Safety Science 117 (2019) 437–446

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/safety

Initiatives for increased safety in the Swedish mining industry: Studying 30 years of improved accident rates

Joel Lööw*, Magnus Nygren

Human Work Science, Luleå University of Technology, Sweden

ARTICLE INFO

Keywords:
Mining industry
Safety
Accidents
Safety management

ABSTRACT

This article investigates safety-related developments in the Swedish mining industry over a 30-year period, from the 1980s to the 2010s. It studies what may have contributed to lowering the accident frequency rates and improvement of safety more broadly in the industry. On this basis, interviews were conducted with informants from mining companies. This material was supplemented with a workshop with mining health and safety representatives and documents relating to the subject. The results are divided into four main themes, showing that from the 1980s and onwards, lowered rates and general safety improvements followed in the wake of technology development. This was complemented by a more direct focus on organisational aspects of safety beginning in the early 2000s. Still the effectiveness of the individual measures is not clear; while they theoretically have an effect, causality is hard to show. In other words, the improvements may not necessarily depend on the specifics of these initiatives. Given this, the article discusses the different initiatives in-depth, and gives suggestions for future research and industry action. This includes recommendations for approaching safety holistically and the development of new proactive indicators.

1. Introduction

Mining, in Sweden and in other countries, is no longer the high-risk industry it used to be. Before, high accident frequency rates as well as severe and fatal accidents characterised its operations. Now, the Swedish mining industry has a safety record that in some respects is similar to the manufacturing or construction industries (Swedish Work Environment Authority, 2017). Though the accident rate is still elevated compared to national averages and highly safe industries, the improvements should not be understated. The lost time injury frequency rate (per million working hours; LTIFR) among the Swedish mining industry's own employees has gone from 51.3 in 1981 to 7.1 in 2015 (SveMin, 2016). The number of fatal accidents per one million working hours was 1.1 in the 1950s (Brand, 1990). Between 2000 and 2009, on average one fatal accident occurred every other year (SveMin, 2010), which is roughly equal to a rate of 0.06. The mining industries of the United States (Katen, 1992) and Canada (Haldane, 2013) have seen similar improvements. In the European Union, the mining industry displayed a positive trend between 1999 and 2007 (European Commission, 2010). In fact, mining was one of the sectors with the largest decrease in accidents during this period.

Nevertheless, the safety situation in some countries is still dire. For example, 1384 miners died in China in 2012 (Feickert, 2013), while 1444 died in Turkey in 2010 (Demiral and Ertürk, 2013). In Poland, where mining is generally modern and mechanised, 311 fatal accidents occurred between 2000 and 2009 (Krzemień and Krzemień, 2013). Even where there have been significant improvements, Elgstrand and Vingård (2013, p. 6) reported that, “Where reliable national statistics exist, mining is generally the sector having the highest, or among 2–3 highest, rates of occupational fatal accidents and notified occupational diseases.” Furthermore, the Swedish mining industry had less than half the fatal occupational injury rate of Spain and New Zealand, while the Australian mining industry had less than half the rate of Sweden (Lilley et al., 2013). Different types of mines also have different safety records; opencast mines are safer than underground mines, and underground coal mining has notably higher accident rate than other underground operations (Nelson, 2011). So even though the mining industry has managed to improve its safety, additional and sometimes significant work remains. What is more, the rate of improvement of the LTIFR in Swedish mining has halted in the last decade (see SveMin, 2016).

To understand how safety in mining can be further improved requires understanding of how safety has improved in the past and the nature of mining-related accidents. Mining operations (including ore processing and related activities) are complex and high-risk. In part, this is due to the physical and technical environment. Hartman and Mutmansky (2002) argued that gases emitted in mines, the potentially

* Corresponding author at: Luleå University of Technology, 97187 Luleå, Sweden.
E-mail address: joel.loow@ltu.se (J. Lööw).

https://doi.org/10.1016/j.ssci.2019.04.043
Received 21 January 2019; Received in revised form 2 April 2019; Accepted 28 April 2019
0925-7535/

explosive nature of certain fuels and the heavy equipment used result in complex and high-risk environments. Laurence (2011) similarly argued that mining-related hazards are particularly complex due to the different types of energies involved (electrical, chemical, mechanical etc.). Differences between different types of mining could also relate to the complexity of the environments (cf. Nelson, 2011). With this reasoning, changes in safety relate to changes in the complexity of, and energies in (cf. Haddon, 1963), the environment.

The increased productivity in the mining industry has led to reduced employment in mining-related work (see SGU, 2015, for the development in Sweden). Parallelly, the mining industry has increased its productivity mainly through bigger machines and bigger loads etc. (Hartman and Mutmansky, 2002). Blank et al. (1998) studied working hours and production volume, respectively, as denominators of risk. They found that the denominators produced similar results as the mining process became more machine- rather than human-based. When mining was labour intensive, the two denominators produced different representations of risk. Blank et al. (1998) argued that the injury rate improved to the extent that technology decreased risk exposure and, possibly, reduced the magnitude of risk. But often the very nature of the accidents complicates any explanation. For example, Laflamme and Blank (1996) studied accident risk in a Swedish mine. They highlighted that "the transformation of production processes in the mine had a more rapid beneficial impact on work productivity than on accident risks," and that "the reduction in accident rates that steadily took place did not favor all age categories of workers to the same extent" (Laflamme and Blank, 1996, p. 486). So, for example, while less people working in a mine might mean less complexity, parallel developments have increased complexity.

In other words, no single factor explains the accident rate development in mining. And historically, a combination of initiatives and measures seems to have contributed to safety. Blank et al. (1996) analysed the relationship between occupational accidents and technology in the Swedish mining industry during 80 years. They found a complex relationship between technological development and occupational accidents. Mechanisation significantly increased the overall risk for accidents (e.g. due to work intensification), but mechanisation and automation had a positive effect on annual mortality rate. Work insurance legislation had the strongest negative relationship with annual accident rate. Similarly, Hartman and Mutmansky (2002) argued that the historic improvement of the accident rate in the US mining industry was due to factors such as fewer employed miners, better ventilation, mechanisation, social enlightenment, production decline and federal legislation.

Later research on safety in the mining industry has been more attentive to human and organisational factors. Some have found that nine out of ten accidents in mining are triggered by human action such as operator errors and violations, with unsafe leadership and organisational factors featuring in up to two thirds of accidents (Lenné et al., 2012; Patterson and Shappell, 2010). Zhang et al. (2014) investigated fatal accidents in surface mining related to haul trucks and found causes related to inadequate or improper pre-operational checks, poor maintenance, use of alcohol and failure to follow rules. Ruff et al. (2011) investigated worker activity at the time of accidents and found that 25 per cent of all injuries and fatalities occurred during maintenance and repair of machinery.

