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KLM Technology Group P. O. Box 281 Bandar Johor Bahru, 80000 Johor Bahru, Johor, West Malaysia	Kolmetz Handbook of Process Equipment Design SAFETY RISK MANAGEMENT AND LOSS PREVENTION (ENGINEERING DESIGN GUIDELINES)	Editor / Author Karl Kolmetz

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INTRODUCTION

Scope

Over the years, the process industries have evolved several strategic approaches for chemical accident and loss prevention. In general, a process plant should operate in a safe and non-harmful manner. However, there are process upsets and aging factors which lead to Loss of Containment (LoC) or an uncontrolled process leading to a major event. The need for Safety and Loss Prevention is to be found in the “Laws of the Land”, which addresses the health and safety of people, and the need to maintain the integrity of the Process Plant and the cash flow of the Company.

Safety is a relative notion whereby inherent risks are acceptable in a “safe” system. Safety is increasingly viewed as the management of risk. Safety is the state in which the risk of harm to persons or of property damage is reduced to, and maintained at or below an acceptable level through a continuing process of hazard identification and risk management. Since safety is defined in terms of risk, any consideration of safety must therefore involve the concept of risk. The inevitability of risk taking place in any industry cannot be over-emphasized

Each risk identified must be evaluated and prioritized. This evaluation requires the compilation and analysis of all available data. The data is then assessed to determine the extent of the hazard. A database may be required to facilitate the storage and retrieval of the data. Appropriate tools are needed to analyze the data. Having validated a safety deficiency, decisions must then be made as to the most appropriate action to avoid or eliminate the hazard or reduce the associated risks. The solution must take into account the local conditions, as “one size” does not fit all situations. Care must be taken that the solution does not introduce new hazards. This is the process of risk management.

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General Design Considerations

For many years, companies focused their accident prevention efforts on improving the technology and human factors. In the mid-1980s, following a series of serious chemical accidents around the world, companies, industries, and governments began to identify management systems (or the lack thereof) as the underlying cause for accident. Causes of chemical process incidents can be grouped in one or more of the following categories:

- Technology failures
- Human failures
- Management system failures
- External circumstances and natural phenomena

Over the years, the process industries have evolved several strategic approaches for chemical accident and loss prevention. Below is figure of the evolution of process safety.

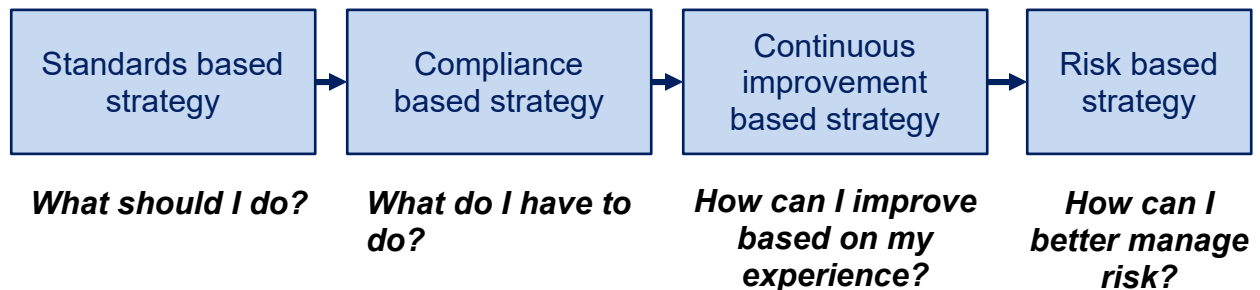


Figure 1: Evolution of Process Safety and Accident/Loss Prevention Strategies

Safety is a relative notion whereby inherent risks are acceptable in a “safe” system. Safety is increasingly viewed as the management of risk. Safety is the state in which the risk of harm to persons or of property damage is reduced to, and maintained at or below an acceptable level through a continuing process of hazard identification and risk management.

