Chapter 15
Risk Analysis and Risk Management

The risk in a project is proportional to the square of the hype associated with it.

Abstract This chapter introduces the concept of risk, gives references to standards and major documents which deal with risk, and defines terms relating to risk. The procedures in the management of risk are then outlined and the legislative approach to risk is discussed and illustrated by an example. Various types of risk are described, and hazard analysis and the assessment of consequences are discussed. Factors in mitigating risk and contingency planning are presented. The chapter concludes with an example of risk analysis and management in a water supply system. Risk considerations in safety critical plant are addressed in the separate chapter under the title of "Safety." *Outcomes* After reading this chapter you will know how to analyze and treat risk. This will include an awareness of the legal approach based on meeting duty of care and regulatory obligations, and the analysis and assessment of risk in relation to projects and to plant and machinery. You will be aware of techniques of hazard analysis, the assessment of consequences, the use of contingency allowances, and of methods of mitigating risk. You will have seen how risk analysis was used in a water supply system application.

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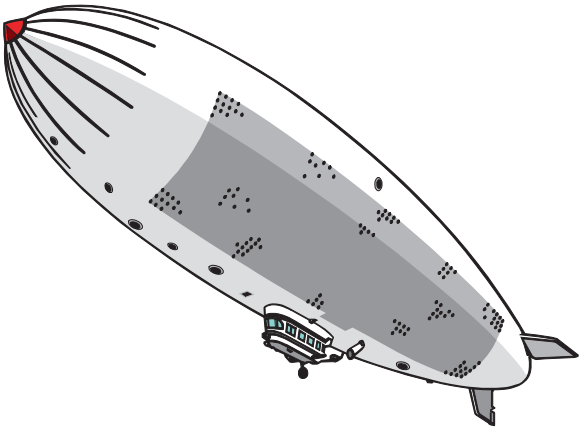
15.1 Aim



The aim of risk analysis and risk management is to address four fundamental questions:

- What can go wrong?
- How likely is this to happen?
- What are the consequences if it does?
- How can the likelihood and consequences be reduced or mitigated?

Risk is a very broadly based concept, and one whose range has expanded in recent times to cover everything except a racing certainty. There is a strong emphasis on risk in the ISO 55000 Asset Management standards.[1]

15.2 References

The following documents deal in detail with the issue of risk in a variety of contexts.

- ISO 31,000 Risk management—Principles and guidelines.
- ISO 31,010 Risk management—Risk assessment techniques.
- ISO/IEC Guide 73, Risk management—Vocabulary—Guidelines for use in standards.
- AS 3931 or IEC 60300-3-9. Risk analysis of technological systems.
- IEC 61882. Risk analysis in chemical plants and other high risk environments: HAZOP—Hazard and Operability Studies. Hazard and Operability Studies Application Guide.

[1] ISO 55001 Clause 6.1 'Actions to address risks and opportunities…' "The organization shall plan actions to address risks and opportunities…."

- API 580 and API 581 Risk-Based Inspection. Oil and gas industries. There are many publications and training programs from the American Petroleum Institute.
- Lees' "Loss Prevention in the Process Industries" published by Elsevier, (3 volumes) provides a comprehensive cover of risk.
- ISO 22,000, Food safety management systems—Requirements for any organization in the food chain.
- Hazard Analysis Critical Control Point—HACCP is a system which identifies, evaluates, and controls hazards in the food industry. It is used internationally to provide assurance that food is safe for consumption. Guidelines are issued by the Codex Alimentarius Commission.

15.3 Risk Analysis

Risk analysis is concerned with identifying risks and assessing potential likelihood and consequences. Events can have favorable as well as unfavorable consequences, for example, a construction project may encounter good or bad weather. Risk analysis should assist us to avoid adverse effects, and to be prepared to deal with them if and when they do occur. Risk assessment involves a willingness to consider possibilities which we would rather not consider.

Over zealous commitment to a project and the wide engagement of senior personnel and high-level stakeholders make it harder to admit and avoid risk. Had the voyage of the Titanic not been such a high-profile event, it is most probable that the ship's captain would have slowed down and not hit an iceberg at fatal speed.

15.4 Definitions

ISO Guide 73 defines a range of terms relating to risk. The following are key terms:

Risk the chance of something happening (an event) that will have an impact on objectives.

Hazard a source of potential harm.

Consequence the outcome of an event in the form of loss, gain, disadvantage, advantage, or injury.

Likelihood a qualitative description of probability or frequency of occurrence of an event.

