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From operational hazards to organizational weaknesses: changing the focus for improvement

Georges Loiselle^a, Dragan Komljenovic^{b*}, Mustafa Kumral^c

^a Engineer; Hydro-Quebec Production, Canada

^b Researcher; Hydro-Quebec Research Institute (IREQ), Canada

^c Professor; McGill University, Mining Engineering, Canada

ABSTRACT

The daily operations in the mining industry are still a significant source of risk with regard to occupational safety and health (OS&H). Various research studies and statistical data world-wide show that the number of serious injuries and fatalities still remains high despite substantial efforts to decrease those numbers put in place by the industry in recent years. This paper argues that the next level of safety performance will have to consider a transition from coping solely with workplace dangers, to a more systemic model taking organizational risks into consideration. In this particular aspect, lessons learned from the nuclear industry may be useful, as organizational learning processes are more universal than the technology in which they are used. With the notable exception of major accidents, organizational performance has not received all the attention it deserves. A key element for reaching the next level of performance is to include organizational factors in low level events analyses, and approach management as a risk control system. These factors will then appear not only in event analysis, but also in supervision activities, audits, change management and the like. Many recent event analyses across various industries have shown that organizational factors play a key role in creating conditions for triggering major accidents (aviation, railway transportation, nuclear industry, oil exploitation, mining etc.). In the following paper, we will present a perspective that may be used in supervisory activities, self-assessments and minor events investigations. When ingrained in an organizational culture, this perspective has the highest potential for continuous safety improvement.

KEYWORDS: Occupational safety and health, safety culture, organizational performance, risk analysis and management

1. INTRODUCTION

The business and operational environment has changed considerably for the majority of organizations. One of the peculiarities of this change comes from the integration of various industrial, technical, political, economic, environmental, and financial pressures with regulatory adjustments ensuing from it (OECD, 2009, Homer-Dixon, 2011, Rzevski 2011, Komljenovic et al, 2015). The operation of these sectors, which were previously relatively autonomous and independent, becomes more complex as the number of stakeholders increases, including the advent of new technologies and interrelations between entities that are not anymore isolated and independent. A direct consequence of these changes is the nature of the events which continue to occur. While the accidents which arose previously generally found their cause in known and assumed factors, modern events find their origin in unforeseen interactions between elements without visible links. The linear story-telling of events is thus less suited for improvement in conventional and public safety (Carrillo, 2011; Dekker et al, 2011; Homer-Dixon, 2011; Leveson, 2011). This diagnosis is not limited to major accidents but also applies to other types of events (such as process disruptions or bankruptcy). In this paper, we discuss the evolution of the nature of the causal factors, and talk about approaches and tools developed and used in the nuclear industry to take into account the complexity of its operational environment. This experience can be transposed to other industries, including mining.

2. THE CLASSIC VIEW OF AN EVENT: FAILURE OF A WEAK LINK

We are accustomed to simplistic story-telling of significant events and accidents. It is natural

to identify a barrier, which if it had worked adequately, would have prevented the undesired occurrence. The barrier analysis allows us to identify the less than adequate performance of defences and to propose specific corrective actions. Even more elaborate methodologies, such as MORT (Johnson, 1975), stands on the identification of independent administrative barriers in complicated organizational systems, but not necessarily complex interactions. This view of an event supposes some linearity (a time line) which could be representative of reality to a certain extent. Even if some aspects were not reflected by the analysis, the identification of some weak barriers remained good enough for effective actions. Today, for most situations, such a linear approach is insufficient to allow a complete and useful understanding of the stakes and challenges regarding safety (Carrillo, 2011; Dekker et al, 2011; Leveson, 2011).

