Occupational Risk Assessment and Management: Challenges and Guidelines for the Romanian Organization's Practice

LUCIAN-IONEL CIOCA
Department of Economic Engineering
„Lucian Blaga" University of Sibiu
10, Victoriei Bd., 550024-Sibiu
ROMANIA
lucian.cioca@ulbsibiu.ro http://www. ulbsibiu.ro
GABRIEL-BUJOR BĂBUȚ
Department of Mining Engineering and Industrial Safety
University of Petroşani
20, University Street, 302006-Petroşani
ROMANIA
gabriel_babut@yahoo.com http://www.upet.ro
ROLAND-IOSIF MORARU
Department of Mining Engineering and Industrial Safety
University of Petroşani
20, University Street, 302006-Petroşani
ROMANIA
roland_moraru@yahoo.com http://www.upet.ro

Abstract: Integrating risk assessment in an organization is a process that generally follows a sequence of phases. To be effective, the company culture must be willing to embrace the risk assessment process, and cultural acceptance stems from management leadership. Emphasizing some of the major benchmarks in occupational risk assessment approaches, the paper summarizes and outlines several basic principles directed towards practical risk assessment process improvement. The article discusses the principles that underlie a coherent and efficient assessment for occupational health, safety and well-being: the need of a global approach of these problems not only at the workplace but for the whole of the living conditions at work; a clear understanding of the complementary character between the different partners of this prevention; the role of actor of the workers and therefore the absolute necessity of a participative approach; the real usefulness of measurements and of risk quantification in general; the differences between risk assessment and risk management. The paper demonstrates how a sound risk assessment approach can lead not only to better risk management, but to the pro-active prediction of occupational risk accidents and incidents and ultimately its prevention, considering the need of changing minds in Romania when it comes to occupational risk assessment and management.

Key-Words: risk, assessment, management, occupational health and safety, guidance principles

1 Introduction

Modern risk assessment began over three decades ago with applications in the military and nuclear power, beginning with the Reactor Safety Study [23]. In the late 1970s it gradually expanded, and was applied to the vast array of chemical risks being regulated under dozens of federal environmental statutes. For example, risk assessment has been used as the foundation for: setting drinking water, ambient water quality, and air quality standards; review and renewal of pesticide applications; and determining levels of site cleanup under the Superfund program. Applications to engineered systems, and in particular infrastructure, are common; examples are given in Lave and Balvanyos [10]. Blockley [2] also devotes a number of chapters to civil engineering topics (e.g., design codes or risk assessment in structural engineering), and several infrastructure-engineering applications (e.g., dam safety, marine structures). Risk assessment connotes „a systematic approach to organizing and analyzing scientific knowledge and information for potentially hazardous activities or for substances that might pose risks under specified circumstances" [16]. This definition reflects the flexibility that has been incorporated into the concept over the years since it was first introduced. Thus, fundamentally, risk depends both on the probability or frequency of an adverse outcome, and also on the severity of that outcome. Risk has similarly been defined generally as "the potential for realization of unwanted, negative consequences of an event" [6]. More quantitatively, Sage and White [17] define risk as "the probability per unit time of the occurrence of a unit cost burden", and state that it "represents the statistical likelihood of a randomly exposed individual being adversely affected by some hazardous event". Thus, risk has been defined at many different levels of detail.

The goal of risk assessment is to reduce risks to an acceptable (or tolerable) level [3, 13]. A zero risk level is not attainable. Efforts to distinguish terms such as "acceptable" or "tolerable" risk can lead to inadvertent errors, even by organizations that wish to promote a difference in the terms.

Risk reduction efforts to achieve acceptable risk must work within the real world constraints of feasibility, practicality and cost. Resources are always limited. Cost is an important factor in obtaining acceptable risk. A practical solution to achieving acceptable risk is a good faith application of the hierarchy of controls within the risk assessment process.

Terms used in the risk assessment process are defined in literature [7, 11] but many terms have more than one meaning. A basic rule is to be certain that the risk assessment team is working with a common definition. The number of methods aiming at assessing the risks is definitely greater than the number of methods aiming at preventing them and these methods relate to generally only one factor of particular risk.

