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MANAGING RISKS FROM PROCESS SYSTEMS

"Although my commitment to the goal of immortality is unswerving, I am not positive that a zero risk society is yet in the scientific cards"

Daniel I. Koshland, Jr.
Nature, 17 April 1987

A quick look through the daily newspapers shows that all human activity is surrounded by hazards and associated risks. Road accidents, disease, fires, financial collapse are all part of human existence.

In personal affairs, we tend to manage risks implicitly. In a visit to the local grocery store on foot, we tend to avoid high traffic routes, cross roads at traffic lights or pedestrian crossings to minimize risk of injury or death. When it comes to managing risks to stakeholders in an enterprise, more formal and explicit measures are required.

Risk management has been practised for millennia in all areas of human activity. The earliest concept of loss prevention was self-defence to save one's possessions and property against attacks by enemy tribes. Since the industrial revolution, and in the aftermath of industrial disasters costing multiple lives, there has been a gradual, though not necessarily systematic improvement in work place safety. With the advent of major public companies in the 20th century and the depression of the 1930s, the need for financial risk management and protection of shareholders' interests has evolved as a separate field of study.

In the meantime, the insurance industry has been engaged in risk management in its own way. The focus has been largely on minimising losses in the aftermath of an accident event, and hence reducing the magnitude of claims by policy holders, rather than proactive prevention of loss incidents. Industries have also come to realise that an insurance policy is not a panacea against loss events, as the policy would not compensate for the full extent of the loss. For instance, in a major fire resulting in loss of assets, the insurance policy may replace the assets, but not the loss of market share due to prolonged downtime.

With the rapid development of modern technology, the level of complexity in industrial activities increased in the latter half of the 20th century. Correspondingly, the scale of loss events has increased, as has the extent to which they can affect not only the industrial facility and its employees, but also the surrounding local population. Classic examples are the chemical factory explosion at Flixborough in England (1974); the Three Mile Island (1979) and Chernobyl (1986) incidents involving nuclear power generation plants; the major gas explosion in Mexico City (1984) with loss of hundreds of lives; the major toxic gas release at Bhopal, India (1984) resulting in loss of lives and injuries running into thousands and the Piper Alpha oil platform disaster in the North Sea (1988). It is not surprising that most of the major industrial accidents were in process facilities, due to the hazardous properties of materials stored and handled.

Each major incident prompted the legislators to tighten up safety regulations, the insurers to seek more informed risk management techniques, and the industry to adopt formal risk management systems as part of ensuring operational integrity in day-to-day operations. Thus the subject of risk management has been steadily gaining prominence in the last 25 years.

1.1 WHY RISK MANAGEMENT?

There are many reasons why the technical and operational risks in an organisation must be assessed systematically.

1.1.1 Regulatory Requirements

Regulations covering the various aspects of risks from process operations exist in all industrialised countries and most developing countries covering the various aspects of risks from process operations. Regulatory compliance requires a dedicated organisational structure to undertake risk assessment and management to protect the health and safety of employees and the public, and the biophysical environment.

1.1.2 Common Law Duty of Care

In addition to complying with the statutory regulations, there is the all-embracing 'duty of care' on the part of the corporation, to protect the health and safety of its employees and the public from the corporation's activities.

The requirement is on the organisation to demonstrate that all reasonable care has been taken in identifying the hazards associated with the facility and its operations, and that adequate hazard control measures have been put in place.

Where the duty of care has not been visibly demonstrated, there is potential for criminal liability on the part of the company, should an incident occur resulting in serious injury or fatality to employees or the public, as a result of the activities of the company.

1.1.3 Commercial Reasons

There are strong commercial reasons for minimising business interruptions and equipment damage. Systematic risk management not only identifies the hazards, but also helps to rank the allocation of resources in a cost and time effective manner. Such an approach also assists in minimising the organisation's overall costs.

EXAMPLE 1-1 GAS PRODUCTION

A gas producer has contracted to supply natural gas to a distributor at a high availability. This is generally an onerous task, as a major incident in the gas production facility can interrupt gas supply for extended periods.

In September 1998, an explosion occurred at the gas processing plant of Esso Australia in Longford, Victoria. The accident resulted in loss of gas supply to consumers for several weeks, with significant consequential losses. The Royal Commission of inquiry into the accident attributed one of the causes to the failure of the risk management process in place (Hopkins 2000).

The accident showed that, without a systematic hazard identification study and an 'effective' risk management system, it is not always possible to meet the contractual obligations.

1.1.4 Evaluation of Alternative Options

In project feasibility evaluations, several alternatives are initially considered. The options may be related to siting of the facility, the process technology to be adopted, logistics of raw material supply and product distribution, availability of skill base, etc. The final short list of options would generally be based on locational and commercial considerations.

However, if we make an assessment of the risks associated with each of the options, an additional dimension of input to decision making emerges. It is possible that the options initially arrived at may have to be reconsidered based on risk.

EXAMPLE 1-2 VETERINARY CHEMICALS FACILITY

A producer of animal health and veterinary chemicals decided to construct a new formulation plant near a major metropolitan area. Three possible locations were selected. All the locations were suitable in terms of area of land, land prices and proximity to markets.

Before making a final decision on purchase arrangements for a specific piece of land, the company decided to undertake a preliminary risk assessment study of the impact of the proposed manufacturing and storage on the surrounding areas.

For near identical operations, each of the sites revealed quite different aspects of risk. These were related to environmental issues such as proximity to sensitive waterways, and transportation issues such as movement of toxic chemicals along

highly populated thoroughfares. It also became apparent that the costs of mitigating the risks in the three sites were so different that, when these costs were included in the cost-benefit analysis of the project, there was only one clear winner.

If a risk management survey had not been undertaken, and a piece of land had been purchased without consideration of this additional dimension, not only might the project have become financially non-viable, but there could also have been a number of difficulties in obtaining the necessary planning and environmental approvals from statutory authorities.

The following sections introduce some of the basic concepts surrounding modern risk management practice. In particular an emphasis is given to systems approaches to process risk management within the framework of the process life cycle.

1.2 HAZARD AND RISK

The terms 'hazard' and 'risk' appear extensively throughout this book and it is vital to be clear about what we mean by these terms. In popular parlance they are often used interchangeably. However in the context of process systems we make a clear distinction between these two complementary terms.

1.2.1 Hazard

In the case of 'hazard' we understand this to be an attribute of a thing or activity that has the potential for harm or loss. The term 'risk' relates to chance or probability of harm or loss. The following sets out formal definitions of the terms, giving a range of examples to illustrate the concepts.

Hazard can be formally expressed as:

"a source of potential harm or a situation with a potential to cause loss."

This is a definition in-line with that developed by safety professionals (Jones, 1992) or national standards like AS4360 (Standards Australia 2004). The key ideas embodied in the definition are:

a source or situation - meaning an inherent property of a thing or a set of circumstances that come into play.

a potential - implying that given the right circumstances or conditions some effects can be realised.

harm or loss - implying unwanted effects that could impact on people, property, environment or other nominated receptors such as corporate reputation, financial situation, heritage values, and the like.

EXAMPLE 1-3 HAZARDS IN INDUSTRIAL OPERATIONS

In the context of an industrial operation the following can be regarded as hazards:

(i) The presence of high pressures or temperatures in the system
(ii) The act of smoking in certain areas
(iii) Explosive properties of a material
(iv) Inappropriate behaviour of staff
(v) Storage of large quantities of toxic substances
(vi) Industrial operations near to high population density urban areas.

It is important that identification of hazards be comprehensive and thorough in addressing loss issues. This is the topic of Chapter 4.

It needs to be emphasized that hazard is a *potential* for harm or loss not a *realized* harm or loss. The role of risk management is to ensure that the potential is not realized, and should it be realized, then the consequences are mitigated.

Hence, the storage of large amounts of liquefied petroleum gas (LPG) for commercial use is designed and operated to ensure that the flammable and explosive potential of the material does not lead to harm or loss.

1.2.2 Risk

Risk is often associated with the likelihood of an adverse outcome. It is a rather vague term used widely in common language across many contexts. The English word has its origins in Latin (riscare) where it meant to "run into danger". A few examples help to illustrate the point.