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A. Process Safety

Processes can be divided into those that are intrinsically safe, and those for in which the safety must be engineered. An intrinsically safe process is one in which safe operation is inherent in the nature of the process; a process which causes no danger, or negligible danger, under all foreseeable circumstances (all possible deviations from the design operating conditions). The term inherently safe is often preferred to intrinsically safe, to avoid confusion with the narrower use of the term intrinsically safe as applied to electrical equipment.

The safe operation of such processes depends on the design and provision of engineered safety devices, and on good operating practices, to prevent a dangerous situation developing, and to minimize the consequences of any incident that arises from the failure of these safeguards. In any system, it is necessary to set and measure performance outcomes in order to determine whether the system is operating in accordance with expectations, and to identify where action may be required to enhance performance levels to meet these expectations.

Considering the fact that in an aviation setting, losses occurring in any single incident are usually huge, all hands must therefore not only be on deck to avoid any slight occurrence but continuous measures and institutional checks and balances ranging from human to technical concerns are inbuilt in all aviation operations to forestall at least in any eventuality a reasonable amount of damage and losses achievable through measures emphasizing acceptable level of safety. The concept of acceptable level of safety is expressed by two measures/metrics (safety performance indicators and safety performance targets) and implemented through various safety requirements (Okunola et al, 2012).

- Safety performance indicators are a measure of the safety performance of an aviation organization or a sector of the industry. Safety indicators should be easy to measure and be linked to the major components of a State's safety program, or an operator's/service provider's Safety Management System (SMS).
- Safety performance targets (sometimes referred to as goals or objectives) are determined by considering what safety performance levels are desirable and realistic for individual operators/service providers. Safety targets should be measurable, acceptable to stakeholders, and consistent with the State's safety program.

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- Safety requirements are needed to achieve the safety performance indicators and safety performance targets. They include the operational procedures, technology, systems and program to which measures of reliability, availability, performance and/or accuracy can be specified.

The ultimate responsibility for preventing accidents and controlling hazards rests with management. The keys to effective safety performance are management procedures that assign accountability. The following is a suggested list of responsibilities for various positions in the organization.

Table 1: responsibilities for various positions in the organization.

Positions	Responsibilities
Department/Agency Head	<ol style="list-style-type: none"> 1. Full responsibility for safety. 2. Authorizes necessary expenditures to provide safe work conditions. 3. Approves safety policies as formulated by the safety officer or safety committee. 4. Participates in the safety program as recommended by the safety officer or committee
Department/Loss Prevention Coordinator	<ol style="list-style-type: none"> 1. Primary responsibility for coordinating the safety operations at each facility or Agency. 2. Keeping and analyzing accident records. 3. Conducting educational activities. 4. Conducting activities to stimulate and maintain interest in safety among employees. 5. Serving on the safety committee. 6. Supervising and appraising accident investigations. 7. Planning and directing a regular program of safety inspections. 8. Checking for compliance with applicable safety laws and codes.

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Positions	Responsibilities
	9. Issuing regular reports showing safety performance and accident trends.
Agency Loss Prevention Representative	1. Planning and directing a regular program of safety inspections and accident investigations. 2. Conducting safety meetings. 3. Conducting activities to stimulate and maintain interest in safety among employees. 4. Serving on the safety committee. 5. Checking for compliance with applicable safety laws and codes. 6. Communicating with Departmental safety coordinator
Maintenance Department	1. Works with safety committee, Agency loss prevention representative, and foremen to ensure safe work conditions. 2. Executes work orders promptly. 3. Cooperates in devising safety equipment, guards, and appliances. 4. Maintains a regular maintenance schedule on all equipment and keeps maintenance records. 5. Makes regularly scheduled inspections as instructed by safety Department and makes reports.
Supervisor/Foreman	1. Inspects work area for compliance with safe work practices and safety rules. 2. Trains employees to work safely. 3. Corrects unsafe conditions and unsafe acts. 4. Obtains prompt first aid for the injured. 5. Reports and investigates accidents and works with Agency loss prevention representative to determine

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Positions	Responsibilities
	cause and correct any problems. 6. Serves on safety committee. 7. Holds crew safety meetings. 8. Discusses safety with individual employees.
Employee	1. Works in accordance with accepted safety practices. 2. Reports unsafe conditions and practices. 3. Observes safety rules and regulations. 4. Makes safety suggestions. 5. Serves on safety committees. 6. Asks for assistance or further explanation when needed.