Most of them were developed by experts (as we defined them) whose responsibility and interests are mainly to establish the dose-response relationships, rather than to solve a particular problem in a particular work situation. It is thus necessary to discourage the systematic and at first quantification, which is likely to distract from the first goal, prevention. In each case, it is up to the OHS practitioner to determine if he must or not conduct a quantification of the risks and the reasons (epidemiologic, technical, political) for which he must conduct it.

In Romania, since 2006 when the new Occupational Health and Safety Act [24] have stated that the risk assessment is compulsory, several approaches were in use but only one method is extended. It appears as obvious that a large number of practitioners are resorting to a single method, without considering the great variety of working systems and conditions which are requiring specific approaches and techniques. Methods are used to classify the risks and to define priorities for actions - what is certainly very desirable - but often by neglecting the analysis of the elements defining these risks, the reasons and the means of improving the situation.

The prevention approach consists in seeking the most effective means to reduce the risk, by acting on one or several of its components: elimination of the risk factor, reduction of the exposure, increase of the reliability of the work system. It is thus essential that the analysis of the risk be not simply a recording of its components, but consists in a careful analysis of the reasons of the exposure, the circumstances of this exposure, the severity of the consequences and the most relevant and reasonably practicable means to reduce them [5].

The final quantitative evaluation of the risk is consequently secondary, the most important thing being to study the components and the details on which it is going to be possible to act. Rather than speaking about risk assessment, it is thus more appropriate to speak about risk management.

2 Hazard scenario and risk interpretation

An approach to identifying a hazard is to consider it a sequence of specific events or an accident (loss scenario). The accident-loss scenario consists of three elements (source, mechanism, and outcome) that describe the hazard. The outcome, or undesired event, is the result of the mechanism occurring due to the source being present. Some examples of outcomes, mechanisms and sources are listed below in table 1.

Over the years, evaluators have developed many investigative tools to aid in identifying hazards [6]. One set of these tools, called hazard analyses, provides a systematic method of identifying hazards. All hazard analyses evaluate a given activity to identify hazards; however, each type of analysis does so in a different manner, and therefore, each has its strengths and weaknesses. With experience, the evaluator learns which analysis tool is best for investigating which type of activity. The qualities of a good hazard analysis are:

- clear, concise, and a well-defined method that a reviewer or reader can readily understand;
- orderly and consistent in systematically reviewing the activity or system for risk;
- a closed loop where the assessor reviews each hazard control for its impact on the other hazards and their controls;
- objective in that reviewers and users can understand and verify each step of analysis.

Table 1. Examples of outcomes, mechanisms and sources

Outcome or undesired effect	Mechanism or effect	Sources or causes
Auto crash	Hydroplaning	Rain-slick roadway
Asphyxia	Leaking pipe joint	Inert gas
Fall from elevation	Inattentive walking	Open-sided platform
Electrocution	Unprotected hand contact	Exposed electrical wire
Detonation or explosion	Exposure to heat	Stored blasting materials
Cut	Hand contact	Unprotected sharp edges
Sprained ankle	Inattentive walking	Rocky terrain

Towards the hazard scenario development, the evaluator uses the hazard matrix to associate potential failures with the generic hazards from the hazard list. The potential failure area represents those areas where if the hazard occurred, it would most likely have an effect on the activity, such as structural failures, power systems failures, pressure failures, leakage, spills, mechanical failures, personnel failures, or procedural failures. These investigated areas may be tailored to fit the operation or systems being evaluated.

After hazard scenario development, the next step is the risk assessment [20], which involves evaluating each hazard and assigning a level of risk based on the estimated probability and severity for the likelihood and impact of the hazard on the system.

Risk always deals with uncertainty or events that cannot be predicted with certainty. If the events could be predicted with surety, there would be no risk. Risk involves estimating future losses, where neither the likelihood nor magnitude is known with certainty. Risk is defined as the measure of the expected loss from a given hazard or group of hazards, usually estimated as the combination of the likelihood (probability) and consequences (severity) of the loss.

Probability has no dimension but must be attached to an interval of exposure (for example, one operating year, a million vehicle miles, 1,000 landings, and so on). Severity is an approximation of the amount of potential harm, damage, or injury associated with a given hazard scenario or accident.