15.5 Management of Risk

Risk management involves recognizing risk and taking steps as may be necessary to reduce the potential effects. This involves the creation of roles, responsibilities, and authorities in relation to risk.

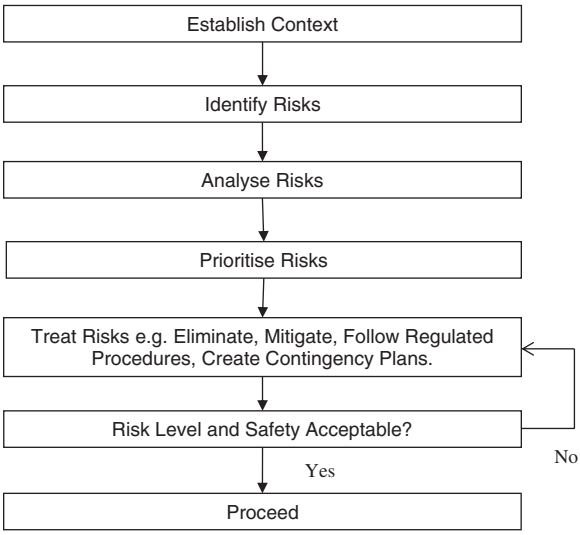


Fig. 15.1 Risk management outline

In practice, this means that a hazard analysis is undertaken in which we make a list of the risks, known as a risk register. We then analyze the risks, considering their significance and how they may be overcome or mitigated. We then create the necessary controls, procedures, and contingency plans. A general outline of the procedure is shown in Fig. 15.1, which is based on diagrams in the standards previously cited.

In setting roles, responsibilities, and authorities, the general principle is that managers with budgetary authority over an area have responsibilities for risk in that area. This is because budgetary authority is required in order to take the steps necessary to address any risk issue.

Specialist advice is also likely to be required in relation to technical functions and specific hazards. For this purpose, we may create a company-wide risk assessment team which specializes in understanding the types of risk that occur in the business. This can be a task of the asset management group, or the relevant asset manager, but it is also important to engage local operations personnel. Specific equipment specialists, legal liability specialists, and health, safety, and environmental specialists may be involved as necessary. The risk assessment team advises on the analysis of risk, risk mitigation activity, and contingency plans and recommends funding support to the regular budgetary authority, such as a plant manager.

15.5.1 Risk Management Documents

To manage risk, appropriate documentation is required. Key documents are:

- Risk Management Policy Statement;
- Risk Register showing identified risks and risk ratings;
- Risk Treatment Schedule and Plan; and
- Risk Action Plan.

Examples are given later in this chapter.

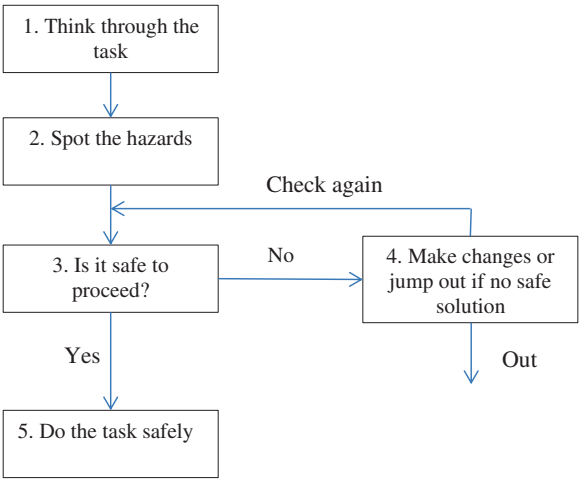


Fig. 15.2 Take 5 Risk management process

15.6 Take 5[2]

Take 5 is technique aimed at encouraging the widespread adoption of risk management, by summarizing the process in a simple form. In the Take 5 process, the individual reviews the job, the workplace, the system of work, and the work environment immediately prior to starting a task. The individual is responsible for the decision to proceed with the task or not, based on the Take 5 process outcomes. If it is unsafe, the task must not be started. Figure 15.2 shows the step by step process.

15.7 Legislative Approach

The legal approach to risk centers on meeting the requirements of existing legislation, existing standards or, in the absence of these, of good practice. It is important to be aware of legislation and related standards which apply to your activities, and to comply with these. The documents listed earlier in this chapter form a useful starting point, and some other relevant standards are listed in the Standards section at the end of this book.