In order to keep safety risks at an acceptable level with the increasing levels of activity, modern safety management practices are shifting from a purely reactive to a more proactive mode (Okunola et al, 2012).

- application of scientifically-based risk management methods;
- senior management’s commitment to the management of safety;
- a corporate safety culture that fosters safe practices, encourages safety communications and actively manages safety with the same attention to results as financial management;
- effective implementation of standard operating procedures (SOPs), including the use of checklists and briefings;
- a non-punitive environment (or just culture) to foster effective incident and hazard reporting;
- systems to collect, analyze and share safety-related data arising from normal operations;
- competent investigation of accidents and serious incidents identifying systemic safety deficiencies (rather than just targets for blame);

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- integration of safety training (including Human Factors) for operational personnel;
- sharing safety lessons learned and best practices through the active exchange of safety information (among companies and States); and
- systematic safety oversight and performance monitoring aimed at assessing safety performance and reducing or eliminating emerging problem areas.

B. History of Risk Management

Risk management is a relatively recent corporate function. Historical milestones are helpful to illustrate its evolution. Modern risk management started after 1955. New forms of pure risk management emerged during the mid-1950s as alternatives to market insurance when different types of insurance coverage became very costly and incomplete. Several business risks were costly or impossible to insure. During the 1960s, contingent planning activities were developed, and various risk prevention or self-protection activities and self-insurance instruments against some losses were put in place. Protection activities and coverage for work-related illnesses and accidents also arose at companies during this period.

Since the early 1970s, the concept of financial risk management evolved considerably when financial risk management became a priority for many companies including banks, insurers, and non-financial enterprises exposed to various price fluctuations such as risk related to interest rates, stock market returns, exchange rates, and the prices of raw materials or commodities.

This revolution was sparked by the major increase in the price fluctuations mentioned above. In particular, fixed currency parities disappeared, and prices of commodities became much more volatile. The risks of natural catastrophe also magnified considerably. Historically, to protect themselves from these financial risks, companies used balance sheets or real activities (liquidity reserves). To increase flexibility or to reduce the cost of traditional hedging activities, derivatives were then increasingly used.

The use of derivatives as risk management instruments arose during the 1970s, and expanded rapidly during the 1980s, as companies intensified their financial risk management. Derivatives are contracts that protect the holder from certain risks. Their value depends on the value and volatility of the underlier, or of the assets or value indices on which the contracts are based.

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The best-known derivatives are forwards, options, futures, and swaps. Derivatives were first viewed as forms of insurance to protect individuals and companies from major fluctuations in risks. However, speculation quickly arose in various markets, creating other risks that are increasingly difficult to control or manage. In addition, the proliferation of derivatives made it very difficult to assess companies' global risks (specifically aggregating and identifying functional forms of distribution of prices or returns). Notably, risk management has become less limited to market insurance coverage, which is now considered a competing protection tool that complements several other risk management activities.

After World War II, large companies with diversified portfolios of physical assets began to develop self-insurance against risks, which they covered as effectively as insurers for many small risks. Self-insurance covers the financial consequences of an adverse event or losses from an accident (Erllich and Becker, 1972; Dionne and Eeckhoudt, 1985).

