Turner, J. Rodney
The Handbook of Project-Based Management
Improving the Process for Achieving Strategic Objectives
McGraw-Hill Companies, London, 1999:229-258
ISBN 0-07-709161-2

10 Managing risk

10.1 Introduction

The last five chapters have described methods, tools and techniques for the five functions of project management, managing scope, project organization, quality, cost and time. All five of these require us to make predictions about future performance, and, as we all know, we cannot predict the future. We can only make informed guesses. We have seen several times over the last nine chapters, that the more effort that is put into our estimates (guesses) the more accurate they will be, and the more historical information that can be used in guiding those estimates, the more accurate they will be. However, if we put too much effort into our estimates, we reach a point where the estimate costs more than the impact of the inherent risk. In a repetitive production environment the uncertainty can be reduced to a very low level, and the emphasis of management becomes to eliminate any variations from the status quo, because variations remove certainty and hence reintroduce risk. In a project environment, because of the essential uniqueness of projects, some uncertainty must always remain, and hence the emphasis of management becomes to manage the risk. In my view, the essence of project management is risk management.

In spite of that, six years ago, when I wrote the first edition of this book, risk management was one of the most poorly researched and documented areas of project management. There were books on the management of risk on large projects,[1] but virtually nothing on the essentials of risk management, accessible by all project managers. How that has changed, and now risk management is one of the most well-researched and documented areas,[2,3,4,5] and has been codified into the *project risk analysis and management methodology* (PRAM).[2,3]

In this chapter I describe risk management, as a four-step process. First you identify the risks on your project, and then you assess their impact, by assessing their impact individually and then jointly. Next you develop strategies for reducing the risk, and, finally, you monitor and control the risks as they occur (or not) and the effectiveness of your strategies. The next four sections of this chapter describe these four steps. In the final section I briefly describe the PRAM methodology, and its predecessor SCERT, and relate them to the four-step process described here.

10.2 Identifying risk

I cannot tell you what risks you are likely to encounter on your projects. What I can do is tell you about two ways of categorizing risk, which may help you identify the risks on your projects. Risks can be categorized according to:

- the impact they have
- where control of the risk lies.

Impact of the risk

There are two types of risk under this heading, business risks and insurable risks. Sometimes the word 'risk' is reserved for the second of these, and the first is called 'uncertainty'.

BUSINESS RISKS

These are the risks (or uncertainty) inherent in all our estimates. People tend to treat their project estimates as point-wise correct. However, in reality, our estimates just represent some mid-range value, and they can turn out better or worse than that. (It never ceases to amaze me that in their lives people accept some uncertainty in their estimates of how long things will take, but on their projects they expect their estimates to be exactly correct (Example 10.1).) Business risk is a two-sided risk or uncertainty. Sometimes our projects will turn out better than we expect, when we will make more profit, and sometimes worse, when we will make less profit or even a loss.

I did a series of workshops with a small consultancy who were having a problem with overruns on their assignments. (Over a period of three years, they reduced their overruns from an average of 10 per cent, twice their annual profit, to about 2 per cent). At an early workshop, a director gave a list of overruns. He grouped them by size of overrun in pounds. He started with some nightmares, jobs estimated to cost £20,000, and ending up costing £50,000. His last group were projects with overruns between £1,000 and £2,000, and the last was a project estimated at £200,000 that overran by just over £1,000. I pointed out that the last one only overran by one half of one per cent, and nobody could expect to estimate better than that. He was not pleased by my contribution.

Example 10.1 Uncertainty of estimates

INSURABLE RISKS

These are risks which can only go wrong. There is a hopefully small and random chance that some item of the project will fail. They are called insurable risks, but that is not to say either that an insurance company will want to buy the risk off us, or that we would want them to.

WHY DO PROJECTS FAIL?

I said business risks might turn out better or worse. This concept explains why we need to add the contingency described in Section 8.5, and why projects often fail. The reason for this is as follows. What we estimate is some measure of the mid-range value, usually the most likely out-turn for the work element. The actual out-turn can be better or worse. However, the amount it can be better by is usually constrained, whereas the amount it can be worse is almost limitless, although at what point a bad out-turn becomes an insurable risk is a moot point. Hence the range of expected out-turns is a skew distribution, with more above the most likely than below. There are two other measures of mid-range value, the median, (half the out-turns will be greater than this value and half less), and the mean or average, (if we do the activity a large number of times what will the out-turn be on average). If a distribution is skewed, the median is on the skewed side of the mode (most likely) and the mean on the skewed side of the median. Now the way we estimate our projects is to estimate the cost and duration of the activities, and then say the expected cost is the sum of all the activity costs, and the duration is the sum of the durations along the critical path. What we have said is that the most likely out-turn for the project is the sum of the most likely out-turns. This is incorrect. What we can say is the expected out-turn for the project is the sum of the average out-turns. This makes the expected out-turn greater than the estimate obtained by adding up the raw estimates, which means our projects will almost certainly fail unless we add a contingency as described in Section 8.5.

