RISK ANALYSIS

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INTRODUCTION TO SECOND EDITION

Three years ago, the introduction to the first edition of Risk Analysis began with a listing of major disasters. Since 1987, this list can be added to by such events as the King's Cross tube fire, Piper Alpha, Clapham rail crash, Lockerbie, Hillsborough and many others. All of those are in addition to the less dramatic catalogue of losses by fire, theft, accident, injury and disease.

The terrible toll of risk shows no sign of reducing and it is ever more important that organisations take steps to respond to risk in appropriate ways.

The first step in any risk management programme is the identification of risk. Nothing can be done by way of control and management unless risks are identified. The focus of this text remains the identification and analysis of risks.

Prof. G.C.A. Dickson
Glasgow December 1990

INTRODUCTION TO FIRST EDITION

Events such as those at Flixborough, Three Mile Island, Mexico City and Zeebrugge have impressed upon the public the importance of risk and of being able to identify it. In a much less dramatic way we are all exposed to risk both in our private and business life. The toll of risk in financial and human terms continues to increase each year and if risk is to be managed then the first step is to ensure that we have adequate mechanisms for identification and analysis. There can be little doubt that as business becomes more and more complex there will be ever increasing demands on those whose task it is to identify risk.

This book looks at the whole question of risk analysis. It starts with individual people and examines their attitude to risk and then moves on to the more objective ground of identification methodologies and statistical risk analysis. It concludes, as it started, with people and the communication of the results of risk analysis by means of reports.

Those who are new to the business of risk analysis will find that they are unfamiliar with many of the concepts in this book. They are however concepts which are widely used in industry. It is worthwhile remembering that the techniques of risk identification and analysis are practical and not theoretical tools. They had their origin in solving practical problems and so while you may not use all of them they nevertheless have their part to play. It is not possible to cover every industry type and so readers will have to take the basic theory and apply it to their own industry as best they can. However, risk analysis is important in its own right quite apart from any particular form of risk or individual industry.

Finally, I have benefited from discussions with very many risk managers over the years and I hope that this is reflected in the text. While it may be possible to measure the part other risk managers have played, the contribution of ones own family is beyond measure and their continued support is acknowledged now.

Dr G. C. A. Dickson

Glasgow, October 1987

Risk Analysis

Chapter One

RISK ANALYSIS

1.0 No course in Risk Management would be complete without the inclusion of a major component on risk analysis. Risk analysis acts as a kind of hub, around which many other practical aspects of risk management rotate.

This book concentrates on risk analysis and later in this chapter we will outline the scope of the book. In the meantime let us be clear what we mean by risk analysis. Collins New English Dictionary defines analysis as 'the division of a physical or abstract whole into its constituent parts to examine or determine their relationship'.

This is a good way to begin to think about the task of risk analysis. We are going to divide risk into its constituent parts. Viewed this way, risk analysis is more than just the identification of risks or the measurement of risk. It is a far broader task which will incorporate these two specific functions and others.

The diagram in Fig. 1.1 shows the various stages of risk analysis.

Fig. 1.1

Every risk is caused by some factor or factors and results in some effect or effects. It can be viewed rather like a chain. The cause is linked to the nature of the risk and the risk itself is linked to the effect. Risk analysis is necessary at each stage in the chain.

There is need for the analysis of causes not yet known. We must look, in other words, for potential causes of risk. For example we must be vigilant in monitoring the use of new chemicals or other hazardous substances. New processes or methods of construction must be looked at carefully. Risk analysis is not limited to identifying those things which we know can cause loss.

The second link is between known causes and risk. We must apply careful and rigorous analysis to ensure that all known causes of risk are high-lighted.

Thirdly we must evaluate the impact of risk on an organisation, this is the third link, and at the fourth and last link we must ensure that all effects are identified not just ones which have previously occurred.

1.1 The Nature of Risk Analysis

So far we have not said exactly what we mean by risk analysis. We have decided that it is a comprehensive task involving the risk manager and his department in a great deal of work, but what does that work entail?

For the purposes of this course and text book, we have divided risk analysis into three broad areas. Those areas are not necessarily of any operational importance but they should help us to build up a picture of all that is involved in the analysis of risk.

1.1.1 Risk and Human Behaviour

The first of our three aspects of risk analysis looks at the psychology of risk. It is important that those who will carry out risk analysis understand how others view risk and how they behave in the face of risk. If we understand a little better how people respond to risk then we may be able to frame our proposals and suggestions to them in different ways.

It is also important that we understand how people behave in groups as this is such an important aspect of business life. Many decisions are taken by groups or committees and the risk manager will often find himself having to report to or convince a committee on some point or other.

Chapter two looks at this whole area and attempts to provide a practical insight into risk and human behaviour.

1.1.2 Risk Analysis Methodology

The risk manager is not without practical assistance when he begins the task of risk analysis. He can call on an armoury of techniques designed to aid his task. It is unlikely that one technique will solve all problems or indeed that one technique alone is suitable for all industry types. There is a range of techniques, some of which are quantitative in nature and some qualitative on which he can call.

These techniques have all been developed in the industrial setting, normally in response to some practical business problem and they include, physical inspections, organisational charts, check lists, flow charts, fault trees, hazard and operability studies and hazard indices.

Chapters three and four concentrate on these techniques and make use of a practical business problem which is followed through the two chapters.

1.1.3 Statistical Analysis

There is no doubt that we are moving into an era when the use of numbers will become more and more important. The inexpensive desk-top micro computers mean that many computational processes can now be carried out with ease and with the minimum of expertise.

In the field of risk management where data should be readily available then it is essential that the modern risk manager be aware of the uses to which he can put statistical analysis. Chapters five, six and seven provide an introduction to both statistics and probability by introducing readers to the basic concepts. The theory has been kept to a minimum and the emphasis is very much on practical application.

As we said earlier, these three aspects of risk analysis should not be looked upon as discrete components of the one discipline. They are split in this way only for the purposes of learning and in the real world there should be a large measure of transferability among the three.

1.2 The Cost of Risk

Before moving on to look at all of these three aspects of risk analysis we shall take time here to place risk in perspective and to consider its cost.

Events at Flixborough, Seveso, Bhopal and Chernobyl have served to concentrate the mind of many on the catastrophic cost of certain risks. Fortunately these large scale incidents are relatively infrequent and the day-to-day work of the risk manager revolves around much smaller incidents. They may be smaller but the personal suffering and financial effect may be just as acute.

1.2.1 The Costs to Individuals

For individuals the cost of risk can be measured in a number of ways. There are those risks which involve a personal injury, a loss of personal effects, damage to property and so on. There will be few people in the country who have not suffered at the hands of some risk or know someone who has.

The following Table illustrates some national figures for different forms of risk:

The Reality of Risk

Type		*Number*
Road Casualties[1]	- Deaths	5,052
	- Serious Injury	63,491
	- Slight Injury	253,762
Fatal Work Injuries[2]		659
Thefts of or from vehicles[3] (England & Wales)		987,336
Burglaries in private houses[3] (England & Wales)		441,02

[1] Central Statistical Office - table 13.4 (1989)
[2] Annual Abstract of Statistics - table 3 36 (1987)
[3] ABI Facts and Figures (1988)

These incidents are everyday occurrences and put risk in perspective as far as individuals are concerned. What these figures show is that, for example, there are more than 37 road casualties every hour of every day throughout the year, that there are almost two thefts of or from vehicles every minute throughout the year and that 50 houses are burgled during the time it takes you to watch your favourite soap opera.

1.2.2 The Costs to the Country

Measuring the impact of risk on the country as a whole is a much more difficult task. We can fairly easily ask individuals how much they lost, for example in a fire, and what the personal trauma was like. It is not so easy to ask a large company and it is almost impossible to gauge the impact of, say, the fire risk on a country.

What we can do is look at some of the available figures.

The estimated fire damage for 1988 was £645.9m. This means that, on average, £20.76 went up in flames every single second of that year. Put another way it means that if this loss was to be borne by the population, every man, woman and child would have to pay £11.58, or if we limited payment to those in work then such people would have to pay £30.93.

It is important to make one point in relation to the cost of fire damage. It is that the fire waste figure of £645.9m for 1988 does not include, according to the Association of British Insurers, "losses to the economy caused by disruption of business and employment, lost overseas markets and lost production". The figure of £645.9m is simply the material damage figure, whether insured or uninsured. This means that all business interruption losses i.e., loss of profits, increase in cost of working etc., together with all the spin-off effects of fires are not included.

It is impossible to measure what multiplier should be applied to the fire damage figure in order to arrive at the total impact on the country. Some industrial economists have suggested a multiplier of eight. Whatever multiplier we use, we end up with an extremely large figure and in terms of the cost to the country, fire makes a considerable impact.

We have already mentioned the number of people killed at work, when we discussed the cost of risk to individuals. Many more are injured than killed in 1987 A.B.I. member companies estimated they would pay £366m for employers' liability claims. This is the same as saying that every single person at work is paid over £15.68. This again is a huge sum of money and just like the fire figures, it is not the whole storey.

Whenever there is a serious injury at work then there will be lost production time, with all the consequences of that, there may be the need for re-training, cleaning or repair of machinery, time off for attendance at court or inquests. Again, a multiplier would be required to arrive at the full impact on the country.

So far we have only mentioned fire and employers' liability, but in 1988 insurance companies paid £134.7m for money and theft claims, £285.9m for domestic thefts and we need to add to that list product liability claims, fraud, motor fleet accidents, marine and aviation claims, etc., etc.

All of these losses are a cost to the country and must be paid for in some way. There may be insurance in force but in the end the cost of that insurance and indeed the cost of losses where there is no insurance, is simply passed on to the consumer. In exactly the same way, the cost to the country of individual personal losses is also a drain on the economy as money has to be directed towards it rather than to some other, more productive use.

The whole role of risk analysis is one of national importance. Risks have to be identified and their impact measured. Private individuals and organisations of all kinds must venture on in the face of risk and the role of the risk manager, in relation to his organisation, is to ensure that he has adequately analysed the risks to which his company is exposed.

1.3 The Cost of Risk Analysis

So far we have tried to place risk itself in perspective. We will conclude this chapter by looking at the cost of risk analysis and try to place these costs in perspective.

Two points are worth making. The first is the obvious point that you cannot spend a ridiculous amount on risk analysis. There would be no point in going to elaborate steps to mount risk analysis for a risk which even in the worst case could not cost as much as the analysis. Students of risk analysis often miss this point in their enthusiasm. Faced with a question or problem they will apply elaborate and sophisticated risk analysis tools when the risk was not worthy of that level of attention.

The second point is that the company may not want to spend a lot of money on analysis of a particular risk. There may be some risk which is well known by the company and accepted as a necessary trading cost. It has been looked at carefully over the years and so there is little need to spend more time on it.

Having made these two preliminary points we could go on to say that we must always look for some benefit from the cost of risk analysis. We hope that the risk analysis will highlight risks which have not been identified before and will then allow us to take controlling action, thus reducing losses and consequently loss costs. However the benefit from our analysis may not be apparent immediately and may not even be apparent in the short to medium term.

Consequently, it is very difficult to decide when you are no longer getting benefit from the analysis. There will come a point when each additional pound spent on risk analysis is in fact losing money for the company rather than saving it.

The drawing in Fig 1.2. tries to illustrate this point. We can see that as the costs of risk analysis increase, so the return changes from positive to negative. The risk manager must always have a picture like this in his mind so that he continues to work within reasonable financial parameters.

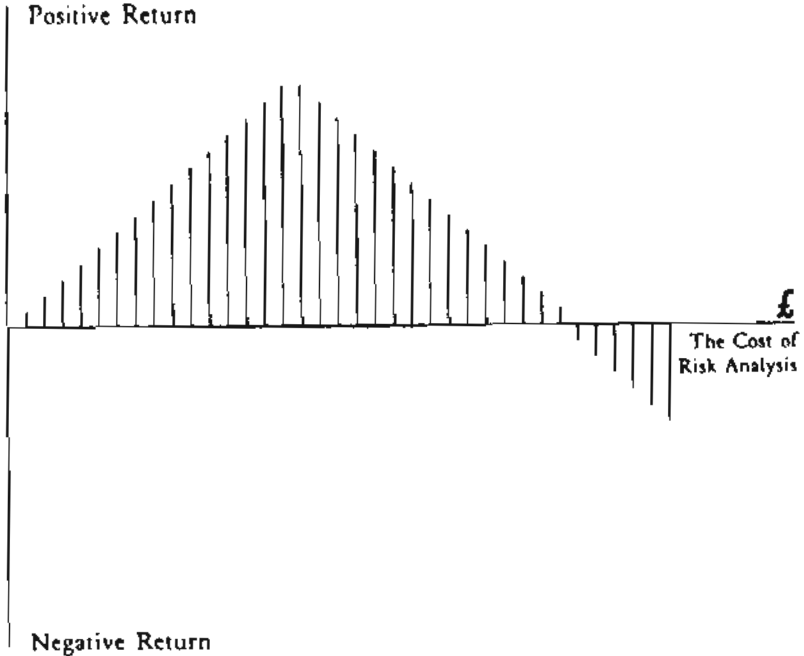


Fig. 1.2

1.4 Conclusion

Having made all these introductory remarks concerning risk analysis we can now move on to the technicalities of the process itself. As we have said already, the remainder of this text concentrates on the different aspects of risk analysis;

Chapter 2 – Risk and Human Behaviour
Chapter 3 – Identifying Risk 1
Chapter 4 – Identifying Risk 2
Chapter 5 – Statistical analysis of Risk 1
Chapter 6 – Statistical analysis of Risk 2
Chapter 7 – Probability
Chapter 8 – Report writing

Chapter Two

RISK AND HUMAN BEHAVIOUR

2.0 In any book or course of study concerned with risk management a grea proportion of space and time must be devoted to the practical aspects o risk identification, measurement and control. Often, however, in the rusl to introduce those ideas, comparatively little attention is given to th nature of risk itself.

In Chapter One we tried to bring risk into perspective and in this presen chapter we endeavour to place risk in a human perspective. We do thi not in an attempt to dwell needlessly on theory but in an effort to enhanc our total understanding of risk and its management. The whole area o risk and human behaviour could well occupy an entire text but in th context of a book on Risk Analysis we can confine ourselves to particula aspects.

The chapter is roughly in two parts. The first part concentrates o attitudes to risk and how such attitudes can be measured. The second par is concerned with the role that risk plays in the decision making process a process with which the risk manager is not unfamiliar!

2.1 Risk and Human Behaviour

The picture painted in the previous chapter is one which emphasises th pervasive nature of risk. Risk enters into all aspects of life, it is as on person put it, “the sugar and salt of life”. In the face of this omnipreser risk each one of us must make our choices as to how we will behave.

When we look around we see wide variations in response to risk. Ther are those who voluntarily assume risk by, for example, participating i some dangerous sport, those who select a hazardous occupation and other who gamble regularly. On the other hand some people rarely venture ou of their armchair, prefer sedentary jobs and insure everything in sight. I short we are all different. There is no one ‘correct’ behavioural respons to risky situations.

If this is the case for private individuals then it is equally accurate fo business. Some banks lend money on far riskier ventures than other some oil companies seem to exhibit more risky behaviour in their drillin decisions than others, certain exporters transact business with countrie where the risk element is high while others avoid such countries.

This phenomenon exists and is easy to observe in the real world. Whe we turn our attention to risk management then the whole question c behaviour in risky situations is brought into sharp focus. In ris management we see individual behaviour combining with corporat behaviour. From the individual's point of view we see him or her face with the risk of, for example, personal injury and having to decid whether or not to use the machine guard, the ‘hard hat’, the safety shiel or the barrier cream. From the standpoint of the company we see responding to exactly the same risks but for different reasons. It is not only concerned with the personal injury of the employees but must also consider the overall costs to the company of any risk materialising.

In situations like this it would clearly be advantageous for the behaviour of the individual to match the needs of the organisation, for example, by the person responding positively to safety advice. In order, however, to maximise the likelihood of this it would be useful to understand, to a certain extent, the nature of human behaviour in risky situations. If we can move towards some understanding of this, then such knowledge would not be limited to applications in the field of safety and accident prevention. An understanding of behaviour in risky situations could be applied to the whole range of risk management including, as we will see later, the important function of decision making.

2.1.1 In the meantime let us comment briefly on the relationship between attitudes and behaviour. So far we have concentrated only on behaviour. This is understandable as it is how people behave which is important, but what influence does attitude have? The extent to which attitudes determine behaviour represents a vast area of literature, and one which is full of competing views. For our purposes we might follow a model provided by the psychologist Kurt Lewin in the 1930's. He suggested that behaviour was a function of the interaction of a person's inner determinants, including attitudes, and environmental features as perceived by the individual.

This may seem rather theoretical but in operational terms it does make sense. You may have a very strong attitude against cigarette smoking, and if you were sitting in a restaurant and smoke began to drift in front of you, your reaction might be to object. When you look round and see that the person responsible is a six and a half feet 'all-in' wrestler you may allow this 'environmental' factor to modify your attitude.

In terms of risk management we can imagine circumstances where less extreme modifications of attitude may result. For example, a person may wish to avoid the risk of injury from a machine but may only use the guard when his 'mates' are not looking, just in case they think he is less of a man; a risk manager may have a very risk averse attitude and may want to spend money on some risk control mechanism but may have to modify his plans in the light of budget targets set by his finance manager.

Behaviour, then, is the result of your attitude reacting with the environment, as you see it. When the environment matches what we want to do then our attitude is a good predictor of behaviour but in other cases the person's perception of the environment may lead to some different form of behaviour than that predicted solely by attitude.

Whatever happens we all respond in some way and it might be useful to be able to predetermine what kind of attitude people have to risk. If we could do this then we might avoid placing people who may take risks, into dangerous situations. In the same way we might avoid placing people who avoid risk into situations where some element of risk taking may be required. In other words the company knows the kind of people it would like in given situations and could use the knowledge gained of attitudes towards risk in the placing of individuals and their matching to specific tasks.

A knowledge of what a workforce feel about risk could also be useful in terms of how the company should promote safety training and education. If we have some idea of how the workforce perceive risks within the workplace then this could give positive guidance to the risk manager for his overall approach to safety education.

2.2 Measuring Attitudes Towards Risk

From the vast literature on measuring attitudes towards risk we can detect, at least, two broad methods emerging. It is important to say at this stage that it is extremely difficult, verging on impossible, to state that one person is a risk seeker and another a risk avoider. The best that can be achieved by most tests is a differentiation among people so that we can then say that one person is more of a risk seeker than another.

The first method is based around a concept known as the "Standard Gamble" and is concerned with measuring attitude to risk in a financial setting. The second category of measurement techniques does not rely on judgement in a financial setting. It is more concerned with measuring "how" individuals perceive risk. This latter category of methods is probably more important to risk management but in view of its importance, in the overall study of attitudes to risk, let us mention briefly the meaning of the standard gamble.

2.2.1 The Standard Gamble

Let us say that you were offered a gamble where you stood to win £40 on the toss of a coin. If the coin lands heads up you win £40, if tails up you win £0. This is a straight-forward 50/50 bet, there is a 50% chance of winning £40 and a 50% chance of gaining nothing. Put this gamble on one side and now assume that you have been offered a certain amount of money, rather than the gamble. In other words you can play the gamble *or* have a sure amount of money. The question is, what is the least amount you would accept, for sure, rather than play the gamble?

For each one of us there is a unique amount of money at which, if we were offered it for sure, we would be indifferent between accepting it and playing the gamble. This is shown in a diagrammatic form in Fig. 2.1.

The sure amount £Z is really the equivalent, in certain money, to the gamble. It is often referred to as the certainty equivalent. In our example A would be £40 and B £0 and the probabilities of achieving either is 50/50. The figure of Z would be decided upon by the individual. A person may, for example, decide that he would be indifferent between accepting £10 for sure and the gamble where he could win £40 or nothing at all at a probability of 0.5 (in a scale where certainty = 1.0).

The Standard Gamble

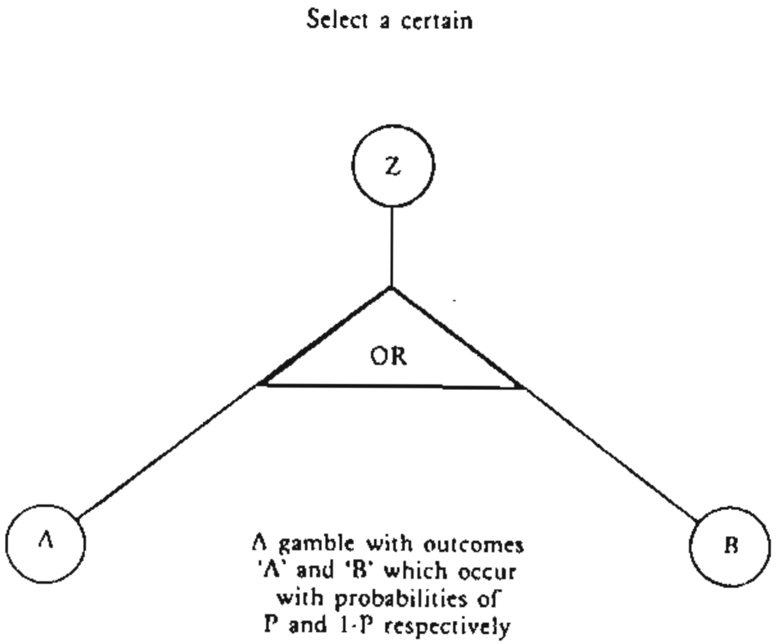


Fig. 2/1

With a large number of people answering the same question we could then rank them according to how much or how little their certainty equivalents were. Apart from that we can measure the extent to which each person deviated from the "mathematically rational" answer. this mathematical or objectively rational answer is based on the fact that the 'expected value' of the gamble is £20 i.e., half the time you win £40 and half the time you gain nothing, therefore, in the long run you should 'expect' £20. If a person would accept less than the expected value then he has a preference for certainty while the person who would require more than the expected value could be classed as a risk taker.