A simple self-insurance activity involves creating a fairly liquid reserve of funds to cover losses resulting from an accident or a negative market fluctuation. Risk mitigation, now frequently used to reduce the financial consequences of natural catastrophes, is a form of self-insurance. Financial institutions, including banks and insurance companies, intensified their market and credit risk management activities during the 1980s.

Insurers' traditional role was seriously questioned in the United States in the 1980s, particularly during the liability insurance crisis characterized by exorbitant premiums and partial risk coverage. In that decade, alternative forms of protection from various risks emerged, such as captives (company subsidiaries that insure various risks and reinsure the largest ones), risk retention groups (groups of companies in an industry or region that pool together to protect themselves from common risks), and finite insurance (distribution of risks over time for one unit of exposure to the risk rather than between units of exposure).

Operational risk and liquidity risk management emerged in the 1990s. International risk regulation began in the 1990s, and financial firms developed internal risk management models and capital calculation formulas to hedge against unanticipated risks and reduce regulatory capital. Financial risk management has become complementary to pure risk management for many companies. Concomitantly, governance of risk management became essential, integrated risk management was introduced and the first corporate risk officer positions were created.

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The definition of risk management became more general. Risk management decisions are now financial decisions that must be evaluated based on their effect on firm or portfolio value, rather than on how well they cover certain risks. This change in the definition applies particularly to large public corporations, which, ironically, may be the companies that least need risk protection (apart from speculation risk), because they are able to naturally diversify much more easily than small companies. In particular, shareholders can diversify their portfolios on financial markets at a much lower cost than the companies whose shares they hold.

C. Risk and Loss Prevention

Risks are present in nearly all of firms' financial and economic activities. The risk identification, assessment, and management process is part of companies' strategic development; it must be designed and planned at the highest level, namely the board of directors. Pure risk is a combination of the probability or frequency of an event and its consequences, which is usually negative. It can be measured by the volatility of results but higher moments of the distribution are often necessary. Uncertainty is less precise because the probability of an uncertain event is often unknown, as is its consequence

The safety hazards creating risk may become evident after an obvious breach of safety, such as an accident or incident, or they may be proactively identified through formal safety management program before an actual safety event occurs. Having identified a safety hazard, the associated risks must be assessed. With a clear understanding of the nature of the risks, a determination can be made as to the "acceptability" of the risks.

Since safety is defined in terms of risk, any consideration of safety must therefore involve the concept of risk. There is no such thing as absolute safety. Before any assessment can be made as to whether or not a system is safe, it is first necessary to determine what the acceptable level of risk is for the system. Risks are often expressed as probabilities; however, the concept of risk involves more than probabilities.

Evaluation of the acceptability of a given risk associated with a particular hazard must always take into account both the likelihood of occurrence of the hazard and the severity of its potential consequences. The perceptions of risk can be derived from the following three broad categories (Okunola et al, 2012):

- a. risks that are so high that they are unacceptable;
- b. risks that are so low that they are acceptable; and

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c. risks in between the two categories (a and b), where consideration needs to be given to the various trade-offs between risks and benefits. If the risk does not meet the predetermined acceptability criteria, an attempt must always be made to reduce it to a level that is acceptable, using appropriate mitigation procedures. If the risk cannot be reduced to or below the acceptable level, it may be regarded as tolerable if:

- the risk is less than the predetermined unacceptable limit;
- the risk has been reduced to a level that is as low as reasonably practicable; and
- the benefits of the proposed system or changes are sufficient to justify accepting the risk.

Some level of risk remains; however, the individual or society has accepted that the residual risk is sufficiently low that it is outweighed by the benefits. These concepts are illustrated diagrammatically in the Tolerability of Risk (TOR) triangle in Figure 2 below.