EXAMPLE 1-4 SKY DIVING

We all know that sky diving is a risky sport. The risk here is the potential for serious injury or loss of life in the event of an accident. However, the activity itself does not mean that there is certainty of loss of life, but that the chance of an incident happening and its severity are relatively high compared to other sports. While the severity of a loss is recognised, people still undertake these activities because safeguards have been developed to reduce the chance of an accident. In other words, the likelihood of a loss is minimised. This is done by having redundant parachutes for sky divers, so that in the event that the primary parachute does not open, the spare one would. The chance of both not opening is considered very low. In other words, the 'risk' has been reduced to levels that people involved in the sport would accept.

EXAMPLE 1-5 TOXIC GAS RELEASE IN BHOPAL, INDIA

In December 1984, there was an accidental release of the toxic chemical methyl isocyanate from a pesticide manufacturing plant in Bhopal, India. The gas spread over a few square kilometres in the vicinity of the plant. This happened in the early hours of the morning when most people were in their homes asleep. The gas killed more than 2000 people in the surrounding community and injured tens of thousands of others. The incident had several implications:

- serious injury to, and loss of life of thousands of members of the public
- criminal prosecution of the company
- loss of assets for the company as the plant was never allowed to re-open
- extensive court battles and compensation costs.

This event also brought into focus the high risk nature of these industrial activities. Here the loss was not only material and financial, but also irreplaceable loss of human lives, and the devastation of an entire community. In terms of risk management, the following factors emerged:

- the nature of the material stored and processed, and its potential effect on humans on exposure
- the design and operational safeguards in place to prevent the event, or minimise the chance of its happening to very low levels
- the adequacy of the risk management systems in place and their effectiveness
- the lack of an off-site emergency response plan
- the problems of ensuring an adequate buffer distance between a hazardous facility and populated areas, especially in high population density developing countries
- the various risk exposures of the company whose magnitude had not been foreseen
- the high public costs associated with immediate payment to surviving victims and families of the dead, cost of investigation, heavy toll on the local infrastructure (hospital staff etc.). If the incident had not occurred, the money could have been spent on other community projects.

This is an example of an incident where the potential loss may have been recognised, but the likelihood of occurrence of the event had been grossly underestimated.

EXAMPLE 1-6 AMMONIUM NITRATE EXPLOSION AT AZF, TOULOUSE, FRANCE

In September 2001 an explosion at the fertilizer works of ATOFINA and Grande Paroisse resulted in 30 deaths and around 2500 injuries. Some 40-80 tonnes of ammonium nitrate exploded with the resultant shock wave causing significant damage to surrounding commercial buildings, residences and the Toulouse town centre some 3 kilometres away. Of the 30 deaths, 8 were outside the plant. The blast created a crater some 40 metres in diameter and up to 7 metres deep. Surrounding site buildings were destroyed and tanks containing other substances were damaged or ruptured. Liquid ammonia and chlorine storage facilities were fortuitously shielded by buildings which were themselves destroyed.

The accident highlighted the risks associated with inappropriate urban planning decisions and residential "creep" towards major hazard facilities. Other important risk related factors included better technical knowledge of risks, improved quality of hazard studies, improved land-use planning practices as well as better information to the public.

The above examples illustrate that risk has two dimensions:

- the *severity* or *magnitude* of the loss event
- the *likelihood* or *probability* of occurrence.

The combination of both dimensions is what constitutes risk. However, risk perception by the public of high technology industrial activities tends to be associated more with the severity dimension rather than the probability dimension.

To a large extent, the occurrence of high loss events around the world in the past, and vivid memories of those events, have contributed to this perception. It has led to the idea that risk is the hazard plus the outrage that accompanies it. We discuss risk perception and risk communication in Chapter 15.

It is essential to appreciate the two-dimensional nature of risk. This gives a two-pronged approach to managing risks–namely minimise the extent of loss or severity of the incident, and minimise or eliminate the likelihood of the event.

We are now in a position to develop a definition of risk. One obvious definition incorporates the concept of loss and the two-dimensional nature of risk.

Risk can be formally expressed as:

"the probability of occurrence of an event that could cause a specified level of harm to people, property and the environment or financial loss over a specified period of time".

The key concepts embodied here are:

a probability or likelihood	- hence some frequency or chance of occurrence of the event.
a risk receptor	- meaning a nominated target for the impact, not only limited to people, property, environment or financial impacts but to other issues such as corporate reputation, heritage value or legal action.
a level of harm	- indicating a specific level of impact being considered. For people it could be fatality or injury. Within injury levels we can nominate such issues as the degree of burn, level of toxic impact and the like.
a time frame	- typically over a period of a year, although other measures are often used.

The following examples illustrate the risk concept:

EXAMPLE 1-7 RISK IN COMMERCE AND INDUSTRY

a) Very large oil tankers transport crude oil from production fields to the oil refineries in many parts of the world. If there is an accidental release of oil, there is potential for major environmental damage as was seen in the Exxon Valdez incident in Alaska, and the incident involving a Spanish tanker in the Shetlands, off the coast of Scotland. If we apply the above

definition of risk in this context, the risk in super tankers carrying oil is the probability of a specified quantity of oil leaking into the ocean over a given period of time, say 1 year or 10 years, depending on the scale chosen.

b) Hundreds of people work in underground mines everyday around the world. Underground mining is associated with the risk of serious injury or fatality by roof/ground fall or fires and explosions. If the management of the mining company wishes to define the major risk to employees, and apply the above definition of risk, it may define the risk as the probability of a fatal accident in a given time period, say 1 year.

c) A mineral processing company has a target production to be met for the year. One of the important steps in the operations is the crushing of raw material ore to size for further processing. A large ball mill is used to crush the ore. This is critical equipment, and should a major failure occur in this section of the plant, the downstream processing will have to be shut down, and considerable loss of production could occur. By applying the above definition of risk to the operation, the following measures might be developed:

- Probability of 10% loss of production for 1 week.
- Probability of total loss of production for 1 month.

d) A construction company has a contract to complete a railway overpass that can carry heavy vehicle traffic. The turnkey project is a lump sum contract and is to be completed within an agreed date. A cost penalty would apply for delays. The financial reward is obviously higher for earlier completion. The integrity of the installation is critical as the consequential costs of a structural failure is very high.
The construction company can adopt a number of risk measures such as:

- Probability of project completion delay by a specified period (1-2 months).
- Probability of budget overrun by 15%.
- Probability of a structural failure during the operational life of the overpass.

■ ■ ■

1.2.3 Risk as an Ascribed Quantity

Risk is not a physical entity that one can measure. As mentioned before, risk is a very broad concept and can mean different things to different people. Therefore, the concept of risk can be interpreted differently by different people. Here are three examples:

a) Risk as perceived by a safety professional
A safety professional may interpret risk in a given industrial facility as the chance of a major fire or explosion, or structural failure, with consequent injury or fatality.

b) Risk as perceived by a production manager
A manager in charge of production operations may see risk as the likelihood of a major business interruption resulting in loss of production, resulting from an accident, equipment breakdown, or industrial dispute.

c) Risk as perceived by a fund manager
The fund manager's perspective is quite different. The fund manager may interpret risk as fluctuations in the market, bond rate and interest rate variations, and volatility in foreign exchange rates that could undermine the value of the investment, or affect overseas borrowing, against which hedging is necessary.

Risk is subjective. No one knows what will happen in the future, not even statistically. But, if we assume that the relevant working conditions in an industrial plant and patterns of behaviour of employees at the work place do not change, it is reasonable to assume that some value, R1, equals the corresponding loss rate observed in the past; we can then reasonably assign the same value to R1 for predicting future losses. This is so common a situation that we often talk of 'estimating' the risk. But risk doesn't exist the way a thing or physical attribute such as energy does. Indeed, in many situations, there is either something significant that cannot be assumed constant or there is insufficient data. Therefore it is then important not to assume that risk can be measured, estimated or calculated in all situations.

The subjective nature of risk raises many questions about the credibility of risk analysis, which we deal with in Chapters 9 and 10.

1.3 THE NATURE AND ROLE OF RISK MANAGEMENT

Risk management is the co-ordinated set of activities that direct and control an organization with respect to risk (ISO/IEC:73, 2002). It is the encompassing activity for a range of other tasks that include at the very least:

- Risk assessment (analysis and evaluation)
- Risk treatment (elimination, mitigation, transfer)
- Risk acceptance (tolerability/acceptability criteria)
- Risk communication (information sharing with stakeholders)
- Risk monitoring (auditing, evaluation, compliance).