This can be illustrated by taking the two extremes. If he was indifferent between accepting £1 for sure and taking the gamble then we would say he was extremely risk averse. On the other hand if the least amount a person would accept before giving up his right to gamble was £39 then we would say he had an extreme liking for risk.

There were several variations on the basic theme of the standard gamble but in essence they attempt to elicit some point or figure at which a person is indifferent between recovering, or paying, some certain amount and taking a chance.

One final example may illustrate the standard gamble in the context of risk management. Assume that an employee or third party has raised an action for damages against your company. The writ shows that they are suing for £10,000. As is very common, you know that the individual would accept an "out of court" figure rather than take the trouble and risk associated with pursuing his claim through the court. From the company's position it must decide how much it would be prepared to pay in order to settle the claim. In short, it must decide the point or figure at which it would be indifferent between giving that amount as an out of court settlement and taking the chances associated with the case, of possibly being awarded £10,000 or nothing or some figure in between. This is the basic structure of the standard gamble. Let us say that counsel's opinion is that the plaintiff stands a 50/50 chance of success, referring back to our earlier example, we can judge how risk seeking or risk averse the company is in relation to the "expected" payout of £5,000 (£10,000 - fifty percent of the time).

A company which is basically risk averse, avoids risk, would be willing to pay over £5,000 to settle. A company or individual risk manager, may however be a little more risk seeking and not willing to go more than say £3,000.

Interestingly this same problem can be viewed from the individual plaintiff's point of view. He must decide how much he would accept, this time the minimum he would accept, before preferring to take the case to court with the chances of being awarded £10,000.

2.2.2 Perception of Risks

As we said earlier, the standard gamble has perhaps only limited application in the field of risk management. What we move on to now are techniques which have a more practical outlet.

A number of techniques have been developed which measure a person's view or perception of risk by asking how likely an individual considers certain events to be. For example, a number of causes of death could be given to people and they are to suggest how many died from these causes. In this way we would see not only which causes were inaccurately assessed but also which people were not accurate in their assessment.

In risk management terms we could mention two techniques of this type and we will illustrate each one with a brief example.

Let us say that in a particular factory the risk manager has detected an unwillingness, among the workforce, to use machine guards. This unwillingness has been accompanied by a deterioration in the accident experience. The risk manager has a feeling that the workforce do not consider the machines they use to be as potentially dangerous as they are in fact. He gathers information on the seven types of machines in the factory and finds the number of accidents on each one during the last year to be:

Machines	*Accidents*
A	15
B	10
C	21
D	4
E	7
F	18
G	17

He prepares a brief form which asks the machine operators how many accidents they consider happened on each of the machines last year. There will have to be some careful definition of "accident" and what is meant by "last year". Assuming these points can be overcome then the questions could be put to the employees. It may be useful to provide them with some "anchoring" figure and so he could give them one of the actual figures. The form may look like that shown in Fig. 2.2. The machines would not, of course, be described as A, B, C, etc., but by the name most familiar to the employees. This may or may not be the makers' name but it must clearly define the machine, in the eyes of the employees.

A perception of risk questionnaire

What is your estimate of the number of accidents that happened on each of the following machines during the last twelve months?

As a guide to you, the actual number of accidents on machine "E" has been put in.

Machine	*Your Estimate of No. of Accidents*
A	...
B	...
C	...
D	...
E	7
F	...
G	...

Thanks for your help in completing this form!

Fig. 2.2

To avoid any possibility of collusion it is probably best to give each person a form and wait for it to be completed. Once all the forms are returned the risk manager can calculate the average response for each machine. Let us say he has done this and finds, for the two hundred and fifty employees involved, that the average responses are:

Machine	*Average estimate of No of accidents*
A	13
B	16
C	25
D	3
E	7
F	15
G	16

He can tell at once that of the six estimates, four have been under-estimated and two over-estimated. This can be illustrated by a simple graph as in Fig. 2.3. If the estimated number of accidents had matched the actual number exactly, then we would have ended up with a straight line which would cut the graph at an angle of 45°. What the risk manager found was that in the case of two machines the workforce over-estimated the number of accidents, these are the two above the line. The number

A graph of estimated versus actual number of accidents

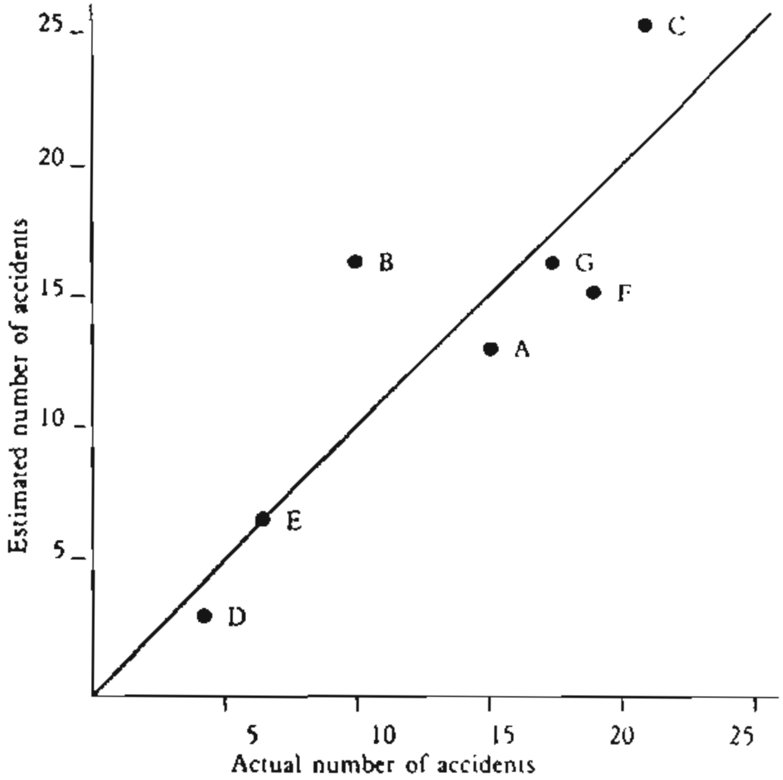


Fig. 2.3

of accidents was under-estimated for four machines, these falling below the line. The actual figure was provided for machine 'E' and so this falls on the line exactly.

The risk manager now has some idea of how the employees perceive the risk of injury from these machines. On the whole they do seem to under-estimate the risks involved. In the case of one machine, however, machine 'B', the risk of injury was dramatically over-estimated. It can be seen from the graph that machines 'B' and 'G' were viewed by people as having the same number of accidents whereas, in fact machine 'B' had seven accidents less than 'G'.

This knowledge may now be of some use to the risk manager in his efforts to encourage the use of machine guards. He has some information on how the workforce perceive the risk of injury from the machines they use and he may perhaps decide to concentrate, as a start, on the machines where accident potential was under-estimated.

The second technique we will illustrate, under the general heading of perception of risk, is one concerning the ranking of risks. In the above illustration people were asked to estimate the actual number representing their perception of risk. In this next technique the task is made simpler by only requiring that each person 'ranks' various things.

Let us say that the risk manager of a large construction company is looking into the whole question of employers' liability claims. He has extracted information from his records of all such incidents over the past few years.

In order to have some national comparison he categorises the various incidents according to the classifications used by the Health and Safety Executive. He finds the following number of incidents under each heading.

Fall or trip on level ground	180
Struck by an object	101
Fall from a height	97
Over exertion, strenuous awkward, movements	45
Caught under or between an object	20
Striking against an object	11
Rubbed, or abrased by an object	5
Electrical current	2

Rather than ask the workforce to estimate the number of accidents they feel are generated within these categories, an alternative strategy is adopted. This time the employees are asked to rank the eight different types of incident in order of likelihood. Therefore if a person believed that the most likely type of accident was that involving over exertion then he would assign it the rank of '1'. The cause which he considered least likely would then be ranked number '8'.

The risk manager knows the correct ranking for his company, as he has the figures which we illustrated above. When the rankings are worked out for the workforce it will give some clue as to how the people, most closely involved, perceive the risk of accident.

A simple question form is shown in Fig. 2.4.

A sample form for Ranking Risks

A number of different causes of accident are shown on this form. You are in the best position to say how important each of these causes is.

Would you decide which cause produces most accidents and put the number 1 against it. Put the number 2 against the cause which in your view produces the next highest number of accidents and so on until you place an 8 against the cause which you think produces the least number of accidents.

Type of Incident

Rubbed or abrased by an object ....
Struck by an object ....
Electrical current ....
Striking against an object ....
Caught under, between an object ....
Over exertion, strenuous, awkward movements ....
Fall from a height ....
Fall or trip on level ground ....

Fig. 2.4

When all the forms have been completed by, say the 500 employees, the risk manager can then calculate the average rank for each incident. From these average rankings it is then possible to rank the incidents according to the average rankings. Let us say this has been done with the following results:

Incident	*Rank*
Fall from a height	1
Over exertion, strenuous awkward movements	2
Striking against an object	3
Struck by an object	4
Electric current	5
Fall or trip on level ground	6
Caught under, between an object	7
Rubbed or abrased by an object	8

On average the 500 employees in this firm considered the most likely source of accident to be falling from a height and the least likely to be rubbing or abrasions by an object. What the risk manager can now do is to examine the extent to which this perception of risk matches reality.

One way in which he can do this is to construct a table showing the actual rankings for the company, the perceived rankings as measured by the risk manager and, if available, the rank order for these incidents on an industry-wide basis. Such a table is shown below.

Incident	Firm's *Rank*	Employees *Rank*	Industry* Wide *Rank*
Fall or trip on level ground	1	6	4
Struck by an object	2	4	1
Fall from height	3	1	3
Over exertion, strenuous, awkward movements	4	2	2
Caught under, between an object	5	7	6
Striking against an object	6	3	5
Rubbed or abrased by an object	7	8	7
Electrical current	8	5	8

*Source: *Health & Safety Executive - Health - Safety - Statistics - 1980*

The risk manager can tell from this form of table that the most prevalent cause of accident, in his firm, is falling or tripping but yet that was not perceived by the workforce to be the most likely source. There does seem to be some miss-match between the employees' perception of risks and the actual incidence of accidents. This may then shape the direction of any safety or accident prevention campaign.

One other interesting comparison is that between the firm's experience and the industry-wide experience. This comparison does reveal some similarities but may point up any differences and perhaps suggest lines of enquiry which he could follow.

2.2.3 Value of Measuring Attitudes Towards Risk

As we said earlier, there is an extensive literature on the whole area of measuring risk attitudes. What we have done so far in this chapter has been to concentrate on individual attitudes towards risk and the means by which these can be measured. Prior to moving on to look at risk in a decision making context let us itemise the value we feel can be derived from a knowledge of individual attitudes towards risk:

- Firstly we would have to say that the whole nature of risk management revolves around the concept of risk. Risk itself must be fully understood by risk managers and this includes all facets of the subject. Human attitudes to, and behaviour in the face of, risk is an important aspect of risk and as such merits careful attention from the risk manager.

- Secondly, a knowledge of how to measure attitudes towards risk, even in a basic way, will give a valuable insight into how employees perceive risks. The risk manager may be alerted to activities, causes of injury or processes which are not viewed realistically by employees. As a result he may be able to take action which could raise levels of perception of risk from certain causes. If it is possible to raise perception then it may also be possible to introduce measures aimed at reducing the incidence of loss producing events.
- Analysis of how people perceive certain risks may also be useful in a job selection sense. There could be jobs where a highly developed awareness of risk may be required. Should this be the case then some form of risk perception enquiry could be made as one part of an overall selection process.
- Finally, the risk manager may also gain a valuable insight into how he himself views risks. Whatever decisions or actions the risk manager may take will, in part, be a function of his own attitude towards risk. Some appreciation of this attitude should be beneficial in the long run.

2.3 Risk in Decision Making

The remainder of this chapter concentrates on one aspect of the risk management process in which risk plays a dominant role, decision making. In only a very few cases are decisions ever taken in a certain environment and in risk management problems there is usually some inherent risk. A range of possible outcomes may be known, but which one will actually occur is not known. Nevertheless a decision has to be taken or a case for a decision, supported.

The remainder of this book is involved with the practical aspects of risk identification and measurement, other books are concerned with equally important and practical features of risk management. However, once all our techniques have been applied to a problem it is usually necessary to make some decision. We may be faced with decisions such as; will we install sprinklers?; should the system of work be altered?; are existing theft prevention measures adequate?; what insurance covers should be purchased?; how much of a risk should be retained?; should a captive be formed?, and so on.

Decision making is an extremely important aspect of risk management. Peter Drucker in his book "The Practice of Management" emphasised the importance of decision making when he wrote, "whatever a manager does he does through decision making. These decisions may be made as a matter of routine, indeed he may not even realise that he is making them .... but management is always a decision making process".

Already we have mentioned the words 'decision making' several times. The use of these words as opposed to decision 'taking' has been quite intentional. We will look upon decision 'making' in the sense of 'building' or 'construction' rather than the final step of selection which is implied by the words 'decision taking'. Decision making is so important in itself that the process by which we make decisions assumes an importance quite distinct from the detail of any one problem.

For our purpose we can say that the decision process is as outlined in the diagram in Fig. 2.5.

The Decision Making Process

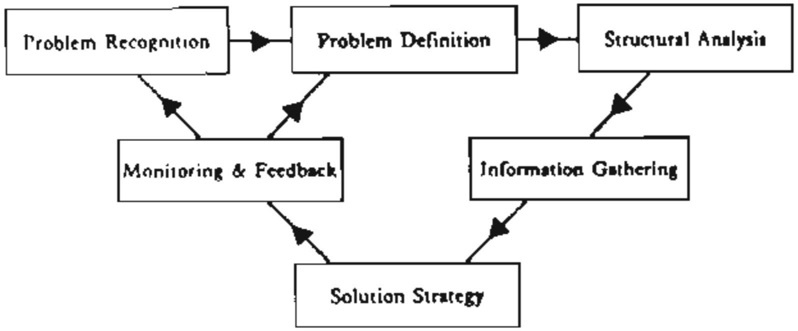


Fig. 2.5

We can recognise three main phases in the process. Firstly there is the recognition and definition of the decision problem and its structural analysis. Secondly there is the gathering of information necessary to lead on to the third phase of actually selecting one course of action. The continuing monitoring and feeding back of information has been slotted in at the second phase.

These phases in the process of making decisions are best illustrated by means of a practical study, during which we can also look at where risk and attitudes to risk play their part.

2.3.1 The Decision Making Process

Let us say that the risk manager of a large departmental retail store group has been studying the figures relating to 'shrinkage'. For this manager's company 'shrinkage' is looked upon as the aggregate of shoplifting and staff pilfering. He realises that the level of shrinkage has fluctuated over past years but does, in any one year represent a substantial financial loss. He decides that something must be done.

2.3.2 Problem Recognition

Here then we have the first part of the process. In this example the recognition of the problem was generated by the risk manager's own review of his records. Some external stimulus could equally well have been important, a report from the finance director, an annual report from the chief accounting officer. The obvious uncertainty here is that problems go unrecognised. The risk manager must therefore be alert, in a practical way, to the need to spend time reviewing his own [illegible] and analysing information which may come to him from outside his own department.

2.3.3 Problem Definition

Having recognised that a problem exists he must now be careful to define it in a precise manner. The eventual solution will only be as good as the definition of the problem allows. The risk here is that the problem is inadequately defined. This may arise in a number of ways at least two of which are important for the risk manager.

The first risk he runs in defining his problem is to think in terms of symptoms rather than causes. For example, a risk manager may have recognised a large and increasing number of back injuries. The problem is not, however, the number of back injuries, this is simply the symptom of the real problem. The problem may be the method of work, equipment used, layout of the plant etc. In our example the symptom of a problem is the level of shrinkage. The problem itself is that there may be inadequate protection, the absence of staff security checks, unwillingness by the company to prosecute thieves etc.

Secondly, the manager must try to avoid defining the problem in terms of implied solutions. A risk manager faced with one particular employee on one process, who is persistently involved in minor accidents, may define the problem as being how to make the process safer. This implies the solution before he has had the opportunity of properly structuring the decision. This disguised solution will then make it difficult for him to turn his mind to a wider range of solutions such as re-training the employee or moving him to another process.

In our decision the problem definition should not, for example, be limited to how better to protect the goods being stolen. This definition then excludes other possible solutions such as prosecuting all persons found stealing, introducing random staff security checks, etc.

2.3.4 Structure of Decisions

Having looked at the nature of the decision problem we must now turn our attention to the structure of the decision itself.

We will identify three components of this structure, starting with the alternative courses of action. It is, in part, the existence of more than one possible course of action which places us in the dilemma of having to make a choice. The list of alternatives must be as comprehensive as possible. It is obvious, but nevertheless worthwhile to state that the best decision will not be taken if the appropriate alternative is missing.

The risk then, is that valid alternative courses of action are omitted. There are a number of factors which may limit the selection of all possible alternatives. Some of these limiting factors may be quite appropriate and outside the control of the risk manager for example, the law, social pressure and company policy. Other alternatives, however, may not appear among the list of alternatives for less obvious reasons and it is in this area that the risk manager must be on his guard. The particular risks, in this respect, should be recognised. The first is the possibility of being "company blind". This is the story of the entrepreneur who has sold a product at £9.99 for years and fails to recognise the potential of a product which sells at, say £20. He has placed a constraint on his own thinking. This risk has to be identified and avoided. In our shrinkage example it could well be that the risk manager does not consider, as an alternative course of action, the introduction of random staff checks. He fails to consider this, not because he dislikes such an idea, but simply because the company has never in the past done this kind of thing.

The second risk connected with not ascertaining all possible courses of action is associated with the previous experience of the risk manager. In the cases where a person has met and resolved a problem in the past, there is a strong tendency to rely on that previous solution. In our example it may have been that this particular risk manager solved shrinkage in another company, by installing glass shelving on top of all open display counters. It is easy to see how this alternative may be given priority in his thinking in relation to this problem. The risk is that an alternative leading to a more optimal decision has been left out.

These same considerations apply to the next component of the decision, states of nature. States of nature is the phrase used to describe the uncertain environment in which the decision has to be taken. A simple example is the decision to invest money. Let us say there are three options open to us, shares, the building society, index linked bonds. The eventual return on the investment, whichever option is selected, will only be known when the interest rate for the year has been fixed. This interest rate could end up being the same as it is at the moment, higher or lower.

It was thought by many that this situation is similar to a game where nature is some mechanism which generates events in the real world. In the investment example, nature may produce high, low, or similar interest rates. We do not know at the outset which event will occur but must nevertheless make our decision.

In the shrinkage example the risk manager will have to consider what events, or states of nature, may play upon the problem over the time period with which he is concerned. Similar comments to those mentioned for alternatives apply to the generation of states of nature and the ways in which all possible states may not be considered.

In the end what the manager has before him is a decision matrix. Down one side he can list all the alternatives he wishes to consider and along the top all the relevant states of nature. Such a matrix is shown below in Fig. 2.6 and from it we can see that this risk manager is contemplating three alternative courses of action and has in mind three states of nature.

Decision Matrix

	Rate of Shrinkage Increases	Rate of Shrinkage Unaltered	Rate of Shrinkage Decreases
Store Detectives and Random Staff Checks	14	12	10
Re-design of the Counter Layout	20	14	9
TV Scanners and Random Staff Checks	18	16	8

Fig. 2.6

For the sake of this illustration we have limited the decision matrix to three alternatives and three states of nature. In the real world there would be many more.

The last of the three components of the structure of the decision is the payoff or outcome. In our example we will have nine payoffs, one corresponding to each alternative and state of nature combination. These have been included in the matrix shown in Fig. 2.6. The payoff is the financial result of selecting an alternative and finding that a particular state of nature occurred. In our matrix the payoffs have been measured in terms of net loss savings i.e., the savings in losses which are expected, less the cost of carrying out the alternative.

We can see from this matrix that if the rate of shrinkage increases then re-designing the counter layout is the optimal choice. Should the rate of shrinkage go down then it would be better to employ the store detective, while an unchanged shrinkage rate would lead you to install the TV scanners.

This is the pattern of decisions where risk and uncertainty exist. We do not know what state of nature will apply but must nevertheless take our decision now. It is not the purpose of this chapter to concentrate on how the decision would, could or should be taken but suffice to say that a substantial body of information including many practical aids now exist to help in the eventual choice of an alternative.

To conclude this chapter we will turn to one important aspect of attitudes to risk which applies both within and outside the realm of decision making, the question of working with others.

2.4 Groups and Risk Taking

A great deal of the time the risk manager works together with others either in departmental groupings, local management committees, safety committees or in other ways. Equally so he is often in the position of having to persuade a group to take a certain course of action. In our shrinkage example he may well have had to sit on a store security committee. During this time he will have been exposed to a range of different views and attitudes to the problem of shrinkage. Following these deliberations he may well then have had to present his case to a financial management group or local board or meeting of store managers.

In short, much of the activity surrounding this decision and its implementation takes place within groups. In view of this it is as well that the risk manager has some knowledge of what takes place within groups.

Fig 2.7 illustrates in diagrammatic form the group process. A number of individuals come to the group with some notion or particular attitude towards a situation and after some group process there evolves a group view.