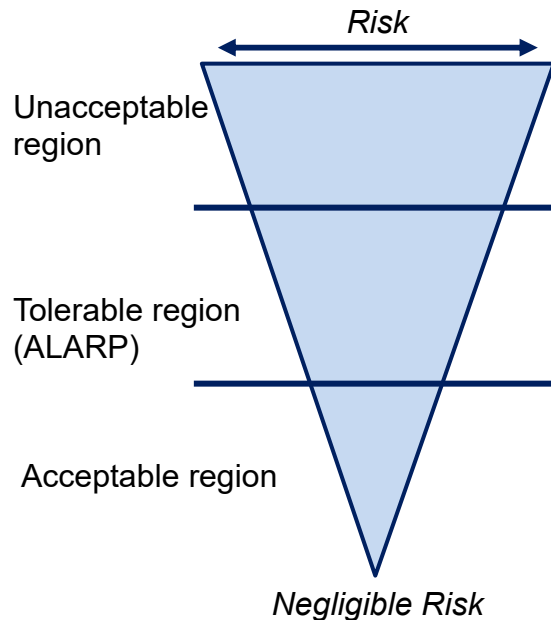


Figure 2: Tolerability of Risk (TOR) triangle (Okunola et al, 2012)

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It is necessary to assess the “risks” and to reduce them to “as low as is reasonably practicable”,

Table 2 General parameters for sources of risk

Source of risk	Examples	Comments
Physical or chemical process	Fire Fall Chemical influence Medical influence	Often based on a mechanism through which energies can cause direct injury or damage
Human influence	Physical act of a person Action of a group Psychological influence Influence by threat	The direct, concrete influences of persons or groups. (The intention does not necessarily have to be negative.)
Disturbance to a technical system	Interruption to service Collapse of system Accidents as side effects	Modern societies are often sensitive to technical disturbances, which can cause numerous problems.
Disturbance to organizational and social functions	Stop in services Shortage of supplies Lost control and panic Open conflict Warfare	A failure in societal functioning can cause difficulties in many ways, but the warning time may be longer.
Disturbance in nature	Flooding Earthquake Loss of provision Ecological loss	These disturbances are natural events, but they might be affected by human actions.

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The assessment and management of risk are integral components of the daily activities of human beings. Risk Management is the complete process of understanding risk, risk assessment, and decision making to ensure effective risk controls are in place and implemented. Risk management adds “value” to an operation in four dimensions (Kaiser & Robinson, 1999):

- Enhances participant experiences. The quality of customers’ experiences increases, especially when providing for safety, and less fear of risk provides greater freedom for participation. The participant experience deteriorates in direct relation to the extent to which he or she is exposed to unreasonable risks for injury. Safety of participants should be a paramount goal of all organizations.
- Provides good stewardship of assets. Financial, physical, and human resources are protected and conserved by good risk management practices which reduce liability exposures. Further, risk management determines the most cost effective operational strategies not only to reduce the frequency and severity of its potential liabilities, but also to finance them.
- Forestalls problems, including legal actions. Risk management forestalls problems, and helps an organization have a better prepared defense if it is sued. A risk management program should deal with the legal risks in a way that protects the provider and those who serve it from undue liability exposure.
- Encourages professional practices. Risk management embodies excellent professional practices, which result in a more effective and efficient operation. It also increases employee and volunteer pride, loyalty, safety, confidence, and productivity.

Risk management begins with actively identifying possible hazards leading to the ongoing management of those risks deemed to be acceptable. Figure 3 show the process of risk management.

