance from the employees.

- **Social operator** – The utilization and implementation of social networking technology in the organisation would allow for better communication possibilities between operators and machines. This also allows for more opportunities for informal knowledge sharing between operators. With the development and implementation of 5G-networks in mining industries, operators and machines can utilize high-speed connections to communicate even from below ground. The greater capabilities to stay connected could, however, lead to a thinning of the lines between work and spare time due to employees being more readily available at all times.

- **Analytical operator** – With more data being gathered from machines and systems, operators can better understand their performance and status. In addition, the increased amount and types of information allows for better forecasts of system and machine performance. This allows for better scheduling of more types of maintenance work. The increased data flow can also come to affect the mining operators in that their work tasks could be focused more on optimization and development.

This classification points to the numerous possibilities of integrating Industry 4.0 with human labour – some good and some bad. But this development is not about *creating new* kinds of jobs. Rather it is a development that means that most current jobs will be *influenced* by these characteristics and developments. Miners will not disappear, but they will be different in the future.

See also

Lööw, Abrahamsson, and Johansson (2019).

14 Mining 4.0 - Utopia or Dystopia

In previous chapters, we have described various development opportunities for future mining work. Here we will try to summarize our experiences in two extremes, a negative dystopian development and a positive utopian. The two visions are read and illustrated on www.xxxvv. The chapter concludes with six recommendations on how to start shaping the future of Mining 4.0 on human terms

How will Mining 4.0 affect tomorrow's mining work? There is no clear answer to that question. There is no inherent technological determinism in the development; it will depend on the choices that we make. It's up to us. The dystopian scenario gives this miserable picture:

> *You have to be grateful that you even have a job. Most of the jobs have disappeared, and the entire municipality is depopulated. There are some qualified jobs located in the control center above ground, but most of these jobs have moved to town and are carried out remotely via the net. Some work is even done from India. It's not just an A and B team anymore; we now also have a C team. What remains is mostly maintenance work. We are wearing augmented-reality glasses and carrying out tasks according to the instructions that we get from central maintenance or a machine supplier. Sometimes we have to put on an exo-skeleton if there is heavy lifting.*
>
> *But everything is not bad. The work is not as dangerous as before, because we do not work at the front nowadays, and there are no diesel vehicles anymore. Underground everything is automated, but of course we must install the electricity and access points, and then you notice that the company has reduced the ventilation. The blasting gases still remain far into the shift and you can feel your heading getting heavier as the day drags on. What I miss most is my workmates; we have our mobile phones and tablets so that we can keep in touch with each other, but it is not the same as when working with the boys.*

The utopian vision becomes much more pleasant to accept:

> *Most of the underground work is automated and no one works near the front anymore. The production control takes place from a bright and pleasant control room above ground. The routine monitoring work has been automated; with AI you get a better stability in production. Our professional role has been extended to include the entire value flow, from mountain to customer. If we see an opportunity for improvement, we can switch over to our digital twin to experiment and test the outcome.It is always fun if you can trim the production; and then not only financial measures apply, but also so-called green measures, such as saving water or reducing greenhouse gas emissions. We are quite proud that our company takes a great social responsibility, not only for*

> *the environment but for a prosperous society that can offer a rich social and cultural environment.*
>
> *When something goes wrong in the production, it is indicated in our mobile phones and usually we can solve it with a few keystrokes. But sometimes we have to go into a VR model and maybe direct a robot to a crusher to break apart a boulder. If the error has not occurred before, we sometimes have to go down into the mine to understand what has happened. When we are forced to go down into the mine, we always wear a safety vest with sensors so that one can follow where we are and warn if any dangerous environmental factors appears, or if something seems strange to our health.*
>
> *Last month my daughter even started working for the company. She is a computer science major but works as much with my colleagues as she does with a computer. For a long time, I thought I would be the last miner in the family. It feels good to know that there will be a new generation, and that young people have stopped moving away. It seems the company's investments in the community, and insistence on training and using locals, really payed off.*