Group Process

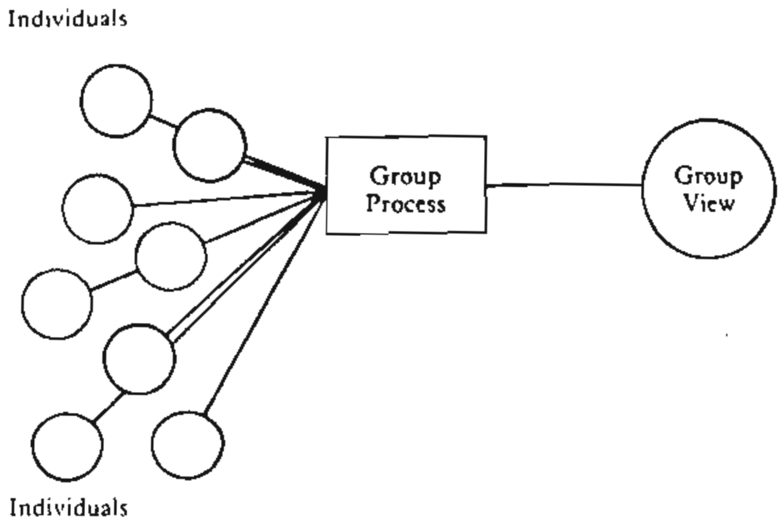


Fig. 2.7

In relation to risk and attitudes to risk, what this means is that individuals approach the group with some attitude and enter upon the group process. The question which must be asked is, do groups of individuals acting together, exhibit the same attitude to risk as the individual members of the group held prior to the group process? The collective response of the group is a function of whatever happens during the group process but will there be any difference between the attitude put forward by the group?

Conventional wisdom might lead us to believe that the group process would result in a 'conservative' approach to any risky problem. We often have a view of groups or committees as being slow, cumbersome and rather reluctant to innovate, ". . . if you want something done don't give it to a committee". With this general impression in mind we might think that groups would be much less risk taking than the individual members.

2.4.1 Risky Shift

This popular wisdom was apparently shown to be inaccurate by the work of one J. A. F. Stoner in 1961. In a Master's Thesis while studying at Massachusetts Institute of Technology he reported the results of research concerning groups and attitudes to risk. He tested a number of people for their attitude to risk and then assigned these people to groups of six. The groups then had to respond to a number of questions aimed at measuring their attitude to risk. He found that the group decision was riskier than that of the individuals, as previously measured. This was against what most people thought would be the case. There followed a large number of articles many of which attempted to explain the phenomenon which by then had become known as "Risky Shift".

Four main points arose. Firstly, it was suggested that during the group process more information was produced about the particular decision. This is fairly obvious, that when acting with others and taking part in discussion there should be more information available to members than they had on their own. This extra information led to greater confidence and this increased confidence in turned to a greater willingness to take risk.

The second explanation of risky shift was based on the nature of leadership within the group. Strong, dominant personalities are actually associated with the risk takers in society. On the other hand the quiet, less forceful individual is the image held by society of the cautious risk averse person. Given these views then the strong members of the group will dominate it and eventually influence the final decision. As they are prone to be risk takers, then the eventual decision will tend to be riskier than that of most of the individual members of the group.

When more than one person is responsible for the decision then it is likely that individuals will tend toward a more adventurous approach than would otherwise be the case. If the decision to cancel a particular form of insurance protection lay with you alone then it is likely that you would also carry the responsibility to answer if the company was later involved in a large loss. When these thoughts run through your mind they may well result in your deciding to retain the cover. Where a similar decision is being taken by a group it is far easier for those in the group to be a little more risky as the responsibility for a 'wrong' decision has been spread.

The final explanation concerns the view that society, in general, has of the risk taker. In general terms it was argued that most people value the risk taker and look less favourably on the cautious risk averter. If this is the case then there may well be a tendency for some in the group to emulate the risk taker or at least assume some of the characteristics of the risk taker.

All of these explanations for the risky shift phenomenon are intuitively appealing but over the years the notion of risky shift has decreased in importance. It was found, on closer examination of the Stoner research, that much more was happening in the group process than simply a shift towards being more risky. In fact when the individual questions, put to the groups by Stoner, were examined there was evidence of a shift towards caution and a number of cases where no shift occurred at all.

2.4.2 Choice Shift

As a result of this, and other work, most people now prefer to talk in terms of a choice shift rather than risky shift. This choice shift can be looked at in two ways.

Firstly there is the possibility that during the group process there will be individual members who look for dominant values held by others. These are the people who need some guide to what they should themselves be thinking. If the dominant value turns out to be one of risk aversion then they will move that way. Similarly they would move towards risk taking if they perceived that to be the dominant value.

Choice Shift

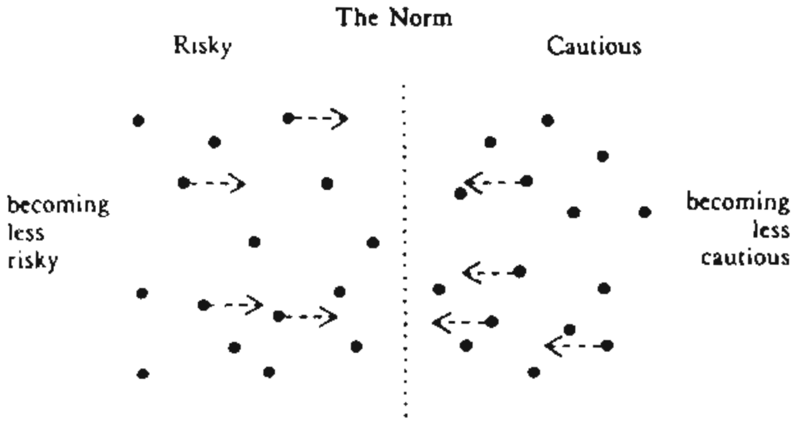


Fig. 2.8

This move towards dominance should not be confused with falling into line with some norm. The dominant value may be quite different from the norm as in the case of one strong, persistant influential voice and a quiet majority which more accurately reflects the norm.

Secondly, choice shift may in fact be caused by social norm. Where some socially or corporately acceptable norm is recognised by members of the group then there can be a move towards that. People will not want to be too far from what they consider to be acceptable. This also involves shifts in both directions as is illustrated in Fig. 2.8.

Some of those who start with a risky view move towards being more cautious while those who began as cautious may move the other way, all in an effort to line up with a perceived norm. There will be others who will stay where they were at the outset of the group process.

Risk and the problems which it brings will always be with us and indeed few of us would relish an environment where no risk or choice existed. This book now develops the analytical approach to the management of risk and it is good to build this upon the foundation of our knowledge of what risk is and how we behave in the face of it.

Chapter Three

IDENTIFYING RISK 1

3.0 The previous two chapters have served to set the scene for the much more practical aspects of risk analysis which occupy the remainder of this book. It has been useful to emphasise that the task of risk analysis must be carried out with realism and with a proper perspective both of the risks themselves and the costs involved in analysis.

In this chapter and the next we will look at a number of different techniques which can be used for the analysis of risk. At this stage it is important to understand what we mean by 'analysis'. In the context of this book we will not enter into a debate about whether identification of risk is the same thing as analysis of risk or whether analysis has some distinct and separate characteristic. For our purposes such a discussion would be of little value and certainly at the end of the day it will not matter whether you *identified* or *analysed* a risk, provided it was economically controlled.

We shall look upon risk analysis as the entire task of identifying and measuring the potential impact of risk. In this chapter and the next we will concentrate on the techniques of identification and in subsequent chapters turn our attention to the problems of measurement.

The techniques we shall look at in this chapter are primarily concerned with the identification of risks, we shall leave the statistical analysis of risk until later chapters. However we can say quite clearly that the role of risk analysis is absolutely crucial in the whole risk management context. Risks can only be measured and controlled once they have been identified and so the process by which risks are identified assumes an importance that is quite distinct from any particular risk.

3.1 Important Features of Risk Identification

While there are a number of different methods or techniques of risk identification there are also a number of common features of importance. Before embarking on a study of the techniques themselves it is valuable to remember the following:

3.1.1 It is unlikely that one particular method of identification will be sufficient to address all the problems of risk posed by any company. It would not be wise to latch onto one or two particular techniques and use them to the exclusion of all others. It is much more likely that a combination of methods will be required in order to ensure that the fullest possible job has been carried out. The risk manager should also be alert to changes in methods and advances in methods of risk identification which may be suitable for his industry. This is easy to say but of course much more difficult to put into practice. However time should be devoted on a semi-regular basis to scanning the relevant magazines for any developments which may be valuable.

3.1.2 It is also the case that certain methods are more useful in some industries than others. This in part reflects the fact that the various methods themselves had their origins in satisfying problems within an industry. A flow chart for example is an appropriate way of identifying risk in an industrial process which involves goods or materials moving through a number of different stages. We shall see this in chapter four. Where however flow is not the main activity as in the case of an office, then another form of identification tool would be better.

The task of matching the method to the risks which are thought to exist is important. It is not possible to lay down firm guidelines as to how this is to be done but it is aided if the risk manager has a firm understanding of his industry in general and of the company in particular.

3.1.3 The previous point mentioned the need to understand the industry and the company fully. This is greatly helped by consulting with as many people outside the risk management department as possible. Before embarking on the task of risk identification the risk manager should identify the people whom he considers could be of help in the task he has to perform. This will mean consulting with various line managers and others of the workforce who know the company and possibly also have their own firm views of the risks which exist. It may seem that you are not getting on with the job of actually identifying any risks but at the end of the day the analysis you eventually carry out will be all the better.

3.1.4 The fourth feature of risk identification is that it should not be a one-off exercise. Mounting a large scale risk identification exercise will probably reveal a number of risks but risks do not respect time and in a few weeks or months new risks will emerge. There must be an on-going programme of risk identification. Quite apart from keeping people on their toes it is essential that risks which have been identified are monitored and new risks highlighted. Having a programme of risk identification involves careful planning on the part of the risk manager.

3.1.5 Whatever you plan to do must be financially reasonable. Remember what was said in chapter one, there is little point in spending £100 to identify a risk which you know can only ever result in a £10 loss. The task of risk identification is crucially important but it must be carried out with realism.

3.1.6 Accurate record keeping must accompany any risk identification. Well before the actual task of risk identification begins it is necessary to prepare the form of record keeping which will be used. Once the job has been done the relevant data must then be inserted on the forms or whatever type of record which is being kept. What is to be remembered is that in another years time you are possibly going to visit that plant again and you will want to be able to recall, fairly easily, what you found the year before.

3.1.7 The final point to make about risk identification is that a certain element of imagination is required. This is something which does not come from reading books or even from passing examinations. Experience is probably the best teacher in this regard and all who are involved in practical risk analysis probably shudder when they look back at early reports of work they carried out. Be prepared to learn from your experiences, both the good ones and the bad ones.

3.2 Types Of Techniques

The methods we are going to study could be categorised in a number of ways. There are some which are predominantly desk based while others could not be completed without site visits. There are others which seem more appropriate to the post loss situation than to the pre loss position. Some involve the use of quantitative analyses while others are essentially qualitative in style.

These various dichotomies are interesting but not terribly valuable in a practical sense. As we said above, the main point is that risks are identified.

Whatever is said here concerning the various risk identification techniques will of necessity be of a general nature. It would be impossible to cover all industry types and all the different forms of risk which exist. What is hoped is that a general framework is put down on to which the individual reader can build his own particular applications.

3.2.1 As a means of assisting understanding of the techniques and in an effort to show their applicability in the real world, a hypothetical company has been created which will act as the base for all the methods we will look at. This company is not intended to represent any known company and any connections which readers may see are unintentional. The actual processes involved in the particular company have been simplified so as not to obscure the main function of the example which is only to act as a common base for all the techniques. Please do not get too involved in the actual technicalities of the industrial process, a broad awareness of what the company is trying to do is sufficient. With that disclaimer made, let us now describe the company.

The company is Imperial Rubber Company plc. (IRC) and has been in existence for eighty five years. It occupies a large sprawling site on the outskirts of Manchester, within easy reach of the airport and the national motorway network. Access to an international container terminal is also fairly easy.

The buildings are the original premises built at the turn of the century with a few additions over the years. The main addition in recent years has been a distribution facility added on to one gable end of the main factory unit. A rough plan of the site is shown in Fig. 3.1.

The company imports raw rubber from three overseas countries and processes it for a number of particular purposes. In the main there are three outlets for the processed rubber. Firstly, the company will make products to order and does so on a large scale for the motor and aircraft industries. It also undertakes large scale contract work of an industrial nature where rubber linings or coatings are required. This contract work can either be carried out at their own premises or at the premises of customers.

Imperial Rubber Company Manchester

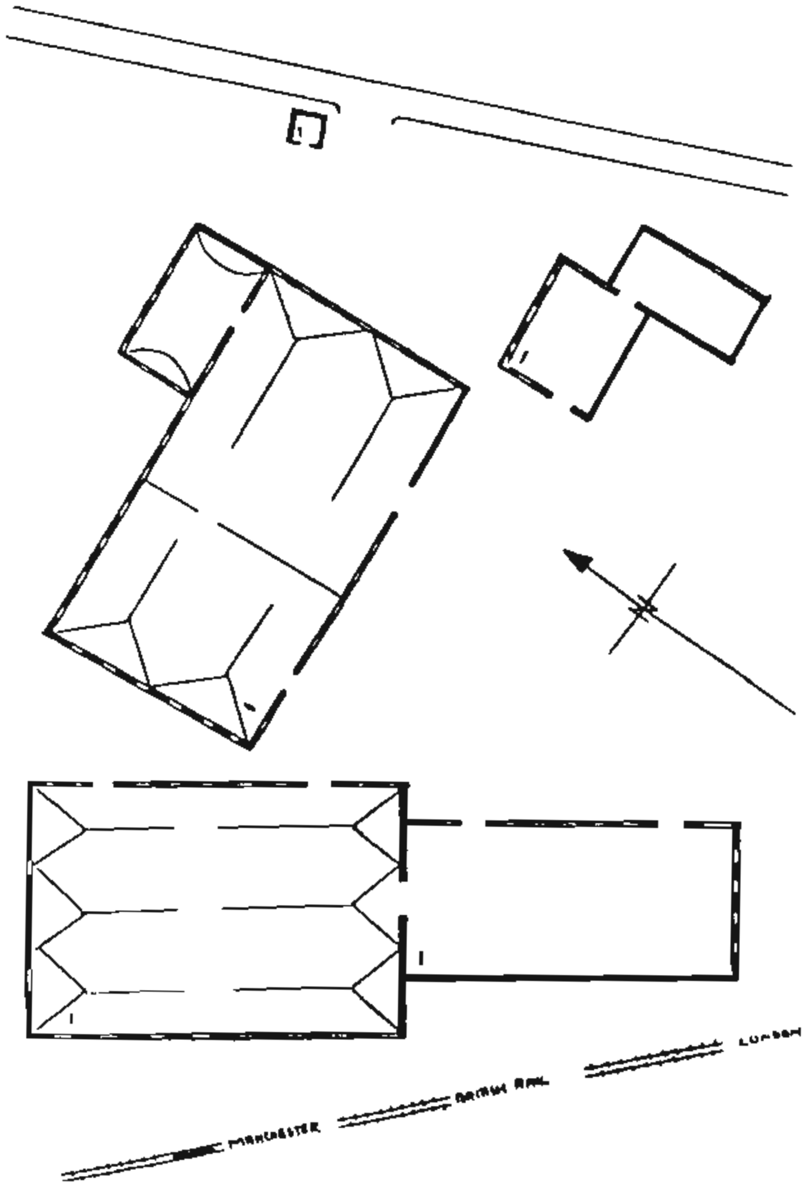


Fig. 3.1

The second outlet is directly into the retail market. The company manufactures a range of products both domestic and industrial which are sold to the public and industry through a number of retail outlets owned by IRC and trading under the name of National Bounce Company. NBC has recently begun moving its outlets to industrial trading estates as the bulk of its business is done with small to medium sized companies, many of which occupy premises on industrial estates.

The third outlet for the rubber is the supplying of two subsidiary companies, Imperial Rubber (Civil Engineering) plc and Imperial Pipes and Hoses plc. These two companies have been operating for many years and supply specialist industrial rubber products. These two concerns are supplied solely by IRC and operate from premises in Birmingham.

The actual process of converting the raw rubber into a marketable product is a complicated one and one which has changed over the years in response to advances in technology. In simple terms the raw rubber is received at the factory and undergoes a process of mastication during which it is reduced to pulp by a system of grinding and crushing. After this various chemicals are added to the pulp before the mixture is vulcanised. During vulcanisation the rubber is treated with sulphur under heat and pressure in order to improve its elasticity and strength. On the completion of the process the product is then sent either for moulding and cutting prior to distribution to National Bounce or is sent to the fabrication area for the completion of orders. The new distribution centre is common to both National Bounce products and customers' orders awaiting dispatch.

The company employs 560 people, 420 of whom are men. There is a Risk and Insurance Manager who is responsible to the Finance Director for all matters of insurance, risk and safety.

This is only a thumb-nail sketch of this hypothetical company and is not intended to represent an accurate account of how rubber products are made or sold. It is however fairly realistic and should serve our purpose of being a skeleton on which to hang our risk identification techniques.

3.3 Physical Inspections

The list of techniques which follows is not in any particular order but this first method of physical inspection is probably the best known and most often used technique for identifying risks. It is also extremely time consuming as apart altogether from the distance which may be involved in travel, there is also the time it would take to carry out an inspection of even a smallish plant such as Imperial Rubber. Before embarking on an inspection it is therefore essential that as much preparatory work as possible is done.

3.3.1 Preparation for The Inspection

- The first and probably most obvious point to get clear is the actual time that the proposed inspection will take. Visiting any plant will have to be programmed into all the other tasks which have to be performed. You will have to give serious thought to how long you anticipate the inspection taking and when in the year it would be best to do it.

- With that preliminary point over you can begin to give more detailed thought to the visit itself. You can imagine that a person just cannot arrive at a plant with no preparation. Even a fairly small plant like the one shown in Fig 3.1 involves a number of different areas and buildings, all of which could house potential risks. There must be some logical approach to the business of identifying risk, an approach which will minimise the chance that something important is overlooked. One way to approach the task is to have some sheet or report to complete as you go round. This could take the form of simply completing an entry for each item you see. An example would be:

NAME OF ITEM	FUNCTION OF ITEM	AGE	CONDITION OF ITEM	FAULTS	ACTIONS

It would now be possible to complete an entry for each item you see on the inspection. An item could be a piece of machinery or a building or even a process. The actual headings to the various columns are less important than the reasons for having a pro-forma. It gives some structure to the visit and may cut down both the time it takes to complete the job and the risk that something important will be overlooked.

It is likely, however, that not all visits can be handled in this way and even where the form is used it may not be suitable for all parts of the plant. The main thing is that you are flexible enough to make use of an aid like this when it is useful and not use it when it could be counter-productive.

- The next thing you will want to do, if this is not the first time you have visited the plant, is to look back at the previous report and see if there are any matters which are still outstanding or any points which you would particularly like to look at again. This is when a pro-forma of the sort we discussed above is valuable. If you completed such a form on a previous visit you can simply turn to it now and recall what you felt was important after the last visit. Say for example you look back and see the following section of the report from last year:

NAME OF ITEM	FUNCTION OF ITEM	AGE	CONDITION OF ITEM	FAULTS	ACTION
Acme Press Company No 471	Rolling rubber during vulcanisation.	14	Fair to poor in need of some work.	automatic safety bar had broken and had not been attended to.	Write to the plant safety manager and send a copy to the plant manager.

- By looking back at this report you can see that a particular machine had a broken guard and that you had written to the Safety Manager and the Plant Manager about it. You can now check on that correspondence to see if anything was done. It is likely that some cross referencing will have been made to avoid having to look up a separate file, but if this is not the case then an actual check of your files will show if the faulty safety bar had been repaired. You may also want to check on the general condition of the machine. It will now be 15 years old and was already in a poor state of repair last year.

- However there may have been no faults detected last year or this could be the first time you have visited the plant. In this case it may be advisable to prepare a list of those points you would especially want to inspect on the forthcoming visit. You may for example want to look at the heat process and check on the chemicals being used, the protection available to the workforce and the extent to which the available protections are used.

There has been a new distribution base built, we noted this above in the description of the company. You will probably have been involved in this at the planning stage but nevertheless you will want to carry out a full scale inspection of this new facility for the first time. (In an ideal world the risk manager will have been consulted during the planning and building of the new extension. However this is not an ideal world and it may be that the visit is the first time the risk manager sees the new extension. If this is the case it does raise a number of questions about the adequacy of the communication flow within the company and these questions cannot be ignored.)

- One final point to clear up before the visit is to ascertain the person to whom you are responsible at the plant. This may well be known before-hand but you should have a clear understanding of the management structure at the plant and the person who is responsible for matters related to risk and insurance.

3.3.2 There is little that can be said about the actual inspection itself. The art of inspecting plant is not one which is acquired by reading a text book. Experience is the great teacher and the more inspections which can be carried out the better. Imagination and flexibility are two words which we have used before and they are particularly appropriate to the task of physical inspections.

3.3.3 After the inspection has been made and you have returned to your office much of the real work of the visit begins. You must now implement all the actions you wrote down during the visit. In addition to any special actions, like the one from last year concerning the machine guard, you will also have a host of more routine matters which require attention. There will for example be all the insurance valuations which will have to be updated and any alterations to the premises or plant notified to insurers. You may well have a department which can handle all of this or more likely you will have to do it all yourself. The main thing is that you do ensure it is done within a reasonable time from the visit.