3. A NEW SOURCE OF RISK IN THE 21ST CENTURY: THE ORGANIZATION

Our understanding of events has changed for one main reason: the nature of its contributory factors. The main source of risk today is the organization itself (DoE, 2009; Leveson, 2011; Kahneman, 2012; IAEA, 2013). Indeed, we can notice that many industrial accidents have essentially organizational components, such as company's the culture, safety culture. communication between groups, decisionmaking by people in authority, centralization and decentralization, organizational clarity, and several other attributes which are more a matter of collective than individual work (Perrow, 1999; DoE, 2009; Carrillo, 2011; Dekker et al, 2011; IAEA, 2013; Mosey, 2014). These new characteristics are consequences of the evolution of two things: the type of barriers which ensure a safe environment, and the new interrelations between entities that were previously isolated and practically independent. Barriers enabling safety of the operational activities evolved with both the complexity of the tasks and the multiplication of involved persons. The main consequence is to change redundant barriers into dependant and interrelated ones, and to make it difficult to anticipate weaknesses in these barriers, leading to failures. This trajectory is well pictured by the metaphor of the slices of cheese, where degradation propagates through holes in lines of defence. This picture is still adequate, but a sequential display of such an event is not so representative of the underlying reality anymore; lines of defence have no more the same redundancy. A more appropriate model would rather present the situation as a degradation of margins, which locally would be individually acceptable but which, collectively, have important consequences that could not be anticipated by a local analysis.

This peculiarity brings us to certain characteristics of complexity. Complexity of the operational environment asks for an organizational answer adapted to face new stakes and challenges.

4. NEW STAKES AND CHALLENGES: COMPLEX INTERFACES

The technological evolution brings an important source of complexity. The automation of several processes conveys more opacity, with many control rules and new information technologies involved. One of the consequences of this situation is the necessity of increasing the technical training for the operator. This training is taken for granted during commissioning but invariably undergoes dilution in time, the inservice training being reduced to certain aspects more critical to health and safety.

Maintenance is another domain where training is often neglected. We usually believe that the procedures of maintenance prove the quality of the tasks output. This hypothesis is not unreasonable at the beginning of the operation of new equipment or system. However, experience shows us that we observe a degradation of conformity with time, with staff developing local adjustments and the management taking certain liberties with regards to the maintenance schedule. We slowly deviate from manufacturer's requirements without providing a new technical basis for changes. Indeed, because a decrease of maintenance does not necessarily cause immediate declining in performance, these deviations are tolerated and even sometimes reinforced because of their short term advantage.

The last element of the impact of these changes is the difficulty for the workers to anticipate the global behavior of all the systems components in interaction. The complexity is thus a matter of interactions between simple and relatively autonomous systems, which brings unexpected reactions of the whole, often amplified by the operator's actions erroneously adapted to those situations (Perrow, 1999; DoE, 2009; Carrillo, 2011; Dekker et al, 2011; Mosey, 2014).

5. COUPLING, COMPLEXITY AND NORMAL ACCIDENTS

This reality brings us to the concept of coupling and complexity introduced by Perrow (1999). In this model, the various types of industries have their characteristics mapped on two axes: complexity and coupling (Figure 1).



Figure 1: Interactions/coupling (Perrow, 1999).

Key attributes of complexity are related to the nature of interactions (interdependent components, common mode vulnerabilities. numerous feedback loops, multiple interacting controls, nonlinear reactions, phase transitions, indirect information, adaptability, phase transitions, etc.), and couplings (short delays, intolerance to variation, uniqueness of the sequence of actions, etc.). Thus, the complexity is associated with the strength of linkages several autonomous between constituent elements of a system that yield interactions that are difficult to grasp and anticipate. It creates an emergent system behaviour which is influenced by uncertain cause-and-effect relationships and unscheduled discontinuities (OECD, 2009; Dekker, 2011; Homer-Dixon, 2011; Rzevski, 2011; Komljenovic et al, 2015). Those interactions and characteristics create both significant uncertainties and overall opaqueness, which consequently make the operator dependent on indirect information reducing his capacity for immediate analysis and ulterior action.

These peculiarities highlight the importance of an organized situational awakening, which can be described as the capacity to estimate the anticipated effects in the short term following actions, and to at least ensure that obvious anomalies are quickly detected and corrected.