Other studies have looked specifically at contractors. For the US mining industry, Muzaffar et al. (2013) concluded that it was three times more likely that a contractor worker would sustain a fatal versus a nonfatal injury compared to mining companies' own personnel. For the Swedish mining industry, Blank et al. (1995) concluded that contractors seemed to get injured more often, sustain more severe injuries and perform work under different conditions than those employed by the mining companies – as well as conduct more dangerous work.

Current research, then, has tended to focus on what causes accidents, or has tried to connect safety trends in the industry to technical and societal developments. The current body of research has more seldom investigated the particular initiatives that have been undertaken by mining companies to improve safety. Thus, this paper sets out to investigate the safety development within the Swedish mining industry over 30 years. It seeks to answer the following question: what initiatives have mining companies taken that, directly or indirectly, could have improved the accident frequency rates? The paper also aims to shed light on why these initiatives may have improved safety more broadly. Through this inquiry, the hope is to contribute to knowledge regarding the possible ways to improve safety in mining and related operations.

2. Study design

The empirical material was collected as part of an exploratory study with the purpose of investigating what companies in the Swedish mining industry have done, directly or indirectly, to improve their safety situation between the 1980s and the 2010s. The study mainly focused on two large mining companies, but additional material was collected with input and insights from representatives from other mining companies, contractors and a former inspector of the Swedish Work Environment Authority (SWEA).

2.1. Study context: A brief statistical portrait

The broader context of the Swedish mining industry is presented below in the form of a brief statistical portrait. This is to give the reader a notion of how the industry is structured and some of the developments that have taken place.

The first set of figures come from Geological Survey of Sweden (2018). The Swedish mining industry produces almost 90 per cent of all iron ore, 11 per cent of copper and 22 per cent of gold and silver of the EU28 countries. Half of all ore produced in Sweden is iron ore; non-ferrous ore such as copper, silver and gold makes up the other half of. In 1983, 10 million tonnes of iron ore was mined. In 2017 this figure had increased three-fold. Iron ore is mined almost exclusively by one company (one of two companies investigated in this study). For non-ferrous ore, total production was almost 900,000 tonnes in 1974. At the time, pyrite mining represented almost half of all production, but excavation of this particular ore ceased completely in 1992. By 2017 the mining of non-ferrous ore reached more than 1 million tonnes.

Additional figures from Geological Survey of Sweden (2018) show that there were almost 100 mines in the 1950s (68 iron ore mines, 27 non-ferrous ore mines). In 1980 the number of mines had decreased to 35 (15 iron ore mines, 20 non-ferrous ore mines). This trend has continued; in 2017 there were only 15 active mines (4 iron ore mines, 11 non-ferrous ore mines). Employment (including white-collar workers) decreased from 12,000 in 1950, to 11,500 in 1980, and then to 6700 in 2017. In 1950, 9300 of mining employees were active in iron ore mining; in 1980, 7600; and in 2017, 3200. That is, iron ore operations employ half of all employees in the Swedish mining industry. The company responsible for this employment was investigated in this study. Non-ferrous ore operations are responsible for the other half. A company that employs 1700 of these people was also investigated. Both companies have opencast and underground operations.

Lööw et al. (2018) compiled data from the National Board of Occupational Health and Safety, the Swedish Work Environment Authority and Statistics Sweden to compare accidents in the Swedish mining industry in the 1980s and 2010s (but note that the two periods cannot be fully compared due to changes in data structures). These figures show that during the 1980s the most common cause for accidents was "fall of person", followed closely by object-handling accidents. Other common causes were strikes by falling objects, contact with machine parts, vehicles etc., and overexertion. For the 2010s the figures show that the most common cause of accidents by far was loss of control of machinery; while manual and physical labour factors were still significant during this period, machine and equipment related causes dominated. Additionally, virtually all frequencies of occurrence have markedly decreased. However, according to SveMin (2010) contractors have regularly had a higher accident frequency rate during the last decade (though these numbers contain some uncertainties regarding hours worked).

Figures compiled by Johansson (1986) show that 10 per cent of all employees of a representative Swedish mining company were white-collar workers in the early 1950s. By the late 1970s and into the 1980s, 22 percent of the workforce were white-collar workers. These kinds of figures are available until 1984. Beyond this period, Lööw et al. (2018) compiled figures on the educational levels in the Swedish mining industry. They show that the proportion of the lowest levels of education have decreased. More jobs now require at least some upper secondary education. In fact, the majority of jobs requires a full three year upper secondary education. On the tertiary level, education to bachelor level or higher has increased almost fourfold. Additional figures (Lööw et al., 2018) show that technology and natural science specialists make up a considerable part of the workforce. In general, low-skilled labour is rare.

None of these figures readily include contractors. Contractor labour now makes up a considerable amount of the hours worked within the industry. Contractors are often hired to conduct auxiliary tasks such as repair and maintenance work. In recent years, Swedish mining companies have made significant investments in expanding and modernising their industrial facilities. This has meant large construction projects, in which contractors often have been hired to do the main work (Nygren, 2018). But contractors generally do not feature in mining industry statistics even if, recently, they have received more attention. For example, the Geological Survey of Sweden (2016) started to include contractors in their publications. Their estimations show that around 12 per cent of all employees in the mining industry are contractors. Other sources put the hours worked by contractors at around 40 per cent in some cases (IF Metall, 2015; Nygren, 2016).

2.2. Data collection

In total, eight semi-structured interviews with informants from two mining companies (four interviewees from each company) were conducted by the authors of this paper. All interviews were recorded after consent had been given. As mentioned above, these companies are responsible for the majority of all mining activity in Sweden, both in terms of employees and production. The informants were senior managers, operations specialists and health and safety specialists – i.e. people with a formal responsibility for health and safety management and, to some extent, technology and business development. They were selected on the basis of their expertise knowledge regarding safety-related issues within their respective companies (cf. “expert interviews” in Flick, 2014). They were therefore purposively sampled and seen as being able to provide “insider accounts” on these matters (see Smith and Elger, 2012). Importantly, they had to have knowledge regarding safety-related development over time to be eligible for the study. No additional requests for interviews were made to other individuals as these eight satisfied the criteria of being experts in the field. Taken together, they were deemed able to provide a comprehensive picture on safety-related issues from an inside perspective.

Little to no disagreement were found in informant responses. This was also the case when comparing to the views expressed during the workshop (see below), which were largely consistent with the informants’ views. An additional interview was conducted with a former inspector of SWEA (the government agency responsible for health and safety in Swedish working life). The inspector had mainly conducted inspections in the mining industry and could provide a broader perspective on the safety development in the industry over the 30-year period. This did not result in any conflicting views either.