Finally the new report should be logged away for future reference and clearly marked to which year or month it refers.

3.3.4 What then are the advantages of carrying out these physical inspections and what are the disadvantages?

The great advantage is that you see the plant for yourself and do not have to rely on reports from others. In addition to seeing for yourself you are also seen by others and this is important. In trying to build up or maintain good links with those on the shop floor and those in charge of various plants, it is essential that you are seen and approachable. Visiting plants does bring you into contact with the people on whom you will rely for much of your information concerning risks and hazards on the shop floor.

The disadvantage is the time it takes to carry out inspections. We have commented on this earlier but despite all that you may do to streamline your activities, you will still have to invest a considerable amount of time in each inspection. This investment of time also means cost, and all of this will have to balance against the advantages you hope to gain from the inspection. Another disadvantage could possibly be that by visiting plants on a regular basis you may in fact discourage others from being vigilant themselves in the identification of risks. Against this is the equally valid point that local plant managers may in fact be more alert to risks knowing that you do visit regularly.

There are pros and cons for physical inspections and whether one is to be carried out or not can only be judged in the light of all the circumstances.

3.4 Checklists

A possible alternative to the actual visit is the completion of a checklist or some other form of questionnaire. This is clearly not as good as going to see for yourself but it does have some advantages as we shall see later.

Once the checklist has been prepared the risk manager can either send it for completion by someone at the plant or, if he wishes, he can use it as a pro-forma to complete while he inspects the plant personally. The main use of checklists however is in having them completed by someone on site. If this is to be the case then the form must be clear and unambiguous in every detail. If you are not there then the person completing the checklist must be in no doubt as to what you want filled in in answer to every question. This is very difficult to achieve and will probably take several drafts before a list emerges with which you are happy. An idea is to seek the assistance of some managers with whom you are on fairly good terms. They may be willing to look over drafts for you by way of a pilot study so that when you send the final version out you are sure it is comprehensible by those intended to complete it.

There are a number of different types of checklists or styles which can be used. The choice of style is really arbitrary but it may be that one form is preferred for one kind of risk or indeed that one style is already used by the company in a checklist employed in connection with another purpose altogether. We shall look at three styles but you will see that they are not exhaustive of all possibilities.

4.1 The first form of checklist calls for a simple checking of facts. An example is shown in Fig 3.2.

IMPERIAL RUBBER COMPANY

Security Checklist

Please ensure that all the items mentioned on this list have been checked. When you are satisfied that all the items are satisfactory then sign the form and have it counter signed before returning it to the Risk Management Department.

Premises
- Alarm systems
- Testing of alarms
- Keyholders
- All locks/bolts
- Roofs
- External fencing and walls

Goods
- Raw materials store
- Stock checks
- Finished goods area
- Despatch building

Money
- Cash
- Money in transit
- Safes

Signed: .... Plant Manager

Date of Completion ....

Counter Signature: .... Accountant

Fig.3.2

You can see that this form really only prompts the memory as to what to look for. The appropriate person needs very little knowledge of risk and can simply enquire into each point raised. The problem is that no direction is given to the person completing the form and what he considers satisfactory may not satisfy you.

The form is signed, in this case by the plant manager and the date of completion inserted. A counter signature is valuable and in this case the accountant has been asked to sign.

3.4.2 An improvement on the simple listing of points to look at is to raise each point in the form of a question. In this way the person completing the form at least has to think about each item in your terms. It is possible to be much more direct in your approach and thus guide the appropriate manager as best you can. An example of this style is shown in Fig 3.3 and is concerned this time with the fire risk.

IMPERIAL RUBBER COMPANY

Fire Checklist

This check list is to be completed by the plant manager and returned to the Risk Management Department by the end of this current month. If any problems are encountered in completing the form please telephone the Risk Management Department for assistance.

Where a negative answer is given please insert in the 'action' column what action you are taking or what action you would suggest the Risk Management Department take.

Distribution Building	*Yes*	*No*	*Action*
Are all fire doors clear?			
Are all the emergency fire exit signs in working order?			
Is there at least 18ins from the sprinkler heads to the goods on the top rack?			
Are all goods stacked neatly?			
Is all heating equipment protected and in a safe place?			
Is all waste material removed regularly?			
Are all goods off the ground?			
Are all unused pallets stored in the yard outside?			
Is all combustible material stored in the brick built combustible store?			
Is there uninterrupted access to the extinguishers and hoses?			
Are all the extinguishers shown in the Fire Safety Manual in position?			
Are all the test cards on the extinguishers marked up to date?			
Are all the sand and water buckets full?			
Are all fire doors in working order?			

Distribution Building	*Yes*	*No*	*Action*
Is the sprinkler test card marked up to date?			
Is the fire alarm test card marked up to date?			
Have all fire drills been completed in accordance with the Manual?			

Are there any other points you wish to raise which are not catered for by the standard form?

Are there any alterations you would suggest should be made to the form as it stands?

Signed: ....
Plant Manager

Date of Completion:............

Counter Signature...
Accountant

Fig. 3.3

The manager has to answer yes or no to each question raised and this has a useful psychological advantage over the previous method. This time the manager is actually stating that something is the case and where a negative answer is given he is also expected to say what he has done. This does seem to place the responsibility on him and is no bad thing in trying to encourage local plant managers to think that they have a part to play in the effective management of risk.

This checklist has been for the Distribution Area only and of course there would have to be a form for all areas of the plant. It may also be advisable to break down the form and have sub-sections dealing with different aspects of risk. This has only been a rough idea of what such a checklist should be like. In common with the example in Fig 3.2 it should be clear and free of ambiguity.

3.4.3 The third style we will look at is rather different from the previous two. This time descriptions of the condition of an activity or piece of property are given and the person completing the form must indicate which description is most appropriate. The form can describe a sub-standard set of circumstances, an above average set of circumstances and a normal position. Fig. 3.4 is an example of this style.

IMPERIAL RUBBER COMPANY

Liability Checklist

Please read the descriptions provided for each of the following activities, events, etc., and indicate which description is most appropriate. The three descriptions are labelled 'A', 'B' and 'C'. If you think that description 'A' is most appropriate in a particular case then place the letter 'A' in the column headed 'Check here'.

Should you have any problems in completing this form then please contact the Risk Management Department as soon as possible. Return the form to the Risk Management Department by the end of this month, having had it counter signed.

Activity	**Check here**	**A Sub Standard**	**B Average Standard**	**C High Standard**
Use of machine guards		Guards are used only rarely and are often not even in working order	Guards are in use most of the time and are operational	Guards are always used and every guard is in excellent working order
Use of face masks and other breathing protection apparatus		The masks etc. are rarely used and not kept in an easily accessable place	Masks etc. are used in most cases and access is reasonable	All masks are issued to staff and are worn at all times
Safety notices and other accident prevention information		Few safety signs are visible and many are out of date	The usual safety signs are posted	In addition to the normal signs there are a number of notices specific to the plant.

Fig. 3.4

This example concentrates on the liability risk and provides the reader with a number of different descriptions. The person completing the form must then decide for himself which description most accurately describes the position at his factory. Comparisons with other plants in the group, if there are any, are therefore possible and could be quite revealing. Once the form has been returned to the risk manager he will want to take action where he considers that activities, machines or processes are generally below standard.

This is a much more difficult form to compile and you can see from the three activities in the example that it is not easy to write brief descriptions. The descriptions you eventually use could of course be based on findings from a previous site visit or a prior run of the form. Either way you must endeavour to derive descriptions which are seen to be relevant by those who are to complete the form.

This is really by way of an early warning system for the risk manager and he is given the opportunity to respond quickly to remedy any potential problems.

One difficulty in completing this kind of form is that the local manger does not want his plant to be shown up in a bad light and therefore understates the poorer aspects of the plant and avoids using the extreme descriptions. This is difficult if not impossible to avoid and arises also to a certain extent with the other methods. Before embarking on any project like this it is essential to 'take the local managers with you' in the sense that they are fully appraised of the objects of the exercise. If they can be made to see that the whole exercise of risk identification will in the end lead to a safer and hence more efficient plant, they may be more willing to complete the forms accurately. This may be rather idealistic but at least it is worth trying.

3.4.4 Before moving on to another technique let us just briefly comment on the principal advantages and disadvantages of checklists:

- The main advantage must be that they are a reasonably inexpensive method of generating a great deal of information about risks within the company. They are inexpensive in time and money in comparison for example with the physical inspection.
- They are also very simple in essence and can be arranged quickly and implemented with not a great deal of fuss.
- They allow for a fairly rapid comparison with previous years and this makes for efficient monitoring of risks year by year.
- They are also adaptable and can be changed very simply to keep up with changes in the company or just to take account of improvement in the layout of the form itself.

Advantages are rarely gained without some price and there are some disadvantages to the use of checklists:

- In most cases they are completed by someone other than the risk manager and as a result it is possible that inaccuracies creep in during their completion.
- It is inevitable, even with the best form, that there will be ambiguities and hence a measure of subjectivity when the forms are being completed. This may lead to a differing standard each year and also to differing standards being applied among different plants within the same group.
- In practical terms it may be difficult to have the forms completed on time and several reminders may be required. If this occurs then some doubt must be cast on the validity of the returns.
- A problem with all questionnaires is that it is not possible to say 'how' the form is completed. It is hoped that the form was given thought and that the answers are valid but there is no way of knowing this unless you actually go with the form and see it completed.

3.5 Organisational Charts

The check list was a desk based method for the identification of risk. Another such method is the organisational chart. These charts are useful in illustrating different aspects of the company's activities and structure. The check list and physical inspection attempted to identify actual risks, the organisational chart endeavours to pinpoint 'areas' of risk. This is a slightly different approach but nevertheless one which is valuable to the risk manager.

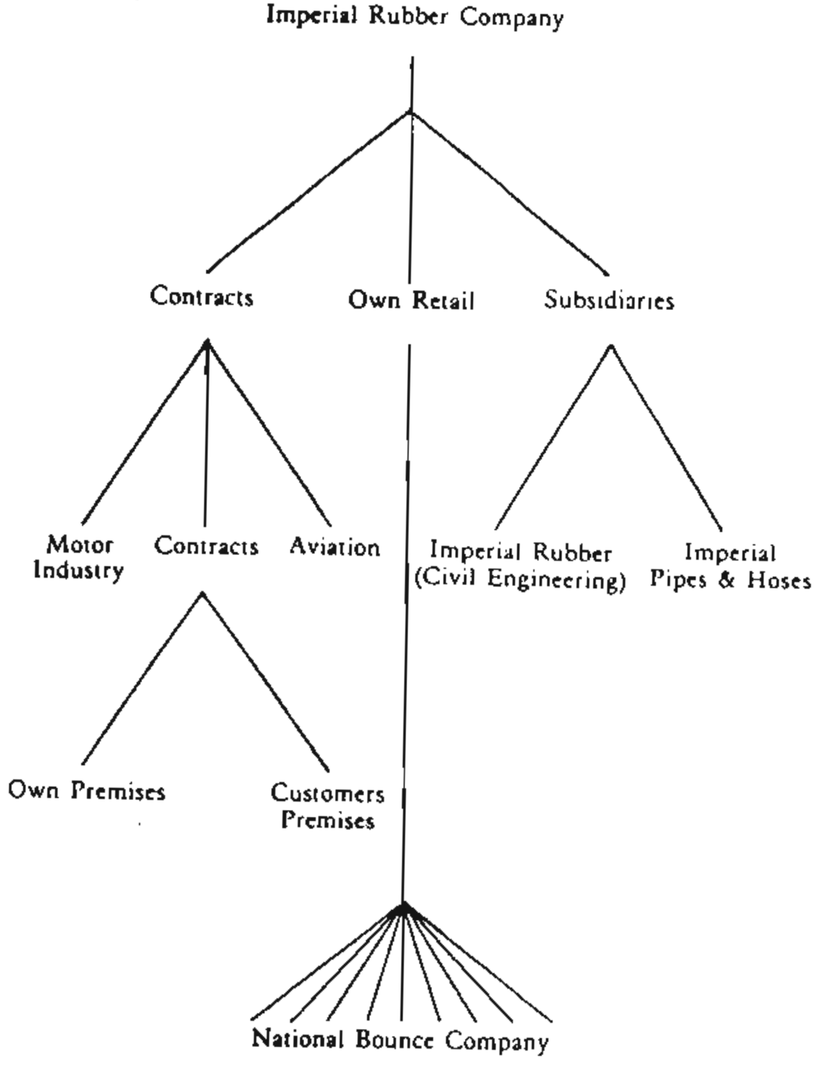


Fig. 3.5

3.5.1 The first step would be to draw a simple chart of the organisation of the group. By looking back at section 3.2.1 we can build up a picture of the structure of the group as a whole. There is the main company, Imperial Rubber, and there are three subsidiary companies plus a contracts division. This could be represented in a chart such as the one shown in Fig. 3.5.

This chart shows the three main aspects of the group's activities, contracts, retail and specialised subsidiaries. There are certainly other ways in which the chart could have been drawn but the main point is that all the areas of activity are shown somewhere. This chart is really an essential starting point for any understanding of the group's work and it is highly likely that a chart such as this would appear in company literature somewhere. If one does not already exist then the risk manager should set about drawing one. Apart altogether from any risk identification value which it may have it is an excellent way of getting to know and understand the structure of a group, and nowadays these structures can be extremely complex.

3.5.2 The chart in Fig. 3.5 was of the structure of the group as a whole, what the risk manager can now do is to construct a chart which is more tailored to the identification of risk. He could for example draw a chart which was company based and showed the management and administrative set up. Such a chart is shown in Fig 3.6.

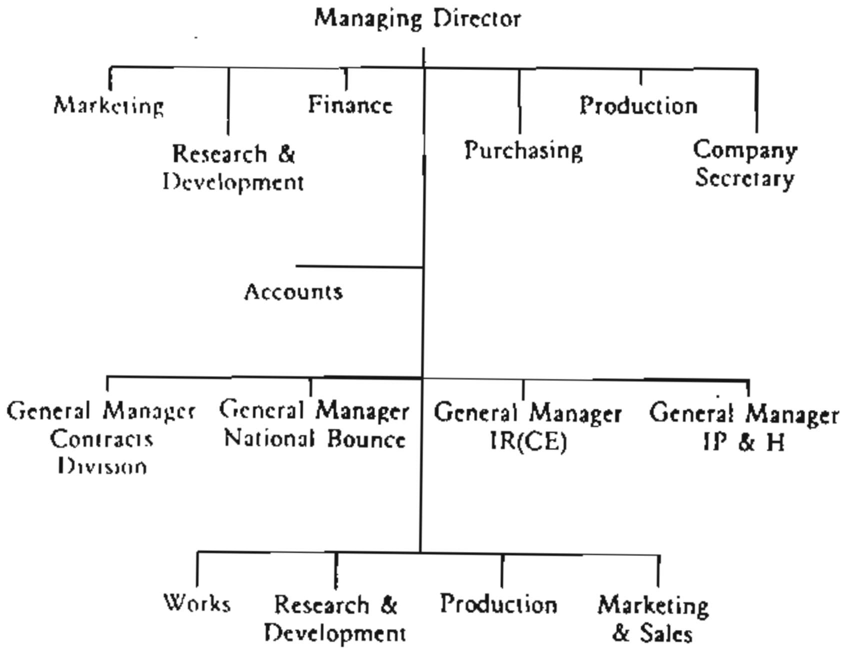


Fig. 3.6

This chart differs from the first one in that it concentrates on the companies which make up the group and on their management structure. The starting point is the same, the managing director of Imperial Rubber. Under him we can see the various functional managers including marketing, research and development, finance, purchasing production and the company secretary. There seems to be a central accounts function and this is displayed on the next level. Under this we have the individual units which make up the group. There is the contracts division, National Bounce and the two specialised subsidiaries, Imperial Rubber (Civil Engineering) and Imperial Pipes and Hoses. Each of these operating units has its own general manager and the chart shows that they also have their own works, research and development, production and marketing managers.

There are no rules about how these charts should be drawn and different companies will present different structures and hence suggest different charts. Where, for example, a company has a number of main products then it may be wise to draw a chart based on these products. In this way you could show all the products and their management teams rather than the subsidiary companies as we have done for Imperial Rubber. The first step is to get the basic structure down on paper and this may well dictate the shape of any other charts you have to draw.

3.5.3 We will look back at the charts we have drawn and see what they tell us about areas of risk within the group but there is one final chart we could draw first. We could take each of the divisions of the group and draw a chart for them. For example we could take Imperial Pipes and Hoses and draw a chart similar to the one in Fig 3.6 but this time only for the one subsidiary. We have done this and the chart is shown in Fig 3.7.

We already know from the chart in Fig 3.6 that there are works, research and development, production and marketing managers for Imperial Pipes and Hoses. The chart in Fig 3.7 can now extend this and show that there is an accounts function and a legal department for the two parts of the company, pipes and hoses. There are heads of these two divisions and then a number of account liaison supervisors. This could be done for all the divisions of the group and the various charts combined to produce an omnibus chart of the management and administrative structure of the entire group.

3.5.4 We said earlier that the organisational chart did not identify individual risks but rather it highlighted areas of risk. We can look back at the three charts we have drawn and see what areas of likely risk have been revealed if any.

These charts usually show up at least three forms of probable risk. They can highlight duplications, dependencies and concentrations. If we look at Fig 3.6 we can see that the research and development function is repeated four times as each of the four main divisions of the group has one. This may not in itself be a risk but the risk manager must satisfy himself that he has good communication links with all of these

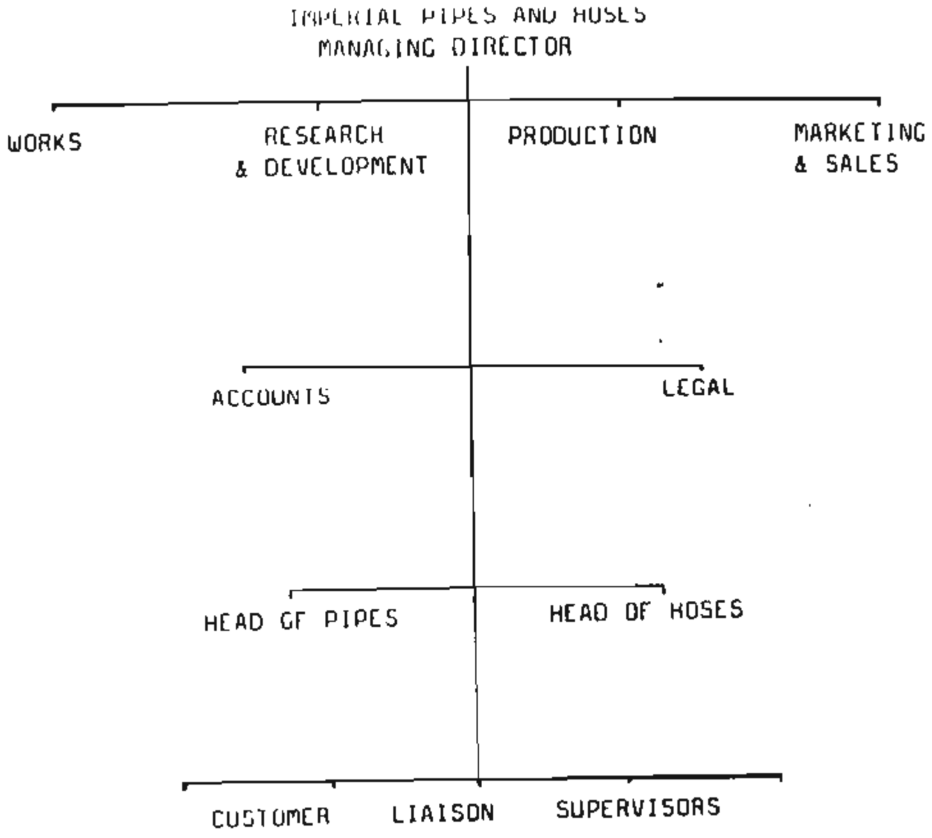


Fig 3.7

departments. The work which is carried out by these departments may well produce risks for the present or the future and be will want to make sure that he is up to date with all the work they are doing. Still with the chart in Fig 3.6 we can see that the marketing function is also repeated for each of the main divisions. Again, this level of devolution of tasks and responsibilities may not be a bad thing and may not increase the risk to which the group is exposed but it should put the risk manager on enquiry. He will want to ensure, for example, that all of the marketing departments are aware of any special instructions which the product liability insurers require to be given with products. Good communication links are once more important and the chart may show deficiencies which otherwise may not have been revealed.

Dependencies may also be uncovered by the chart. The chart in Fig. 3.7 shows that the pipe and hose divisions both rely on the one production

department. There may be nothing wrong with this in itself but once more the risk manager must satisfy himself that there is no increase in risk as a result of this dependency.