Probability helps us figure out the likelihood of something happening. The likelihood of an event can range between 0 and 1.0. Zero represents an event that cannot possibly occur. A probability of 1.0 indicates an event that always occurs. For a probability to be meaningful, an exposure interval must be associated with it. The exposure interval can be a unit of time, an activity (such as, kilometers driven, aircraft landings, operations, machine cycles, units produced) or the life cycle of the facility, equipment, or process. The following examples demonstrate associating an exposure interval with a probability.

- during the year "X", 220 workers died on the job. This results in a probability of 0.0000007 per year of a worker dying on the job. However, the probability of being injured at work during that same year, resulted in a probability of 0.005 injured employees per year, based on 150,560 reported injuries. Again, the exposure interval is "per year".

- if we change the exposure interval to a working life time (from 18 years to 65 years), the probability of being killed increases to 0.000035 during a working life and the probability for being injured increases to 0.25 during a working life. The exposure interval is now "working life" which was stated as 50 years.
- the exposure interval does not always have to be expressed in time interval; other units can be used. In year "Y", aircraft model A experienced 47 events in which one passenger died due solely to the operation of an aircraft. During that same period, aircraft model B had one such event. However, the probability of being killed on aircraft model A is 0.000000005 (5x10–9) per passenger-mile flown, while on aircraft model B, the probability is 0.00000012 (1.2 x 10–7) per passenger-mile flown. In this example, the exposure interval is "per passenger-mile flown". The longer the trip or the more miles a passenger flies in a year, the greater the probability of death. This increasing probability per passenger-mile is shown in the table 2.

Occurrence	**Severity**			
	Catas-trophic	**Major**	**Minor**	**Negligi-ble**
Frequent	A	A	A	C
Probable	A	A	B	C
Occasional	A	B	B	D
Remote	A	B	C	D
Improbable	B	C	C	D

This demonstrates another important concept when dealing with probabilities. Probabilities are estimations and only estimations.

The better the knowledge of the situation, the more factual and historical information used, and the greater the experience of the evaluator, the more accurate the estimation will be. Except in extremely technical evaluation, the probabilities should be considered as falling within a range.

Table 2. Increasing probability versus passenger mile

Miles flown per year by passenger	**Probability of passenger dying Aircraft Model A**	**Probability of passenger dying Aircraft Model B**
1,000	0.00001	0.00012
5,000	0.00003	0.00060
25,000	0.00013	0.00300
75,000	0.00038	0.00900
375,000	0.00188	0.04500
1,000,000	0.00500	0.12000
1,500,000	0.00750	0.18000

In the real world, it is often very hard to determine objective or numerical probability values. The information necessary to derive these values is often missing, or more often than not, there is just not enough time to make the necessary studies. When the information and time is available, an effort should be made to use the numerical probability values. However, in the other situations, it becomes necessary to make subjective decisions in estimating the probability. To aid evaluators, probability ranges have been established using keywords and phrases to help estimate the likelihoods for the occurrence of a accident. Table 3 summarizes an action guide matrix which sould support the risk assessor in selecting the most appropriate analysis tool.

Table 3. Example of a matrix helping to identify hazard assessment method classes

Action Guide

Risk level	**Analysis**
A	Detailed quantitative
B	Semiquantitative
C	Qualitative
D	Not required

3 Risk Assessment Process Improvement

Due to the holistic nature of occupational risk management [21], the process requires the multidisciplinary participation using a range of diverse tools to provide the employer with the knowledge to make informed risk decisions about all the identified losses and their risk. A major threat to combat readiness is losses caused by hazard-based accidents [11]. Therefore, one of the major components of occupational risk management is the decision-making process, as explained in this paper. Practitioners use the risk management process to identify, evaluate, and manage risks to tasks, personnel, equipment, and the environment during working processes due to safety and occupational health factors, design and construction of equipment, and other mishap factors.

The accident risk management is the process of providing recommendations on whether to accept or resolve potential consequences of hazards associated with a given activity. It is neither a "science" in the sense that it provides leadership with a precise prediction of the future events, nor just "common sense" or "something good managers have always done". It uses systematic procedures and specific techniques to analyze safety and occupational health factors, design and construction of equipment, and other situational hazards.