Figure 1-1 shows a schematic representation of risk management concepts similar to the Australian Standard AS4360 2004. Risk management is a life cycle concept, since it is both multifaceted in addressing a range of risks; it is active throughout the life cycle of the process or product; it is multidisciplinary since it can cut across all levels of the corporation, government authorities and local communities; it is dynamic in nature due to an ever-changing environment of legislation, expectations, technology and business pressures.

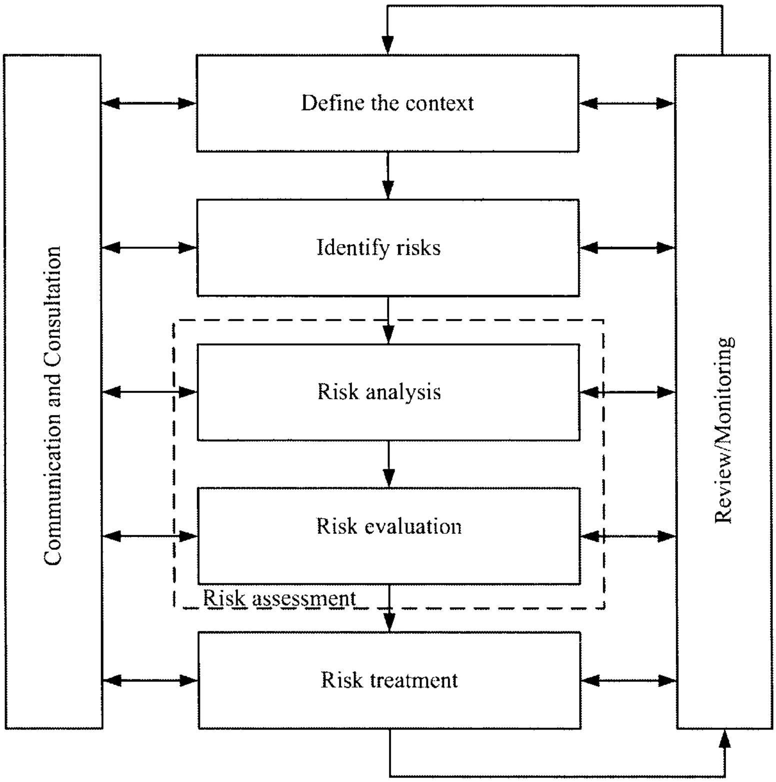

FIGURE 1-1 OVERVIEW OF RISK MANAGEMENT

Figure 1-2, adapted from Rasmussen (1997), shows some of the elements of that dynamic environment in which risk management takes place. This picture, with all its interactions illustrates the challenging nature of modern process risk management.

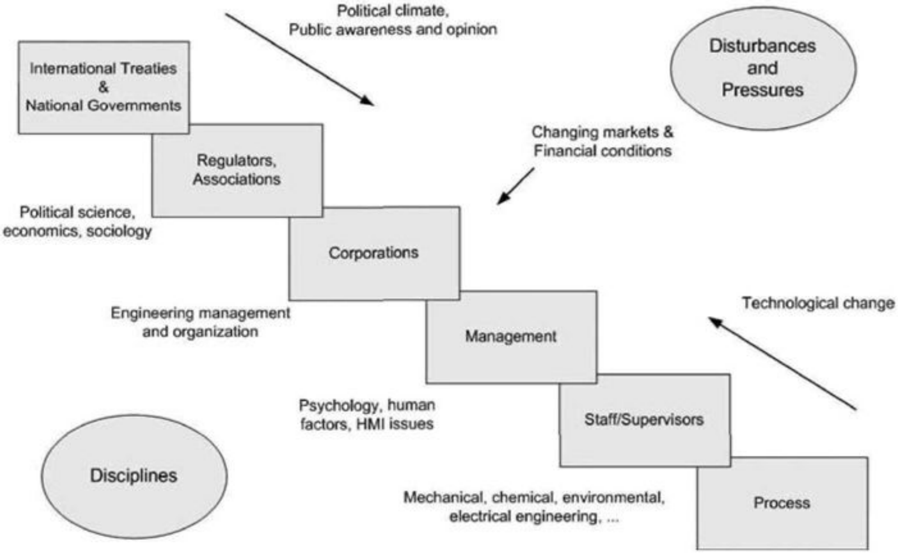

FIGURE 1-2 THE SOCIO-TECHNICAL ENVIRONMENT OF RISK MANAGEMENT

1.3.1 The Dimensions of Risk in Process Systems

The term 'process risk' itself is very broad, and encompasses several categories of risk. All categories are essential as they reflect various facets of an organisation's operations. Therefore, for any given situation, it is important to identify which of the categories of risk apply, before undertaking an analysis.

Risk categories

The main risk categories in process risks are:

- occupational risks (safety and health of employees)
- plant property loss
- environmental risks (safety and health of public, biosphere, heritage)
- liability risks (public, product, failure to provide service, legal prosecution)
- business interruption risks
- project risks (design, contract, construction, delivery).

Each category has its sub-categories. It should be noted that several of these risks are interlinked and overlapping, and cannot be treated in isolation.

Table 1-1 shows the various categories and sub-categories of risk relevant to engineering and other technology-related situations. These are relevant now considered in more detail.

TABLE 1-1 OVERVIEW OF RISK TYPES

Occupational	Property loss	Environmental	Liability	Business interruption	Project
• Workplace injury • Workplace fatality • Occupational hygiene Overlaps employee liability risk	Direct: • Industrial accidents • Natural disasters • Breach of security Indirect: • Drop in property value • Drop in share price • Drop in product value Overlaps business interruption risk	People: • Injury to public • Fatality to public • Health impairment to public Biophysical environment: • Air pollution • Water pollution (surface, groundwater, marine environment) • Soil contamination • Hazardous waste storage/ disposal Heritage: • indigenous sites • pristine environs • wilderness regions Overlaps liability risk	• Contract default • Omissions • Legal • Bankruptcy • Employee • Public • Product • Failure to provide services • Defective services Overlaps occupational, environmental risks	• Equipment failure • Property loss • Liability issues • Industrial disputes • Contract default from outsourcing • Significant cost increases • Sabotage Overlaps occupational, property loss and liability risks	• Cost exceeds budget • Completion time exceeds target • Contract default by third party • Political risk • Project financing problems Overlaps environmental, liability and business interruption risks

1.3.1.1 *Occupational risks*

Occupational risks are workplace related, and would affect employees and contractors at the workplace. There are three sub-categories:

- workplace injury
- workplace fatality
- occupational hygiene and health issues in the work environment.

Workplace injury

This is the most common form of risk experienced by most employees and employers. Four types of classification of these types of injuries can be made–first aid injury, medically treated injury, lost time injury and disability.

a) First aid injury

This is the simplest type of risk, involving cuts, trips or small bruises due to human error, loss of concentration etc. The injured employee is given first aid treatment on the site, and is back at work within a short period.

b) Medically treated injury, involving slip and fall, or overcome by chemical fumes, requiring examination by a medical practitioner. The injured employee is either treated on the site or at the local medical centre, back at work on the same shift, with effectively no lost time due to the injury. The Medically Treated Injury (MTI) has a higher severity ranking than the First Aid Injury.

c) Lost time injury (LTI)
This sub-category is of a higher severity than MTI, and by far one of the largest costs to the industry. The rehabilitation time may extend from one or two days to several months. The financial risk to the employee is reduced by the Workers Compensation Insurance scheme. However, there is a definite risk in the sense that the employee's position may be taken by another skilled person, and the same position may not be available on return. In some situations the injury sustained may not allow the employee to take up one's former position, or equivalent employment.

The costs to the employer are equally high, if not higher. These include both tangible costs and intangible costs:

- Cost of treatment and rehabilitation, partly covered by insurance
- Cost of incident investigation, and implementation of remedial measures. Sometimes a government agency may be involved in the investigation.
- Loss of skilled worker for a period of time and the need to train a substitute person. This could result in operational inefficiency. This is a significant intangible cost.
- Problems related to reallocation of duties and responsibilities to fill the gap until the return of the injured employee, and additional problems if one cannot be returned to the same duty.