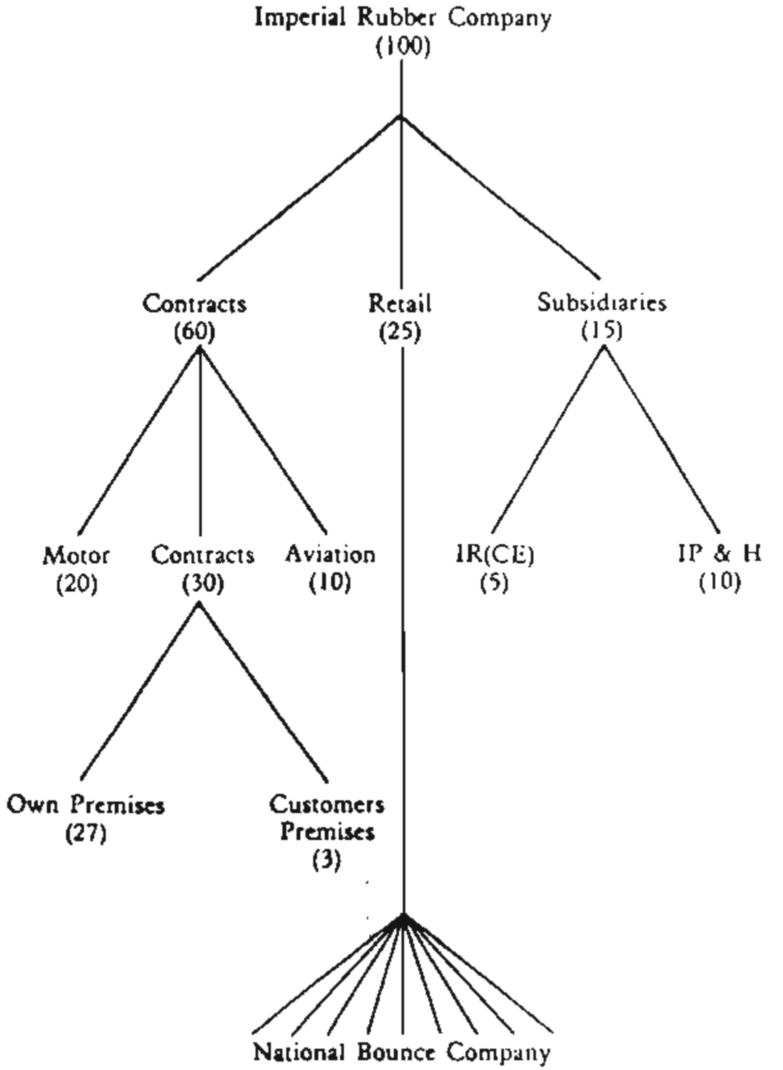


Fig. 3.8

A possible concentration risk is revealed by the chart in Fig. 3.6. It would seem from this chart that all the accounts records are kept in the one place for all the divisions of the group. This may have been a definite decision taken by management but the risk manager must once more ensure that no increase in risk is caused.

One final thing we could do with the charts is to add on some figures. We could for example add on the fact that the two specialised subsidiaries obtain 100% of their raw material from Imperial Rubber. This is clearly a risky situation and one which the risk manager may want to investigate further. There may be no other supplier capable of meeting their demand or it may be that the main company depends on the revenue from the subsidiaries. We could also add on the revenue or profit figures for each part of the group. By adding on the revenue figures to the chart in Fig 3.5 of the structure of the group as a whole we can see which divisions are responsible for the highest levels of revenue.

The contract work done at the premises of Imperial Rubber accounts for 27% of total revenue, the highest single percentage contribution of any division of the group. This is not to say that the work done on the premises for customers is the most profitable but it does produce the highest revenue.

Placing figures on these organisational charts can be of marginal assistance in the identification of risk but there is one technique which can make use of charts and figures and that is the flow chart.

3.6 Flow Charts

The flow chart is not restricted to the organisational structure of the company. It can be used to describe any form of 'flow' within the company. In any organisation there will be many different aspects of flow. There will of course be a production flow, as raw materials are converted into a finished product. In a service company there will be a service flow as the company attempts to satisfy the demands of its customers. There will also be accounting flows, marketing flows, distribution flows and many others. For the risk manager the most important is probably the production flow. From such a flow chart the risk manager can see where the raw materials come from, how they are processed, the various stages of production and the final destination of the product.

At any one of these stages there can be risks and it will be the task of the risk manager, not simply to describe the flow but to interpret the chart in terms of potential risk.

3.6.1 The first step is to ascertain exactly what the various stages in the production process are. This will involve lengthy discussion with those most closely involved in production. It may be that some form of flow chart of production activities already exists but it is a useful exercise for the risk manager to ensure that he knows for himself all that is involved in manufacturing the product.

Once the details of the flow of goods through the plant has been ascertained, a rough chart can be drawn which illustrates the process. Let us take a very simple sub-set of the activities of Imperial Rubber to introduce the idea of the flow chart.

Raw material in the form of vulcanised rubber is moulded to make a particular product. This product is then sent to the finished goods store for eventual use in a further process, while the remainder is sent to the National Bounce Company outlets for sale to the public. Forty percent goes to National Bounce by rail with the remainder being stored by Imperial Rubber for future use. Of every moulding, ten percent of the raw bulk rubber is waste and returned to the raw material store for reprocessing. The moulding process is powered by gas and electricity both of which are drawn from the local town mains supply. With this description we can now begin to draw what we know in readiness for a full flow chart.

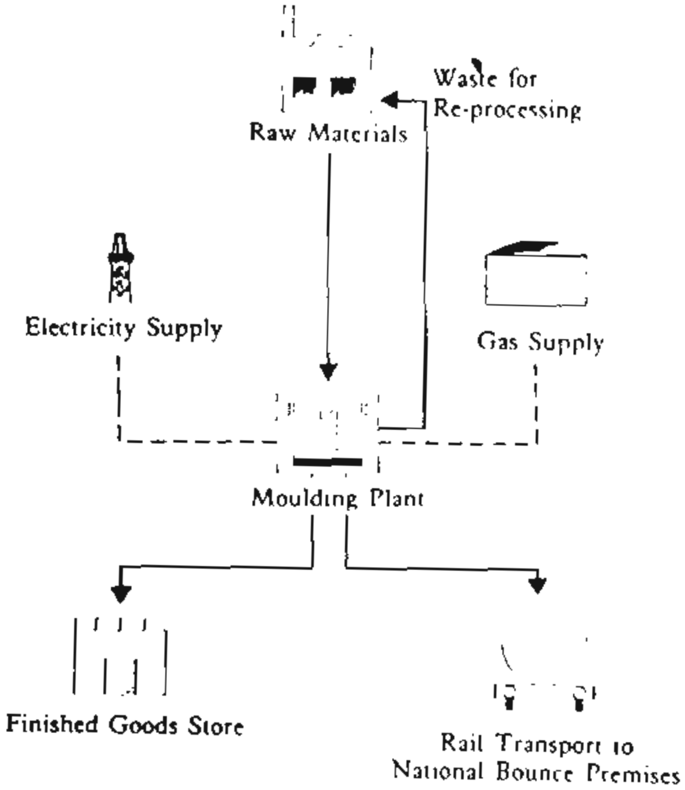


Fig. 3.9

The drawing in Fig 3.9 illustrates what we know of the process. It is not essential to make an illustration like this as it is possible to proceed directly to the flow chart we will use for risk identification. However, such a chart has its uses and if time permits it may be valuable for future purposes to have one drawn. At least now the risk manager has on paper what he has determined is the process and can send this to the various line managers involved for their comments. It is much more likely that they will be able to follow this chart than the one we will eventually draw for risk purposes. By sending this chart out for comment and revision the risk manager can be fairly satisfied that he has a firm understanding of what is happening. With this drawing as a base he can then make any revisions as time passes and alterations are made, sure in the knowledge that at least the starting off point was accurate.

3.6.2 From the drawing in Fig. 3.9 the risk manager can identify the key stages in the process and then set about drawing his own flow chart. In this simple example there is only one process but you can imagine that in a real case there will be a number of processes taking place at the same time and the possibility that a complex web of inter-relationships will exist. We will see something of this when we attempt a flow chart of the whole operation of Imperial Rubber .... but not until we have tried to master this simpler example.

There are no real conventions for the drawing of these flow charts in risk management and so the risk manager can draw according to what pleases him and produce a drawing with which he is perfectly happy. One simple rule would be to use a square symbol for the input stages of a process, such as the stores of raw materials and to use a circle for process stages such as the moulding plant. A flow chart is shown in Fig. 3.10, study this for a moment and try to see the connection between it and the drawing in Fig. 3.9.

This flow chart shows that a quantity of raw rubber blocks was sent for moulding. This could be a quantity for a day, a run of the machine, a shift or any other time period which was thought appropriate. The quantities would relate of course to the time period and would be defined in a document which would have to accompany the chart. In this example the time period is one shift and the quantity is measured in pounds.

We can see that 300lbs of raw rubber is passed to the moulding press and during the process we produce 90% of the raw rubber in the form of the finished product. Out of the 270lbs of product produced, 60% is sent to the finished goods store and will be used by Imperial Rubber in some later process. 40% goes directly to National Bounce. The remaining 30lbs of raw material is in the form of waste and the flow chart shows that this is returned to the store for future use.

The materials involved in the flow are described by letters, and so 'R' is the raw material, 'P' the finished product and 'W' is the waste. The volume of the material which is flowing from stage to stage is shown against the line of flow and so we can see that 300R is passed from the raw material store to the moulding plant. In a larger flow chart there is the need to conserve space and the use of these abbreviations will be essential. It is necessary however to remember to include some form of key for your own use and the use of anyone else who may need to read the chart.

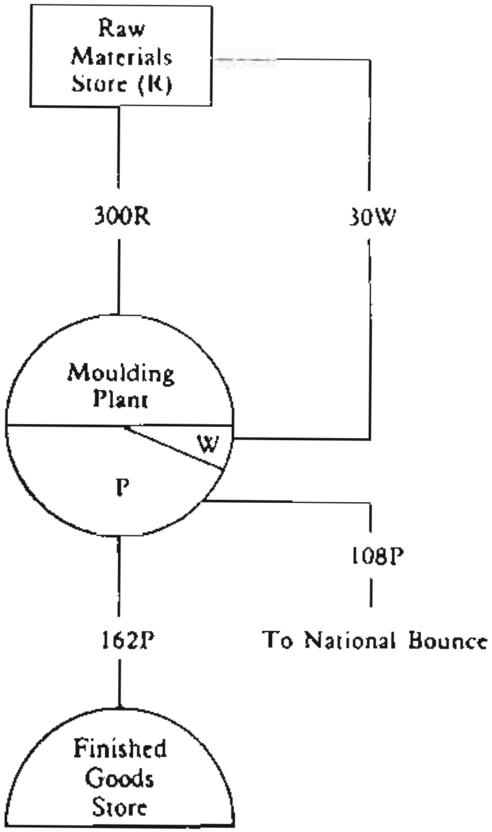


Fig. 3.10

Drawing the flow is the simple part of the whole exercise. It is now that the risk manager must interpret what he has drawn. We have said already in this chapter that an imaginative and flexible mind is required for the task of risk identification and these qualities are required in great measure now, if the flow chart is to be made to reveal all the risks in the process.

The flow chart is not intended to identify the causes of loss such as fire, theft, liability etc. what it does do is to highlight the effect of certain events. The risk manager can ask a number of 'what if' questions and use the chart to suggest the answers.

For example in our simple chart we could ask what would happen if the electricity or gas supplies were cut off. We are not so much concerned at this stage with how we could lose the supply but more with what will happen if the supply is lost. This is the classic pattern of the 'what if' line of enquiry. If the source of power was interrupted we would lose the use of the moulding machine and hence all the production for the duration of the power loss. This would lead us to ask whether or not there was an alternative source of power. It could lead us into an enquiry of the total expected cost of any lost production and the comparable cost of having a secondary source of power available.

What if the moulding press broke down for some reason, what would be the effect of this? In essence the effect is exactly the same as if we had lost the power. The machine will not be able to produce the finished product. This will mean that the supply will have to stop and we will have to enquire as to the effect this will have on the company as a whole. It will be the case that the production schedule will take into account the demand made by the moulding machine. Now that this demand has ceased what effect will it have on their production. Does National Bounce have an alternative supplier? We know from our earlier description that it obtains all its stock from Imperial Rubber and so a stop in production will have serious consequences for its sales.

3.6.3 We could continue this line of enquiry until we felt that we had exhausted all possibilities. There is however a certain lack of structure to our approach and the chance is there that we miss something altogether, not because it was omitted from the chart but because we did not ask the right question.

One way to bring some structure to the interpretation of the flow chart is to produce a simple table for completion as you read the chart. For example your table could have four simple headings such as:

Stage	Likely Loss Producing Events	Likely Causes	Possible Consequences

We could now take each stage in turn and list all the events which are likely to cause a loss and then look at causes and consequences. If we do this for the moulding stage in our simple flow chart we could end up with the following:

Stage	Likely Loss Producing Events	Likely Causes	Possible Consequences
Moulding press	Moulding press out of action	– Fire – Explosion – No gas – No electricity – Industrial action	– Lost production – Over capacity in production of 'R' – Loss of revenue to National Bounce – Reduction in Imperial Rubber stock

If this had been a chart involving several different stages you can see how such a table could be of value in structuring the approach to risk identification. What we could add is a column for possible actions. Alternatively we could simply keep a note of what we intend to do in the light of the risks we have found.

Notice, once more, that what we have used the chart for is to identify broad areas of risk rather than individual perils. Approaching the problem of risk from this broad perspective will inevitably lead to consideration of individual perils but it is felt that casting the net as wide as possible in the early stages of analysis yields better results in the end.

3.6.4 We have said already that the flow chart in Fig. 3.10 was fairly simple in comparison to what we may find in the real world. The flow chart in Fig. 3.11 is a little more complicated but still much simpler than could be the case. This chart is for the entire operation of Imperial Rubber as we have described it.

The various materials are described by letters and the quantities by numbers. These quantities and numbers are shown alongside the lines which connect the different stages of the flow. Starting at the top of the chart we see that 1620A, this could be 1620lbs or 1620 tons of raw rubber, is sent in equal portions to plants 1 and 2. These plants are where the raw rubber is broken down and various chemicals are added. We see that three chemicals are added in different quantities. In total a volume of 180 is added which means that 180 plus the 1620, 1800ABCD, then flows on to the next stage which is plant 3. Plant 3 is simply a combining stage where the product of plants 1 and 2 are mixed together before being sent for the vulcanising process in plants 4 and 5. Notice that during this combining process there is a residue of property A left and this is sent back to the raw material bulk store of A and is used again in the process. At plant 3 the total quantity of ABCD which is passed on to the next stage is 1700 and 1000 is sent to plant 4 with the remainder going to plant 5. The output of plant 5 is therefore 700R. 400 is sent for rolling in plant 6 and is then despatched to the contracts division for use by Imperial Rubber in their contract work. The remaining 300R is transported to Birmingham for use by Imperial Rubber (Civil Engineering) and Imperial Pipes and Hoses. Plant 4 treats the other 1000ABCD which comes from plant 3. This 1000ABCD is split among plants 7, 8 and 9 in the quantities 400, 300 and 300 respectively. There is waste to the extent of ten percent at each of these plants and so in total 100W is produced. (This section of the flow chart is the sub-section we looked at in Figs. 3.9 and 3.10 , if you look back to these charts you will see the vulcanising process and then the moulding press with the ten percent waste.) Plants 7, 8 and 9 are moulding presses which produce products P1 and P2. P1 is for use by Imperial Rubber and P2 is for sale to the public through National Bounce outlets. You will see that plant 7 is exclusively devoted to products for Imperial Rubber, while plant 9 is devoted to National Bounce goods. Plant 8 is divided between the two. The waste from the three moulding presses is sent to plant 10 where there is a reprocessing

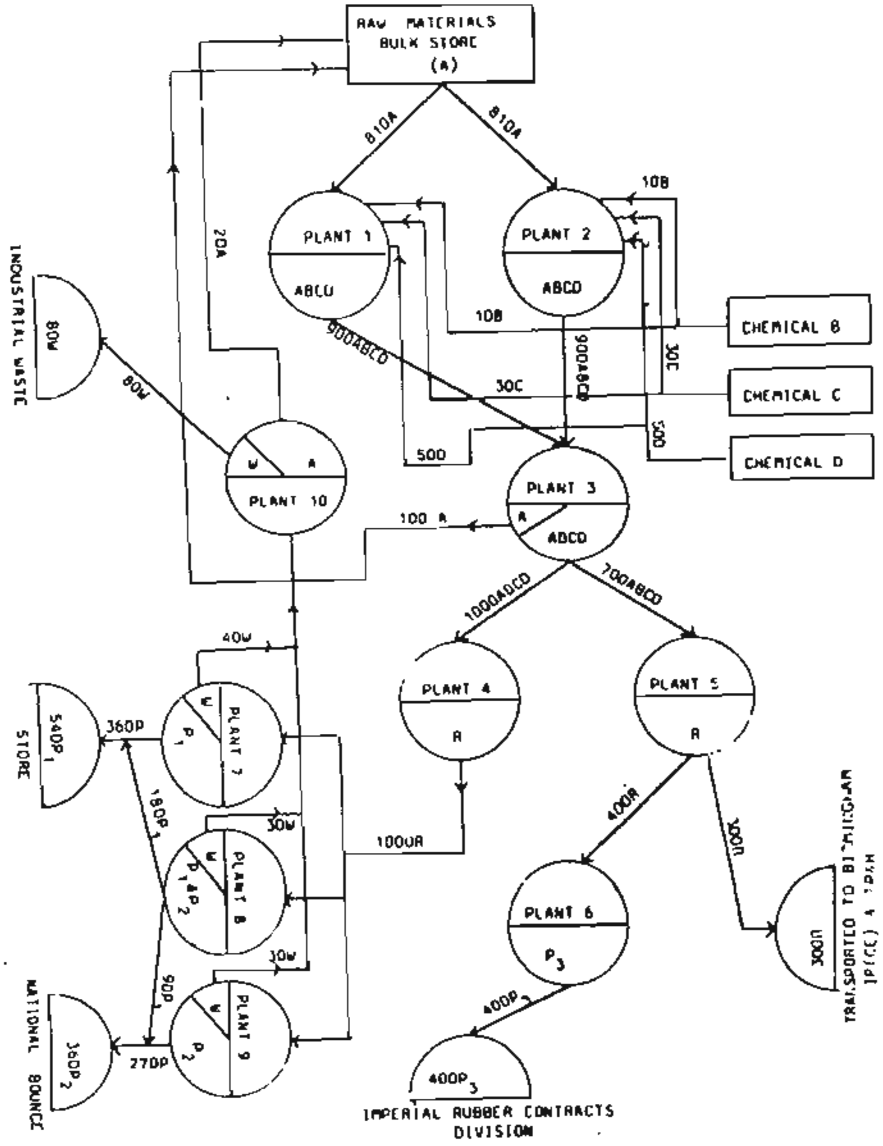


Fig. 3.11

machine capable of recovering 20 percent A out of the waste it receives. This 20A is returned to the bulk store and the 80W, which is looked upon as industrial waste is then disposed of by an industrial waste contractor.

Fig. 3.12 shows a rough drawing of the whole process and is the kind of drawing which could have preceded the actual flow chart itself. Fig. 3.12 is the equivalent of Fig. 3.9 in our simple example.

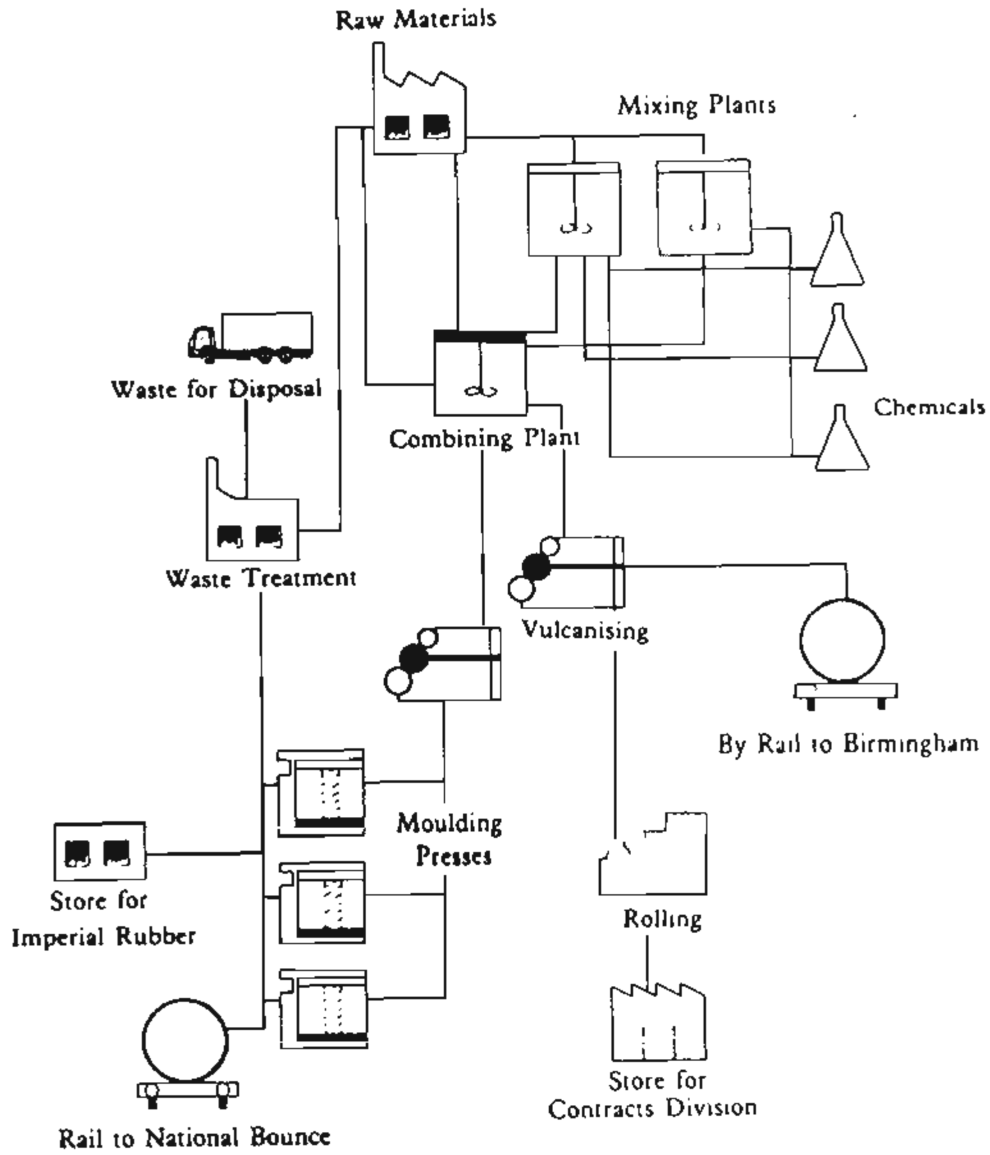


Fig. 3.12

This has taken a little while to explain but is a small plant in comparison to many and the complexities of the actual process have been reduced to the minimum, as anyone who knows anything about the production of rubber products will see. However, the main point of all of this is not to understand the rubber industry but to understand the use of the flow chart in the identification of risk. What we would do now is to draw up a chart so that we could go through each stage of the process and describe the likely loss producing events, likely causes and possible consequences. For the chart we have drawn this would take some considerable time and you are urged to look at the chart carefully and try to draw your own conclusions from it.