The scenarios are exaggerated but probable. Mining 4.0 can definitely represent a positive development, but there are many questions that must be cleared. Based on our experiences and and previous research, we want to bring forward six recommendations that can be considered as a beginning of a road map for developing Mining 4.0 on human terms:

- We need more ways of measuring success, ways that capture social factors.
- Any reduction in the workforce must be managed with great transparency and in close cooperation with the trade unions.
- All employees must be included in competence development; leave nobody behind.
- Create a flat organization that empowers employees and encourages their creativity.
- Handle privacy and integrity issues in close cooperation with the trade unions and workers.
- Embed all changes in a context of great social responsibility

It is important that the mining industry is active in creating Mining 4.0, but we also know that it will take time and there will be many obstacles along the way. To succeed we must be vigilant and attentive to all aspect of modern mining – future as well as past.

See also

Lööw, Abrahamsson, and Johansson (2019)
Lööw et al. (2018)

15 More research is needed

Future efficient mining operations will be dependent upon a highly competent and well motivated work force, on all levels. The mining companies will have to recruit their personnel from a limited group of talented individuals with high demands and expectations on future work. To cope with the future labour supply, the mining industry must change the image of mining work and increase the attractiveness of working in the sector, especially for young women and men.

We know a lot about what creates an attractive job, but we don't know everything. It is important that the mining industry keeps up with this quest for knowledge, the world is changing and new knowledge is required. The winners are the ones who apply the knowledge quickly and translate it into practice.

Below we describe a number of activities required in order to attract and keep skilled personnel in the future mining industry. To achieve this, we have identified six areas that need further clarification through research:

- Digitalization opens up for new opportunities to create attractive workplaces in a safe environment, and jobs that provide space for the employee's full expertise and creativity. But there are also risks that need to be addressed, such as privacy issues, increased stress and work-life boundaries.
- With the increased digitization, new qualifications are needed. These must be identified and programmes for reskilling and lifelong learning must be formed.
- Research on health and safety has been successful, but the industry still needs innovative methods to control health and safety-related issues. To be perceived as a safe industry, a zero vision is required based on better proactive safety work.
- Health and safety conditions for contractors must be explored and more inclusive safety cultures must be developed.
- Companies must be proactive and try to avoid creating problems in the first place. This is especially important in mining where initial mistakes can have consequences for a very long time.
- Finally, to develop a holistic concept for the attractive mine that can attract young people.

Research must work with these issues from different time perspectives. The long-term vision is the zero-entry mine where all machines are self-regulated or remote-controlled from operations centres above ground. These centres are designed to promote co-operation and creative problem solving in multi-skilled teams of men and women. Basic safety level is not an issue anymore: dangerous work tasks are performed by robots.

In a shorter perspective, many workers remain underground. Here, there are new methods for iterative mine planning that take work environment and safety into account and reduce common initial design errors when mines are planned; production is organised through a holistic approach based on production teams and broad professional skills among management and miners; mining work has been transformed into being attractive to both women and men, not only because of the wages, but also because it is an interesting occupation with good potential for personal and professional development and lifelong learning in a safe and sound working environment. Still, a number of issues of attractive workplaces should be considered in future research and innovation as well; the most important are addressed below.

First, digitisation and its effects have an obvious place in a future research agenda. Used correctly, digitalisation can create attractive jobs that provide space for the employee's full expertise and creativity. But there are also risks which need to be analysed and considered. Furthermore, competence development, learning at work etc. should be prioritized. These topics are vital in order to meet the demands of new technology and can guarantee flexibility for the company and development in one's professional role. Important focus areas for research are:

- How can the new roles of the operators (i.e. "Operator 4.0") meet the values and expectations that young women and men have when they enter work life?
- How should digitised production systems address privacy issues?
- How to gain acceptance and avoid resistance for new technology?