All of the interviews were conducted at the respective personal offices of the participants and digitally recorded. Both authors were present; one led the conversation and the other took additional notes and formulated follow-up questions. Before the interviews the informants were presented with a written notice explaining the overall purpose of the interview and were asked whether or not they would consent to participating. All of the informants accepted the terms of the interviews.

Table 1
Summary of interviews.

Organisation/Role	Interview length
Company 1	
Senior human resources manager	One hour
Senior health and safety manager	One hour
Operations specialist	One hour
Operations specialist	50 min
Company 2	
Operations specialist	One hour
Health and safety specialist	90 min
Health and safety specialist	One hour
Section manager, technology	One hour
Swedish Work Environment Authority	
Former health and safety inspector	90 min

Due to the exploratory nature of the study, the interviews were open; the informants were allowed to “go off track” to some extent but always within the general bounds of the topics of the interview guide (see Appendix A). In every interview, the authors presented the informant with a graph of the lost time accident frequency rate of the Swedish mining industry and asked him or her to try to explain this development. Each interview lasted around one hour (see Table 1).

The interviews were complemented with a workshop that the authors conducted with the members of the formal health and safety committee of the Swedish mining industry organisation, during one of their regular meetings. Approximately 20 people were present at the workshop, representing most Swedish mining companies, as well as several contractors and equipment providers. During the workshop, one of the authors presented the previously mentioned graph and asked the group to explain what may have contributed to the development. Two versions of the graph was used: one presenting the span of 1981–2013 and one of 1995–2013. The reasoning behind this was that the later period might be more fresh in the participants’ minds, who could then provide more detailed explanations. The workshop was used to validate some of the findings, i.e. to test whether explanations given in the interviews for the improved safety of the individual companies also held true for the industry as a whole. While one of the authors conducted the workshop, the other one took notes of the responses (the workshop session was not recorded).

In addition to these formal data collection activities, informal conversations were used to enrich the material – a triangulation of data was sought in order to corroborate the findings (Bowen, 2009). For example, several conversations regarding safety-related issues were had with members of the committee (outside of the workshop setting) and with individuals in managerial positions working for either of the two mining companies. Where available, documents were consulted to investigate statements by the informants.

2.3. Data analysis

The interviews were transcribed verbatim by the two authors and a thematic analysis in vein of Braun and Clarke (2014) was performed. At this stage of the process, all of the informants were anonymized. The focus of the analysis was on the explicit meanings of the data. It was inductive, as the codes and themes were developed from the data itself (as opposed to deductive, theory-driven approaches). The themes consequently focused on the explicit responses rather than the authors’ interpretations of what was said. In other words, a realist perspective was taken during the interviews and the subsequent analysis; the interviews were viewed as means to access the subjective experiences of informants and "richly textured accounts" (Smith and Elger, 2012, p. 14) of actual events in their complex social reality.

The interview transcripts were imported into NVivo 11, split between the two authors and read through multiple times during which initial and preliminary ideas for codes were noted. The overall analysis was guided by the research question, "what may have contributed to lowering the lost time injury frequency rate and seemingly improvement of overall safety". Following this, the authors met and discussed the codes consisting of sentences encapsulating the essence of various parts of the interview data. After this, specific themes were developed and refined in light of the original and full interview transcripts and notes from the workshop. These discussions were also important to avoid biases in the creation of the themes – i.e. to make it reasonably certain that the themes actually represented the participants' expressed perspectives and views, rather than the authors' individual subjective interpretations. Finally, the themes were analysed in relation to the additional data in the form of informal conversations and documents. Examples of the connection between individual interview excerpts, codes and subthemes are provided in Appendix B.

3. Results

The thematic analysis resulted in four themes that describe what may have contributed to the reduced accident frequency rate and overall improvement of safety. A final, fifth theme describes what the informants believed should be prioritised in the future to increase safety further. These themes and associated subthemes are outlined in Table 2.

3.1. Technological development and an improved physical work environment

According to the informants the overall *technological development* has positively impacted safety – together with other factors it contributed to the significant reduction in accident rates in the early 1990s. For example, over the 30-year period the amount of physically heavy work was said to have decreased due to improved work equipment.

A clear theme regarding technological development is that it was seen as having helped to protect against the rock or "mountain" through, for example, shotcreting (spraying tunnels and drifts with concrete). The development has involved improvements of the technology itself, such as better rock bolts, but also the application of this technology. In the early 1980s it was rare that underground locations were reinforced as a standard preventative measure; locations were reinforced only if they were deemed unsafe. In contemporary operations all underground locations are reinforced, regardless of actual rock conditions.

Another focus area for the companies has been improved ventilation, as well as safer and more efficient machinery such as loaders fitted with protective and reinforced cabins. The location of the operator in relation to certain mining operations has also changed over time. In contemporary mining, remote controlled machinery can be used where there is "risky mountain" (e.g. where the mine has not been shotcreted or the ventilation has not removed all blasting gases), instead of machinery piloted by an onboard operator. In cases where remote control is not applied, the operator works from an isolated cabin which generally protects against falling rock, poor air etc.

Technological development was also linked to *improvements in the operators' work environment* – better interfaces and displays had been introduced (making operating machinery less complex) as well as better alarm management. This too was seen as having positively impacted safety, both in underground mining operations and ore processing facilities above ground.

3.2. Changing formal health and safety management

A frequently addressed theme was the importance of *systematic health and safety management*, and how the systematic aspects of these practices in particular have contributed to the reduced accident rates. The informants connected this development to three specific changes made to the legal framework over the years. First, the introduction of regulations for "internal control" in the early 1990s, which stipulated what employers were required to do to ensure the health and safety of their workers. Second, the expansion of these regulations into systematic work environment management in 2001. Third, the regulations focusing on organisational and social work environment introduced in 2015.

One particularly important aspect is the increased focus on, and indeed requirement of, systematised safety practices (e.g. risk assessments), including having a proper system for documentation in place. The regulations regarding social and organisational matters were seen as a positive development because it forced employers to specifically focus on issues such as work-related stress and workload. The former SWEA inspector mentioned that the heavy workload that middle managers in the industry in general experience, being in charge of specific operations and their overall functioning, is especially important to consider. Some informants suspected stress-related issues would increase for this group due to their work situation.

Another important aspect is the *certification towards OHSAS 18001*. One of the companies began this process as early as 2006. Informants from both companies mentioned this development as having contributed to more efficient health and safety management overall. One informant said that the certification led to the introduction of a management system that ensured that risk analyses are conducted to the required and necessary extent. It was also said to have led to proper documentation describing how staff should work with these issues and where risks exist. Another informant had a similar perspective: during the certification process, most of the risks were analysed, in particular

Table 2
Summary of themes.