3.6.5 In the meantime let us take one stage and see what the chart could tell us about the risks faced by Imperial Rubber. We will look at plant 2, this is one of the two plants where the raw material is broken down and the chemicals added prior to the vulcanising process. The likely loss producing events at this stage include the loss of use of the plant either permanently or temporarily. The causes of such a stoppage could include fire or other perils, mechanical or electrical breakdown or industrial action. For the risk manager, who may already be quite well aware of most of the causes of loss at the site, the more important aaspect of the chart will be to identify the likely consequences of the loss of use of the plant.

These consequences will include:

- If plant 2 is out of action there will be a reduced demand for the chemicals B,C and D. Is the supplier of these chemicals in a position to reduce the supply at short notice or if not is it possible to store the chemicals until they are required? This raises a number of risk related questions for the risk manager to enquire into and follow up.
- Plant 3 will not be able to work at its normal capacity if the production from plant 2 is lost. This may mean laying men off or short time working.
- There will now be only about 850ABCD produced instead of 1700 and this will mean of course that the amount going to Imperial Rubber (Civil Engineering), Imperial Pipes and Hoses, the contracts division and National Bounce will all have to be reduced. What will be the effect of doing this? Will the two specialist subsidiaries have contracts to fulfill? Would it be better to shut down one of the plants, either plant 4 or 5, rather than run on short measure?
- Depending on whether we shut down 4 or 5 we may have to close one or more of plants 7, 8 or 9. In any event the output will be reduced and plans will have to be made as to how best the shortfall is to be managed.
- The reprocessing plant, plant 10, will sustain a substantial reduction in the amount of waste it will receive and it may be better to shut this plant down until the stoppage in plant 2 is over. The waste could then either be stored or sent for disposal without trying to recover any raw material from it.
- Some of the raw material which is used at the beginning of the process does in fact come from later parts of the process itself. On the flow chart we can see that 20A comes from plant 10 and 100A comes from plant 3. Some or all of this will be lost and therefore the amount of A going into the process at the start will be reduced. This may not be a problem as we will be looking for ways of reducing the throughput of material until the plant is fully operational but we will have to remember that reducing the input of A will result in a consequent fall in the store of A.

There are many other consequences which we could list and a great deal more detail we could have gone into, particularly in the effect on the main operating subsidiaries such as National Bounce, Pipes and Hoses etc.

Having listed the possible consequences of the loss producing event the risk manager could be keeping a note of what actions he would take. This means that should the loss occur at some time in the future he will have at least a start in knowing what actions to take. He could for example consider the possibilities of doubling the output of plant 1 or having two shifts at plant 1. He may also institute enquiries to see if any raw material could be purchased at short notice from some other supplier. It is certainly best to make all these plans in the relative calm of the pre-loss situation rather than in the heat of the post-loss activity.

What we have looked at is only one stage in the whole process and the risk manager would have to move on now to another stage and another until all important stages had been covered and all loss producing events identified and consequences plotted. You can see that this will be a lengthy process but one that will be rewarding both in terms of the insight gained into the operation of the firm and the risks which may be revealed.

Some may look back over the list of events, causes and consequences we have mapped out and wonder if they really are the province of the risk manager. It may well be that certain of the events we identified would be handled by some other member of the management team but that is not an excuse for the risk manager to ignore them. The history of large scale industrial incidents is chequered with managers assuming that someone else was doing the job of managing risk. The sole function of the risk manager is to manage risk and it will not be good enough, the day after a loss, for him to say that he thought someone else looked after a particular form of risk.

3.6.6 Before leaving the flow chart let us say what we believe the advantages and disadvantages are. On the plus side we could say that the use of flow charting is an excellent example of breaking a problem down into manageable proportions. It is a daunting task at the best of times to begin the job of risk identification but once a large problem is broken down into smaller sections then the work can at least begin.

The chart also has the advantage of letting the risk manager see the whole process in the one chart. For complex operations this may mean more than one chart but nevertheless the advantage remains that the manager can look at a chart and see the entire operational flow of the company. This is much preferable to having to read a number of publications describing the processes.

The chart also allows for structured thinking about the problems of risk. It not only allows for structured thinking but almost demands it if the chart is to be used properly. This logical approach to risk identification is often what is missing but the chart guides the manager through the process of identifying risk.

The disadvantages of the flow chart certainly include the time it takes to complete a study. From understanding the processes involved to drawing the chart can take a considerable amount of time and then the real work of interpreting the chart begins.

It is also possible for some charts to be extremely complex and this can be a disadvantage. If the chart is so complex that it obscures the risks then it may well be that a flow chart is not the best technique to adopt.

The chart could also be said to be very general in nature. It covers the whole process in a general sense but does not concentrate on any one specific part of the process which itself may conceal all kinds of risks. This is a disadvantage associated with any form of risk identification which takes the broad brush approach adopted by the flow chart.

A final disadvantage is that the flow chart does not comment on the likelihood of events occurring. We mention likely loss producing events but we do not say whether we believe the events to be extremely likely or hardly likely at all. This absence of any measure of likelihood will be favoured by those who shy clear of using numbers but it is nevertheless a disadvantage which we should recognise.

The final two disadvantages, that of the general nature of the flow chart and the lack of measurement are taken up in chapter four when we turn our attention to a number of techniques which are far more detailed in nature and make use of numbers in the quantification of likelihood.

Chapter Four

IDENTIFYING RISK 2

4.0 In the previous chapter we looked at a number of techniques for the identification of risk. They were all in the main concerned with highlighting broad risk areas. We looked at physical inspections, check lists, organisational charts and flow charts. Each of these methods adopts a kind of broad brush approach to risk and is not concerned with identifying individual sources of risk, no matter how small. When we listed the possible disadvantages of the flow chart we said that it was a very general technique and also lacked any quantification of likelihood.

In this current chapter we are going to turn our attention to certain techniques which overcome these disadvantages. The first is the hazard and operability study.

4.1 Hazard and Operability Studies

The hazard and operability study (HAZOP) is a qualitative approach to risk identification which can be employed at the planning stages of projects. It has had its origin in work done by ICI and is now used extensively in the chemical industry. In essence the HAZOP is a critical enquiry into the operation of a plant, from the hazard point of view. It follows the basic logic we have seen already that many problems are extremely complex and must be broken down into manageable parts. A plant is divided into a number of parts and each part is then examined extensively in order to identify all the hazards associated with it. A logical framework is laid down by which this identification is achieved.

4.1.1 There are four main questions with which the HAZOP study is concerned:

- the intention of the part examined.
- the deviations from the declared intention.
- the causes of the deviations.
- the consequences of the deviations.

A particular section of the plant is selected and the intention of that section is defined. This is clearly a crucial stage as if the intention is not accurately stated then the deviations from it will also be suspect. The HAZOP is best carried out by a team and the team will jointly derive the intention of the section of the plant under enquiry. The study is not just on the one selected section as once the work on that part is done then another section and another will be chosen until the entire plant has been examined. It is important that the team, rather than an individual, describes the intention of the part as no one person on the site is likely to have a comprehensive knowledge of all that the particular section is intended to achieve. In addition different people will perceive the purpose of the section from their own perspective and this may not be the only, or correct, perspective.

Once the intention is declared then the deviations from the intention are to be listed. What we are interested in are all the possible departures from the declared intention. Here again the team approach is valuable in viewing the problem in the widest possible way. These deviations are obviously at the core of the HAZOP study and a great deal of time is required on them. Rather than leave the team to spot deviations in a non-structured way the HAZOP method makes use of a number of guide words which are to be applied to each part or section being studied. These guide words are examined later when we look at our first example of a study.

A cause or list of causes for each deviation is then drawn up. Again the team is valuable in being able to bring their own area of expertise to play on the problem. All possible causes are to be listed, not just the ones which seem most likely or have already occurred in the past.

The results of the various deviations are then listed and these will give rise to a number of possible actions which the team may want implemented once the study is over. It is as well to note these actions down as the study is being carried out rather than at the end.

The approach we have described briefly is similar to the flow chart method we looked at in the last chapter, we approach the task with a pre-arranged method of enquiry and structure our thinking about how to identify possible risks.

4.1.2 Let us take a very simple example and try to illustrate the use of HAZOP in action. We will assume that Imperial Rubber has an underground petrol tank which it uses to store fuel for its fleet of motor vehicles. There is one hand pump and associated valves and displays of how much fuel is used. A rough drawing is shown in Fig. 4.1 from which you can see that the petrol is stored underground and is drawn to the surface by means of a pump. The pump is activated when the hand-held nozzle is removed from its casing in the pump assembly. This is similar to the petrol pumps seen in many filling stations.

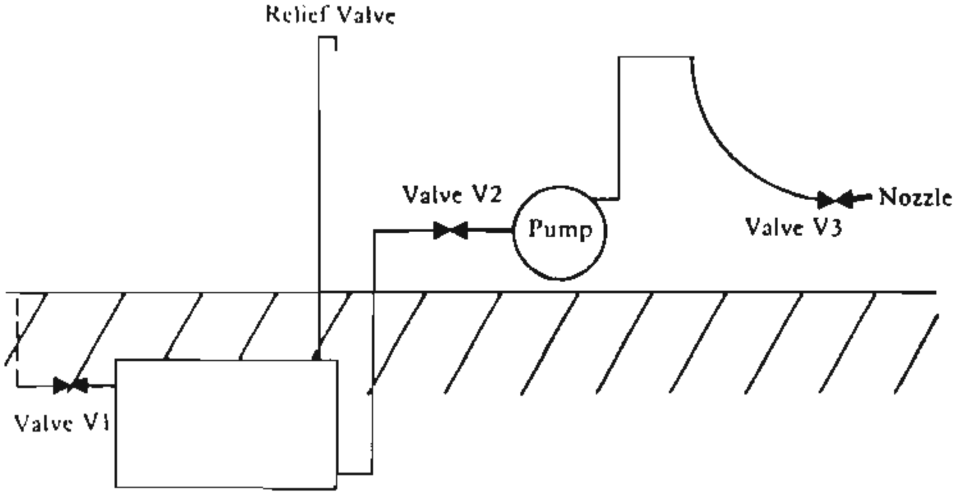


Fig. 4.1

This could have been a small section of a large plant or process system and we could have selected it as the first section to study. We have however decided to look upon it as an entire system for the sake of illustrating the concept of hazard and operability studies.

The first thing to do is to decide what the intention of the system is. Let us say that the intention is to store petrol for motor vehicles underground and to withdraw it as required for use by the vehicles. What we need now is a chart so that we can plot our way through the structure suggested by the HAZOP method of working. We will need columns for deviations, causes, consequences and actions plus a column for the guide word which will alert us to the deviations from the design intention of the system. We could head up a sheet of paper, or more probably several sheets, in the following way;

Guide	Deviation	Causes	Consequences	Actions

Before saying anything about the guide words we will have to decide what aspect of the system, or what property of the system, we are going to investigate. We know that the system in Fig. 4.1 is the entire system but we must decide if it is the flow through the system with which we are interested or the pressure or some other property of it. In most plants and with most systems there will be a number of different properties which could be potentially hazardous and in need of investigation. Properties such as flow, volume, temperature, pressure are all properties which could, if they deviate from the norm, cause loss. Once the intention of the system or part of the system is decided then the team must list the important properties and begin their task.

In this case we will say that the property under investigation is that of flow, the flow of the petrol from the tank to the vehicle

4.1.3 We now know the intention of the system, we know that it is the flow of petrol with which we are concerned and so we can begin to apply the various guide words. These guide words are shown below and are intended to 'guide' the user through the different possibilities. This is again similar to the 'what if' line of questioning we mentioned in the previous chapter.

Hazard and Operability - Guide Words

Guide Words	*Meanings*	*Comments*
No or Not	This is the complete negation of the intention	No part of the intention is achieved, i.e. there is no flow or no heat or no pressure. Nothing else happens, there is simply no part of the intention achieved.
More **Less**	There is an increase or a decrease in the quantity of the property.	There could be more flow than was the intention or less flow. In the same way there could be more heat or less pressure, etc.
As well as	There is a qualitative increase in the property.	The design intentions are achieved but an additional activity occurs, e.g. water gets into the system and flows into the petrol tank of a vehicle.
Part of	There is a qualitative decrease in the property	Only some of the intention is achieved and some is not. This is not a quantitative decrease that would be *less than* but is a decrease in the quality of the property.
Reverse	The logical opposite of the intention.	An example of this could be where the flow is reversed or instead of boiling a liquid it is frozen.
Other than	The complete substitution of the intention	No part of the original intention is achieved and something entirely different takes place. For example some other liquid may be put in the tank and then flow down the pipe to the vehicle.

4.1.4 We can now head up our paper with the columns shown in 4.1.2 and begin the actual analysis of the system.

We could go at length thinking of all the possible deviations which could occur and all their associated causes and consequences but we will stop here. The general idea of the HAZOP study can be seen from this simple example. We have defined the intention of a small system and then set about determining all that could possibly go wrong with the system. Each cause has been numbered and the corresponding consequences and actions inserted with the appropriate number.

You can see how this method is particularly suitable for the design stage of any process or plant. The design team, including the risk manager, can sit down and explore all possibilities long before any actual construction work starts. We must stress once more that imagination and flexibility of thought are of the essence in doing this kind of work. This is best achieved or at least aided by working with others and pooling the resources of several experts.

Guide	*Deviations*	*Causes*	*Consequences*	*Actions*
No	No flow	1. Tank empty 2. Inlet valve V1 is shut 3. Pump not working 4. Other two valves shut 5. Hose blocked	1-5. No petrol gets to vehicles 4. Petrol seeps out of pipes 5. Hose bursts	1. Regular checking of tank 2,4 Valves to be checked every day 3. Regular maintenance on the pump
More	More flow	1. Pump faulty	1. Spillage	1. Regular maintenance
Less	Less flow	1. Pump faulty 2. Valves not fully open 3. Hose partly blocked	1-3. Longer to fill tank in vehicle	1-3. As for no flow
As well as	Water as well as petrol	1. Water in storage tank	1. Water gets into the tanks of vehicles	1. Regular cleaning out of storage tank

4.1.5 Now that we have introduced the concept with a simple example let us imagine a more complicated problem involving Imperial Rubber. Let us say that they are contemplating a new automated system for breaking down the rubber and mixing in the various chemical additives. The new system is still very much at the design stage and it has been decided to carry out a hazard and operability study. A team has been formed and the risk manager is to be a member.

The system under consideration is shown in Fig. 4.2. In brief terms the raw rubber would be fed into the bunker at the top of the diagram and would be partly broken down. It then drops on to a conveyor belt which carries it to the next part of the system. Here the partly broken rubber is dropped into a further bin where it is broken down into finer particles, fed by suction into a tank into which the chemicals are added. There is a pressure relief valve on the tank. After the mixing process is complete the whole mixture is sucked into an outlet pipe and carried on to the next stage in the process.

This is only a proposed system and so you cannot go and see it working for yourself. You must therefore rely on the drawing to tell you all you need to know before conducting the HAZOP study. Let us say that the drawing in Fig. 4.2 is the only one available at the moment and so you must work from it. The first thing to do is to draw up a sheet with the appropriate columns on it of;

- guide words
- deviations
- causes
- consequences
- actions

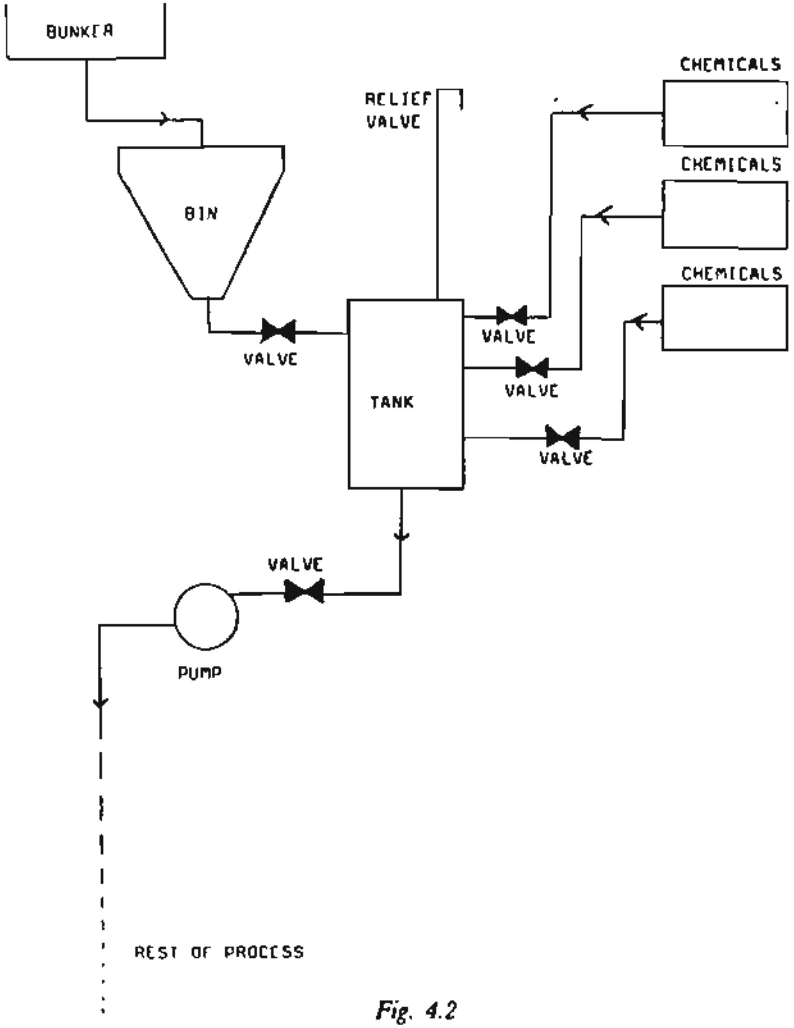


Fig. 4.2

Once you have done this you can start with the first most appropriate guide word and work you way through them all. Remember that not all the guide words may apply to this particular problem but you will be working in a team and it is likely that the combined knowledge of everyone involved will produce the best list of guide words possible.

When the sheet with the columns has been headed up and the first guide word selected you are almost ready to start the task of identifying causes and consequences. Before doing that there are two things still to be done. The first is to work out the order in which you are going to work your way through the system. The earlier example we used was an entire system in itself and we simply carried out the HAZOP on it as a whole.

The drawing in Fig. 4.2 shows a system with a number of different lines and tanks etc. So that we do not miss anything important we should section the drawing off into small parts for the purposes of the HAZOP study.

The second preliminary step is to decide exactly which property of the system you are investigating. Remember that in any system you may have a number of quite different properties, as we mentioned above. In this example we could have flow, pressure, suction and possibly others. We will concentrate on flow.

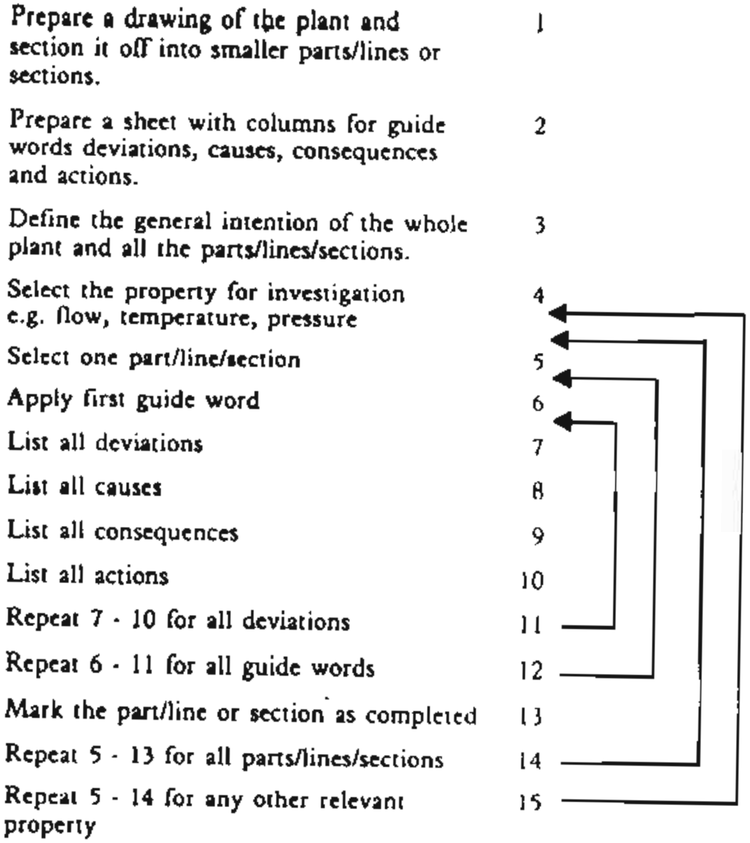
Let us assume that all these preliminary decisions have been taken and that we are now ready to carry out the analysis of the section of pipe leading from the bottom of the bin to the tank where the rubber is mixed with the chemicals. This section of pipe has one valve on it and the rubber particles are drawn through it by suction, as we were informed earlier.