A *duty of care* exists (under Common Law) where there is a foreseeable and predictable cause and a hazardous effect and where it is practicable to remove the cause or control the effect. If a zoo keeps a tiger, it is up to the zoo to ensure that the tiger does not get out and kill someone. Conforming to an appropriate regulation can provide a legal defense in a prosecution for breach of an obligation. Where there is no defined regulation, you must be able to show that you took

[2] BHP Billiton Western Australia Iron Ore Health and Safety Take 5.

reasonable precautions and exercised due diligence in managing exposure to risk. If the procedures associated with the precautions are not documented, then they do not exist!

Maintenance specified by a manufacturer must be carried out unless a convincing reason otherwise can be presented. The maintenance that is carried out must be recorded. Regulations applying to the design or operation of equipment must be complied with, and good practice must be followed in regard to issues such as operation and supervision by competent persons. This will often extend to the assessment of equipment condition by technically qualified staff.

Figure 15.3 illustrates the issue of satisfying a duty of care in an application involving an electricity cable. A contractor digs up and severs the cable causing damage and disruption to businesses. The contractor argues that the electricity company which owns the cable has failed in its duty of care. The duty of care of the electricity company covers four regulated features;

- marking the position of the cable;
- placing it at the correct depth;
- aligning it correctly in relation to nearby buildings; and
- providing protection in physical and electrical terms (e.g., circuit breakers).

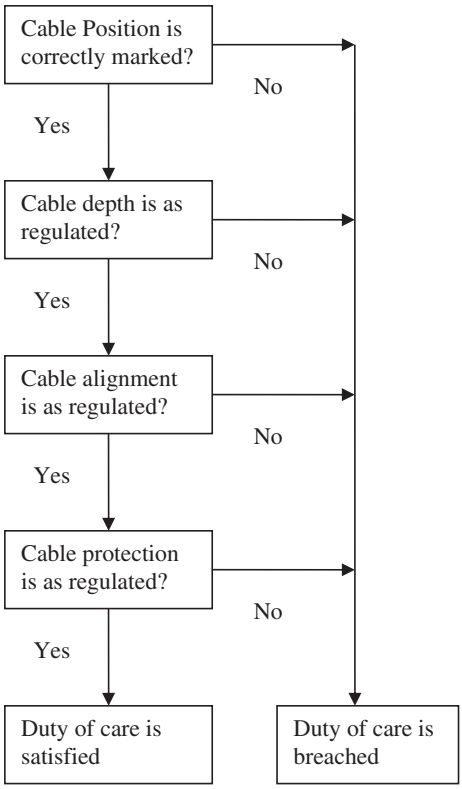


Fig. 15.3 Satisfying a duty of care

If the electricity company has carried out these duties correctly, it will have a presentable defense against the contractor's arguments.

15.8 Types of Risk

15.8.1 Sovereign Risk

Sovereign risk is risk associated with high-level events outside your organizational control, particularly those involving government actions.

- Government changes the law, the regulatory rules, or the level of subsidies after you have invested;
- Political change of sentiment;
- War and peace.

Sovereign risk may be offset by *force majeure* clauses in a contract which specify that certain risks are excluded from the contractor's liability.

15.8.2 Solution Risk

Solution risk is where the expected solution to a problem, or the technology underlying a project, turns out not to work or to be prohibitively expensive. Solution risk is easy to overlook or underestimate. Many major losses have occurred because the wrong solution was selected for a development. Project managers should be aware of this issue and avoid excessive commitment to a solution which is in fact unproven. If in doubt, undertake a pilot study or do more research.

15.8.3 Technical Development Risk

Development work is notoriously risky. Assumed technical progress is often not realized. Projects involving software, combining software and hardware, or integrating of two or more systems are particularly difficult. It is advisable to regard development strictly as development, and not to jump into a production phase before a concept is proven.

15.8.4 Performance Risk

The performance resulting from development may prove to be unsatisfactory. Production or support aspects of a development may prove unsatisfactory, or new developments may overtake the original concept.

15.8.5 Commercial or Financial Risk

Sales may not be realized—fewer buyers or users may appear than forecast. The profit margin will then be eroded by lack of sales. Competition is another factor that can depress sales. Costs may be higher than forecast, leading to an eroded profit margin. Anticipated capital funds may not become available.

15.8.6 Administrative Risk

Risks can arise from events inside your organization but outside your project. Other departments do not commit; there are delays in or lack of approvals, and delays in, or nondelivery of, related activities needed for your project. A rendezvous is a weakness in a plan.

15.8.7 Safety and Environmental

Safety and environmental impact are often risk factors. Extensive legislation and procedures relating safety and environmental protection are normally specified for any hazardous industry or occupation and the relevant rules must be identified and followed. Safety is discussed further in the chapter with that title.