6. IMPACT OF THE NATURE OF RISK ON THE FUNCTIONS OF THE ORGANIZATION

Figure 1 shows that mining is an activity having complex interactions but loose coupling. This statement does not always apply to the management of tailing dams or underground coal mining, which may have tight coupling as an attribute. The characterization of an industry on Perrow's diagram also gives an indication of its organizational structure and work process requirements. An organization operating in a complex and strongly coupled operational environment has to pay attention to centralization and decentralization of the decision-making process (Rzevski, 2011). Considering the unique and irreversible character of particular event initiators, some decision-making in the field cannot allow delays. The chain of authority has to then be modified to allow a timely reaction, reflecting a global direction already known by the organization members (system behavior is too complex to enable a centralized real-time control). Thus, organization should have enough flexibility to be applicable in a large number of different and unanticipated situations. Such "onthe-spot" decision-making has to be supported by transverse (cross-functional) functions. The latter involves a participation of several ad hoc specialized units which can act in unison to realize an analysis by taking into account all the relevant aspects while facing an unforeseen situation.

7. HUMAN AND ORGANIZATIONAL PREFORMANCE MODEL

An organizational and human performance model has to be coherent, adapted and universal. The advantage of such a higher level model consists in enabling to share a taxonomy, which is common to event analyses, supervision, and planning an even safety and organizational culture. Indeed, operating experience can benefit a lot from a model that can be used in all activities, a must in pre-job briefings for the infrequent evolutions.

Strength of the model resides also in its capability to present events as complex interactions with several potential influences and not limiting itself to a unique sequence. It goes beyond the "simple" approach of redundant barriers, which gives a very linear reading of the events.

To err is human: The basic premise of human performance is that everyone is willing to

perform adequately and tries to fulfill his tasks to meet expectations. However, we all make mistakes and this cannot be avoided. These errors are basically predictable and controllable in many ways. Thus, their frequency may be reduced. An improvement in human performance means reducing the factors favourable to error occurrences. Given that they cannot be completely eliminated, one should limit their consequences (DoE, 2009; IAEA, 2013). Figure 2 provides an illustration of the elements that exist before a typical event occurs. Breaking the linkages may prevent events.



Figure 2: Anatomy of an event (DoE, 2009).

For events involving human performance, the most interesting aspect is the error itself. Not as a cause of an event, but as the event itself. In fact, both success and failure share the same mental processes and only the outcome differs. An error is considered as such because of the unwanted result it brings. The human error which generates an event is only a symptom for which we have to find the cause. In this context, an analysis will have to determine why the event happened (direct cause) and why it was not prevented (fundamental cause). That fundamental cause should question and target the organization (expanded fundamental causes). The direct cause is associated to preventive barriers, mitigating barriers, and error precursors.

The function of a preventive barrier is to preclude errors or lapses. Procedures, training, qualification, work practices are all preventive barriers and aim at reducing the number of errors. Mitigating barriers, on the other hand, aim to limit the consequences that may follow an inadequate action. Steel cap boots or inflating bags in cars are mitigating barriers to limit consequences of mistakes.

Precursors are sneakier. They include more or less subtle elements in the working environment, or invisible constraints within the task. Abnormal configurations or pressure to execute a task with tight deadlines are all conditions which have a direct or indirect negative influence on the cognitive processes required for the safe execution of a task (DoE, 2009; Kahneman, 2012; IAEA, 2013).

Both supervision and the organizational oversight are processes designed for validating that barriers are adequate and efficient. Such as mentioned above, people in positions of authority ensure the adequacy of the measures in place to allow the orderly, secure and effective completion of the tasks assigned to the staff. This adequacy must be verified by an ongoing process to make sure that the required measures are well organized, that expectations are communicated and met, and that nothing invalidates the organizational hypotheses. Supervision is the real time twin of audit and oversight. If gaps are detected between expectations and observations, additional error prevention tools should be considered.

We call "organizational" the various factors that imply a collective behaviour. Communications, organizational clarity, and centralization of decision-making are examples of such factors. The weakness of one or several of these factors can compromise the quality of the activities and their products.

8. IMPORTANCE OF A MODEL FOR EVALUATING DEVIATIONS

As noted earlier, the notion of deviation or anomaly can vary significantly from an organization to another. However, this concept implies inevitably a model of conformity (to define non-compliances). For example, a lost time accident will initiate a formal causal analysis. The expectation then may be to identify failures and improvement opportunities under the influence range of supervisors. We shall thus ask the analysts to evaluate conformity in terms of procedure adherence, use of protective equipment, fitness for duty, and employees motivation. This first evaluation can then be completed by the evaluation of the qualification and the staff training, the profile of the actors (individual capacity to realize the tasks which are assigned to them) or the workload.

