RISK ASSESSMENT TRAITS IN VARIOUS MINE OPERATION STAGES

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Abstract: *Awkward identification, superficial knowledge and misperception of occupational risks related to underground working environment in Romanian mining industry, basically linked to their probability of occurrence and severity, but also to the lack of scenario development generated in the last decades a series of undesired events with great losses, both in terms of human lives and property damage. Managing hazards in underground mining operations necessarily involves a systematic and structured process based on proactive behaviour of all stakeholders. The process should be initiated and, then, developed and spotted from exploration to closure of mining activities, namely throughout the entire life cycle of any mine unit. Nowadays, despite a strong regression of the Romanian mining industry, or quite for this reason, the commitment for quality, consistency and effectiveness of performed occupational risk analysis and management across the remaining mine units should become more accurate and holistic, considering the particular risks related to industry restriction. More and more complex evaluation tools should be applied, bringing their related benefits and consequently providing the opportunity to practically achieve higher effectiveness of decision-making processes. This paper is aimed to highlight the structure and spot the light on the main problems to be addressed by occupational health and safety engineers and managers from any mine, when setting the strategic, organizational and risk management goals, context and framework needed to perform a usable and rational risk assessment. Another goal of our systematization effort is to emphasize and offer guidance on how an adequate and targeted risk analysis method applicable in every life cycle stage of a mine, ranging from design until closure and rehabilitation should be selected.*

Keywords: accident, hazard identification, mining industry, risk assessment method, risk management

1. Introduction

In order for any industry to be successful, it should meet the requirements not only of production, but also to maintain the highest standards of safety for all parties involved. The industry must identify hazards, to assess risks and bring risks to an acceptable level. Different types of approaches concerning safety in mining, there are various tools available and appropriate measures should be taken to create better and safer conditions at workplace in mining industry. As part of the overall management of hazards associated with any operation, it would be anticipated that the organization would have a Safety Management System (SMS). This system would be an integral part of the operation's total management process [1]. The purpose of the SMS is to ensure safe operation of a mining facility, by providing a comprehensive and integrated process for systematically managing all aspects of the adopted control measures. To achieve this purpose, the SMS must not only be comprehensive and integrated with respect to the control measures, it needs to be suitable and appropriate to the specific facility, it must be used in practice, and must be reviewed and revised whenever the circumstances require.

A SMS will typically have a set of generic elements forming a continuous improvement cycle. Such a cycle could be: a) policy and objectives; b) standards and targets; c) planning and prioritizing; d) implementation; e) monitoring; f) audit; g) corrective action; h) review.

As a specific example, an Occupational Safety and Health Management System is comprised of five components in a continual improvement loop. The components are defined as:

1. Corporate vision, Policy and Management Commitment
2. Plan
- Management Leadership
- Responsibilities/Accountabilities
- Risk Assessment/Management
- Compliance and other requirements
- EHS Planning and Programmes
3. Do
- Personnel Training and Contractor Services
- Documentation and communications
- Facilities design and construction
- Operations, Maintenance and Management of Change

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- Community Awareness and Emergency Response

4. Assess

- EHS Performance Monitoring and Measurement
- Incident Investigation, Reporting and Analysis
- EHS Management Systems Audits

5. Adjust (Management Review and Adjustment)

As can be seen Risk Assessment/Management is a key component of the Planning stage on which the remainder of the cycle depends.

2. Setting the strategic, organizational and risk management context

Expected outcomes of this step include [3]:

- **Corporate/site commitment**

There should be a documented organization or site commitment to the process of proactively considering hazards and risks during the making of key decisions in the project or operation. This type of commitment may be mentioned in Risk Management related documents but should be expanded in more detail, for example in a procedure, in order to deal with issues noted below.

- **Application and defined expected deliverables of risk assessment and risk management**

The context for risk assessment (i.e. the procedure) in an organization or site should identify the situations where application of risk assessment is required. The selected applications would likely consider the most important decisions in the organization. This might include identification of expected deliverables such as procedures, plans, operating guidelines, design finalization information or others. Defining the deliverables of the risk assessment is necessary before the selection of the most appropriate analytical method. Some organizations have "procedures" that cover the method(s) of risk assessment but give little guidance on the reasons for applying the methods. This may lead to the situation where risk assessment is done without a clear image of the desired deliverable. In other words the objective is to do a risk assessment, rather than produce a useful deliverable such as a key plan, operational recommendations, design review recommendations, safe job procedure, etc. This problem may lead to ineffective use and appreciation of risk assessment, particularly in the specific conditions of the mining industry.

3. Defining required resources and timing of risk assessment

Resources are required for a risk assessment and, as such, should be recognized in the relevant policy or procedure. Resources for some risk assessment methods include a facilitator, a suitable team, a suitable room, information recording equipment, the required time, etc. However, in addition there may be resources to scope or design the risk assessment and resources to gather information on the existence, nature or magnitude of hazards, as well as resources to take the required action as a result of the assessment [4].

Sometimes risk assessment teams are created with conveniently available personnel such as those on light duties, even though they may be, at best, only basically familiar with the system being reviewed when compared to other site personnel. This is undesirable and compromising to the entire process.