15.8.8 Supplier Risk

A supplier may fail to deliver, or there may be delay in delivery. There may be changes to pricing or level of support.

15.8.9 Resources

Physical facilities or human resources in design, development, acquisition, production, operations, or sales may fail to eventuate.

15.9 Hazard Analysis

Hazard analysis means considering all the things that might go wrong and making a list of them. This is a basic step in addressing risk. Hazard analysis should be carried out by persons with a thorough knowledge of the plant or service characteristics and methods of operation—steady-state and transient. Formal processes have been developed and extensively documented to assist with hazard analysis, including the following. References are given in the references section at the beginning of this chapter.

- Hazard Identification (HAZID)
- Hazard and Operability Analysis (HAZOP)
- Failure Mode and Effects Analysis (FMEA)
- Risk-Based Inspection (RBI).

15.10 Consequences

A *consequence* is the result of an adverse event occurring. Consequences associated with risk include the following:

- loss of business, at minor or major level;
- legal liability and costs;
- loss of reputation;
- lost production;
- project failure;
- project delays or additional costs;
- emergency service costs;
- repair costs;
- secondary damage;
- adverse environmental impact;
- injury; and
- loss of life.

Figure 15.4 illustrates an adverse consequence of risk.

15.11 Risk Analysis and Risk Rating

Risk analysis is an assessment of the seriousness of the risks that we have identified. As part of the analysis, we consider any existing controls that may be applied and the effectiveness of those controls.

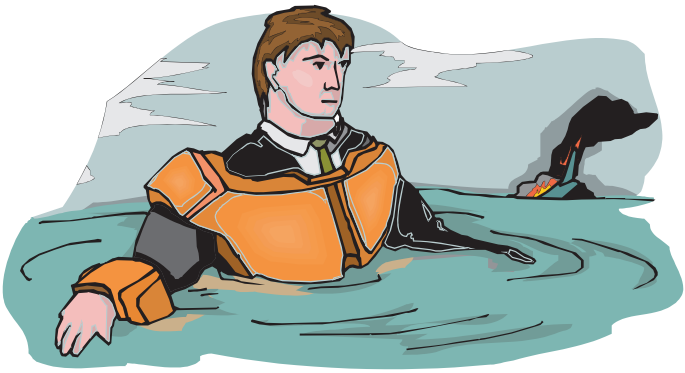


Fig. 15.4 An adverse consequence of risk

At its simplest, risk analysis may be done by a direct judgment approach in which we rate and rank the risks. We then proceed to consider how we might reduce or mitigate those risks that we have judged to be sufficiently serious to warrant attention.

A more structured approach is to apply qualitative scales to assess the likelihood of each risk the consequences if it occurs. The likelihoods and consequences are then combined to determine a risk rating. Table 15.1 Risk Level Matrix, shows the approach. This is based on the type of risk matrix in IEC 30010.

15.11.1 Risk Matrix

In Table 15.1 the following qualitative ratings are used. An alternative is to use 1–5 numeric ratings.

- *Likelihood* Rare, Unlikely, Moderate, Likely, and Almost Certain
- *Consequence* Insignificant, Minor, Moderate, Major, and Severe
- *Risk Rating* Low, Medium, High, and Extreme.

Table 15.1 Risk level matrix

Likelihood	Consequence				
	Insignificant	Minor	Moderate	Major	Severe
Almost certain	Medium	Medium	High	High	Extreme
Likely	Medium	Medium	Medium	High	Extreme
Moderate	Low	Medium	Medium	High	High
Unlikely	Low	Low	Medium	Medium	High
Rare	Low	Low	Low	Medium	Medium

We may then specify that the various levels of risk call for action to be taken at suitable levels of management and within suitable time scales, such as the following:

- *Extreme* Immediate executive action is required
- *High* Executive action is required
- *Medium* Management assignment of action and responsibilities is required
- *Low* Manage using routine processes.

15.11.2 Consequence Ratings

In manufacturing applications, the consequence rating options might take the following form:

Consequence ratings

- Insignificant,
- Customer complaint,
- Product recall,
- Serious illness/injury,
- Fatality.

15.12 Risk Register

Each identified risk should be entered into a risk register. The format may vary with the various techniques. For each risk identified, a risk register records such factors as:

- source;
- nature;
- existing controls;
- likelihood and consequences;
- initial rating; and
- vulnerability to change.

15.13 Mitigating Risk

The primary reason for considering risk is in order to avoid undesirable consequences. This means that we need to take steps to eliminate, mitigate, or reduce risk.