Many employers look upon lost time injury as a risk purely contributed by human error, without considering the fact that in many instances, the risk could be eliminated by proper engineering measures. As a result, not only time and money are wasted in excessive training and re-training, but very often there is no tangible reduction in injury frequency.

d) Disability
This is by far the most serious form of workplace injury, with high cost to the employer and the employee, and should be prevented by all reasonably practicable means.

Disability injuries could occur from accidental deviations in routine industrial processes. Some examples are:

- burn injuries from a process fire
- injuries sustained in a gas explosion from the ignition of leaking flammable gas

- exposure to toxic chemical resulting in irreversible damage to specific organs
- body part caught in moving machinery such as a conveyor
- failure to isolate rotating machinery prior to maintenance work being carried out.

Workplace fatality

A much higher order of severity than disability from workplace injury is workplace fatality. A fatal accident affects the morale of other employees, affects a local community, and makes for adverse publicity for the organisation. If there are multiple fatalities, the ramifications for the organisation are far more serious. By far the largest number of fatalities in a work place accident has been the explosion and subsequent loss of the Piper Alpha platform in the North Sea in 1988, with the loss of 167 lives. We shall focus on the prevention of such incidents in organisations and applicable prevention techniques in Chapters 11 and 12.

Occupational hygiene issues at work

The risks concerning occupational hygiene include:

- use of chemicals in the workplace and potential for worker exposure, including chemicals which could be confirmed or suspected human carcinogens with potential for long-term health effects
- exposure to excessive noise from rotating machinery or construction equipment
- absence of ergonomic design of equipment resulting in injury, e.g. back strain.

Unlike a workplace injury which is acute, inadequate occupational hygiene at the workplace could result in chronic health problems in the long term, if potential exposure is not properly controlled.

1.3.1.2 *Property and plant loss risks*

Loss of asset from accidental events is a serious risk in process systems. These losses can be divided into two major sub-categories–direct and indirect losses.

Direct losses

Direct losses of assets fall under three headings:

a) Industrial accidents
These are the most common form of major asset loss. Examples are fires in warehouses and explosions in industrial processes. The consequences are not only loss of assets, but also injury or fatality to people, employee or public.

EXAMPLE 1-8 POLYETHYLENE PRODUCTION

Following the 1989 vapour cloud explosion at the Phillips 66 polyethylene plant at Pasadena, near Houston (USA), some 23 people died and extensive damage occurred to the plant. The cost of rebuilding parts of the process was in excess of $400 million. The company was also fined $4 million for licence breaches.

b) Natural disasters
These relate to storms, floods and earthquakes. Special precautions are required if the facility is located in flood prone areas, or higher risk earthquake zones.

c) Breach of security
These losses mainly relate to burglary, theft etc., although they could also involve breach of 'intellectual security', such as industrial espionage. It is an important risk to be identified and managed by the organisation. The cost of breach of intellectual security in an Information Technology (IT) company can be very high.

Indirect losses

Indirect loss generally results as a secondary effect of a different category of risk. The causes may be internal or external to the organisation. It is not only the direct losses that are important, but the indirect losses as a consequence can far exceed direct losses.

Indirect losses can also be characterised into the following types:

a) Drop in property value
In our current world of rapidly changing technology, an organisation's assets in plant and equipment could be worthless if the technology is completely superseded.

EXAMPLE 1-9 CONTAMINATED SITES

Many companies purchase land for purposes of industrial development. If, during previous uses of the land, the soil and possibly the groundwater table underneath the land had been contaminated with chemicals, and the purchaser does not take this into account, not only the value of the property drops significantly, but there is also the liability risk of clean-up.

It is essential to identify the broader risks to the organisation arising from specific incidents, rather than focus only on the specific events

b) Drop in value of products in the market
The market value of an organisation's products in the market place could drop as a result of the following:

- Defective products endangering consumer safety. If an automobile manufacturer or food/pharmaceutical manufacturer is seen to be issuing recall notices on products frequently, consumer confidence in the company's products would fall, along with the value of the products.

- New products of next generation technology replacing old products. A classic example is the compact disc revolution, making vinyl records almost obsolete.
- A superior product from another company through technological innovation at competitive prices would cause a drop in the product price. The technology and market share competition between IBM and Apple Computers, and the entry of several other smaller manufacturers into the market in the 1980s resulted in the drop in prices of personal computers.

1.3.1.3 Environmental risks

Awareness of environmental risks among organisations became significant in the 1980s. Since 'environment' covers everything around us, including ourselves, the risks are all encompassing. Organisations such as Greenpeace and Friends of the Earth have successfully brought this risk into public awareness and encouraged it to become part of the decision-making and risk-management processes of several companies. There are a number of environmental regulations in nearly every country in the world to protect people and the biophysical environment from industrial processes and industrial accidents.

One of the major problem areas for an organisation in the management of environmental risk is the longer term impact. Unlike loss of property in a fire, which can be quickly replaced, damage to the environment takes a long time to recover, and costs significantly more in clean-up and monitoring. The example of Exxon Valdez has already been mentioned.

Some other examples of environmental risk are:

EXAMPLE 1-10 EQUIPMENT AND OPERATIONAL FAILURES

a) Failure of pollution control equipment and release to the environment.

In 2000, there was a major release of cyanide from the tailings dam of a gold mine in Romania, operated by the Romanian Government and the Esmeralda Company. The cyanide found its way into the Tisa River and ultimately into the Danube, affecting aquatic life in Romania, Hungary and Yugoslavia.

b) Breakdown of operating equipment during routine operation, resulting in loss of containment and emission to the atmosphere.

A sulphuric acid plant converts sulphur dioxide to sulphur trioxide in a catalytic reactor. The sulphur trioxide is absorbed in a dilute solution of sulphuric acid in an absorption tower to make concentrated product acid. If the absorption tower circulation pump fails during normal operation, then the sulphur trioxide would not be absorbed, but escape to the atmosphere through the stack. Depending on the quantity of release and prevailing meteorological conditions, the acid mist could disperse hundred or thousands of metres downwind and affect local population centres.

c) Escape of contaminated firewater in a factory/warehouse fire into storm water system.

- In 1986 a fire occurred near Basel in Switzerland in a Sandoz warehouse containing agro-chemicals. Approximately 10,000 tonnes of firewater was used to bring the fire under control, but the contaminated firewater with about 30 tonnes of chemicals escaped through the storm water system into the Rhine and polluted the river several kilometres downstream.
- In 1991 a fire at Diversey Chemicals in Sydney, Australia resulted in escape of contaminated firewater into the nearby Toongabbie Creek, polluting the waterway.

d) Health risk to the public through exposure to soil and groundwater contaminated by industrial pollutants.

Although known, this risk was not taken seriously by regulatory authorities until the late 1970s. The Love Canal and other polluted sites in the USA gave rise to the Superfund for clean-up.

1.3.1.4 Liability risks

This type of risk in some aspects overlaps the previous ones. For example, environmental impairment or public injury from an incident carries a liability for the organisation, either under a regulation or under common law.

Risk of contract default

In many process enterprises, part or all of the project work is contracted to external firms. A default in terms of performance guarantee, meeting deadlines, or breach of quality of deliverables carries a liability on the part of the contractor.

The risk is not only for the contractor, but there are significant costs to the organisation as well. These include project delays resulting in increased interest payment on borrowing, depreciation on non-performing assets and loss of market share due to delays, all of which may not be recovered through liability claims alone.

With more and more organisations outsourcing goods and services, the risk of contract default becomes an issue worthy of serious consideration in risk management. In the public sector, risk of contractor default is a significant risk in privatisation, and outsourcing of services.

Acts and Omissions

Omissions on the part of a goods or services provider carry liability risks. The omission could be intentional or through negligence. If an organisation designs a bridge, and there are design faults in the project resulting in a failure of the structure, a whole range of liabilities arise. These include financial liability in rebuilding to a correct design, compensations for the injured, and legal costs

associated with facing a possible criminal negligence charge, should fatalities occur in the accident.

Legal

Legal liability may arise from the following:

- common law claims on the company by a third party
- industrial accidents that requires coronial inquiry or inquest
- prosecution by a government agency for breach of Occupational Health and Safety (OH&S) legislation as a result of a workplace injury
- product defects that threaten the safety of the consumer such as defective toys that could affect child safety)
- third-party damages arising from a firm's industrial activity; these may arise from injury, environmental impairment, loss of amenities and the like.
- breach of environmental licence regulations prescribed by environmental protection authorities.