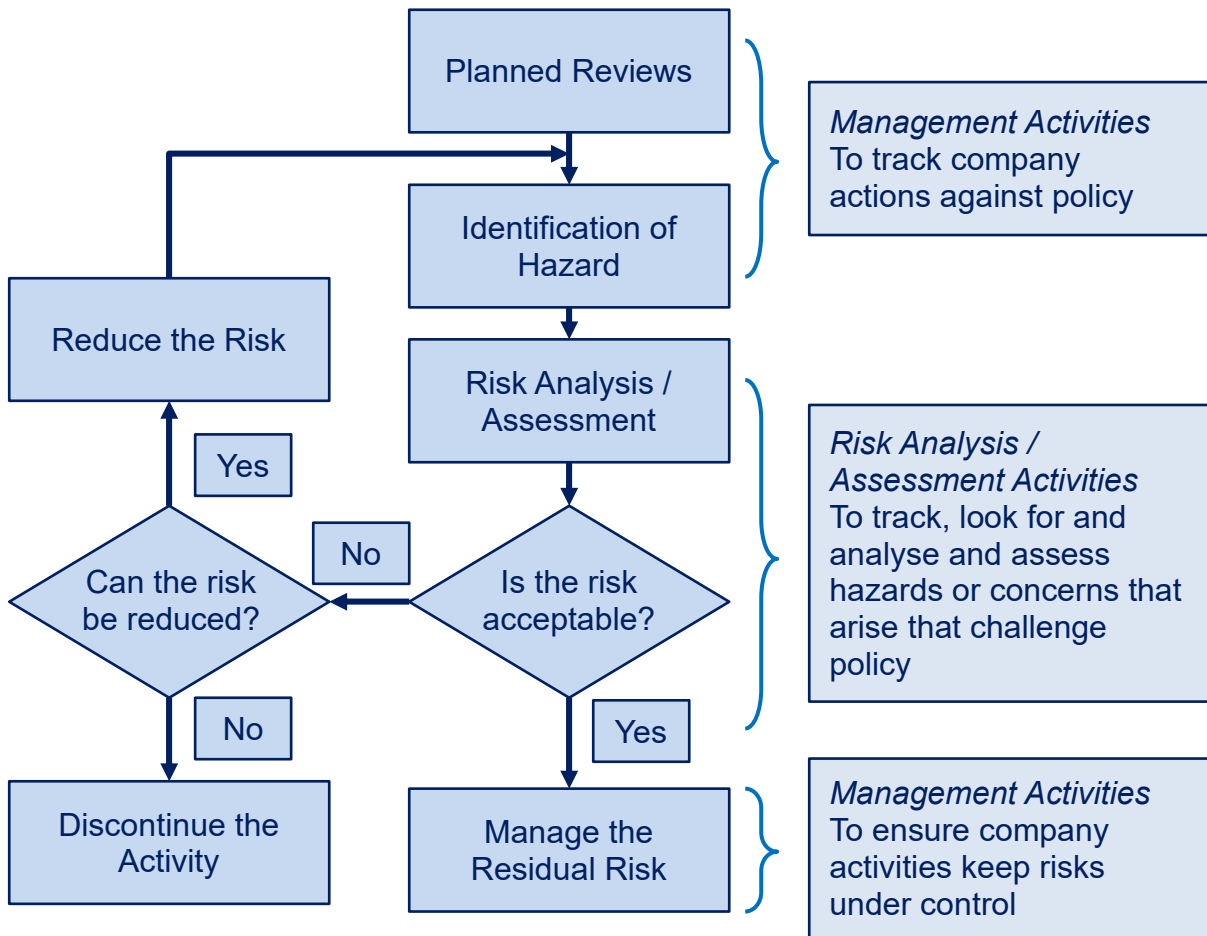


Figure 3: The process of risk management (Amyote et al, 2006)

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1. Planned reviews

This is a management function in which reviews are conducted to provide the data needed to monitor operations or develop new project designs. This is essentially the database for an effective safety and loss management system. It would include incident investigations, insurance company reviews, regulatory activities (pressure vessel inspections, environmental reporting, asset renewal needs, changes to laws, code updates, etc.) – in addition to the regular data collected on business operations and maintenance activities. The objective in this step is to be proactive, so that gathering the data and doing trend analyses in conjunction with statistical analyses will keep a company out of difficulty.