It is often not possible to eliminate risk entirely, and in this case the aim will be to substantially reduce risk. One approach to this is described as reducing risk to a level which is As Low As Reasonably Practicable (ALARP). An alternative terminology is that risks should be reduced So Far As is Reasonably Practical (SFAIRP). There is debate about how different these approaches are. ALARP may be said to imply some form of numerical estimation of the remaining risk. SFAIRP is described as "precautionary," meaning that evident precautions should be taken, without implying that numerical estimation is involved. The precautionary or SFAIRP approach appears to carry more legal weight.

At the general business level, some techniques which we may use to reduce risk are as follows:

- Risk identification to create awareness and good practice.
- Creating and implementing plans to reduce risk.
- Adopting safety precautions.
- Contingency planning.
- Contract terms to limit business risk.
- Using the skills of a group of experts to assess risk and mitigate risk.
- Use skills of experienced estimators and managers in creating and managing projects.
- Record and apply corporate knowledge of previous risks.

In the remainder of this section, we provide a brief resume of more technical techniques in the risk mitigation area, but note that it is important in practice to be aware of and follow the detailed techniques relevant to the actual situation of any particular industry or service.

15.14 Contingency Planning[3]

Contingency planning is making plans to be brought into effect if adverse conditions eventuate.

15.14.1 Contingency Allowance

Contingency allowances are a common way of allowing for risk in projects. Typically, 10–20 % contingency funds will be allowed in project budgets. The level depends on an assessment of the risks. Contingency allowances are best held on a central basis, as this allows for flexibility. However, the existence of contingency allowances should not be taken as a substitute for good management.

[3] ISO 55001 Clause 6.2.2: "The organization shall ensure that…risks are considered…including contingency planning."

15.14.2 Contingency Plan

An example from a contingency plan is shown in Fig. 15.5, which shows the locations to be adopted by crew members of a passenger ferry in the event of various types of emergency. Further detailed procedures for different circumstances would form part of the contingency plan.

15.14.3 Retirement of Risk

When a risk is no longer relevant, it should be retired from the analysis and any corresponding contingency allowance should then be discontinued. An issue that arises is whether, as contingency funds are retired, they should be applied to increasing capability within the same project or should be returned to higher levels for reallocation. In principle, return to higher level is the norm, but project managers often put forward strong and successful cases for using retired contingency to enhance their particular project.

15.15 Quantitative Risk Analysis

Quantitative risk analysis works in terms of a definition of risk as a probability.

Person	**Fire**	**Collision**	**Mechanical Failure**
Captain	Bridge	Bridge	Bridge
1st Officer	Direct fire fighting priorities	Assess and report damage status	Assess and report navigational status
2nd Officer	Report fire status	Monitor external danger	Monitor external danger
Engineer	Engine room	Damage site, direct action	Failure site, direct repairs
Assistant Engineer	Manage fire fighting	Engine room	Engine room
Crew	Fight fire	Repair activities	Repair activities
Radio Op.	Send alarm	Send alarm	Notify status
Chief Steward	Control passengers	Control passengers	Communicate with passengers
Stewards	Lifeboat stations	Lifeboat stations	Assist passengers

Fig. 15.5 Contingency plan for passenger ferry

Concepts in a quantitative approach are,

- *Probability of occurrence* The probability that an event occurs in some defined period or situation of risk.
- *Occurrence Rate* The average number of times an event occurs per year, or other time interval.
- *Risk-cost* The probability that an adverse event occurs multiplied by the cost if it does.
- *Risk-cost per year* The occurrence rate of events per year × $ cost per event.

Techniques for estimating risk-cost include the following:

- statistical analysis of failure and successful performance data
- "gut feel" based on experience and judgment
- use of event trees, or simulation.

Although risk-cost can be a guide to our thinking, the product of a very low occurrence rate multiplied by a very high cost does not always result in a meaningful number when related to conventional financial analysis.

The risk-cost of business liabilities can be difficult to assess. It is desirable to get senior management to make an assessment of potential risks and costs, as middle management can waste time and resources on excessively detailed studies, when a decision, say to replace or retain a certain group of old equipment, may be quickly made by a senior manager with a more overall view of the situation.