The timing of a risk assessment depends of the required deliverable but the general principle is the earlier the better. Sometimes the use of a life cycle approach can be helpful to consider the timing of risk assessment [2].

Multiple techniques vary from simple qualitative methods to advanced quantitative methods which are available to help identify and analyze hazards. The use of multiple hazard analysis techniques is recommended because each has its own purpose, strengths and weaknesses.

In Romania are used risk assessment methods in different branches of industry, but the number of references for solving exploitation problems are limited. Investigations showed that the methods mentioned above are applicable for solving mining complex problems. However, prevention of dangerous situations are morally, ethically and economically, rather than to deal with the negative consequences. At the design stage, the above-mentioned methods give unique opportunity to anticipate the negative consequences and will allow developing tools for avoiding and mitigating risk factors. Risk assessment methods, provides information on mining and its environmental influence. Having the information, the management of a mine can head to the appropriate political and strategic decisions.

The mining life cycle illustrates the various stages in any project. The most cost effective timing for risk assessment is in the concept/design phase. Risk Assessments should, at least, be done at the earliest possible point in each life cycle stage. Minimally, the timing of risk assessment should allow time for a quality analysis, as well as time to effectively apply the deliverables from the analysis. The context of risk assessment (such as a procedure) should include guidance on timing and resource expectations.

Table 1 and table 2 are providing an indication of what is being looked for at each of the stages in the project life cycle and indicate which techniques might be appropriate for the particular stage. The choice of a specific technique depends on the specific project, study, timing etc.

Table 1. **Risk assessment issues in various mine operation stage**

Stage	**Stage-specific issues**
Project Concept	• Require understanding of the project its processes and materials sufficient to address safety, health and environment issues during design stage • Consider possibilities of eliminating hazards by redesign or alternative technologies • Completion of PHA (Preliminary Hazard Analysis) type assessment • Generate Hazard Inventory • Incorporate the preliminary thinking regarding closure of the operation and the hazards to be managed at that time • Document decision process and outcomes in all phases of the project
Project Feasibility	• Include assessment of cost of possible controls for major risk areas • Revise PHA to incorporate current understanding
Project Design	• Systematically review the design to identify any hazards (including Health issues) • Identify and estimate the consequences of such hazards and identify controls • Consider all transient conditions eg start up, shut down, emergencies and upsets • Consider ergonomics and manual handling • Manage all changes to the design to ensure that new hazards are not introduced or risks increased • Update PHA to a full assessment using appropriate techniques e.g. HAZOP, ETA, FTA, FMEA etc. • Generate initial Hazard Register
Construction	• Review the construction methodology and identify, evaluate and propose methods to control specific hazards • Identify construction/existing operation conflicts and management strategy • Ensure measures are in place to ensure design intent and hazard controls are all complied with • Ensure a process is in place for managing any and all changes
Acquisition	• Require a review to identify that there has been a full risk management process in place at the acquisition and to determine any gaps that will need to be assessed
Commissioning	• Conduct a risk assessment of the proposed commissioning sequence • Identify transient hazards created by stepped commissioning • Review previous assessments to ensure all actions and controls are implemented
Operation	• Ensure that facility is constructed to design intent • Review operations to ensure that these are consistent with design • Intent and verify that the assumptions made in all earlier studies are valid • Ensure that the standard operating procedures (SOP), maintenance procedures and emergency response incorporate all requirements identified in earlier studies. • Ensure changes developed during commissioning and ongoing operation are consistent with the previous studies and do not introduce or exacerbate risks • Review operations for previously unidentified risks • Systematically review procedures for the facility
Maintenance	• Ensure all controls and specifically critical controls are identified and subject to a maintenance regime that meets the control intent, including the maintenance plan, SOPs, etc. • Ensure that the SOPs, maintenance procedures and emergency response incorporate all requirements identified in earlier studies. • As with operations
Modification	• There is an absolute requirement to assess all changes to the facility whether managerial, operational, maintenance, shut down, new process, new chemicals etc to ensure that there are no new hazards introduced without controls • Develop documentation of the decisions reached for each change
Disposal Closure	• Assess the hazards related to the removal of equipment, closure of pits and dumps, demolition of structures, rehabilitation of dumps, access by others once facility is closed, community issues etc.

Table 2 **Application of Risk Assessment Methods**

Mine Life Cycle Stage "Timing"	**Informal RA**	**FMEA**	**JSA/JHA**	**PHA/HAZAN RAC**	**FTA**	**ETA**	**FMECA**	**HEA**	**LOPA**	**HAZOP**	**Risk Rank**	**Checklist**
Project Concept "Gleam in the eye"				**X**							**X**	**X**
Project Feasibility "Board agree to investigate"	**X**			**X**							**X**	**X**
Project Design "Funding provided to develop design"		**X**		**X**	**X**	**X**	**X**	**X**	**X**	**X**		**X**
Construction "Completed during Design"			**X**					**X**			**X**	**X**
Acquisition "As soon as access is negotiated"				**X**							**X**	**X**
Commissioning "During Design and Construction"			**X**					**X**		**X**	**X**	**X**
Operation "During Design Construction and Commissioning"		**X**	**X**	**X**	**X**	**X**		**X**		**X**	**X**	**X**
Maintenance "During design, construction and commissioning"		**X**	**X**	**X**		**X**	**X**	**X**	**X**	**X**	**X**	**X**
Modification "At all times"	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Disposal Closure "From the start up of the facility"	**X**		**X**	**X**							**X**	**X**