Risk assessments are conducted primarily to support the decision-making process regarding the occupational health and safety. Decisions on the adequacy of a design usually occur during a design review [4, 8]. Risk assessment supports the design review process by providing the underlying analysis on which safety decisions can be made. Risk assessments take time to conduct effectively, typically more time than can occur within a design review session. In most cases the assessment should occur separately from the design review.

Corrective actions that may be taken to introduce or improve safety through design efforts include formalizing existing but informal design processes that include elements of risk assessment, acquiring tools and training to conduct risk assessments, and advocating training on safety through design [10]. A very broad cross section of methods documents the current state of the art and wealth of activity in the risk assessment process [7]. Risk assessment methods are being deployed in many industries, and that the momentum will likely continue. Although the level of sophistication in risk assessment processes varies from industry to industry and within industries, the general risk assessment process applies across all industries and applications.

When all is said and done, someone needs to get his or her hands dirty and actually do the risk assessment. This section focuses on the practical application of the risk assessment process, representing a resource for getting up to speed quickly on the different options available and the means to introduce and implement risk assessments.

The step by step basics of the risk assessment process comprise the same basic stages. Although many companies and industries use different risk assessment methods, the fundamentals of the risk assessment process are common:

- identify hazards;
- assess risk;
- reduce risk;
- document the results.

A general risk assessment process describes the basic steps in completing a risk assessment. One step in particular, identifying hazards, is critical because if major hazards are omitted the associated risks will remain unknown.

Several practical, real world applications of risk assessment demonstrate the risk assessment process and the results drawing on the author's experiences in conducting risk assessments in industry. The examples include work process designs, product designs, and interactions with government authorities in different industries. Integrating risk assessment in an organization is a process that generally follows a sequence of phases.

To be effective, the company culture must be willing to embrace the risk assessment process, and cultural acceptance stems from management leadership. Engineering design needs to change to include the risk assessment process to more effectively move safety into design. Only by changing the design process will risk assessment efforts succeed.

A team of interested persons should conduct the risk assessment. The team members can be drawn from several areas such as engineering, operations, safety, users and others. They may include different participants as the assessment evolves. To integrate risk assessment into the design process engineers will likely need education and training on risk assessment in some form.

Unfortunately, most engineering design efforts do not currently include formal risk assessments. Engineering design must include the risk assessment process to more effectively move safety into design. Introducing the risk assessment process will explicitly change the design process, allowing hazards to be identified and risk reduction methods to be incorporated early in the design process. If the design process does not change, long term efforts to improve worker and product user safety will fail even if risk assessments are deployed.

Risk assessment does have limitations. Several limitations should be considered and discussed in order to minimize unrealistic expectations. Successfully integrating the risk assessment process into an organization requires time and effort [15]. In consumer product and component product applications, the manufacturer is responsible for conducting the risk assessment, if applicable. Product users typically have no risk assessment responsibilities beyond using the product in conformance with the product information. In industrial product or process applications, both equipment suppliers and users should perform risk assessments and be involved in the risk assessment process.

Tips and guidance on how to most effectively introduce the risk assessment process to an organization, and how to conduct them thereafter can be extracted from different sources, but the most valuable information source remains the practical experience gained by effectively performing the risk assessment.

Practical guidance should be provided for companies get started and make progress in the risk assessment process. Topics addressed include: the time to complete an assessment, forming a team, what to expect, when to stop a risk assessment, what to do in cross industry situations, when to revise an existing risk assessment, making changes to the protocol, results of risk assessment, and others. "Risk ranking matrix" is the term that describes how risks are assessed, employing a method-specific tool.

There are many variables, factors and combinations that must be considered in selecting a risk ranking matrix. Since there are many different systems used to arrive at risk levels, as a combination of probability and consequences, the different variables that are used to rate risk are requiring a proper understanding. The three most common types of risk ranking systems are qualitative, semi-quantitative and quantitative.

Given the subjective nature of rating risk, risk scoring systems will likely continue to emerge and proliferate as users refine and improve their risk assessment process. This divergence of methods should be considered healthy. In time, convergence to one or a few risk scoring systems may occur as efforts to harmonize and standardize risk assessment methods occur. This process will require some time. A very broad cross section of methods documents the current state of the art and wealth of activity in the risk assessment process. Risk assessment methods are being deployed in many industries, and that the momentum will likely continue. A heated debate often occurs when discussing the issue of documenting risk assessments.