15.16 Other Methods[4]

Other methods of risk analysis involve a more analytical or detailed level of approach. These include:

a. Analysis of reliability and maintenance data.
b. Use scaling systems for factors such as event probability, severity, and detectability as in Failure Mode and Effects Analysis (FMEA).
c. Application of hazard indices, see for example, Lees' op cit, Volume 1, Chap. 8.
d. Analysis of wear rates based on materials and operational temperatures and pressures, as applied in Risk-Based Inspection.
e. Test and evaluation procedures, for example in estimating fatigue life or corrosion or degradation rates under specified conditions.
f. Event trees.
g. Fault trees analysis, described, for example, by J.P. Bentley, "Quality and Reliability Engineering", Longman.
h. Sensitivity analysis for various scenarios: Optimistic, Best Estimate, and Pessimistic.

[4] An extensive list of risk analysis techniques is given in IEC 31010.

i. Risk adjusted discount factor. The discount factor is increased to penalize risky investments.
j. Simulation modeling including reliability block diagrams.

15.17 Project Risk Examples

These are some examples of risks in acquisition projects.

Machinery is being purchased from an overseas supplier whose technical documentation, operating procedures, and training manuals are in another language. A local contractor has been engaged to provide translation of the documentation, and adaptation to local technical and environmental standards. The possibility that the local contractor has bitten off more than he can chew constitutes a risk in the overall acquisition and deployment.

A number of complex machines are being made to order. Demand on the manufacturer for products generally is rising, and there is a risk that our production will be delayed. Although this will give rise to cost penalties, the negative impact on our company may be significant.

Equipment may fail acceptance requirements. This is always a possibility, but the position will become clearer from early results and supplier responses to problems.

15.18 Water Supply System Example

The following example, relates to the assessment of risk in a water supply system. The system involves pumping water from a river to supply an irrigation system and a town. A flowchart of the system is shown in Fig. 15.6. The heavy arrows indicate water flows.

The hazards were identified using the system flowchart and fault trees. The flowchart identified each component of the system, e.g., pumps, rising main, pipes, valves, channels, power supply, switchboard, control system, and communication system.

Fault trees were then used to identify possible faults in each component. Figure 15.7 shows an example.

For each possible fault, risk assessments were then made. The results were recorded on forms using the concepts suggested in the risk standards, although the actual form layouts were specific to the application. Examples of completed forms are shown in Fig. 15.8.

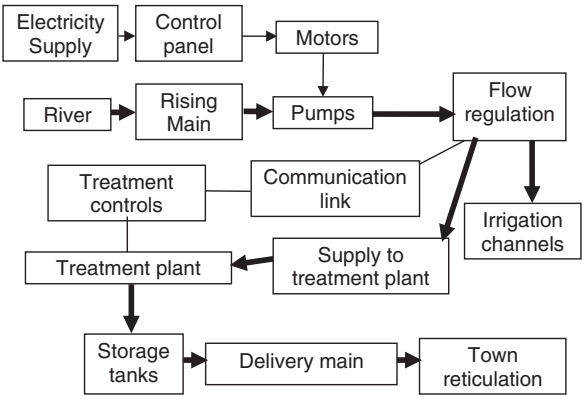


Fig. 15.6 Flow chart for water supply system

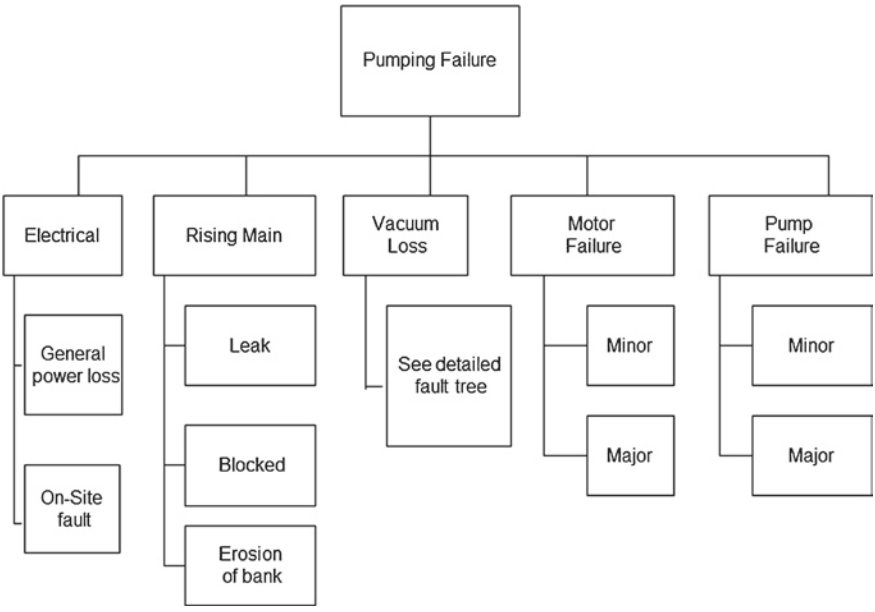


Fig. 15.7 Fault tree for pumping failure

Fig. 15.8 Hazard analysis risk ranking scale

0 =Zero
1=Very Low,
2=Low,
3=Medium,
4=High,
5=Very High

15.18.1 Hazard Analysis

In this application, the fault or hazard rate assessments were based qualitatively on the scale shown in Fig. 15.9. The scale was refined by allowing noninteger values in the range 0–1 to reflect varying degrees of likelihood of rare events.