Themes	Subthemes
Technological development and an improved physical work environment	Technology contributes to safety improvements Focus on improving the physical work environment
Changing formal health and safety management	New regulations drives improvements Certification towards OHSAS 18001
Adopting broader safety management strategies	Changing attitudes towards safety Safety First as an overarching safety philosophy Increased focus on safety culture
Safety for contractors and other suppliers	Taking contractors' safety into account Clarifying contractor safety practices
Future developments for increased safety	On the right path Focus on quality Ensuring skills and competencies Psychosocial work environment

risks connected to recurring work. If something was classified as being an unacceptable risk, a special routine was written for that specific task. In other words, it was a matter of creating a systematic approach to risk analyses and associated written procedures. This process also helped create the sought-after involvement of managers and workers in contributing to the overall safety of the workplaces; supervisors, safety representatives and employees directly participated in the assessments and analyses. This in turn was supported by major investments in safety training – courses which focused on the importance of participation in safety-related activities, among other things. It was also said that the regulations for systematic work environment management in particular helped pave way for this development.

3.3. Adopting broader safety management strategies

The informants noted a *change in how safety is viewed*, in recent decades, among employees. Although there is still a macho culture within the industry, they emphasised that it is not *as* important to be "tough" and to normalise risks, which was often the case during the 1980s and 1990s.

Connected to this is the increased focus on lean production. In one of the companies lean production has served as its main production philosophy since its implementation in 2004. In the beginning, issues related to workplace safety were not included. But after a couple of years the company had integrated its overall safety management into, and made the management practices a part of, the production philosophy. One informant believed one of the main features of this integration to be the concept of "5S", a method stemming from lean production. On the one hand, this concept revolves around creating a more organised work environment ("standardise" being one of the five Ss) that contributes to increased safety. The informant held, on the other hand, that stress can also be reduced this way – e.g. by always knowing where equipment can be found – and thus simultaneously improve the psychosocial work environment.

Fundamentally, the notion of *Safety First* was said to be widespread. One of the informants emphasised that is has gone from a question mainly driven by the union, to now being a concrete management issue. Above all, in both companies, the concept is taken literally, being the first point of agenda at any meeting. Moreover, if no meeting participant have anything to address under this point, the participants question this; there should always be some safety-related issue to address. Safety First was also seen as representing an important issue in investments; it has become increasingly more common that health and safety risks are analysed before making an investment. The inspector described this as if it was like the industry as a whole decided to pay closer attention to these issues roughly around the same time in 2005.

Besides Safety First both companies introduced the concept of *safety culture* with a number of associated practices. In one of the companies, a safety culture project was conducted in the mid-2010s at a ore processing facility, with a main focus on increasing participation in safety-related activities. This involved individuals participating in safety committees and safety rounds, reporting deviations from normal operations and constantly being a good role-model to their colleagues by prioritising safety-related matters. This project also led to the practice of "management time" being introduced, which required that all supervisors allocate time each morning to be available to their staff.

In the other company, a similar programme began in 2009. The reason for introducing the programme was that a number of managers had begun to express frustration over difficulties of getting staff to report risks and incidents. There was a problem with a lack of motivation among these managers regarding safety practices. Thus a greater focus was placed on motivating and inspiring these individuals when it came to safety management. Over time, various training initiatives aimed at both managers and employees were developed based on reflective discussions about attitudes and behaviour regarding safety. It was in connection to this programme that the managers' ability to "set the bar" for safety and communicate the right things to the employees emerged as a more concrete strategic focus area within this particular company. In 2010 educational initiatives began to include the psychosocial work environment to continue the development towards healthier and safer work environments. Both companies were said to regularly conduct personnel surveys, where specific psychosocial issues such as stress and workload are addressed.

3.4. Safety for contractors and other suppliers

The informants mentioned that there had been a change in how the companies *perceive and handle contractors* entering their operations to conduct work. One informant said that a few years ago it became evident that the company did not focus enough on contractor workers and their safety. The informant emphasised that this had changed significantly and that they had begun collecting statistics regarding these groups in the same manner as their own employees. (But they had to make estimates regarding the number of working hours in some cases in order to calculate the accident frequency rates.) In some departments and sections they had begun systematising the planning together with contractors. They developed specific tools that evaluate the contractor companies and their employees, whether they have the right safety education etc. Both companies had also begun to train their own employees in what their own coordination responsibilities vis-à-vis the work conducted by contractors actually entails.

In one of the companies, a specific committee consisting of managers from different departments had become responsible for overseeing *changes to policies, procedures and work practices* in relation to contractors. This included the development of procedures for how health and safety is supposed to be handled in outsourced operations, and the development of a handbook with the most important rules and procedures. This is now a mandatory document that all contractors that perform work within the company must consult.

3.5. Future developments for increased safety

For future developments, the informants mentioned the importance of continuing to move the operator away from the "front" (where actual mining activities take place). They also mentioned encouraging even more participation in safety-related activities in general. The informants furthermore wanted a leadership-style that enables employees to get involved and take an interest in the safety of their own work situation. This was seen as a primary requirement to reduce the accident rate even further; they wanted to "turn the hierarchy" so that the responsibility and ownership of safety practices lies with the employees themselves – something that was specifically linked to the lean production concept in one of the companies.

There was thus consensus among the informants that the companies are *on the right path* regarding the focus on safety culture, behaviour and attitudes among managers and employees. However, there was a number of other focus areas mentioned as well. One informant placed great emphasis on the continued development of proactive leading indicators, for instance to ensure that all workplaces conduct safety rounds and that there are reliable and effective ways to measure this. Focus should also be placed, it was argued, on actually remedying the problems that have been identified. This can be linked to a tradition within the industry in general which was said to focus primarily on reactive indicators and related metrics, such as lost time injury frequency rates. When the necessary systems and working methods are in place (e.g. systematic health and safety management, risk assessments), the actual *quality of these* should be prioritised. A telling example was when one informant commented on the fact that for long the company focused on getting operators to report risks; now that the practice was in place, the issue was to find a way of working through these reports and addressing the actual issues.

One informant, who worked with strategic technology issues on a daily basis, said that although safety issues are important in themselves, a specific future focus area should be to *ensure the skills and competencies* with regards to certain key roles – especially when it comes to technology. According to the informant, their company risks losing important knowledge and competencies when certain individuals retire. This could ultimately affect safety if there are no competent persons available to handle the technology properly in the different operations. As technological development is expected to continue, new types of knowledge will also be needed in the future to meet the new requirements.

Finally, the importance of continuing to *prioritise problems related to the psychosocial work environment* was mentioned by all of the informants. Getting a clearer picture of how many people that experience stress at work was considered as important as analysing causes of accidents. A person who is stressed may make choices that they would not have made otherwise, which could ultimately have negative consequences for safety. Middle managers – the individuals that have been identified as "norm builders" within the organisations through the safety culture development programmes – were highlighted specifically as being in risk of experiencing negative stress.