The major costs of legal liability are legal costs, cost of complying with injunctions and court orders for specific performance, money for settlements, verdicts and fines, and compensatory damages.

Employee liability

This could arise from a breach of Occupational Health and Safety Regulations, intentionally or through negligence. Liability could be in terms of payment through the Workers Compensation scheme, or directly being sued by an employee under common law. This risk is part of the legal risk discussed above, but has been listed separately to highlight its importance to the organisation.

1.3.1.5 Business interruption risks

There is considerable overlap between business interruption risk and the other risks discussed above as these could be significant contributors to business interruption. Interruption to business could occur from the following:

- Major breakdown of critical equipment. The facility may not carry the spare parts to carry out repairs, or in the event of a major failure requiring replacement of the equipment item, there may be considerable lead time for delivery/installation.
- Property loss from fires or explosions. There are significant delays due to investigations, insurance loss adjustment and claims processing, as well as the lead time for replacing equipment before production can re-commence.
- Liability issues temporarily halting operations. A product defect could be identified, and there could be product liability issues relating to marketing the product even as 'seconds'. Until the cause of the defect is identified and corrected, production may have to be suspended. The alleged defects in

Firestone Tyres that caused automobile accidents, is one example of the product liability stopping production.

- Inability to cover liability resulting in closure of business. This is part of the bankruptcy risk.
- Industrial disputes.
- Reduction in internal resources of the organisation.
  There has been an increasing trend in organisations in industrialised countries towards reducing internal resources. Reducing the size of the organisation and outsourcing goods and services previously provided from within the organisation have their own intrinsic risks. These risks relate to loss of skills within the organisation and consequent inability to assess the quality of an external service (e.g. design), contract default on the part of the third-party service providers, indirect liability issues arising from the use of non-quality goods and services from external providers etc.
  In smaller organisations, the sudden loss of a few key employees through resignation may seriously upset the operations until a suitable replacement could be found. This may not be so severe for large organisations that they must redeploy resources from other areas of the organisation.
- Significant increase in costs. Loss of market share during the period of business interruption could be made up by a supply through continued manufacturing by a sub-contractor, and/or major advertising and marketing thrust. Either of these would result in an increase in overall costs.

1.3.1.6 Project risks

In undertaking engineering projects, it is essential to understand clearly at the outset the risks associated with the project and plan for it. Some of the risks discussed above would be present as part of overall project risk.

Key aspects of project risk are:

- Project budget blow out. This can seriously delay the project. If the project is in its early stages, it may cause abandonment of the project by the management as the projected return on the investment on which the project decision was made, could be significantly lowered.
- Project completion delayed. This can result in financial loss due to interest payment on non-performing capital, and any cost penalties for delivery delays in the contract.
- Contract default by third-party services. While this can be partially covered by liability clauses in the contract, the cost and completion time of the project would both exceed budget.
- Political risk. Project delays due to environmental issues associated with the project, raised by external interest groups with political influence, causing delays, abandonment, significant design modification, all result in an increase in overall costs.

It is essential to keep in mind the environmental and political risks for a project. Even if all the economic indicators of the project were positive, the environmental and political risk may force the company to abandon a project, or

modify it significantly, with associated costs. Project risk issues are discussed by Grey (1995) and Chapman and Ward (1998), and are not further pursued in this book.

Risk management of process systems can be seen to have a wide range of foci – from employee risks to environmental and corporate reputation. Comprehensive risk management needs to provide the appropriate focus on all relevant aspects that directly or indirectly affect the well-being of the corporation, its employees and related stakeholders.

The following section focuses on the key hazards and risks common to process systems.

1.3.2 The Key Players in Risk Management

Process risk management is a stakeholders' paradise. Stakeholders and interested parties are a vital aspect of effective risk management, since it is essential to ensure that all affected groups have the necessary input to the process and that the communication between groups is effective over the life cycle of the process.

Figure 1-3 shows the principal players in process risk management clustered under three general areas of:

- Corporation
- Government
- Community

The general risk management process in Figure 1-1 shows the necessity for communication to all relevant parties at *each* stage of the process. Major hazard developments will often result in a wide ranging consultation process through the environmental impact assessment (EIA) process, common to many state and national government regulations.

The general issues for the various players can be set out as follows:

National/state governments:

- strategic planning
- regional and economic development
- development control

[redacted] FIGURE 1-3 PROCESS RISK MANAGEMENT STAKEHOLDERS

Local authorities:

- development control plans
- town planning schemes
- potential impacts
- environmental concerns (air, noise, water, waste)
- social concerns (health, safety, consultation)
- infrastructure issues (services, transport, effluent)

Corporation:

- economic viability
- on-site safety
- off-site safety
- communication
- access (markets, raw materials, services)
- operational certainty (nearby land uses)

Public:

- maintenance of amenity
- noise, odour, pollution, lighting
- transport corridors
- natural environment
- refuse and wastewater
- hazards and risks (acute and chronic)
- heritage issues

All these issues play a very important role in the land use planning of major hazard facilities (MHF) and other process related operations. These are addressed in Chapter 13. Risk management provides an accepted framework to help address these concerns in a structured manner. However as we discuss in Chapter 15, the issue of risk perception is vital in the overall effectiveness of risk management practice.

1.4 HAZARD AND RISK IN PROCESS SYSTEMS

1.4.1 The Incident Spectrum

Section 1.1.1 discussed what constitutes a hazard. What is clear is that hazards arise from a number of areas – the substances used, the types of activities carried out, the way things are done.

Harmful effects flowing from these hazards were also considered and these can cover a wide range of potential impacts–minor injury to death, minor to catastrophic damage. Hence there is a spectrum of potential impacts based on severity.

Coupled with this is the question of 'how often?' these incidents occur. It's clear that in the workplace we might experience a large number of minor effects from hazards. For example, minor cuts, abrasions, strains and the like. However, the incidents at the other end of the spectrum which lead to death or catastrophic damage are usually and thankfully rare. Figure 1-4 shows this spectrum of incidents.

In terms of the control of these incidents, the far left end (low impact, frequent occurrence) is usually associated with occupational health and safety issues. The far right end (high impact, rare occurrence) are those events which require special analysis and which engender particularly strong responses from the public and particular concern to corporations. The whole spectrum is the focus of process systems risk management.

In the following sections events and incidents within the process industries are highlighted.

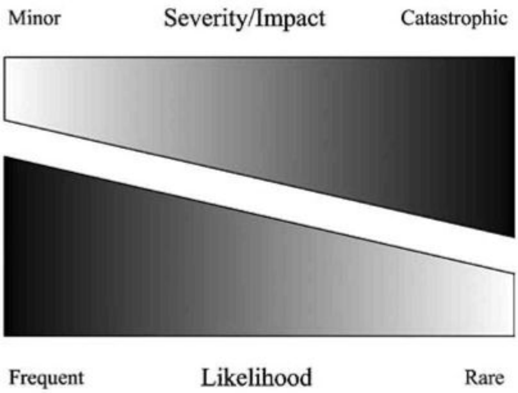

FIGURE 1-4 THE INCIDENT SPECTRUM

1.4.2 Events and Incidents in Process Systems

In the context of this book we make specific use of the words 'event', 'incident' and 'accident'.

An 'event' refers to a single happening or occurrence such as a liquid release, evaporation or a fire. A probability or frequency can be assigned to each.

An 'incident' is a sequence of events that could result in adverse impacts or disruption, whereas an 'accident' is a sequence of uncontrolled events producing unintended consequences affecting the on-going functioning of the system.

1.4.2.1 Minor incidents

In the context of the process industries or in the transport of dangerous goods the types of minor events incidents can include:

- Slips, trips and falls
- Nuisance/minor distress from exposure to harmful environments
- Minor burns

1.4.2.2 Fires, explosions, toxic release

There are several events which fall into this category, simply because they have a potential for direct major impact, or impact from incident escalation. These events include:

- Fire (pools, jet, spray, flash)
- BLEVE (Boiling Liquid Expanding Vapour Explosion)
- Vapour cloud explosion (VCE)
- Dust explosions
- Toxic gas releases
- Toxic liquid or solid releases
- Toxic combustion products from fires

All these events have, and can occur in the storage, processing and transport of hazardous materials. Table 1-2 gives a selection of some accidents which have occurred over the last 80 years, showing that these accidents are not confined to a few countries or to a few types of operations but cover a broad range of activities across geographical boundaries.