There remains considerable resistance to creating risk assessment documents from the legal community primarily due to product liability concerns. However, good engineering practice, continuous improvement and risk assessment requirements all push for documenting risk assessments.

Documenting the risk assessment process is required or recommended by even guideline, standard or technical description of risk assessment. There are many variations in risk ranking systems because different risk ranking systems work well in different applications. There are many risk ranking systems in use, each offering its strengths and weaknesses. This variation reflects the great diversity of opinion on risk assessment. Some of the most significant differences between risk assessment methods used today involve how risk is assessed. There is a continuum of risk ranking systems from qualitative to quantitative that effectively address a variety of risk assessment applications. Very few benchmarks use quantitative risk ranking systems. However, there is no indication that any particular risk ranking system is better than another for all applications.

One of the most critical considerations in selecting an approach to risk assessment is logistics. In many instances logistics can be the overriding criteria due to implementation challenges that arise. The costs and logistics of performing quantitative risk assessments are prohibitive in many industries. In these applications new methods, approaches, or software tools may be needed rather than those developed for the sophisticated situations.

With the level of activity occurring today in risk assessment, there remains plenty to learn. In many instances an individual or organization starts with an existing risk assessment method and finds it to be lacking in one or more respects. Thus begins a search for a better method. The search can take one of two paths - look for other methods and adopt all or part of them, or modify the existing approach to create a method better suited for the application. There are several reasons for and against harmonizing the various risk assessment methods. Although both viewpoints have merit, some basic steps toward harmonization appear achievable. However, complete harmonization is not likely to occur soon. If a harmonized risk assessment process is to be developed, flexibility will be a critical factor to its success. Although most standards specifically seek to avoid flexibility, a harmonization effort will likely fail unless a standard framework can be provided that permits flexible application of the details. There appears to be very little value in attempting to compare the results of risk assessments from vastly different applications to one another. Such comparisons provide no useful information to achieving acceptable risk. Since the goal of the risk assessment process is achieving acceptable risk, the risk assessment method one uses to attain this goal is less important than achieving the goal.

4 Practical Guidance Principles in Risk Assessment and Management

Based on the above-mentioned benchmarks, the following eight principles directed towards practical risk assessment process improvement can be stated:

- **minimize the use of labels:** the use of labels to describe portions of the risk assessment process need to be minimized. The terms used in assessing risk can be very confusing. There exists confusion or at least no common understanding as to the meanings of the terms of risk assessment, risk analysis, risk estimation, risk evaluation. The term "risk assessment" can mean the specific steps related to calculating a risk level, an overall term for the entire process, or to refer to any method that assesses risks. Efforts at harmonizing, standardizing or even communicating are severely hampered by the current confusion and different uses of the term „risk assessment" and others. The practitioner trying to conduct a risk assessment does not care about terms or labels. He just wants to know what he need to do to complete an effective the risk assessment. Extra terms detract from this objective. Unnecessary terms that add no value should be removed from the risk assessment process. Labels that provide no value only add confusion.
- **simplify the risk assessment process:** the steps of the risk assessment process should be written using active verbs rather than labels or titles. The steps of the risk assessment process need to be simple and straightforward, and provide the reader very clear direction on what he or she needs to do. There are many instances where clear direction is lacking or the steps are unnecessarily confusing or ambiguous. Simplifying the risk assessment process by using active verbs and clear and simple steps will assist those engaged in conducting risk assessments.
- **adopt "risk assessment process" as overall term:** the term „risk assessment process" should be adopted to describe the overall process of identifying hazards, assessing risk and reducing risk. The terms "risk analysis", "risk assessment", "risk management" and others have different definitions depending on the industry using them. The two most frequently used terms to describe the overall risk assessment effort are "risk assessment" and "risk management". Although arguments can he made for either term, the use of "the risk assessment process" seems the best for referring to the overall process of identifying hazards, assessing risks, and reducing risks.
- **the risk assessment process includes risk reduction:** there is no point in assessing the risks of a system, design, process or product unless one plans to perform risk reduction. The risk reduction effort is always completed even though not every residual risk requires further risk reduction (the risk may already be acceptable). This implies that risk reduction is a necessary part of, and should be included in, the overall risk assessment process regardless of the term used to describe that overall process.
- **adopt the risk assessment process flow chart:** figure 1 presents a typical risk assessment process incorporating principles 1 to 4. This figure should be adapted because it simplifies the process and reflects how risk assessment is conducted in industrial practice.
- **subjective judgment needs to be accepted:** subjectivity is a necessary part of risk assessment. Even in quantitative risk assessments subjective judgment occurs. However, the subjectivity does not diminish the value or credibility of the risk assessment process. Safety is not an absolute state, but a relative one. Engineers, safety practitioners and decision makers need to become comfortable with subjectivity, and recognize that the subjective risk assessments do offer value.