Guide	*Deviations*	*Causes*	*Consequences*	*Actions*
No	No flow	1. Bunker empty 2. Bin empty 3. Conveyor broken 4. Valve shut 5. Outlet jammed 6. Suction fails 7. Industrial action	1-7. No raw rubber in tank 1-7. Excess of chemicals in tank 1-7 Possible explosive mixture 1-7 Lack of supply to the rest of the process	1-3. Visual check on bunker and checklist completed 3 Visual check and regular maintenance 4. As for 3 5. Test runs 6. Install a gauge to be read by the operator
More	More flow	1. Excess of raw rubber 2. Suction is excessive 3. Conveyor too fast	1-3. Wrong ingredients in tank 1-3 Lost production 1-3. Contaminated goods 2 Suction system breaks down 3. Conveyor over-heats	1. Visual check on quantity 2. Install a gauge 3. Install a speed meter

Guide	*Deviations*	*Causes*	*Consequences*	*Actions*
Less	Less flow	1. Suction not working properly 2. Blockage in pipe 3. Valve partly shut 4. Tank already full 5. Less than usual amount being fed into the bunker 6. Conveyor too slow	1-6. Lost production 1-6. Wrong ingredients in tank 1-6. Contaminated goods 1-6. Excess of chemicals in the tank	1-6. Same as for More flow
As well as	As well as other material	1. Faulty loading of bunker 2. Dust or debris in bunker or bin 3. Wrong raw material delivered by supplier	1-3. Contaminated goods 1-3. Lost production	1. Manual check 2. Grids on bin and bunker 3. Spot check deliveries
Reverse	suction reversed	1. Raw rubber drawn back into bin 2. Possibility of chemicals being drawn into bin	1. Bin overfills 1. Loss of rubber 2. Contamination of rubber 2. Possible explosive mixture in bin 1-2. Lost production	1-2. Install a non-return valve on pipe
Other than	Something other than rubber flows	1. Wrong raw material in bunker	1. Lost production	1. Manual check on all the deliveries

We can now mark this particular line or pipe as having been examined and move on to the next section. You can see that an extensive list of causes and consequences can be derived. Remember that this is only for the one section of pipe, all the other sections have still to be done. At the end of the exercise there would be a comprehensive list of possible causes of loss, their consequences and the actions to be taken. We can begin to see the advantages of structuring our thinking about risk in this way. Not all of the causes, consequences or actions would be the direct responsibility of the risk manager but there is sufficient to concern him in the study as to justify his full involvement.

4.1.6 Now that the study has been started the team will want to ensure that it does not accidently leave out a part of the system. You can see how this could come about, especially in a complex system with many different vessels, tanks and pipe lines. It is useful to have a simple flow chart which can guide you through the work. Such a chart is shown in Fig. 4.3.



Prepare a drawing of the plant and section it off into smaller parts/lines or sections. 1

Prepare a sheet with columns for guide words deviations, causes, consequences and actions. 2

Define the general intention of the whole plant and all the parts/lines/sections. 3

Select the property for investigation e.g. flow, temperature, pressure 4

Select one part/line/section 5

Apply first guide word 6

List all deviations 7

List all causes 8

List all consequences 9

List all actions 10

Repeat 7 - 10 for all deviations 11

Repeat 6 - 11 for all guide words 12

Mark the part/line or section as completed 13

Repeat 5 - 13 for all parts/lines/sections 14

Repeat 5 - 14 for any other relevant property 15

Fig. 4.3

The chart simply shows the various stages in the study and should minimise the chance that you overlook any section.

Once the entire process has been examined the drawing should show that all the sections have been examined and the sheets, containing all the comments made, can be filed away with the drawing for future reference. It will be necessary to diary ahead many of the actions so that you can keep a track on when they have been taken.

4.1.7 We will conclude this section on the HAZOP study by looking, briefly, at the main advantages and disadvantages. As far as advantages of the study are concerned we could say that the identification of possible risks is carried out in an extensive way. There is little likelihood that anything major will be omitted, assuming the study has been carried out properly. It also has the advantage of involving a team of people in the task of risk identification and this may well pay dividends in the future for the risk manager. The HAZOP also allows each part of a complicated system to be examined in detail and this is something which can be very hard to achieve in the absence of a structured approach.

The main disadvantage is the time involved in carrying out the HAZOP study. Not only will the risk manager be involved but there will be others on the team and the combined investment of time will be expensive. A further disadvantage is that it may be necessary to simplify a system in order to draw a diagram and then work your way through it. If this is done then there is the risk that some aspect which may be risky could be omitted.

Taking all the advantages and disadvantages together we must conclude that the HAZOP is an important technique for the identification of risk and one with which the risk manager should become familiar. It may well be that HAZOPs are being carried out in many firms without the involvement of the risk manager, but this may be due to his lack of knowledge of the technique rather than an unwillingness, on the part of others, to involve him. The risk manager should endeavour to keep up to date with modern risk identification methods and not be content with the traditional physical inspection or checklist as the sole or primary source of information.

4.2 Fault Trees

At the end of chapter three we said that the flow chart had two weaknesses, among others. We said that it dealt with risk in a broad way without concentrating on the detail of systems. The HAZOP study is certainly an answer to that disadvantage. The other weakness was that the flow chart did not make use of figures to quantify the likelihood of events occurring. We move on now to a method which can use numbers in the quantification of risk, the fault tree.

We say that the fault tree 'can' make use of quantitative analysis as it does not always do so. Fault trees are essentially quantitative in nature but they can certainly be used as a qualitative tool and indeed this is possibly the best way to introduce them.

4.2.1 Fault trees were probably first developed in the sixties by the Bell Telephone Laboratories in America when working on the Minuteman space project. Since then there has been considerable development in the field and even now people are still working on refining the technique, particularly with the aid of computers. The fault tree is a diagrammatic representation of all the events which may give rise to some major event. It shows the way in which individual events can combine together to produce potentially dangerous situations and it forces us to consider all aspects of the problem, including quantification of likelihood.

4.2.2 We will start with a small example, as we have done with other new techniques, and then work our way up to a more complex illustration. Look back at the drawing in Fig. 4.2. This is the drawing of the proposed new system for processing the raw rubber. Let us say that we are concerned that the pressure in the tank may reach such a level that an explosion could result. You will recall that when we were carrying out the HAZOP we did mention the risk of explosion on a few occasions. The raw rubber is sucked into the tank at one end and the chemicals enter at the other side. The mixture is then drawn from the tank by a pump. There is a pressure relief valve on the tank but we can still imagine circumstances where an explosion could occur. In simple terms there would be an explosion if the pressure in the tank rises and the relief valve does not operate. This is shown in Fig. 4.4.

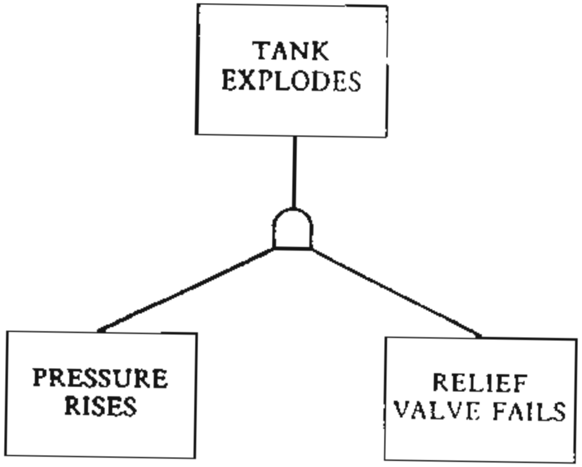


Fig. 4.4.

The event that there is an explosion is at the top of the tree and the two events which may give rise to the explosion are shown as the branches of the tree. The two events are linked to the top event by an AND gate as both events must happen for there to be an explosion.

It is often the case that one or other of two or more events could cause another event and so there is the need for an OR gate in addition to the AND gate. Fig. 4.5. shows a simple tree with an OR gate.

This time we are interested in the event that the pressure rises in the tank. This can come about, we have decided, in one of two ways, either the pump fails to operate and the rubber particles are not extracted from the tank or there is an excessive amount of raw material fed into the tank at the top end. Either one of these two events could cause the pressure in the tank to rise, they both do not need to happen but of course they both could.

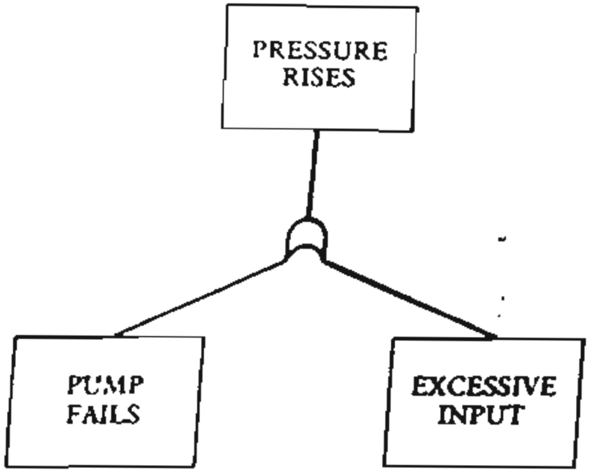


Fig. 4.5.

Both of these simple examples use the same logic in their design:

- the event with which we are concerned is shown at the top of the tree. It is also possible to show the main event at the left or right of the tree but either way it is at the tip of the tree.
- in building the tree we work down from the main event. We do not start with all the causes we can imagine but begin with the event and then consider all the ways it may come about.
- the branches of the tree represent all the ways that events may come about and are linked by the use of gates.
- gates can only be AND gates or OR gates, there are no other possibilities. These are logical gates and must conform with 'common sense' in their interpretation.

4.2.3 What we have not shown so far is any mention of likelihood and we can now introduce this to the two simple examples in Figs. 4.4 and 4.5. Two amended trees are shown in Fig. 4.6.

In Fig. 4.6 (a) we have inserted the likelihood that the pressure rises and that the valve fails to operate. Normally we would measure these events over the period of one year and so we can see that the pressure has risen twice. This is probably an average measurement and not simply taken from one year on its own. We may have gathered information on all the occasions when pressure has risen and on average this worked out at twice per annum. An explosion does not occur each time there is a pressure rise as the relief valve will operate to release the excess pressure. An explosion will follow when the relief valve fails to function during a time of high pressure. This is shown clearly on the tree as the two events are linked, in the logic of the tree, by an AND gate. Let us say that the probability of a valve failure is estimated at 1 x 10^{-4}. In other words there is a one in ten thousand chance that the valve will fail. The notation 10^{-4} is an example of a form of notation which is very common when referring to

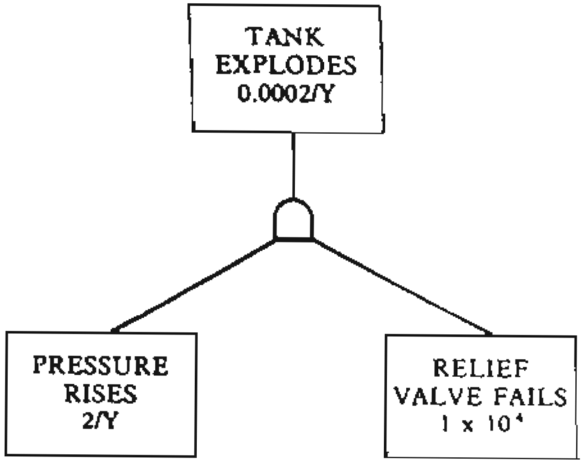


Fig. 4.6 (a)

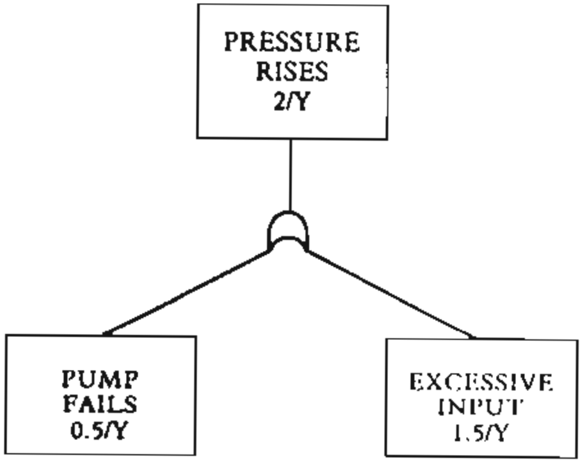


Fig. 4.6 (b)

events where the probability is extremely low. There may be some who are unfamiliar with this style of expressing probabilities and so a brief explanation is given in paragraph 4.2.4. Those who feel quite confident with the notation can omit this paragraph and move straight on to 4.2.5, where the text continues.

4.2.4 We know that probabilities measure the likelihood of events occurring. Probabilities can be any number between 0 and 1, where 1 equals certainty. We can express these probabilities as fractions or decimal fractions and so the probability of getting a head on the flip of a fair coin is ½ or 0.5. The more unlikely the event becomes, the less certain it is, then the smaller is the fraction. The chance of drawing the Queen of Hearts from a pack of playing cards is 1/52 or 0.0192307.

An event which occurs one time in a hundred would then have a probability of 1/100 or 0.01. One in a thousand would be 1/1000 or 0.001. One in ten thousand would be 1/10,000 or 0.0001, one in one hundred thousand would be 1/100,000 or 0.00001 and one in a million would be 1/1,000,000 or 0.000001. Including probabilities such as these in a fault tree or other calculation would be very cumbersome and so a shorthand means of saying the same thing is employed.

You will recall from your school algebra and arithmetic, or maybe you won't!, that we can express fractions by raising figures to negative powers. In this way we can say that 10^2 is 100 and that 10^{-2} is 1/100 or 0.01. For those who are interested in 'why' this is so then we must go back to the way in which 'exponents', the powers, are multiplied and divided.

10^2 multiplied by 10^2 is 100 x 100 or 10,000. We know that 10,000 is the same thing as 10^4. And so we can say that $(10^2)(10^2) = 10^{(2+2)} = 10^4$. The exponents are added together when numbers carrying exponents are multiplied. When they are being divided the exponents are subtracted.

An example would be the case of dividing 10^2 by 10^4. We know that this is 100/10,000 or 1/100 or 0.01. Remembering what we have said about subtracting the exponents then what we have is, $10^{(2-4)} = 10^{-2}$. And so 10^{-2} is the same thing as one in a hundred, 1/100 or 0.01.

Raising numbers to negative powers simply produces fractions and so one in a hundred becomes 10^{-2}, one in a million is 10^{-6} and so on. These very small numbers are useful for extremely unlikely events that can often be seen in use when describing the risks associated with the nuclear industry. They are also used in comparing mortality statistics for different causes of death. In these cases the numbers of people dying from particular causes are often expressed as a rate per one hundred thousand or per million. If there were 170 deaths in an industry which employed, nationally, 85,000 people then the risk of death is 170/85,000. By dividing both parts of this fraction by 85 we get 2/1,000 which can be expressed as 2×10^{-3}, there is a two in one thousand risk of death in this industry. We can now compare this with figures for any other industry simply by expressing all figures as deaths per 1,000.

This has possibly been a round about way of saying that 10^{-4} is a one in ten thousand risk or 0.0001. It is a form of notation which is common and one with which the risk manager should not be totally unfamiliar.

4.2.5 The two events, pressure rises and relief valve fails, are joined by an AND gate and so both must occur to cause the explosion. The risk that both will occur is found by multiplying the two together. This is an example of Boolean algebra but all we have to remember is that events linked by an AND gate are multiplied and events linked by an OR gate are added. The result of multiplying the frequency and the probability gives us the likelihood that pressure will rise and at the same time the valve will fail. The result is shown on the tree in Fig. 4.6(a), there is a frequency of explosion of 0.0002 per year. This is extremely low, it is equal to one explosion every 5,000 years, but it is for the company to decide if the risk is acceptable or not.

4.2.6 Fig. 4.6(b) illustrates the tree using the OR gate, this time with the relevant likelihood figures included. We can see that the pump fails, on average, once every two years or 0.5 times per year. The input of raw rubber has been found to be excessive, on average, once every eight months or at an annual rate of 1.5. Either a pump failure or an excessive volume of rubber will bring about the increase in pressure, and we can see this by the use of the OR gate on the tree. As we said above we must add these either/or frequencies to ascertain the likelihood of the pressure rising and when this is done we see that pressure will rise, on average, twice per year.

4.2.7 The trees we have used so far have involved either an AND gate or an OR gate, this is rather simplistic as clearly both kinds of gate could easily be in the one tree. Fig. 4.7 shows a tree which is the two trees in Fig. 4.6 combined. Here we have the main event, the tank exploding, still at the top of the tree and we can see that this event is contingent on both pressure rising and the relief valve failing to operate. Pressure will rise if either the pump fails or there is an excessive input of raw rubber. The frequencies have been included, as in Fig. 4.6, and the main event is seen to have a frequency of 0.0002 occurrencies in a year, which we earlier said was equivalent to an explosion once every 5,000 years.

This is still a simple tree in comparison to many and we will move on to elaborate on it but in the meantime let us make a note of what we consider the value of trees like this to be.

4.2.8 These trees have considerable practical value and are in use in many different areas of industry and it is as well that the modern risk manager familiarises himself with them. We could say the same here as we said about the HAZOP study, the risk manager may not feel that he gets involved in studies using this technique but that may be because he himself is unfamiliar with it. The value of the fault tree method can be seen in the following ways:

- The fault tree is an excellent way of describing a complicated process or system. It provides the structure which may be required in order to fully understand how a particular process works. Drawing the tree is a discipline in itself and even if we went no further we should at least understand the system a little better.

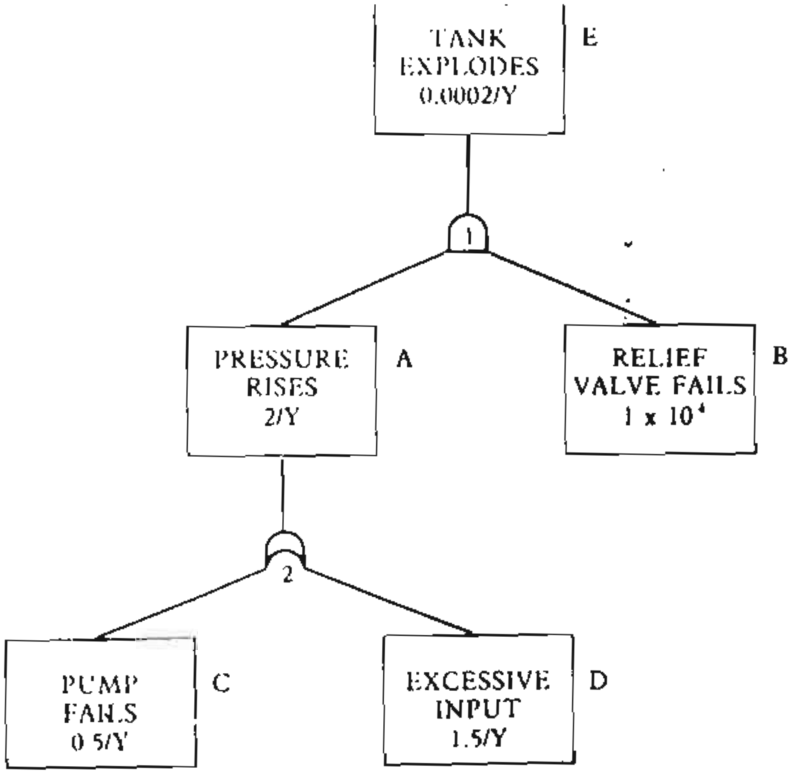


Fig. 4.7

- The tree approach also allows for the identification of risk as the tree is being built. Building the tree involves not only an understanding of the process or system but also the risks which are inherent in it. In our simple example we had to work out all the events which could result in an explosion of the tank. Once these events had been identified they themselves had to be analysed to see all the ways by which they could come about.

- Once the tree has been drawn it can be used to see how sensitive it is to changes in the system or to ascertain which parts of the system or process have the most impact in terms of risk. Let us say that a new valve is proposed which the manufacturers say has a failure rate of 1 x 10^{-6} rather than the existing rate of 1 x 10^{-4}. This means that the new valve has a one in a million chance of failing. If this is so then the risk of the tank exploding will be 0.000002 per year or once every 500,000 years. This compares to the existing rate of failure which is once in 5,000 years. This proposed change in the valve does seem to bring about a major reduction in the risk of explosion.

We could now compare this suggestion to a proposal to buy a new pump. Remember that the tank will only explode if the pressure rises and the valve fails at the same time. Replacing the valve is one way to bring about a change in the risk but another possibility is to minimise the chance of the pressure rising. This could be done by purchasing a pump which had a lower failure rate than the one you already have. Let us say that a pump with an estimated failure rate of 0.25 occurrencies per annum is on offer. This compares to the current pump which has a failure rate of 0.5 per annum. If we bought this pump then the pressure would rise, on average, 1.75 times per year (0.25/Y + 1.5Y). The risk of the tank exploding would then be (1.75/Y)(1 x 10^{-4}) = 0.000175/Y. This is a failure rate of once every 5,714 years on average, which compares to the existing rate of once every 5,000 years. The change, the reduction in risk, is not very great. You may however argue that the comparison is not very valid as the frequency of the pump failing has been halved from 0.5 to 0.25 occurrencies per year but the probability of the valve failing dropped from one in ten thousand to one in a million.