4. Discussion

In roughly summarising the safety initiatives in the Swedish mining industry during the last 30 years, two broad phases can be identified (see Fig. 1). The interview accounts indicate that from the 1980s and onwards, safety improvements followed in the wake of technology development (e.g. improved rock bolting, safer machines). In the 2000s, due in part to new regulations, focus shifted towards organisational aspects of safety (e.g. new routines, safety programmes). On possible future developments, the accounts indicate a focus on behaviour, quality, knowledge and competences, and psychosocial work environment.

Whether the introduction of new regulations should be considered its own phase of safety improvement is unclear, as the focus of this study is on initiatives undertaken by the *companies*. On the one hand, instead of a phase, one could talk of selective regulatory measures that primarily came to inform how the companies conduct health and safety management. On the other, the informants saw the new regulation that was introduced in 2001 as particularly important. Its introduction also coincided with the emergence of organisational issues as prioritised areas for the companies.

In any case, both in mining and in general the discussion on safety initiatives seems to have taken place on a spectrum; to use the terminology of Reason (1997), on one ranging from "hard" (with a technical focus) to "soft" (with focus on organisational and human aspects). Such shifts between a "rational-instrumental" and "social-institutional" discourse have been observed in organisations in general (Røvik, 2000); their presence in this study can to an extent be expected. But, importantly, a focus on either technical or organisational measures does not automatically reflect the nature of the problem to be solved. Rather, the focus areas may reflect what is generally considered by the companies as appropriate solutions to *any* safety-related problem at the time – whatever that problem may be. In other words, a measure may be implemented without a thorough consideration of the actual causal mechanisms. Still the initiatives do have certain effects that depend on the situation in which they were deployed. That is, the same measure may produce different effects depending on in which context it is implemented. Analysing in more detail the different measures, contexts and potential effects stands to give insight into how safety has been, and can be, improved in the Swedish mining industry.

4.1. Safety improved due to technology development

For the most part, technology must protect vulnerable objects (e.g. humans) from harmful energies (cf. Haddon, 1963) to prevent accidents. Introducing barriers, reducing energies, and separating energy and object accomplishes this. Technology can act as a stronger barrier, introduce a "low-energy" alternative or move operators from dangerous environments. The technological development in the mining industry has accomplished this. For example, better vehicle cabs and improved rock-bolting represents improved barriers; using remote control to move the miner away from the mining environment in turn represents separation. Swedish accident figures indicate the effects of this development (e.g. SveMin, 2016). Between 2011 and 2015 less than 10 percent of all accidents were due to mucking, falling rock or traffic – accidents with clear connection to lacking protection from energy. By comparison, walking, jumping or tripping accounted for around 22 per cent of all accidents. Service and repair accounted for almost 40 per cent. One interpretation of this is that technology has managed to successfully protect operators from a complex, high-energy environment.

But the ability for technology to offer this type of protection diminishes, it could be argued, as accidents become more trivial. Consider

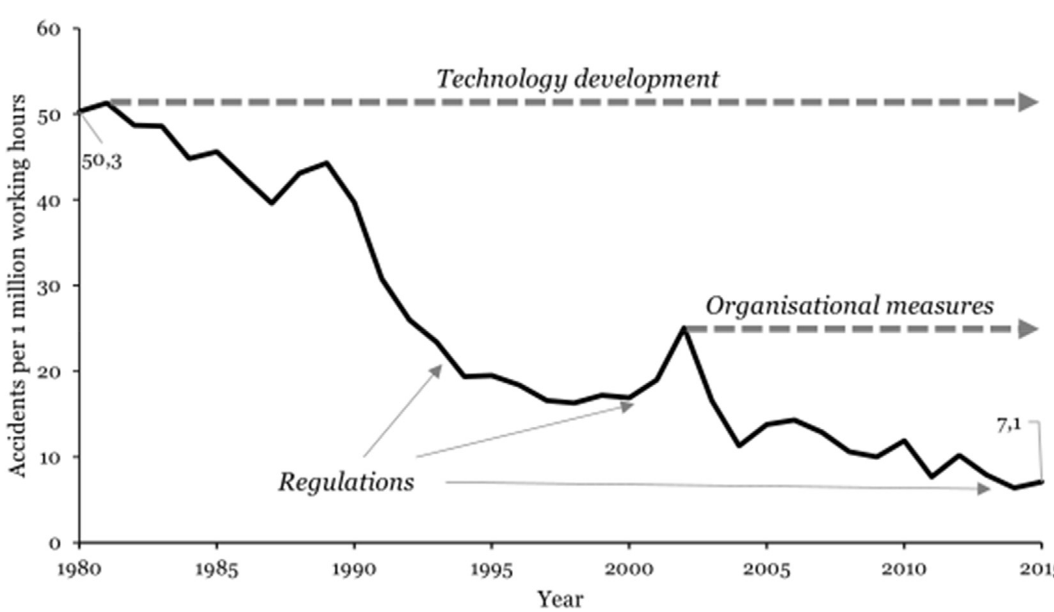

Fig. 1. A rough summary of safety initiatives in the Swedish mining industry in relation to the LTIFR.

slip, trip and fall accidents: while energy is certainly a part of these accidents (i.e. kinetic energy), technology is not as readily able to offer protection. People trip because of irregularities in the floor, for exemple. Here technology can only protect the operator to the extent that it either separates the operator from irregularities in the floor or results in more regular floor surfaces. This kind of accident remains a significant problem in the industry, and the informants recognised that preventing them is less of a question of technology than it is of safe behaviour.

Moreover, technology is only efficient to the extent that it is actually used. In the interviews this was addressed in relation to the improved *design* of technology, such as through improved machine interfaces. However, the use of technology is not only dictated by its design or availability, but also by organisational aspects. For example, rock-bolting and shotcreting technology have been available for a long time. The technology has improved over the years, but the more important factors seems to be its extended *use*; where before only certain parts of mines were reinforced using rock-bolts, now they are always installed and in the entire mine.

At the same time, technology does not unequivocally improve safety. Consider maintenance: its different activities now account for 40 per cent of all serious accidents (SveMin, 2016; see also Ruff et al., 2011). Maintenance requirements increase as technology becomes more sophisticated, and might become more complex. Further automation and autonomous vehicles will probably continue to improve safety. But there is a risk that safety will only improve in primary activities (blasting, loading and so on) as the design of new mining technology tends to overlook auxiliary tasks such as maintenance (Horberry et al., 2011; Simpson et al., 2009). What is more, contractors commonly undertake maintenance activities (Nygren, 2018) – a group that already experiences lower safety.