A quick perusal of the list shows several "classic" accidents such as Flixborough (1974), Seveso (1976), Bhopal (1984) and Piper Alpha (1988) that have led to significant regulatory changes in risk management both nationally and internationally.

1.4.3 Contributing Factors to Process Risk

There are many significant contributing factors when considering process risks and the following sections highlight these. They are the subject of further consideration in later chapters.

1.4.3.1 Properties of hazardous materials

Inherent properties of substances or mixtures are important factors in risk assessment. These are the contributing factors to the hazardous nature of the material. We recognise a number of these factors in the case of hazardous substances, including (Lewis 1996):

- Toxicity
  seen as: Lethal dose (LD_{50})
  Threshold Limit Value (TLV)
- Flammability
  seen as: Flash-point
  Auto-ignition point
  Flammability limits (when mixed in air)

TABLE 1-2 SELECTED MAJOR ACCIDENTS

Date	Location	Substance	Event	Death/ Injury
1921	Oppau, Germany	ammonium nitrate	explosion	561d
1942	Honheiko	coal dust	explosion	1572d
1944	Cleveland, USA	LNG	explosion	131d
1947	Texas, USA	ammonium nitrate	explosion	576d
1948	Ludwigshafen	dimethyl ether	explosion	207d
1956	Cali, Colombia	dynamite	explosion	1100d
1968	Hull, UK	acetic acid	explosion	2d, 13i
1969	Basel, Switzerland	nitro liquid	explosion	3d, 28i
1969	Teeside, UK	cyclohexane	fire	2d, 23i
1970	Philadelphia, USA	cat. cracker	fire	1d, 50i
1971	Houston, USA	VCM	BLEVE	1d, 50i
1972	Brazil	butane	explosion	37d, 53i
1972	Netherlands	hydrogen	explosion	4d, 4i
1973	Potschefstroom	ammonia	toxic	18d
1974	Flixborough, UK	cyclohexane	UVCE	28d, 53i
1975	Antwerp, Belgium	ethylene	explosion	6d
1976	Baton Rouge, USA	chlorine	toxic	10000 evac
1976	Houston, USA	ammonia	toxic	6d, 200i
1976	Seveso, Italy	dioxin	toxic	1000+ i
1977	Columbia	ammonia	toxic	30d, 22i
1978	San Carlos de la Rapita, Spain	propylene	fire/explosion	211d
1978	Chicago, USA	H_2S	toxic	8d, 29i
1979	Bantry Bay, Eire	oil	explosion	50d
1984	Bhopal, India	MIC	toxic	3800d, 250000+i
1984	Mexico City	LPG	fire/explosion	450+d
1986	Rhodes, NSW	oil	explosion	5d
1987	Laverton, Vic	hot-metal	explosion	2d
1987	Cairns, Qld	LPG	BLEVE	1d, 5i
1988	North Sea (Piper Alpha)	gas	fire/explosion	167d
1989	Ufa, USSR	LPG	explosion	500d?
1990	Sydney, NSW	LPG	BLEVE	-
1992	Guadalajara, Mexico	Hexane	explosion	170d, 500+i
1995	Sao Paulo, Brazil	oil pipeline	fire	1d, 5i
1997	Blaye, France	grain	dust explosion	11d, 1i
1999	Martinez, California	naphtha	fire	4d, 1i
2000	Enschede, Netherlands	fireworks	explosion	25d, 1000i
2001	Toulouse, France	ammonium nitrate	explosion	30d, 2000i
2002	Al-Rawdatayn, Kuwait	oil	explosion/fire	4d, 19i
2003	Amman, Jordan	fuel	tanker fire	10d, 18i
2004	Skikda, Algeria	natural gas	explosion/fire	27d, 72i

- Explosion
  seen as: Detonation (e.g. TNT)
  Deflagration (e.g. LPG)

Vapour cloud explosion
BLEVE (e.g. LPG)
Dust explosion (e.g. grain, coal, powder, metal)

In attempting to deal with the issue of hazards, classification of certain chemical substances have been internationally accepted under the UN practice (http://www.unece.org/trans/danger/danger.htm), and the International Maritime Dangerous Goods (IMDG) Code. Equivalent national codes have been developed in many countries. These classify a large number of substances into 9 dangerous goods classes. Figure 1-5 shows the classes which are currently used in most dangerous goods codes.

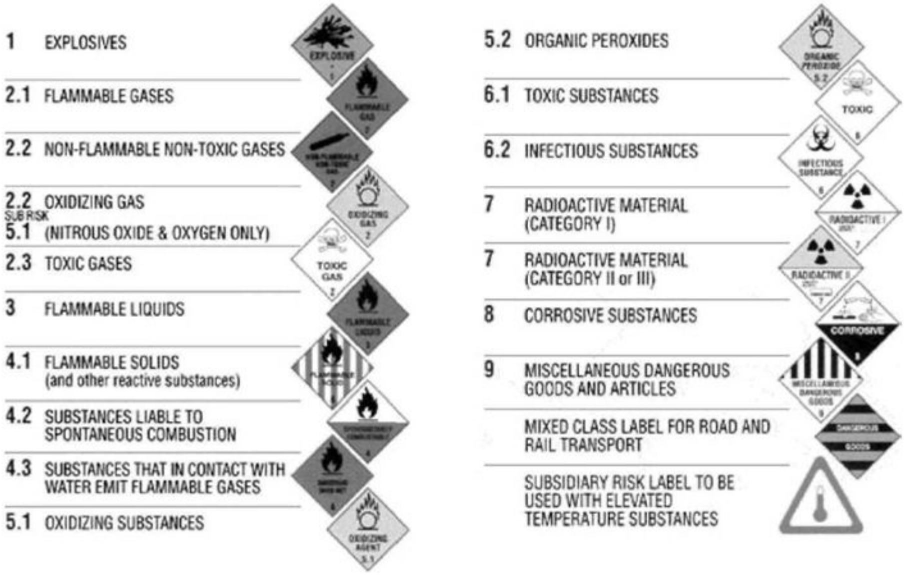

FIGURE 1-5 DANGEROUS GOODS CLASSES (CHEM UNIT 2004)

Once the dangerous goods classification of a substance is known, the appropriate emergency response information can be found in the codes.

A supplementary form of classification is through the use of “risk phrases”. These are typically referred to as R1, R4, R17 etc. and supplement the dangerous goods classifications. The intention is to give further specific hazardous information on the substance. As well as risk phrases there are "safety phrases" which set out details of handling, safe storage and personal protection for a range of substances. Both risk and safety phrases are adopted from European Union initiatives. Again, most substances can be classified under 1 or more of these categories.

A comprehensive list of risk and safety phrases is to be found in Worksafe Australia Code NOHSC: 2012 (1994), as well as the International Labour Organization Convention 170 (http://www.ilo.org).

1.4.3.2 *Process design, control and operational factors*

Details of hazard identification, design, control and operational factors are described in Chapter 4. Methods of assessing and managing the hazards are described in Chapters 5-14. Only an overview is provided here.

Contributing factors related to the operations might involve deviations from good practice covering,

- Major variables (levels, temperatures, pressures, etc.)
- Time of actions
- Sequence of operations
- Human factors (See Section 1.4.3.3)
- Identification and control of ignition sources
- Operational policies and practices

Process design

The underlying design is the fundamental starting point in process risk management considerations. The principal factors which are relevant include:

- Process development philosophy, that seeks to address inherently safer designs
- Processing routes, including process structure and the degree of coupling in the system
- Process complexity in the design including the unit operations and chemical species present
- Process layout, which influences inherent safety such as segregation, separation, maintenance access and emergency response.
- Process design standards, that can be purely compliance based or risk based.

The importance of process design factors is seen in the following examples.