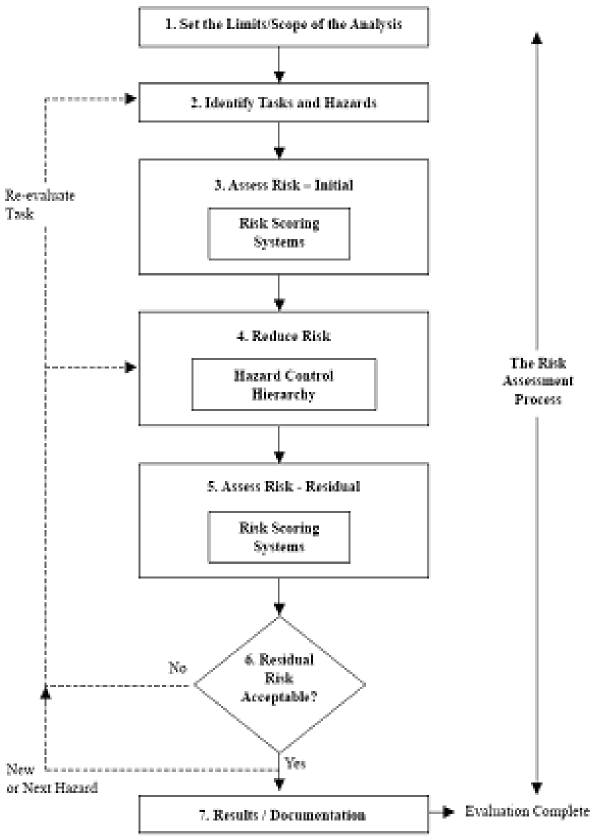

Figure 1 The Risk Assessment Process

- **accept uncertainty:** uncertainty enters risk assessment as assumptions, estimates and subjective judgments. Even in quantitative assessments there often remains substantial uncertainty. Risk is uncertain. Performing a risk assessment does not create the uncertainty. Uncertainty is, and should be accepted as, an integral part of the risk assessment process.
- **define "risk assessment":** very different definitions of the term „risk assessment" exist. The two primary differences tend to be whether the term is used as a verb to mean any method used to assess risk (such as FMEA, What if, HAZOP, Fault Tree Analysis, Job Safety Analysis, MOSAR), or used as a noun to refer to a specific type of analysis. No current consensus exists in this regard. It could be very difficult for those seeking to harmonize the various risk assessment methods to make significant progress until some agreement is reached on the definition of the term. Engineers, safety practitioners, risk assessment teams, and standards writing committees need to develop a common definition within their working group(s).

According to the ISO 31000 Standard "Risk management - Principles and guidelines for implementation, the risk management process should follow the structure given in figure 2 [25].