4.2. Organisational aspects: The role of the organisation and leadership

On the "soft" side of the spectrum are the organisational measures. Their effect on safety and safe behaviour has been investigated previously. Beus et al. (2016), for example, found empirical support that safe behaviour in general is affected by organisational and personal factors. (Personal factors include personal resources, safety knowledge, skills and motivation. Organisational factors include policies, practices, safety culture, job characteristics and so on.) Since the 2000s the companies of this study have to a large extent focused on such measures, alongside continued technological improvements. On the organisational side, these initiatives include a focus on safety culture, changed policies, routines etc. On the personal side, these include educational efforts and an increased focus on behaviours.

While causal effects were not investigated in the present study, the organisational safety initiatives have theoretically had an effect on safety. Previous research has found organisational factors to be prevalent in mine accidents; some studies conclude that up to 50 per cent of all accidents involve such factors (Lenné et al., 2012; Patterson and Shappell, 2010). Similarly, Laurence (2011) found that many accidents in mining are caused by lack of awareness of or compliance with rules, poor communication, production taking priority over safety, inadequate training and so on. The informants' accounts contain similar sentiments. Therefore, to the extent that organisational measures have addressed these issues, they could be assumed to have improved safety.

Expanding on this, however, the relationship between individual measures and safety is unclear. Both companies utilised safety culture programmes and voluntary work environment management certification (i.e. OHSAS 18001). But while one company went through certification first and then started safety culture initiatives, the other company did this the other way around. Yet any major difference between the companies in terms of accident frequency rate is not discernable. In other words, while safety culture programmes and certification both can improve safety (Beus et al., 2016; Madsen et al., 2018), based on this study it seems one initiative does not have to precede the other. Nor does it seem that the effects are possible only through the use of these specific initiatives. The LTIFR of the Swedish mining industry to a large extent represents the rate of individual Swedish mining companies. The participants during the workshop indicated that certain *types* of initiatives have improved safety, but the improvement does not necessarily depend on the *specifics* of these initiatives. Note, however, that the informants held that regulations for systematic work environment management specifically paved the way for the subsequent voluntary initiatives. It may therefore also be that all of the initiatives share common and fundamental denominators that may lead to improved safety – but characteristics that still remain to be clarified.

The unclear relationship between measure and outcome has another dimension as well. In both companies, more attention has been placed on middle managers in their capacities as "norm builders". The companies view middle managers as creators and facilitators of safety culture through their leadership. Yet this is in addition to other responsibilities. The informants recognised the increased pressures, resulting in stress, on this group due to this. Thus, a unilateral focus on establishing the central role of this group in facilitating safety also carries risks. Too much stress, increased responsibilities with insufficient increase in resources, could in the worst case scenario contribute to unsafe behaviour among the managers themselves. With a view on this group as norm builders (or role models) that "set the bar" for safety, they also risk sending the wrong message to the workers under their leadership through this behaviour.

Finally, the results show that mining companies have increased the scope of their safety practices to include contractors. This indicates a shift in the organisation and management of mining-related operations. Rather than viewing the operations as vertically integrated with a workforce tied primarily to a single employer, the informants recognised that the proper way of describing some operations is what can be called "multi-employer worksites". This has led to an increased focus on clarifying the extent to which accidents actually occur among contractors. Attention is also given to how management and coordination practices in multi-employer arrangements can be improved. The importance of clarifying management and coordination practices as means of increasing safety across organisational boundaries has also received some support in studies focusing on the manufacturing industry (see e.g. Nenonen and Vasara, 2013). However, although the informants viewed this development as something positive for overall safety, it should be noted that this does not directly relate to the lowered accident frequency rate in the industry as a whole per se; the overall LTIFR presented in Fig. 1 only represent the reported accidents among the mining companies' own personnel over time.

4.3. Conclusions

Mining companies operate in an environment of complex organisational, physical and technical relationships. Attention to any one of these factors in relation to safety needs to recognise the other factors as well; the approach to safety in mining needs to incorporate both "hard" and "soft" perspectives on safety. Swedish mining companies have used both technical (hard) and organisational (soft) strategies to improve their safety records. The informants also saw continued focus on technical as well as organisational and behavioural measures as key to further improvements to safety.

While individual measures can have effects, they risk losing their full potential if a wider perspective is not also employed. Leadership and psychosocial aspects are illustrative here. Focus on middle managerial norm builders and individual motivation for safety is important but must include the right resources, routines and technologies. The idea here of turning the hierarchy is a suitable future endeavour if it it comes with increased resources (including education). That is, not only should the hierarchy be turned, but the conditions for doing so must also be created. Additionally, one informant noted the importance in securing future competence. In this case, effects from new technology can be lost if mining companies do not have the competences to fully exploit it.

This study also focused on the implementation of different initiatives over time, actualising issues related to the order in which they were implemented. The present study shows that, in general, technical measures were followed by organisational measures, with regulatory measures implemented periodically. It might be tempting to describe this as a stepwise development, where physical measures create the foundation for organisational measures. It has been suggested that development has happened this way in the process industry (Kariuki and Löwe, 2012), and a roughly similar development can be identified in the present study. Still it is difficult to conclude determinism from this. For the most part, the Swedish mining industry has gone through concurrent changes. Judging from the material of this study, individual companies have seldom deviated far from general developments in the mining industry as a whole. At the same time, safety initiatives can change the safety situation which then requires new kinds of initiatives. For example, one of the companies had long focused on implementing systems and a practice for reporting accidents and suchlike. Having succeeded in this, one informant reported that the challenge changed to actually dealing with these reports. In this sense, certain initiatives preceed others (working with reported incidents is hard if there are no incident reports).

Related to this, different accidents require different measures. For example, Groves et al. (2007) found a pronounced difference between fatal and non-fatal accidents, including equipment involved, in equipment-related mining accidents. The fatal injury rate in Swedish mining industry has improved more than the lost-time injury frequency rate. Less serious accidents are now more common in the industry. The approach to preventing fatal accidents is probably different from the approach to preventing non-fatal accidents, which is different than preventing light injuries. For example, the informants recognised that preventing slip, trip and fall accidents requires a focus on behaviour rather than technological solutions. Still, questions remain as to whether an organisational focus, for example, can only follow certain technological developments that has reduced the accident rate to a certain level. Or if there is a level beyond which technical or organisational measures cannot further improve safety.

Finding clarity in these question stands to help mining companies in their safety work by giving priority to different measures. Ultimately, this also requires knowledge of the situation into which initiatives are implemented. Indicators are central in this. As indicated in this study, traditional measures become too blunt. The development of proactive indicators in the industry (see ICMM, 2012) is positive in this regard. But it is likewise important to develop *new* types of indicators that are able to merge perspectives (technology and organisation) in such a way that long-held assumptions about safety are challenged. This should provide the ground for future safety developments, both practically and theoretically.