EXAMPLE 1-11 DESIGN RELATED RISK FACTORS

a) The historic change in nitroglycerine production from large batch reactors to very small continuous production facilities using nitration injectors led to a huge reduction in risk through improved design and ease of operation.

b) The storage of intermediate chemical products in the process can often be eliminated by immediate use of the intermediate in the next reaction stage. At Bhopal the methyl isocyanate was an intermediate used to produce carbaryl. Some 90 tonnes were held, whereas new process designs have a maximum inventory of only 10 kg. (Willey, 1998).

c) Alternate reaction pathways exist for many chemical products, that lead to routes that are more inherently safer options. The route to carbaryl is one such case where the less hazardous intermediate α-naphthol

chloroformate is produced that can then be reacted with methylamine to give carbaryl.

Process Control

Process control is an inevitable result of dealing with a system that operates under a range of disturbances.

Contributing risk factors from control include:

- Control feedback structures and increased information complexity
- Failure in control loop components such as sensors, controllers, actuators and valves.
- Multivariable control schemes whose status and root causes of failures are often difficult to interpret when they occur
- Inadequate instruments, alarms, interlocks and maintenance
- Poor human-machine interface (HMI) designs that are difficult to interpret by operators in emergency situations.
- Poor control room layout that creates problems under emergency conditions.

Some examples include:

EXAMPLE 1-12 CONTROL RELATED RISK FACTORS

a) Partial failure of a naphtha stripper level control by-pass valve at the Tosco Refinery, California prevented isolation of the line from the process unit contributing to loss of naphtha and subsequent fire that killed 4 workers. (CSB, 2000.)

b) During the Three Mile Island (TMI) nuclear power plant partial meltdown, operators were unaware that a pilot operated relief valve had opened. Multiple alarms and warnings overwhelmed the operators resulting in actions that made conditions worse.
Alarm management and adequate instrumentation were control-related factors contributing to the accident.

1.4.3.3 *Human factors*

One can take the view that all incidents are ultimately traceable to human failings. A cursory reading of accounts of major accidents (Chiles, 2001; Hopkins, 2000; Perrow, 1999; Reason, 1990, 1997; Dörner, 1989) emphasizes this point. Human factors are vitally important and Cacciabue (2000) estimates that the human factor contribution to risk is as high as 70-80% and much more visible due to the rapidly increasing reliability of mechanical and electronic components. Working environments for operators have become more demanding on cognitive-reasoning abilities due to increased design and operational complexities.

Identification of human failure modes is described in Chapter 4. Human factors related to reliability are described in Chapter 8, and facility life cycle issues are commented on in Chapter 12.

The literature on the area of human factors in risk management is voluminous (CCPS 1994). It is also a well recognized issue in risk assessment and management as evidenced by major worldwide regulations. These include the European Union through such standards as IEC300-3, Dependability Management which specifically mentions the important role of human factors in risk and the use of human reliability analysis (HRA), task analysis (TA) and human error identification (HEI) as tools to be used in tackling these issues.

In the USA, a number of regulations and codes of practice emphasise similar concerns. The Occupational Safety and Health (OSHA) Process Safety Management (PSM) standard CFR 1910.119 and the EPA Risk Management Plan (RMP) deal with human factor issues. Industry codes such as the American Petroleum Institute (API) Safety Environmental Management Plan (SEMP) RP75 for off-shore operations emphasizes similar human factor concerns.

What is clear from the mass of literature is the increasing focus on human factors in technological systems as well as the difficulties in effectively and comprehensively addressing the issues. It remains one of the most difficult and challenging areas of consideration in process risk management.

Some typical examples where human factors played major roles in accidents are:

EXAMPLE 1-13 HUMAN FACTORS RELATED TO RISK

a) The accident at Three Mile Island nuclear power plant had numerous human factors playing a leading role. One was training for incident scenarios that appeared to not consider multiple failures. Another factor was related to design flaws in the control system, making diagnosis extremely difficult and hence affecting decision-making (Perrow 1999).

b) The Piper Alpha offshore platform disaster in the North Sea in 1988 was permeated with many human errors. Maintenance failures to isolate open relief valve flanges, communication failures between operating shifts, superficial inspection regimes, poor decision-making on isolation of emergency fire pumps were all part of the recipe for disaster that killed 167 people.

c) The gas plant explosion at Esso's Longford plant in Victoria Australia in 1999 was strongly linked to organizational failures. Lack of hazard identification, operator training deficiencies, lack of knowledge and corporate responsibility were major human factors that were evident in the post-accident Royal Commission (Hopkins 2000).

These few examples illustrate the absolute need to fully address the human risk factors through the complete life cycle of the process to ensure the design, construction and operation are fully considered from this perspective.

1.4.4 The Ubiquitous Nature of Uncertainty

Uncertainty pervades all areas of risk management. It is important that due recognition is given to the role that uncertainty plays in each phase of risk management as was outlined in Figure 1-1.

Here the forms of uncertainty and their representation at each phase require careful consideration in any risk analysis and the subsequent decision-making that takes place. We cannot avoid uncertainty, we need to treat it appropriately. It is an inevitable fact due to limited knowledge and assumptions made. In Chapter 10, explicit treatment of uncertainty in the decision-making process is discussed. However, earlier chapters on hazard identification, consequence analysis, causal and frequency analysis highlight uncertainty contributions to overall assessment.

The concept of the precautionary principle is often used to deal with some aspects of uncertainty and sometimes as an excuse to avoid analysing its impact! Whatever the approach adopted it will always play a role in process risk management.

1.5 THE REGULATORY ENVIRONMENT OF RISK MANAGEMENT

1.5.1 International Conventions

International conventions through such organizations as the International Labor Organization (ILO), the United Nations (UN) or United Nations Environment Program (UNEP) provide umbrella principles under which signatories have established national and regional legislation with accompanying regulations. The International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) also develop major standards impacting on worldwide risk management practices.

Within Europe, the European Communities (EC) have been active in establishing directives that address issues of major importance to the member companies. Such directives as the Seveso II directive (EC96) for major hazards and the directive on Classification, Packaging and Labelling of Dangerous Substances (EC99) provide some harmonization framework across community member states. The individual member states adopt directives and express them in national legislation and regulations relevant to the country (Milburn and Cameron, 1992).

1.5.2 National and Local Regulatory Frameworks

In all industrialised countries, there is some form of legislation that governs risk management when protecting the health and safety of employees, the environment, and public health.

In Australia as in other jurisdictions this legislation varies from state to state. Instead of providing a list of acts and regulations, the common features of the legislation are provided here to gain an appreciation of the role regulations play in the overall risk management process.

The legislation may be broadly grouped into three classes:

Group 1: Protection of employees at the workplace

The legislation and regulations that govern this include:

- Acts relating to health and safety at work
- Occupational Health and Safety regulations
- Exposure levels for contaminants in the workplace
- Risk assessment and management in major hazard facilities
- Storage and handling of dangerous goods and hazardous substances
- Fire protection and building regulations

Group 2: Protection of environment

The regulations in this area have been numerous, with ongoing changes. Major regulations generally cover the following:

- Protection of the environment (air, water, noise control)
- Environmentally hazardous chemicals control
- Contaminated land management
- Waste generation and disposal
- Various other pollution control regulations

Group 3: Protection of public and public health

Regulations in this area tend to overlap the health and safety at work acts and the environmental protection acts.

Major regulations are:

- Environmental planning regulations
- Siting of hazardous industries in relation to land use safety
- 'Safety Report' requirements from major hazard facility operators addressing public safety issues.
- Health risk regulations from contaminated land and contaminants in surface/groundwater
- Drinking water quality standards
- Surface water quality standards.

Regulatory considerations also include the application of various design Codes, Standards and industry Recommended Practices, many of which have been explicitly and implicitly called for in the regulations.

The number of regulations is vast, and specific references should be made for each country, state or jurisdiction. Some examples follow.

In Australia, there is no federal regulation in the above 3 categories. Each state has its own range of regulations for occupational health and safety, and environmental protection. In the area of control of major hazard facilities, the National Occupational Health and Safety Commission has published a National Standard and Code of Practice, (NOHSC 1014, 2002), but it is advisory only.

Among the states of Australia, Victoria legislated for control of major hazard facilities in 2000, and Queensland in 2001. Other states will follow.

The European Commission has developed community legislation that includes the environment, consumers and health protection. Member countries have developed regulations to address these issues. The main framework for control of major hazards is Directive No. 96/82/EC of December 1996, known as the Seveso II Directive, replacing the previous Directive of 1982.