Such an approach thus considers implicitly an occupational incident as a possible although unwanted situation. Indeed, it does not question the organization and represents an implicit model which does not exclude such events because we already are expecting to handle such situations. We call that first loop learning, because the event does not indicate a loss of control (as it was considered possible) and does not challenge the organization.

On the other hand, second learning loop involves investigating why an event was not prevented and what the organizational (fundamental) cause of the mishap is (Argyris. and Schön, 1996). This part is a real challenge for management as it requires introspection and is often perceived as a self-blaming exercise. Nevertheless, it is an inescapable for root cause identification.

9. CASE STUDY

We will use the official MSHA report on Upper Big Branch Mine Accident to illustrate the model discussed above. On April 5, 2010, at approximately 3:02 p.m., a massive coal dust explosion occurred at the mine, killing 29 miners and injuring two (MSHA, 2011; NRC, 2012). The physical conditions that led to the explosion were the result of a series of basic safety violations and were entirely preventable. When violations of particular safety standards led to the conditions that resulted in the explosion, the unlawful policies and practices implemented by the owner were the root cause of this tragedy.

First, the preventive and mitigating barriers were not adequately implemented or maintained. Corrective action program (CAP) weaknesses led to understating assessed hazards. The basic training in non-compliance, hazard recognition, and prevention of accidents, roof control, ventilation, and new tasks was less than adequate. Tests for dust and methane were not consistently carried out. Those barriers, required for worker's health and safety protection, were not effective.

Precursors, on-the-spot factors that facilitates committing errors, were also numerous. For instance, conditions like not performing adequate pre-shift, on-shift, or weekly examinations were observed frequently. Numerous existing hazardous conditions were not identified, hence not corrected. Multi-gas detectors were often not energized, leading to less than adequate air measurements. Log wall shearers were not kept in safe operating conditions (worn bits on the face ring). Cleaning and rock dusting (90% of samples were noncompliant) were not satisfactory. Clogged water sprays were impacting particle detection. Finally, there was a significant accumulation of loose coal, coal dust, and float coal dust.

Validation processes (audits and CAP) did not report safety problems. Employees were discouraged from listing hazards, hence not correcting them. For instance, there were numerous non-compliances to the approved ventilation plan.

As for supervisory activities, it was noted that advance notice was given to personnel of MSHA presence on site. Correcting and fixing hazards was a priority only prior to MSHA visits. False measurements were recorded on numerous times. Hazardous conditions were not corrected or even posted as hazards.

As for decision making, even if for safety concerns it should be a decentralised, the right of workers to participate in their own safety was not recognized.

The accident of Upper Big Branch also brought a comment from the NRC about weaknesses in safety cultural attributes expected in an organization with a solid safety culture. They mention among other missing attributes leadership in valuing safety, identification, processing and issue resolution of safety problems, work processes, continuous learning, and questioning attitude (NRC, 2012).

10. CONCLUSION

Initiatives in human performance are percolating from nuclear power industry and high risk organizations, where they were used successfully in the last decades, to other types of industries. For instance, the NERC initiated the implementation of a methodology of event analyses directly borrowed from INPO (Institute of Nuclear Power Operators). This initiative doubtlessly reflects the thinking on the lessons learned from the loss of North-East Grid in 2003 (NERC, 2011).

The nuclear industry developed multiple tools to integrate human performance into the daily activities of operation. Human factors, initially a technical speciality centred on ergonomics and man-machine interfaces, became a set of fundamentals of the everyday life used by all the actors and agents of the organization. This implementation succeeded because the basic statement was that the working environment was essentially complex and that attributes of complexity must be taken into account.

Considering the evolution of the industrial environment characteristics, we believe that these approaches and tools can and should be used as a more global methodology for analyses of accidents and low level events (LLE), and for their inclusion in a general frame of organizational culture. Recent events illustrate the presence of these factors and the advantages to recognize their harm and the potential consequences of organizational failures, which can be detected in a preventive way with a LLE analysis process.

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