To make the comparison absolutely fair we could make a comparison based on the same decrease in risk for the pump and the valve. The pump failure frequency is half the existing frequency, let us say then that the valve failure probability is also half the existing figure. This would give a failure rate of 0.5 x 10^{-4} instead of the 1 x 10^{-4}, a risk of one in twenty thousand rather than one in ten thousand. The risk of the tank exploding, given this new valve, would then be (2/Y)(0.5 x 10^{-4}) = 0.0001 or once in ten thousand years. This compares directly to the figure of once in 5,714 years if we installed the new pump.

We can see now that the same reduction in the risk of different, subsidiary events occurring will not necessarily bring about the same change in the likelihood of the main event. You can see how the tree provides the mechanism for calculating the sensitivity of changes in the system.

- Finally, the fault tree allows us to calculate all the ways in which a main event may come about and, more importantly, it lets us determine the minimum number of combinations of events which can bring about the main event. An industrial process or system could have several different aspects to it all producing a complicated tree diagram. The main event being considered could be dependent on a large number of subsidiary events, some of which could overlap or be duplicated elsewhere in the process and hence elsewhere in the tree. If we could work out the minimum number of ways in which the main event could come about then we could see which set of events is the most likely, which has the greatest impact on the main event and where changes in the system could be most effective.

In fault tree jargon the minimum number of ways a main event can occur is known as the 'set of minimum cut sets', and the cut set is the group of events or primary sources of failure which can bring about the main event. In the example shown in Fig. 4.7 we can deduce the minimum cut set, the minimum number of ways the tank can explode, by looking at all the primary events in an algebraic way.

The main event is E and this comes about if both A and B occur,

$$E = A.B$$

The event A occurs if either C or D occur and so we can substitute this in the equation;

$$E = (C+D)B$$
$$E = CB + DB$$

When we insert the appropriate frequencies and probabilities we get;

$$E = (0.5/Y)(1 \times 10^{-4}) + (1.5/Y)(1 \times 10^{-4})$$
$$E = 0.00005/Y + 0.00015/Y$$
$$E = 0.0002/Y$$

The minimum number of ways that we could have an explosion is two, C and B or D and B. In words this does make sense as it says that the explosion can only occur if either the pump fails and the valve fails or there is excessive input of material and the valve fails. And so we can see now that the event DB is the more likely of the two sets of events and that changes in the design to minimise the risk of there being an excessive input of material is likely to be an effective way of reducing the risk of the tank exploding.

4.2.9 One final tree is shown in Fig. 4.8. This is an extension of the trees we have already used and shows a number of additional events. Read this tree and make sure that you can understand how all the events contribute to the main event of the tank exploding. You will see that we have added on the way in which the pump could fail. We have said that the speed of the pump increases and the speed gauge did not register the correct speed. If the gauge had been in good working order then the operator would have switched the pump off or taken some other steps to prevent a total failure. You will also see that the excessive input of material can be caused either by the conveyor running too fast or some human error, not defined. Human error is also a possible cause of the valve failing, dirt in the valve being the other.

This tree differs from the others in that the primary or source events are enclosed in a circle rather than a box. This is the usual way of displaying these events and indicate that the event in the circle is a root cause and not one which has any subsidiary causes. We may simply believe that it is not worth enquiring any further.

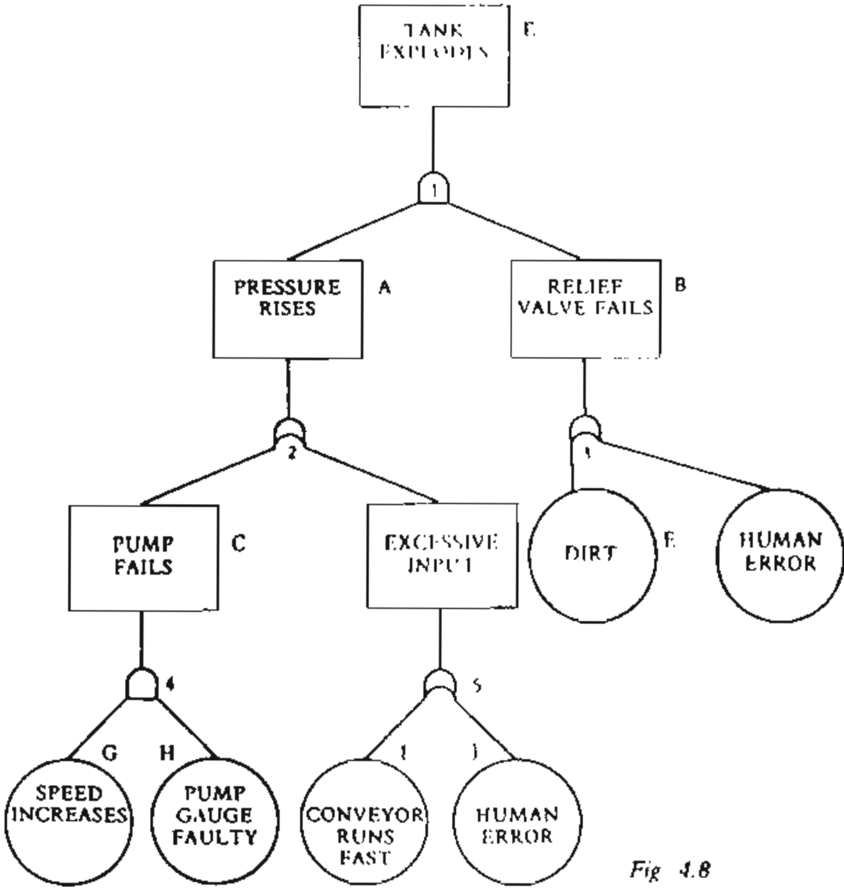


Fig 4.8

4.2.10 The minimum cut set for this tree is a little more difficult to calculate. We could do it by the algebraic method we used above but there is clearly the need for some method by which we can deduce the minimum number of ways a main event can occur. There are indeed a number of such methods and we will look briefly at one proposed by a Mr. Fussell.

This method arrives at the minimum cut set by working its way through all the gates. It starts first by completing a table as follows:

Gate	Type	Inputs	Input Numbers
1	and	2	2 3
2	or	2	4 5
3	or	2	E F
4	and	2	G H
5	or	2	I J

You can see that we have inserted the gate number and then the type of gate, the number of inputs into the gate and finally the numbers from the tree of the inputs to the gate. Gate 1 was an AND gate with two inputs which were gates 2 and 3. Gate 3 was an OR gate with the inputs E and F.

Once the table has been drawn a series of matrix charts are compiled in the following way:

1	

2	3

4	3
5	3

4	E
4	F
5	E
5	F

G	H	E
G	H	F
	I	E
	J	E
	I	F
	J	F

The first gate is shown at the top left hand corner of the first matrix. In the second matrix this gate has been replaced by its inputs from the table, namely 2 and 3. These are shown across the matrix from left to right because gate 1 is an AND gate. In the third matrix the gate 2 has been replaced with its inputs of 4 and 5. This time the inputs are inserted down the way from top to bottom as gate 2 is an OR gate. Notice that when 4 and 5 are inserted we also associate input 3 with each one as 2 was linked to 3 by an AND gate. This is continued and in the fifth matrix we end up with the minimum number of independent ways that the main event can occur.

4.2.11 Let us conclude this section on the fault tree with some comment on the main advantages and disadvantages. The advantages have been referred to as we have gone along. They included the structured approach to risk identification, simpler analysis of complex systems, tracing of causes and their impact, etc.

The disadvantages include the time it takes to carry out a study using a fault tree and the time which may be involved in learning the appropriate techniques. These are disadvantages which are shared with many risk identification methodologies but are nevertheless important and real if you are the person implementing them.

One major problem with the fault tree which was not apparent with the other methods, so far, is the derivation of probabilities. We have to work out where the relevant probabilities are to come from as if they are not accurate then the rest of the calculations, particularly the measurement of the likelihood of the main event, will be suspect. There are a number of sources of which the following are a few:

- There may be some past experience at the plant or elsewhere within the company upon which frequencies can be based. Most firms will have records going back over a considerable time and these can often be used to get a good measure of likelihood.

- If company based figures are not available then there are possibly industry wide figures which could be used. Trade groups or professional bodies often keep records of relevant events and these figures may be useful.
- Manufacturers may also be a source of figures especially on the failure rate of equipment. They may keep such information or may be prepared to put you in touch with a major user to get some measure of reliability from them.
- Finally it is possible to extract subjective probabilities from your own company employees. Methods of deriving subjective probabilities are well established but without going into them we can imagine presenting relevant people with our measure of how likely we believe an event to be and then asking them to refine our judgement. We could do this a number of times until we were confident in the assessment.

4.3 Hazard Indices

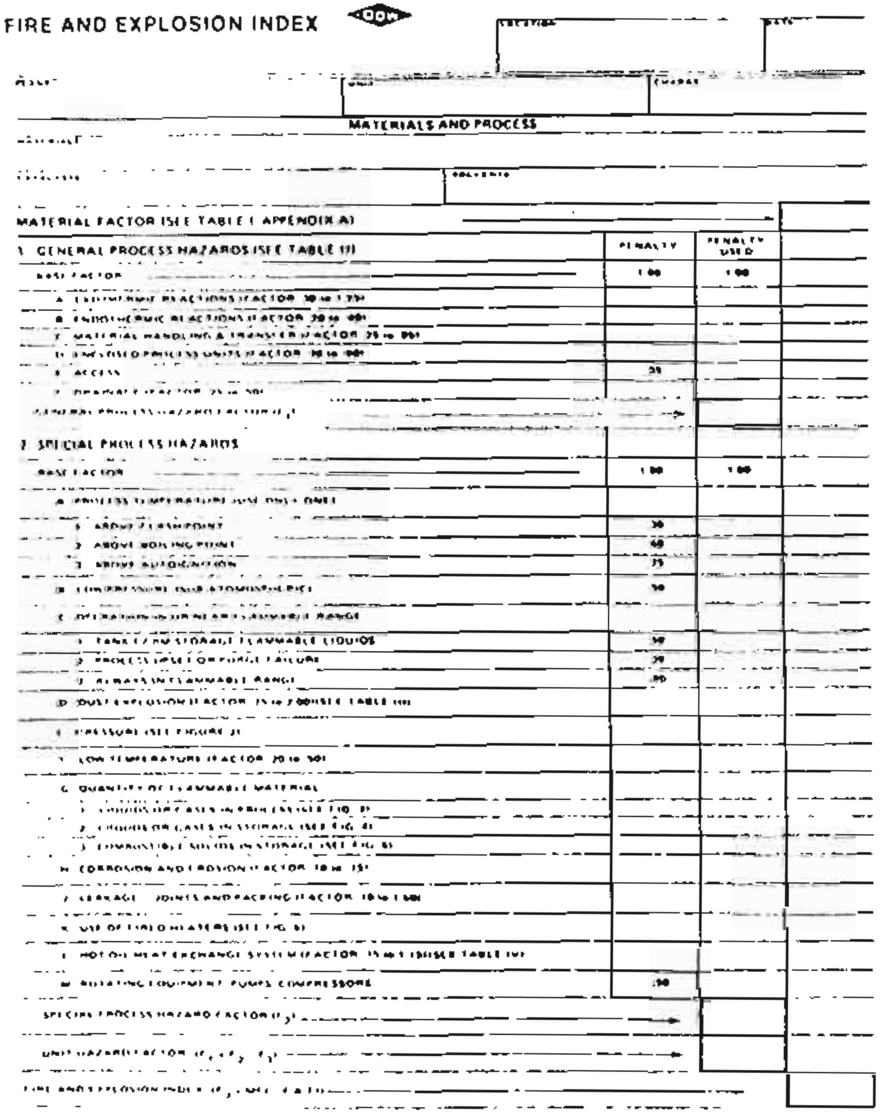
The third technique we will examine in this chapter is the hazard index. This is a technique which attempts to express the degree of hazard by using a number. There are a number of different ways in which this can be done but probably the most common method is the Dow Fire and Explosion Index. This is a method refined over the years since 1964 by the Dow Chemical Company and now used fairly extensively. A number of other methods have also been developed by industrial concerns and risk management consultancies. In essence they share the same basic philosophy as the Dow Index and that is to measure the likelihood of loss and express the result as a number to which others can then be compared and annual changes monitored.

4.3.1 We shall concentrate on the Dow Index and use it as an illustration of how a hazard index is constructed. A number of the technical features will be abbreviated as the index itself goes into considerable detail in order to arrive at the correct assessment of likelihood. We can summarise a number of these details without prejudicing our chances of understanding the concept.

The best way to see how the index is compiled is to follow each step in its construction, in turn:

1. The starting off point is to decide which 'process units' would have the greatest impact on a fire or would contribute most to a fire or explosion. Once this unit, or more than one if this is necessary, has been identified then the Material Factor must be calculated. This Material Factor is a measure of the intensity of energy release from certain named chemicals or substances which you may have in the Process Unit. The Material Factor is an indication of the hazard which it is estimated is present when the particular chemical or substance is used. A comprehensive listing of chemicals and substances is provided with the documentation accompanying the

Index. The person computing the Index would then check for all the relevant chemicals and substances in the Process Unit and calculate the Material Factor. The resultant figure will be between 1 and 40, as a result of the way in which the tables of values have been compiled.



FIRE AND EXPLOSION INDEX

MATERIALS AND PROCESS

MATERIAL FACTOR (SEE TABLE I APPENDIX A)

	PENALTY	PENALTY USED
1. GENERAL PROCESS HAZARDS (SEE TABLE II)		
BASE FACTOR	1.00	1.00
ACCESS	.35	
2. SPECIAL PROCESS HAZARDS		
BASE FACTOR	1.00	1.00
[illegible]	.30	
[illegible]	.60	
[illegible]	.75	
[illegible]	.50	
TANK FARM STORAGE FLAMMABLE LIQUIDS	.50	
[illegible]	.30	
[illegible]	.80	
CORROSION AND EROSION		
ROTATING EQUIPMENT PUMPS COMPRESSORS	.50	

Fig. 4.9

A form is supplied with the documentation accompanying the Index and this is shown in Fig. 4.9. The Material Factor is inserted at the top of the form.

2. The next step is to consider hazards other than those strictly connected to the materials used in the process. These additional hazards are in two categories;

   a) *General process hazards*

      These are features which could increase the magnitude of the loss and include such items as
      - the handling and transfer of materials
      - types of reactions in the process
      - access
      - drainage

      Penalties are applied as appropriate and inserted at the relevant place on the form in Fig. 4.9.

   b) *Special process hazards*

      These are hazards which are known to contribute to incidents which increase the probability of fire or explosion and so they include
      - temperature
      - dust
      - pressure
      - quantity of flammable material
      - heaters

      Penalties are again applied and inserted on the form at the appropriate place.

3. Once all the general and special factors have been calculated they are multiplied together to produce the Unit Hazard Factor. The individual penalty factors of a general nature are added and this gives F(1). The special hazard factors are added and this gives F(2). The Unit Hazard Factor, F(3) is F(1) x F(2).

4. This Unit Factor is then applied to the Material Factor to produce the Fire and Explosion Index. Let us say that we have a Material Factor of 30 in a particular Process Unit. The general hazards come to a penalty of 2, and the special hazards aggregate to 1.5. This would mean that the Unit Hazard Factor i.e. the hazard rate associated with the particular unit under consideration would be 2 x 1.5 = 3. We then multiply this factor, which is a measure of the riskiness of the unit, by the Material Factor which is a measure of the riskiness of the materials we are using. This gives a figure of 3 x 30 = 90. The Fire and Explosion Index is therefore 90.

5. It is possible that we could have two Process Units which had the same Unit Hazard Factor i.e. two units which had the same general and special hazards associated with their processes. We could

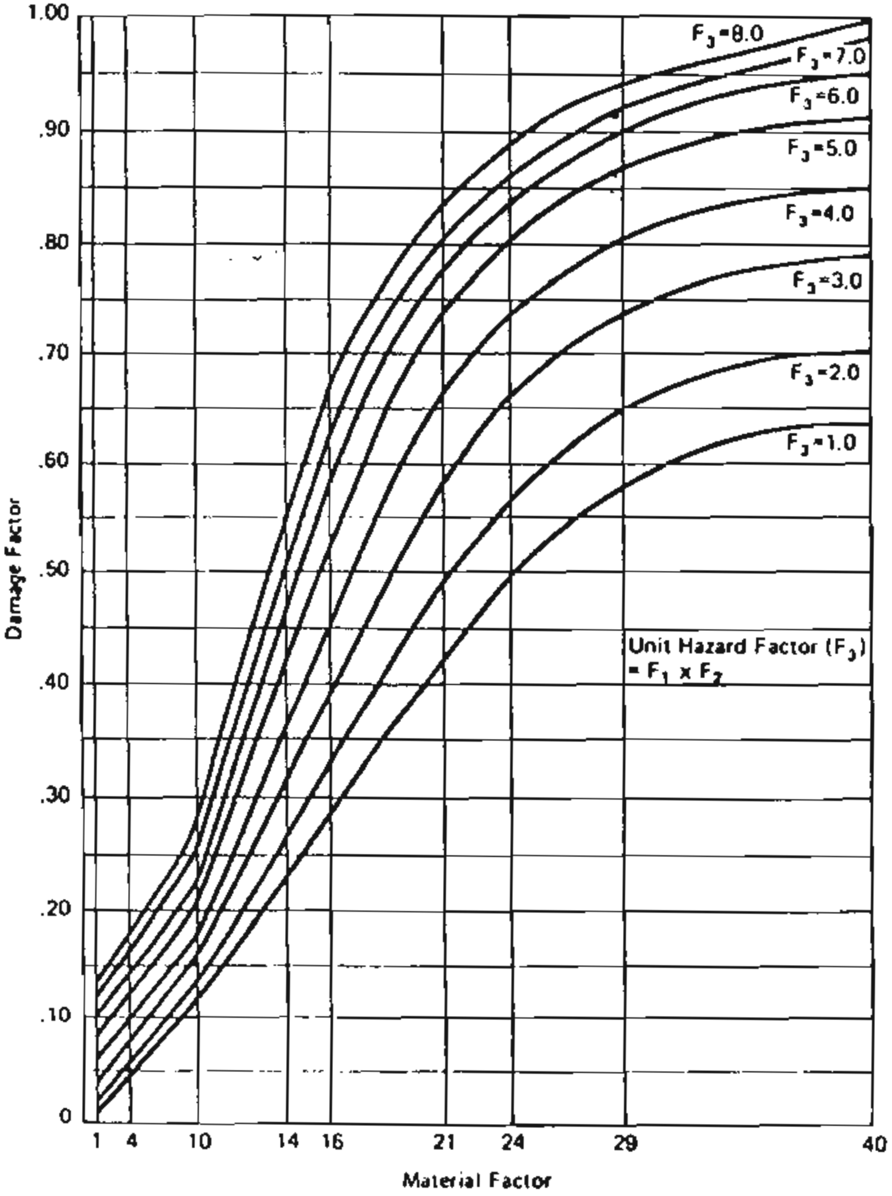


Fig. 4.10

therefore have ended up with another unit having the same Unit Factor of 3. This however would not in itself tell us that the two plants presented the same hazard as they may both process entirely different materials. It is necessary then to relate the Unit Hazard Factor to the materials. The table in Fig. 4.10 does this.

The vertical axis is a measure of the overall effect of a fire or a blast and is a scale from 0 to 1. The graph simply converts the Unit Hazard factor into an estimate of effect by relating it to the materials used. In our example we had a Unit Hazard Factor of 3 and a Material Factor of 30. From the graph we can see that the Damage Factor is approximately 0.74. What this means is that a fire could have no effect at all, at one extreme, or could result in total destruction, at the other extreme. We have estimated that the combination of process hazards and materials at this unit could result in a fire representing 74% destruction. This figure of 0.74 or 74% is known as the Damage Factor.

It is clearly the combination of the general and special process hazards and the materials used in the process which increase the potential for damage. The Damage Factor combines these aspects of risk and provides some measure of hazard. As we said earlier it would not be accurate simply to take either the process hazards or the material on their own. This would not result in a true reflection of hazard. We can illustrate this by looking at two Process Units which happen to have the same Unit Hazard Factor i.e. the hazards associated with the processes are the same but the materials are different:

	Process Unit One	Process Unit Two
Unit Hazard Factor	3	3
Material Factor	30	14
Damage Factor	0.74	0.32
Fire & Explosion Index	90	42

The probable extent of damage at Process Unit two is very much smaller than at unit one and this is due solely to the different Material Factor brought about by the different materials which must be used in the process.

6. You will see from the example above that the Fire and Explosion Index for the two units is also different. This index figure is now used to find the area of exposure which is likely to be affected by the fire or explosion. The graph in Fig. 4.11 is used to convert the Fire and explosion figure into an Area of Exposure.

The Index is plotted along the horizontal axis and the Area is read off. For our Unit One the Index is 90 and hence the radius of exposure is found to be approximately 76 feet. The Area of Exposure is therefore 18,152 square feet (The area of any circle is π times the radius squared or 3.1427 x 5776). We can now consult our plans and see what plant is within this area as there is 74%