The nature of the risks was assessed under the headings:

- Safety,
- Cost,
- Function,
- Environment.

The consequences were assessed on the same 1–5 scale as Fig. 15.8, giving a risk rating under each heading. A risk rating was then calculated for each potential fault using the formula:

$$\text{Risk Rating} = \text{Hazard Rate} * (\text{Safety} + \text{Cost} + \text{Function} + \text{Environment.})$$

For example at Ref. 3 of the Risk Register in Fig. 15.9, the following hazard analysis is shown:

1. Hazard is "Unable to Supply Water Due to Pump Failure"
2. Hazard Rate: 3 = Medium
3. Consequences:
   a. Safety: 1 = Very Low
   b. Cost: 4 = High
   c. Function: 5 = Very High
   d. Environment: 1 = Low

$$\begin{aligned}\text{Risk Rating} &= \text{HazardRate} * (\text{Safety} + \text{Cost} + \text{Function} + \text{Environment}) \\ &= 3 * (1 + 4 + 5 + 1) = 33\end{aligned}$$

The highest score (worst case) is a rating of 100.

Mitigation for this hazard (pump failure) was to have a trailer-mounted standby pump available to cover a number of locations and applications.

15.18.2 Risk Treatment

Examples of a risk treatment analysis and risk treatment plans are shown in the second and third parts of Fig. 15.9. The example focuses on the risks associated with failure of the control switchboard of the water supply system. This is the hazard listed at Ref. 7 in the risk register on the first page of Fig. 15.9. In this study, the risk of loss of the switchboard, due to a fire, flood, or cyclone, for example, was considered significant, and a risk treatment analysis was developed.

Risk Register		Compiled by	NAJH			Date		
Title	Irrigation System	Revised by				Date		
Ref.	Hazard	Current Controls	Rate	Safety	Cost	Func-tion	Enviro-nment	Risk Rating = R*(S+C+F+E)
1	Unable to supply water due to leak in rising main resulting	None	2	1	5	5	1	24
2	Unable to supply water due to pipework seal failure.	Inspect annually	2	2	3	3	2	20
3	Unable to supply water due to pump failure	Routine maintenance	3	1	4	5	1	33
4	Flooding of property.	Operating procedures	1	3	2	2	2	9
5	Unable to supply treated water to town due to control failure.	Communication link	1	3	3	3	5	14
6	Unable to supply water due to switchboard minor failure.	None	1	1	2	5	1	9
7	Unable to supply water due to switchboard major failure.	None	1	2	5	5	1	13

Fig. 15.9 Water supply risk documents

Risk Treatment Schedule and Plan	**Compiled by NAJH**	**Date**	23-Dec-00		
Title: Irrigation System	**Revised by**	**Date**			
Ref. Hazard	**Current Controls**				
7. Unable to supply water due to switchboard major failure.	None				
Treatment Options	**Cost Benefit Summary**				
A. Upgraded fire detection and alarm system and regular thermographic monitoring.	A. Cost estimate $20,000 plus $3000 per year. May not entirely prevent failure.				
B. As option A but with additional contingency plan with jury rig switchboard which can be activated in 6 hours.	B. Cost estimate $30,000 plus $5000 per year. Loss of supply for 6 hours may occur.				
C. Keep standby switchboard.	C. Initial cost $100,000. Also significant costs in maintaining duplicate board as system develops.				
		Initial		**Revised**	
Implementation Recommendation:	Option B.	Rate	0.2	Rate	0.02
Person responsible:	Northern Engineering Manager.	Safety	2	Safety	2
Action Plan Reference:	AP 4/2000	Cost	5	Cost	5
Timing:	To be in place by 1 July 2001	Function	5	Function	5
		Environment	1	Enviro	1
		Risk Rating	2.6	Risk Rating	0.26

Fig. 15.9 (continued)