In the UK, major hazards are controlled by the COMAH (Control of Major Accident Hazards) regulations (1999) administered by the UK Health and Safety Executive. This is in response to the Seveso II Directive of the EC. The Health and Safety at Work Act and its associated Statutory Instruments cover a very wide range of activities.

The COMAH Regulations require an operator to identify the hazards, the impact of the hazard on habitats, species or communities, the severity and likely duration of the effects, and what the operator has in place to prevent major accidents, limit their consequence to persons and environment, assess damage, and/or repair damage after an accident.

The COMAH Regulations also require operators of establishments handling prescribed dangerous substances to prepare on-site emergency plans, and the local authorities to prepare off-site emergency plans.

In the USA, two federal regulations apply to control of hazardous materials:

- USA - OSHA 29 CFR 1910.119
- US EPA Rule 40 CFR Part 68.

In addition, the control of Major Hazard Facilities (MHF) is dealt with by individual state regulations. All relevant laws and regulations appear in the Federal Code of Regulations.

To a large extent, meeting the regulatory requirements would implicitly result in a significant improvement in managing the risks in Major Hazard Facilities. This is further discussed in Chapter 13.

Some useful web sites regarding legislation are:

http://www.austlii.edu.au
- provides a list of legislation in Australia.

http://www.hse.gov.uk
- UK Health and Safety Executive site.

http://europa.eu.int/comm/environment/index-en.htm
- European Commission for the Environment.

http://www.epa.gov
- US Environmental Protection Agency

http://www.osha.gov
- US Occupational Safety and Health Administration

http://www.gpoaccess.gov.cfr
- US Code of Federal Regulations

1.6 REVIEW

Hazards and risks are the inevitable result of human activity. The only sure way of eliminating risk - that is the zero chance option is for the activity not to exist. There is no such thing as zero risk for any human activity.

In this chapter we have noted the fundamental difference between hazard and risk. Hazards have the potential to do harm, and arise from the materials or processes associated with the activity. Risk is the likelihood or chance of a nominated level of harm occurring either in a given time or under specified circumstances.

We also saw that there are various contributing factors to hazards, especially when related to activities involving dangerous substances. These must be controlled or eliminated depending on their importance and the viability of doing so. We could call these 'source' oriented factors. As well a popular view of risk which involves the level of outrage is a very real phenomenon and must be dealt with by governments and industry proponents. We all view the risk issue from quite different perspectives, conditioned by our worldview and our experiences.

The task of risk management is to identify risks and treat them accordingly. It is a structured, systems approach that provides the most effective means of achieving risk control.

In summary, the concept of hazard and risk may be put in a few simple words:

- Consider a situation.
- What can go wrong? (Hazard)
- What are the consequences if the hazard were realised? (Severity, one dimension of risk)
- What is the likelihood of the hazard being realised? (Probability, second dimension of risk)
- Have sufficient measures been adopted to prevent an unwanted outcome and/or mitigate its adverse effects? (Risk management)

1.7 REFERENCES

Cacciabue, P.C. 2000, ‘Human factors impact on risk analysis for complex systems’, *Journal of Hazardous Materials*, vol. 71, pp. 101-116.

CCPS, Center for Chemical Process Safety, *Human Factors in Process Safety Management* 1994, AIChE, NY., ISBN 0-81690-6246.

CHEM Unit 2004, Available at: http://www.emergency.qld.gov.au/chem/dangerous/classes.asp .

Chapman, C. and Ward, S. 1997, *Project Risk management - Processes, techniques and insights*, John Wiley.

Chiles, J.R. 2001, *Inviting Disaster - Lessons from the Edge of Technology*, Harper Business, ISBN 0-06-662081-3.

CSB, US Chemical Safety and Hazard Investigation Board 2000, Available at: http://www.csb.gov .

Dörner, D. 1989, *The Logic of Failure*, Perseus Books, USA, ISBN 0-201-47948-6.

EC96 1997, 'Seveso' II Directive (96/82/EC) on the Control of Major Accident Hazards involving dangerous substances, *Official Journal of European Communities*, L10/13-33.

EC99 1999, Directive 1999/45/EC on Classification, Packaging and labelling of dangerous preparations, *Official Journal of European Communities*, L200/1-68.

Grey, S. 1995, *Practical Risk Management for Project Management*, John Wiley.

Hopkins, A. 2000, *Lessons from Longford - The Esso Gas Plant Explosion*, CCH Australia, ISBN 1-86468-422-4.

International Electrotechnical Commission. *Dependability Management Pt3 Application Guide Section 9: Risk Analysis of Technological Systems*, International Electrotechnical Commission, IEC300-3-9:1995.

International Maritime Dangerous Goods (IMDG) Code, Available at: http://www.imo.org .

ISO/IEC, *Risk management -- Vocabulary -- Guidelines for use in standards*, Guide 73:2002.

Jones, D. 1992, *Nomenclature for Hazard and Risk Assessment in the Process Industries*, 2nd edn, The Institution of Chemical Engineers, Rugby, England.

Lewis, R.J. 1996, *Dangerous Properties of Industrial Materials*, 9th edn, Van Nostrand Reinhold, USA.

Milburn, M. and Cameron, I.T. 1992, *Planning for Hazardous Industrial Activities in Queensland,* Australian Institute of Urban Studies, May, ISBN 0-86419-814-0.

NOHSC, National Occupational Health & Safety Commission Australia. *National Code of Practice for the Labelling of Workplace Substance*, NOHSC 2012: 1994.

NOHSC, National Occupational Health & Safety Commission Australia. *Control of Major Hazard Facilities National Standard*, NOHSC 1014:2002 and *National Code of Practice*, NOHCS 2016:1996.

OSHA, Occupational Health and Safety Administration, USA. *Process safety management of highly hazardous chemicals*, Federal Register, Washington DC. OSHA 29 CFR 1910.119:1992.

Perrow, C. 1999, *Normal accidents - Living with High-Risk Technologies,* Princeton University Press, ISBN 0-691-00412-9.

Rasmussen, J. 1997, 'Risk management in a dynamic society: a modelling problem', *Safety Science*, vol. 27, no. 2, pp. 183-213.

Reason, J. 1990, *Human Error*, Cambridge University Press, UK, ISBN 0-521-31419-4.

Reason, J. 1997, *Managing the Risks of Organizational Accidents*, Ashgate, UK, ISBN 1-84014-105-0.

Standards Australia. *Risk Management*, Standards Australia. AS 4360:2004.

US EPA. *Environmental Protection Agency - Risk management programs for chemical accidental release prevention.* Federal Register, Washington D.C., June. Final Rule, 40 CFR Part 68, 1996.

Willey, R.J. 1998, *The Bhopal Disaster*, SACHE Slide Package, Center for Chemical Process Safety, AIChE, New York.

1.8 NOTATION

ADG	Australian Dangerous Goods Code
API	American Petroleum Institute, USA
AS	Australian Standards
BLEVE	Boiling liquid expanding vapour explosion
COMAH	Control of Major Accident Hazards, UK
CSB	US Chemical Safety & Hazard Investigation Board
DOT	Department of Transport, USA
EC	European Communities
EIA	Environmental impact assessment
EPA	Environmental Protection Agency
HEI	Human error identification
HMI	Human machine interface
HRA	Human Resources Analysis
IChemE	Institution of Chemical Engineers, UK
IEC	International Electrotechnical Commission
ILO	International Labour Organization
IMDG	International Maritime Dangerous Goods Code
ISO	International Organization for Standardization
IT	Information technology
LD_{50}	Lethal dose, 50% of population
LPG	Liquefied Petroleum Gas
LTI	Lost Time Injury
LTIR	Lost Time Injury Rate
LTIIR	Lost Time Injury Incident Rate
MHF	Major hazard facility
MTI	Medically treated injury
NOHSC	National Occupational Health and Safety Commission, Australia
OH&S	Occupational health and safety
OSHA	Occupational Safety and Health Agency, USA
PSM	Process safety management
RMP	Risk Management Plan
SEMP	Safety, Environmental Management Plan (USA)
TA	Task analysis
TLV	Threshold limit value
TMI	Three Mile Island, USA
TNT	Tri-nitro Toluene
UN	United Nations
UNEP	United Nations Environmental Program
VCE	Vapour Cloud Explosion