There is a need for new methods for learning at work, something both employers and employees want. To guarantee development in one's professional role and inhibit becoming stuck in the demands of a special task requires a certain degree of generalness in competence development. Broad work roles are a classic demand that can also be combined with the ideas behind Lean mining. The industry has a general need to recruit more women. Important focus areas for research are:

- Identification of future skills requirements.
- Development of new education programmes for reskilling and competence development of management and workers as part of a lifelong learning.
- Develop a strategy for recruiting more women.
- Develop a mentor system for miners so that professional knowledge is transferred between generations.
- Develop VR and AR for training and simulation, particularly the operations in hazardous environments.

Health and safety at work must have top priority. Mechanisation, remote control and automation are efficient preventive safety measures. They are also appropriate for reducing workload to avoid musculoskeletal injuries and allow for recovery periods. New technology makes it possible to both warn of dangerous working conditions and monitor employees' health conditions in real time. Improved safety is also a matter of a developed safety climate in the form of relevant education, rules and effective leadership, with safety prioritised in the day-to-day-work. In short, there is a need for further development of:

- How we can increase safety by monitoring the operators in real time?
- New methods for monitoring and controlling the work environment.
- Efficient tools for proactive safety control, as well as broader analyses of the impact of digitalization on health and safety in general.
- Upgraded safety climate.

Moreover, the increased number of contractors must be addressed. Focus should be on the benefits and potential problems that come from a workforce of in-house personnel and contractors. This includes strengthening both formal (e.g. implementing joint safety management practices) and informal (e.g. communication and interaction in the workplace) relations in multi-employer worksites. Important issues in this area include:

- Reviews of the health and safety conditions for contractors in mining
- The development a safety culture that includes contractor.

Many problems in the work environment in present mines (and in other industry as well) can be traced back to insufficient initial physical planning and design. Since mining is characterized by huge investments and long term operations it is very important with a well designed physical production system. The physical layout also influences and limits the organizational aspects. If initial mistakes are made the personnel will have to stand the negative consequences for many years to come. The initial design phases of every major development project are therefore critical for establishing a safe and attractive physical and psycho-social work environment in a mine.

The main idea and research task in this challenge is to combine and further develop a general iterative industrial planning and design method (Ranhagen 1996) with available and relevant work environment tools and combine them with the demands of the new technology. The final product, that is planning guidelines with focus on work environment design in underground mines, shall be adapted to the users (pre-study engineers, feasibility engineers, project planners, automation engineers, layout planners, ventilation planners etc.) needs and professional situation. Such guidelines, preferably integrated with CAD-planning and design tools, would help these professional to create more safe and attractive future workplaces in the mines.

Designers of mine productions systems also have quite a lot of legislation and compulsory provisions to regard as well as company specific rules and standards for the work environment and the management of health and safety (Johansson and Johansson 2014). These aspects must also be integrated in the guidelines for work environment planning and design. The major research task can be described as:

- Development of alternative guidelines for early and critical stages of future mine design.

Finally, although the traditional image of mining is not particularly attractive and the industry still has health and safety issues that need to be considered, we think that it is possible to create a new vision of future mining - a vision of a high technology industry that speaks to today's young people. Mining companies must more actively demonstrate their social responsibility. Employees want to feel proud to work in the company, which means that issues such as vision, mission and core values are important. If we manage these problems well, they can be turned into advantages that create new, attractive job roles. All these factors affect the company's image, and thus the possibility of recruiting young talented people to the industry. Overall, broader strategic research areas should include matters related to

- the development of a holistic concept for the zero entry mine;
- the development of efficient programmes for development of attractive societies;
- the development of a model for an ethical, ecological and diverse workplace and recognised as a green branch; and
- give the industry a new image that can attract young people.

The mining industry must be prepared to meet the technological development on human terms. In a longer perspective, this can lead to the recognition of the mining industry as an ethical, ecological and diverse industry that can offer challenging jobs and attractive workplaces.

See also

STRIM (2019)

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