Lastly, significant effort has been made in the industry to clarify management practices as means for increasing safety on worksites involving both mining company and contractor personnel. In a Swedish context there is a division of legal responsibilities for safety management between a client company and a contractor. However, in practice, these distinctions can be difficult to uphold, in part due to the often dominant positions of clients. This can lead to, for example, client managers assuming responsibility of safety-related matters that the contractor managers themselves are legally responsible for (Nygren, 2018). This, in turn, may lead to uncertainties regarding which party is responsible for what and ultimately the overall implementation and functioning of safety management practices. Consequently, although it is necessary to clarify responsibilities and divide certain management tasks, the actual conditions for responsibility-taking in practice need to be considered as well. Here, a focus on issues pertaining to power and possible asymmetry in relations may be key.

Acknowledgment

This research was conducted within the frame of SIP STRIM (Strategic innovation programme for the Swedish mining and metal producing industry), funded by Vinnova, Formas and the Swedish Energy Agency.

Appendix A. Interview guide (translated from Swedish)

A.1. Background

The purpose of the study is to explore the safety-related development in the Swedish mining industry over the last 30 years. Given this, we are interested in clarifying what Swedish mining companies have done under this period that may have affected the accident frequency rate and safety more broadly.

Consequently, by your participation in this study, we hope to shed light on this development and the different initiatives that have been undertaken.

A.2. General questions

- What is your formal job title and what does your work consist of? What are your areas of responsibility?
- How do you work with safety-related matters?/How does your work affect safety?
- Is there any kind of additional information regarding safety (management/practices) that you would like to have in relation to the work you perform? Is there any safety-related issues of which you presently lack information on?
- How would you describe the safety situation in the Swedish mining industry in general? How does your company relate to this situation?
- Is the safety situation the same across the company? Are there differences between different sections, units etc.? How come? What do these differences consist of?
- How would you describe the development over the last 20–30 years in the company regarding:
  - Safety/accidents (including e.g. programmes and initiatives to increase safety)?
  - Technology?
  - Organisation?
- How would you explain this development?

A.3. Technology

- What have been the most significant technological developments in the Swedish mining industry in general and in your company in particular?

- Are safety-related matters taken into consideration when new technology is introduced?

A.4. Safety-related statistics

- How do you work with, and use, statistics regarding safety?
- What is safety-related statistics used for in general within the company?
- Is there any safety-related problem/any particular workplace/work task/factor (e.g. type of machine or type of employment) that "sticks out" in the statistics?
- Is there any kind of information, that you consider important, that is not readily available in the present statistics used within the company?

Appendix B. Examples of interview excerpts, codes and subthemes (translated from Swedish)

Excerpt	Code	Subtheme
"The biggest technological development has occurred in the last ten years, for example new rock reinforcement methods, new shotcreting methods. There are a lot of remote controlled machines today which removes people from the most dangerous areas."	Protection from the rock	Technology contributes to safety improvements
"If it is the case that we reach certification [according to OHSAS 18 001] then we have the structural pieces in place to reach our goal."	Certification is important	Certification towards OHSAS 18001
"The attitude towards health and safety was completely different before. It was more of a macho culture, it was kind of cool to break the rules not wear fall protection equipment. This has changed now."	Diminishing macho culture	Changing attitudes towards safety
"But at the same time, they [contractor workers] have their employers and their norms and their culture et cetera. They [contractor companies] have the employer's responsibility that differs as well, what should we do and not do?"	Division of responsibilities	Clarifying contractor safety practices
"We are too small for our assignment. We are nine people out of which two are on part-time sick leave. We need to get more technology-minded at [the company]. The soft issues are important but we have too little competence regarding technology."	Technological competence	Ensuring skills and competencies

References

Beus, J.M., McCord, M.A., Zohar, D., 2016. Workplace safety: a review and research synthesis. Organ. Psychol. Rev. 6, 352–381. https://doi.org/10.1177/2041386615626243.

Blank, V.L.G., Andersson, R., Lindén, A., Nilsson, B.-C.C., 1995. Hidden accident rates and patterns in the Swedish mining industry due to involvement of contractor workers. Saf. Sci. 21, 23–35. https://doi.org/10.1016/0925-7535(95)00004-6.

Blank, V.L.G., Diderichsen, F., Andersson, R., 1996. Technological development and occupational accidents as a conditional relationship: a study of over eighty years in the Swedish mining industry. J. Safety Res. 27, 137–146. https://doi.org/10.1016/0022-4375(96)00014-X.

Blank, V.L.G., Laflamme, L., Diderichsen, F., Andersson, R., 1998. Choice of a denominator for occupational injury rates: a study of the development of a Swedish iron-ore mine. J. Safety Res. 29, 263–273. https://doi.org/10.1016/s0022-4375(98)00052-8.

Bowen, G.A., 2009. Document analysis as a qualitative research method. Qual. Res. J. 9, 27–40. https://doi.org/10.3316/QRJ0902027.

Brand, S., 1990. Arbetsskador i svenska gruvor. In: Ekström, Ö., Hall, I. (Eds.), Från Yrkesfara till Arbetsmiljö: Yrkesinspektionen 100 År. Arbetarskyddsstyrelsen, Solna, pp. 172–178.

Braun, V., Clarke, V., 2014. Using thematic analysis in psychology. Using thematic analysis in psychology 0887, pp. 37–41.

Demiral, Y., Ertürk, A., 2013. Safety and health in mining in Turkey. In: Elgstrand, K., Vingård, E. (Eds.), Occupational Safety and Health in Mining: Anthology on the Situation in 16 Mining Countries, Arbete & Hälsa. University of Gothenburg, Gothenburg, pp. 87–93.

Elgstrand, K., Vingård, E., 2013. Safety and health in mining. In: Elgstrand, K., Vingård, Eva (Eds.), Occupational Safety and Health in Mining: Anthology on the Situation in 16 Mining Countries, Arbete & Hälsa. University of Gothenburg, Gothenburg, pp. 1–14.

European Commission, 2010. Health and safety at work in Europe (1999-2007) – A statistical portrait. Publications Office of the European Union, Luxembourg.

Feickert, E., 2013. Safety and health in mining in China. In: Elgstrand, K., Vingård, E. (Eds.), Occupational Safety and Health in Mining: Anthology on the Situation in 16 Mining Countries, Arbete & Hälsa. University of Gothenburg, Gothenburg, pp. 23–30.

Flick, U., 2014. An introduction to qualitative research, fifth ed. Sage, Los Angeles.

Geological Survey of Sweden, 2018. Statistics of the Swedish Mining Industry 2017 (No. 2018:1), Periodiska publikationer. Geological Survey of Sweden, Uppsala.