Risk Action Plan		Compiled by:		Date:
Title:	Irrigation System	**Reviewed by:**		**Date:**
Hazard:	7. Unable to supply water due to switchboard major failure.	**Ref.**		
Summary	A. Upgraded fire detection and alarm system and regular thermographic monitoring.additional contingency plan with jury rig switchboard which can be activated in 6 hours.			
Ref. No.	**Proposed Action**	**Responsibility**	**Timing**	**Resource Reqts.**
7.1	Install upgraded smoke alarm and fire detection system	Northern Engineering Manager	by 1/3/2001	
7.2	Install carbon dioxide spray system.	Northern Engineering Manager	by 1/3/2001	
7.3	Establish contract for thermographic monitoring.	Operations manager	ASAP	
7.4	Commission design and manufacture of limited function standby board.	Electrical engineer	by 1/2/2001	
7.5	Install limited function standby board.	Electrical contractor	by 1/7/2001	
	Reporting and Monitoring Required	**Responsibility**	**Timing**	**Resource Reqts.**
7.1.M	Annual functional check of smoke alarm and fire detection system.	Operations manager		
7.2.M	Annual check of carbon dioxide spray system.	Operations manager		
7.3.M	Three monthly thermographic condition monitoring.	Operations manager		
7.4.M	Report to Northern Engineering Manager when limited function standby board ready for installation.	Electrical engineer		
7.5.M	Confirm installation of board to Operations manager.	Electrical contractor		

Fig. 15.9 (continued)

Risk treatment analysis considers the options for treating the various risks. An *action plan* documents the management controls to be adopted and lists the following information:

- Who has responsibility for implementation of the plan.
- What resources are to be utilized.
- Budget allocation.
- Timetable for implementation.
- Details of the mechanism and frequency of review of compliance with the treatment plan.
- Urgent repair or replacement.
- Nonurgent repair or replacement.
- Plant redundancy.
- Insurance spares.
- Contingency plans.
- Condition assessment and monitoring.

15.18.3 Monitoring and Audit

Monitoring and audit records should document:

- Details of the mechanism and frequency of review of risks and the risk management process as a whole.
- The outcomes of audits and other monitoring procedures.
- Details of how review recommendations are followed up and implemented.

Risk tends to increase as items enter the wearout phase. This is due to the long-term degradation of materials such as decay of plastics and other insulating materials, rust, wear, vibration, fatigue, creep, and physical impact. Monitoring of risk should involve a review of current asset condition in relation to these factors.

15.19 Exercises

15.19.1 Self-Assessment Exercise 15.1

1. Identify four basic questions which risk analysis and management techniques are intended to address.
2. Give definitions of the terms Risk, Hazard, Consequence, and Likelihood.
3. Give definitions of Sovereign Risk and Solution Risk.
4. Identify four types of document used in the analysis and management of risk.
5. Identify four methods which can be used to reduce or mitigate risk.

15.19.2 Self-Assessment Exercise 15.1 Solution

1. *Identify four basic questions which risk analysis and management techniques are intended to address.*

   a. What can go wrong?
   b. How likely is this to happen?
   c. What are the consequences if it does?
   d. How can the likelihood and consequences be reduced or mitigated?

2. *Give definitions of the terms Risk, Hazard, Consequence and Likelihood.*

   a. *Risk* the chance of something happening (an event) that will have an impact on objectives.
   b. *Hazard* a source of potential harm.
   c. *Consequence* the outcome of an event in the form of loss, gain, disadvantage, advantage, or injury.
   d. *Likelihood* a qualitative description of probability or frequency of occurrence of an event.

3. *Give definitions of Sovereign Risk and Solution Risk.*

   a. Sovereign risk is risk associated with high-level events outside your organizational control, particularly those involving government actions.
   b. Solution risk is where the expected solution to a problem or the technology underlying a project turns out not to work or to be prohibitively expensive.

4. *Identify four types of document used in the analysis and management of risk.*

   a. Risk Management Policy Statement;
   b. Risk Register showing identified risks and risk ratings;
   c. Risk Treatment Schedule and Plan; and
   d. Risk Action Plan.

5. *Identify four methods which can be used to reduce or mitigate risk.*

Any of the following:

   a. Risk identification to create awareness and good practice.
   b. Creating and implementing plans to reduce risk.
   c. Adopting safety precautions.
   d. Contingency planning.
   e. Contract terms to limit business risk.
   f. Use skills of experienced estimators and managers in creating and managing projects.
   g. Record and apply corporate knowledge of previous risks.
   h. Delphi technique. A group of experts are used to assess risk.