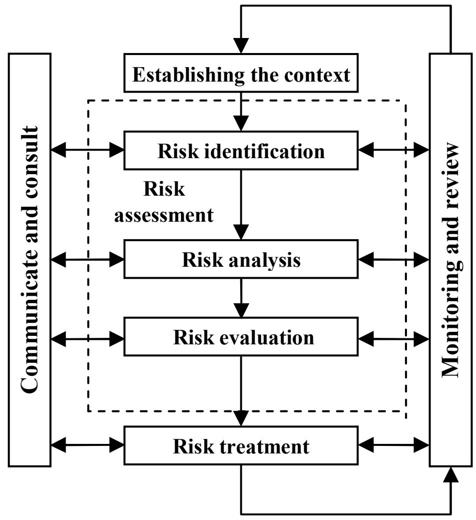

Figure 2 The risk management process

5 Conclusion

Organizations of all kinds are increasingly concerned with achieving and demonstrating sound safety performance by controlling the impacts of their activities, products and services on the environment and health, consistent with their safety, health and environmental policy and objectives. They do so in the context of increasingly stringent legislation, the development of economic policies and other measures that foster safety, health and environmental protection, and increased concern expressed by interested parties about safety and environmental matters and sustainable development. The term "innovation" is usually associated only with technology, in the strictest meaning of the word (new) products and new methods for making them. Nevertheless, innovation refers to the process of bringing any new, problem solving idea into use. Idea (as a step on their way to innovation) for reorganizing, cutting costs, putting in new budgeting systems, improving communication, or assembling products in teams are all innovations, provided the new idea is useful in its user's judgement

In efforts for the improvement of position on the purchaser's market the companies must also consider accordance of operation with valid safety and health protected prescriptions in field of process consumer. The inclusion of enterprises in the international market, the care for reputation, that the enterprise profit with the safety protection and permanent development, places the politics of safety protection to the base of the professional politics.

Health and safety arrangements always depended upon risk assessments although these have generally been based on experience and intuition.

Structured procedures are aiming to manage risks by measuring them against agreed standard and introducing further controls if that standard is not achieved. In order to achieve health and safety policy objectives with reasonable resources and demonstrate compliance, risk assessments should be comprehensive, structured, focused, cumulative and accessible.

However, general assessments of larger units will usually prompt more detailed examination of priority areas identified. The current state of the art is such that most companies are not performing normal risk assessments, but this is changing. The leaders in risk assessment tend to be the companies actually performing them rather than any particular industry, country or standard.

The preceding principles focus on simplifying the risk assessment process, improving it to reflect current practices in industry, and advancing deployment of the risk assessment process. The team conducting the risk assessment needs to quickly come to a common understanding of the terms it uses, its goals and objectives, and the process to attain them. Competent persons should be consulted as appropriate when undertaking risk assessments.

Understanding individual risk appraisal and safety in action is fundamental to risk assessment and managing risk within organizations. Because individuals manage organizational risks, it is vital to understand elements and processes that shape their personal risk appraisals. In this paper, individual risk appraisal is considered through a series of models, and parallels drawn with organizational risk assessment processes. When strategic decisions involving risk are made within organizations, individual appraisals by key people are important.

Risk assessment, as typically carried out by organizations, is increasingly part of a formal exercise using standard frameworks. It is implicit that such risk assessments are objective and unbiased. However, individual risk appraisals are frequently identified as being ad hoc and subject to various biases. Thus, people are generally portrayed as being poor at making risk-related judgements due to the influence of such biases and because of the difficulty of making judgements involving large numbers or probabilities.

However, humans have developed heuristics to aid their decision making in a wide range of situations where issues may be complex and fast moving. Thus, to progress beyond the truism of stating that "people are poor at making risk judgements" we need to understand more about components of individual risk appraisal.

Risk perception also involves interpretation of input on the basis of our previous knowledge and experience.

This information is combined to make a fairly rapid risk appraisal of possible outcomes, and the likelihood of success of the overtaking manoeuvre would be judged qualitatively. Thus, in describing the expertise involved in making what for many people are everyday decisions, humans' alleged poor judgement in respect of making decisions involving risk are largely irrelevant, as our subsequent actions, based upon our experience, nearly always leads to behavior which is successful.

Through many experiences with risk situations, individuals learn about dealing with external stimuli involving risk. Learning about risk results from repeated exposure to different types of risk, making decisions about them and experiencing a range of outcomes based upon those decisions. Some situations involving risk require problem-solving to deal with complex information. At some point a decision is made about what action to take.

The need for a decision may be urgent - for example, when faced with an armed assailant - or it may be possible for the person to defer a decision - for example, house purchase, or for more information to be obtained over a long period - as may be required in control room design.

Choices available to individuals making decisions on risk issues are analogous with strategic options available to organizations - i.e. avoid, defer, reduce, retain, transfer, share or limit the risk, or act so as to mitigate potential damage. Appreciating the nature of individual risk appraisal processes helps in understanding organizational level requirements, for example when risk assessments are carried out as part of risk management processes. The possibility that risk assessments may need to be broadened to incorporate compensation effects by individual operators and others in certain environments could be further investigated.

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