The assessment methods included in table 2 are:

- Informal RA - Informal Risk Assessment;
- FMEA - Failure Modes and Effects Analysis;
- JSA/JHA - Job Safety Analysis/Job Hazard Analysis;
- PHA/HAZAN - Preliminary HAZard Analysis;
- FTA - Failure Tree Analysis;
- ETA - Event Tree Analysis;
- FMECA - Failure Modes, Effects and Criticality Analysis;
- HEA - Human Error Analysis;
- HAZOP - HAZard OPerability;
- Risk Rank - Risk Prioritization.

In the preceding table checklists are identified as an assessment technique. A checklist identifies known hazards, potential design deficiencies and potential incident situations associated with common equipment or operations. It can be used for processes, equipment, materials and procedures. It is most commonly used when there is a significant, large body of experience or knowledge on the subject under study. However general checklists can sometimes be used for new or unusual designs. The method is usually limited to ensuring that a process, piece of equipment, material or procedure conforms to accepted standards. Checklists are noted for being exclusive rather than inclusive in the sense that if an issue is missing from the checklist it probably will be ignored.

In the past, a Romanian mine applied risk assessment to derive the operating guidelines for a new piece of underground equipment before it was transported into the mine. The assessment identified some design modifications and a large amount of operating requirements. However, the risk assessment was scheduled only a few days before the machine was to go underground and commence production. As a result, the assessment was rushed and there was some resistance to significant new controls.

The context (or procedure) should include the accountability for areas such as:

- initiation of a risk assessment in defined circumstances;
- planning or scoping the risk assessment;
- meeting the resource requirements;
- utilization of facilitators (including consideration of external resources for complex assessments);
- methods for implementing deliverables;
- checking the quality of risk assessment activities.

Some organizations have "procedures" with no clear accountability. The "not-my-job" phenomenon occurs, not always deliberately, but often due to human nature. "I do what my boss tells me to do".

4. Risk assessment pitfalls in mining industry

Although risk assessment is a potentially powerful tool, as with all tools, if it is not used with care and understanding, the outcomes may well be totally incorrect and lead to bad decisions being made that are not supportable in reality [3].

The following "common" pitfalls are specific to the risk assessment processes and they are common in mining industry too; and they have to be considered when setting the strategic, organizational and management context:

- carrying out a risk assessment to attempt to justify a decision that has already been made;
- using generic assessment when a site specific assessment is needed;
- carrying out a detailed, quantitative risk assessment without first considering whether any relevant good practice was applicable, or when relevant good practice exists;
- carrying out a risk assessment using inappropriate good practice;
- making decisions on the basis of individual risk estimates when societal risk is the appropriate measure;
- only considering the risk from one activity;
- dividing the time spent on the hazardous activity between several individuals – the "salami slicing" approach to risk estimation;
- not involving a team of people in the assessment or not including employees with practical knowledge of the process/activity being assessed;
- ineffective use of consultants;
- failure to identify all hazards associated with a particular activity;
- failure to consider all possible outcomes;
- inappropriate use of data;
- inappropriate definition of a representative sample of events;
- inappropriate use of risk criteria;
- no consideration of ALARP arguments (i.e. using cost benefit analysis to attempt to argue that it is acceptable to reduce existing safety standards;
- not doing anything with the results of the assessment;
- not linking hazards with risk controls.

5. Conclusions

Formal risk assessment has a longer history in industries other than mining. For example, the petrochemical, nuclear, military, aviation and space industries have applied various formal risk assessment techniques for over 30 years. This proactive approach to improving risk control, as opposed to a reactive "fix - it - when - it - breaks" mentality, was in most cases triggered by major public disasters. Today all the previously listed industries would see risk assessment as an inherent part of their business. Through not as lengthy, risk assessment has had a significant history in the Romanian mining industry. A basic stage in the risk assessment process is the setting of the strategic, organizational and risk management context required in specific conditions, which includes the defining of required resource, the defining of risk assessment project timing and establishing clear accountability. All these issues are discussed in the paper and certain common pitfalls concerning the risk assessment process are highlighted. It is emphasized that the context of risk assessment, such as a procedure, should include guidance on timing and resource expectations. Misunderstanding of hazards, not usually their existence but more commonly their nature and magnitude, has contributed to major or catastrophic incidents in the Romanian mining industry, in the distant and recent past. In some cases, the hazard was identified but not understood so that specific risks were underestimated, leading to inadequate controls and unacceptable residual risk.

One of the main reasons that risks are underestimated is the failure to map all the potential contributors to an incident event and, thereby, clarity the interrelationship of the various modes of failure and event outcomes.

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