2. Identification of Hazards

One of the outcomes of doing the above mandated reviews (as a management team and by paying attention to industry activities in general through trade associations and the news), will be the identification of hazards. A company's management team will receive the data and, in the judgment of the team, will determine what needs to be considered further by means of a risk analysis. There are a variety of tools available for hazard identification – for example, Hazard and Operability Study (HAZOP), What-If Analysis, Checklist, Fault Tree, etc. Below are potential processes which lead to risk.

- Explosive reaction or detonation
- React energetically with water
- Spontaneous polymerization/heating
- Intrinsically unstable compounds
- Exothermic
- Flammables at high temperatures and/or pressures
- Flammable liquids above atmospheric boiling point due to pressure or
- Operating in or near explosive ranges
- Toxic materials, dangerous bacteria, radioactive chemicals
- Dust or mist explosion hazards
- Large inventory of stored pressure energy

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3. Risk Analysis/Assessment

Risk analysis involves gaining an understanding of the risk components – probability and consequences. Probability pertains to the failure of systems, humans, equipment, etc., and in many instances, is readily quantifiable. Some data are available generically, but the most pertinent data are often found in a company’s maintenance records, operational logs and incident investigation reports.

4. Is the Risk Acceptable?

Many company managements have developed a risk matrix describing what is a low-level risk (acceptable), medium-level risk (acceptable with certain conditions), and high-level risk (unacceptable). Such matrices clarify to employees what they must do and what is acceptable. The low-level risks are usually acceptable without any further management involvement or design additions. With respect to medium risk, management needs to be actively involved to ensure the risk is kept under control; it is worthwhile noting here that management’s responsibilities come to the forefront as they (managers) are assuming responsibility for accepting the risk.

5. Manage the Residual Risk

Once a risk is determined to be acceptable, it must be managed. This is arguably the most important step in the process as responsibility has now been taken for assuming the risk and preventing any undesirable incident from occurring. A key engineering tool employed in this stage is a management system appropriate for the risks being managed (e.g. health, occupational safety, process safety, equipment reliability, etc.).

6. Can the Risk be Reduced?

Often there are ways to reduce the risk once its level is determined to be unacceptable. The term inherent safety is used to imply methods which will eliminate or reduce the risk by tackling the underlying hazards themselves. Additionally, further controls, management systems, protective features, and the like can be added to reduce the risk to an acceptable level.

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7. Reduce the Risk

If the proposed risk reduction measures are viable, then the necessary changes must be made to equipment, procedures, hazardous inventories, etc. It is important to note that once a change is made, the risk management cycle is once again used to evaluate possible new hazards and risks.

8. Discontinue the Activity

A very important step is to recognize when the risk is too high. Management needs to be crystal clear on this and make the right decisions. Company values and objectives come into play at this stage – including the factors of lost profits, personal promotions, professional defeat, etc. Discontinuing an activity because the risk is unacceptable is a key decision because it says that a company will not do something that is unsafe, pollutes the environment, damages assets, risks business opportunities needlessly, or impacts the public's view of the company in a negative fashion.

Considering the industry at large, there are huge upsides to having functional loss prevention management systems in place; this allows companies to understand their risks and proactively mitigate their exposures. The reward for having such systems backed up with data showing its success is passed back to the company in the form of cost savings from reduced incidents and by insurers offering lower premiums.

Loss prevention program is intended to identify risks, allocate risks to the party best able to handle the risk, and manage those risks which cannot be transferred. It is a crucial part of every design professional firm's project administration. It not only minimizes the administrative and financial costs of claims and disputes by assuring that all participants to the construction process are aware of their obligations and rights, it enhances their ability to produce a successful project.

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In loss prevention, it prevents material loss (plant, equipment, chemicals), human loss (injury, death), and environmental loss (pollution, contamination) by anticipating potential hazards and applying safety measures. These losses can be issues with:

- Increased plant size and complexity
- More rigorous operating conditions
- Increased potential for loss
- Incentives
 - Moral, public perceptions
 - Legal
 - Economic

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DEFINITIONS

Action Plan - The actions developed or taken after the risk assessment process to reduce the probability and/ or impact of the event.