Geological Survey of Sweden, 2016. Statistics of the Swedish Mining Industry 2015. Geological Survey of Sweden, Uppsala.

Groves, W.A., Kecojevic, V.J., Komljenovic, D., 2007. Analysis of fatalities and injuries involving mining equipment. J. Saf. Res. 38, 461–470. https://doi.org/10.1016/j.jsr.2007.03.011.

Haddon Jr, W., 1963. A note concerning accident theory and research with special reference to motor vehicle accidents. Ann. N. Y. Acad. Sci. 107, 635–646.

Haldane, S., 2013. Safety and health in mining in Canada. In: Elgstrand, K., Vingård, E. (Eds.), Occupational Safety and Health in Mining: Anthology on the Situation in 16 Mining Countries, Arbete & Hälsa. University of Gothenburg, Gothenburg, pp. 129–136.

Hartman, H.L., Mutmansky, J.M., 2002. Introductory mining engineering. Wiley, Hoboken.

Horberry, T.J., Burgess-Limerick, R., Steiner, L.J., 2011. Human Factors for the Design, Operation, and Maintenance of Mining Equipment. CRC Press, Boca Raton.

ICMM, 2012. Overview of leading indicators for occupational health and safety in mining. International Council on Mining & Metals, London.

IF Metall, 2015. Gruvindustrin (No. Rapport #3), Fokus industri. If Metall, Stockholm.

Johansson, J., 1986. Teknisk och organisatorisk gestaltning: Exemplet LKAB. PhD thesis. Luleå University of Technology, Luleå.

Kariuki, G., Löwe, K., 2012. Incorporation of Human Factors in the Design Process. Institute for Plant and Process Technology, Process Safety and Plant Technology, Berlin.

Katen, K.P., 1992. Health and safety standards. In: Hartman, H.L. (Ed.), SME Mining Engineering Handbook. Society for Mining, Metallurgy, and Exploration, Littleton, CO, pp. 162–173.

Krzemień, S., Krzemień, A., 2013. Safety and health in mining in Poland. In: Elgstrand, K., Vingård, E. (Eds.), Occupational Safety and Health in Mining: Anthology on the Situation in 16 Mining Countries, Arbete & Hälsa. University of Gothenburg, Gothenburg, pp. 59–66.

Laflamme, L., Blank, V.L.G., 1996. Age-related accident risks: longitudinal study of Swedish iron ore miners. Am. J. Ind. Med. 30, 479–487. https://doi.org/10.1002/(SICI)1097-0274(199610)30:4<479::AID-AJIM14>3.0.CO;2-1.

Laurence, D., 2011. Mine safety. In: Darling, P. (Ed.), SME Mining Engineering Handbook. Society for Mining, Metallurgy, and Exploration, Englewood, CO, pp. 1557–1566.

Lenné, M.G., Salmon, P.M., Liu, C.C., Trotter, M., 2012. A systems approach to accident causation in mining: an application of the HFACS method. Accid. Anal. Prev. 48, 111–117. https://doi.org/10.1016/j.aap.2011.05.026.

Lilley, R., Samaranayaka, A., Weiss, H., 2013. International comparison of International Labour Organisation published occupational fatal injury rates: How does New Zealand compare internationally? University of Otago, Dunedin.

Lööw, J., Johansson, B., Andersson, E., Johansson, J., 2018. Designing Ergonomic, Safe, and Attractive Mining Workplaces. CRC Press, Boca Raton, FL.

Madsen, C.U., Kirkegaard, M.L., Hasle, P., Dyreborg, J., 2018. "To Him Who Has, More Will Be Given…" – A Realist Review of the OHSAS18001 Standard of OHS Management. In: Proceedings of the 20th Congress of the International Ergonomics Association (IEA 2018). Springer International Publishing. https://doi.org/10.1007/978-3-319-96098-2.

Muzaffar, S., Cummings, K., Hobbs, G., Allison, P., Kreiss, K., 2013. Factors associated with fatal mining injuries among contractors and operators. J. Occup. Environ. Med. 55, 1337–1344.

Nelson, M.G., 2011. Evaluation of mining methods and systems. In: Darling, P. (Ed.), SME Mining Engineering Handbook. Society for Mining, Metallurgy, and Exploration, pp. 341–348.

Nenonen, S., Vasara, J., 2013. Safety management in multiemployer worksites in the manufacturing industry: opinions on co-operation and problems encountered. Int. J. Occup. Safety Ergon. 19, 168–183. https://doi.org/10.1080/10803548.2013.11076976.

Nygren, M., 2018. Safety Management on Multi-Employer Worksites: Responsibilities and Power Relations in the Mining Industry. Luleå University of Technology, Human and technology.

Nygren, M., 2016. Coordinating occupational health and safety: Regulatory demands and practical implementation on multi-employer worksites. In: Presented at the The

Eighth Nordic Working Life Conference, Tampere.
Patterson, J.M., Shappell, S.A., 2010. Operator error and system deficiencies: analysis of 508 mining incidents and accidents from Queensland, Australia using HFACS. Accid. Anal. Prev. 42, 1379–1385. https://doi.org/10.1016/j.aap.2010.02.018.
Reason, J.T., 1997. Managing the Risks of Organizational Accidents. Ashgate, Aldershot, Hants, England; Brookfield, Vt., USA.
Røvik, K.A., 2000. Moderna organisationer: trender inom organisationstänkandet vid millennieskiftet. Liber, Malmö.
Ruff, T., Coleman, P., Martini, L., 2011. Machine-related injuries in the US mining industry and priorities for safety research. Int. J. Inj. Contr. Saf. Promot. 18, 11–20.
SGU, 2015. Statistics of the Swedish Mining Industry 2014. Geological Survey of Sweden, Uppsala.
Simpson, G., Horberry, T., Joy, J., 2009. Understanding Human Error in Mine Safety. Ashgate, Surrey.
Smith, C., Elger, T., 2012. Critical Realism and Interviewing Subjects, Working Paper Series. School of Management, Royal Holloway University of London.
SveMin, 2016. Occupational Injuries and Sick Leave in the Swedish Mining and Mineral Industry 2015. SveMin, Stockholm.
SveMin, 2010. Occupational Injuries and Sick Leave in the Swedish Mining and Mineral Industry 2009. SveMin, Stockholm.
Swedish Work Environment Authority, 2017. Occupational accident and work-related diseases 2016 (No. 2017:1), Arbetsmiljöstatistik Rapport. Swedish Work Environment Authority, Stockholm.
Zhang, M., Kecojevic, V., Komljenovic, D., 2014. Investigation of haul truck-related fatal accidents in surface mining using fault tree analysis. Saf. Sci. 65, 106–117. https://doi.org/10.1016/j.ssci.2014.01.005.