Audit - The systematic review and assessment of the level of compliance of an actual situation or system with a standard of performance.

Consequence - Outcome or impact of an event

Contingent Control - A control measure that is dependent on the happening of an event; and is also known as a corrective control.

Contributing Factor - An event and or issue that may gives rise to a risk event materializing

Enterprise Risk Management (ERM) - A structured and consistent approach that aligns strategy, processes, people, technology and knowledge, with the purpose of evaluating and managing the uncertainties the organization faces to create value.

Extrinsic safety - A process which is rendered safe by careful design and the application of safety systems

Hazard - a physical situation with a potential for human injury, damage to property, damage to the environment or some combination of these.

Individual Risk - The frequency at which an individual may be expected to sustain a given level of harm from the realization of specified hazards.

Inherent Risk - Inherent risk is the risk to an organization in the absence of any controls management might have in place to alter either the risk's impact or probability.

Intrinsically safe process - one in which safe operation is inherent in the nature of the process; a process which causes no danger, or negligible danger, under all foreseeable circumstances (all possible deviations from the design operating conditions).

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Loss Prevention - A systematic approach to preventing accidents or minimizing their effects. The activities may be associated with financial loss or safety issues. (In USA it is called Process Safety and the name Safety Engineering is becoming the norm in UK)

Probability - The chance of occurrence per action, operation or opportunity. Expressed as a number between 1 and 5, with no units and not time related

Proactive safety strategy - Aggressively seeking information from a variety of sources which may be indicative of emerging safety problems.

Reactive safety strategy - Investigate accidents and reportable incidents. This strategy is useful for situations involving failures in technology, or unusual events.

Redundancy - The performance of the same function by a number of identical but independent means.

Risk Appetite - This is the amount of risk, an entity is willing to accept in pursuit of value. It reflects the organization's risk management philosophy and in turn influences the organization's culture and operating style

Risk Assessment - The quantitative evaluation of the likelihood of undesired events and the likelihood of harm or damage being caused, together with the value judgements made concerning the significance of the results. Risk Assessment can be used non-quantitatively for routine day-to-day operations. It is the culture, processes and structures that are directed towards realizing potential opportunities whilst managing adverse effects.

Risk management - the complete process of understanding risk, risk assessment, and decision making to ensure effective risk controls are in place and implemented. Risk management adds "value" to an operation in four dimensions

Risk Ranking - A way of sorting risks or actions arising out of a risk assessment according to the relative magnitude of the risk.

Risk Rating - The numerical rating applied to a risk calculated as the compound of an impact factor, and a probability factor.

Risk Register - A collection of risk information that defines the risk profile of the organization, business unit, project or activity.

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Risk Response - Once the key risks have been identified and assessed management should consider how to manage them and implement controls

Risk - The likelihood of a specified undesired event occurring within a specified period or in specified circumstances. It may be either a frequency (the number of specified events occurring in unit time) or a probability, (the probability of a specified event following a prior event), depending on circumstances.

Safety - The state in which the risk of harm to persons or of property damage is reduced to, and maintained at or below an acceptable level through a continuing process of hazard identification and risk management.

Safety performance indicators - a measure of the safety performance of an aviation organization or a sector of the industry.

Terminate / Avoid - Diversify or avoid an activity that will give rise to the risk
Transfer / Share: Reducing risk likelihood or impact by transferring or otherwise sharing a portion of the risk. Common techniques include purchasing insurance products, engaging in hedging transactions, or outsourcing an activity.

Tolerate / Accept - Tolerating or accepting a risk means that the organization is willing to live with the consequences of a risk materializing.

Treat / Manage - Treating a risk means taking steps to reduce or eliminate the probability of it occurring, the impact on the organization if it arises, or a combination of both in order to bring the risk to acceptable levels in line with the organization's risk appetite.