You will often come across the so called 1:4:1 formula for estimating durations. This is another mantra of project management, the reason for which is lost in the mists of time. In the early days of project management in the 1950s, and especially for use with the PERT methodology, it was felt that better estimates were obtained by estimating the duration of each activity as:

$$d = (t_o + 4t_m + t_p)/6$$

where d = duration of the activity
t_o = most pessimistic out-turn
t_m = most likely out-turn
t_p = most optimistic out-turn.

The cynics version of this formula is the 1:4:3 formula, (see Example 10.2):

$$d = (t_o + 4t_m + 3t_p)/8$$

As an example of skewed estimating, I use my journey to Henley Management College. I live 40 miles from the college, and the most likely journey time is 55 minutes. I have done the journey in 40 minutes, and so this is the most optimistic. It once took me 135 minutes on a Friday evening, and the delay was due to heavy traffic, but you might call this insurable risk. Apart from that one extreme case, the journey can take up to 105 minutes. If I am teaching at nine o'clock in the morning, I must leave home by quarter past seven to virtually guarantee to be there on time. The journey home on Friday evenings can also take 90 minutes. Hence the most pessimistic journey time is 105 minutes. The distribution is what is called *bimodal*, there are two most likely out-turns, one of 55 minutes corresponding to light traffic, and a lesser one of 90 minutes corresponding to heavy traffic. The median journey time is about 60 minutes and the average about 70 minutes. So if I go to the college every day for a week, how long do I expect to spend in the car during my 10 journeys: 400, 550, 600, 700, 900 or 1050 minutes? Well if I am unlucky and every journey corresponds with crawl-hour (bizarre that we should call it 'rush-hour'), then something like 900 minutes would be an appropriate estimate. But overall most of us would say something like 700 minutes. Yet standard project estimating would give 550 minutes, which we can see is a gross underestimate. Applying the 1:4:1 formula gives 610 minutes for ten journeys and the 1:4:3 formula 720 minutes. The latter is more accurate because the distribution is bimodal. Risk management is trying where possible to time my journey not to correspond with crawl-hour, and so eliminate the upper tail of the distribution.

Example 10.2 Skewed estimating

Control of risk

Risk can also be categorized by where control of the risk lies. Control can be internal or external to the project manager's organization, or legal. Internal risks can be technical or non-technical. External risks can be predictable or unpredictable. Legal risks can fall under the criminal law or civil law, and under the civil law they will fall within the jurisdiction of the law of contract or the law of tort.

INTERNAL RISKS

Internal, technical risks are those arising directly from the technology of the work, or the design, construction or operation of the facility, or the design of the ultimate product. They can arise from changes or from a failure to achieve desired levels of performance. They can be 'business' or 'insurable' risks, although in the latter case the risk is borne by the parent organization, not by an outside insurance company.

Internal, non-technical risks are risks within the control of project managers, or their organizations, which are non-technical in nature. They usually arise from a failure of the project organization or resources (human, material or financial) to achieve their expected performance. They may result in schedule delays, cost over-runs or interruption to cash flow. They are usually 'business' risks.

EXTERNAL RISKS

External, predictable but uncertain risks are risks beyond the control of managers or their organizations. We expect to encounter them, but we do not know to what extent. There is usually data that allow us to determine a norm or average, but the actual impact can be above or below this norm. There are two major types of risk in this category: the first is the activity of markets for raw materials or finished goods, which determines prices, availability and demand; the second is fiscal policies affecting currency, inflation and taxation. However, they also include operational requirements such as maintenance, environmental factors such as the weather, and social impacts – which are all 'business' risks.

External, unpredictable risks are risks beyond the control of managers or their organizations; which are totally unpredictable. They can be listed, but we cannot say which will be encountered on a given project. They arise from the action of government or third parties, acts of God, or from failure to complete the project due to external influences. Government or regulatory intervention can relate to the supply of raw materials or finished good, environmental requirement, design or production standards, or pricing. Whether a change of government at an election falls in this or the following category is a moot point. Actions of third parties can include sabotage or war, and acts of God are natural hazards such as an earthquake, flood, or the sinking of a ship. Failure to complete can arise from the failure of third parties to deliver supporting infrastructure or finance, or their failure through bankruptcy, or a totally inappropriate project design. By their nature, these risks are almost all 'insurable' risks.

TURNING INTERNAL RISKS INTO EXTERNAL RISKS

Before discussing legal risks, I wish to discuss a point arising from this issue of internal and external risk. Standard contracting practice in the UK is to try to dump risk down the contract chain. The client passes risk on to the contractor and the contractor on to the subcontractor. What you sometimes do is take a risk that the client could control and do something about reducing, and convert it into a risk external to the contractor's organization, for which they can do nothing but allow a contingency. The client then chooses a contractor via compulsory competitive tendering, and awards the job to the contractor that bids the least amount, that is the contractor that has allowed the least contingency and is therefore most likely to fail. In Example 10.2, do you award the job of driving me to and from Henley to the contractor that bids 400, 550, 600, 700, 900 or 1050 minutes? If you award the work to the firm that bids 400 minutes, and they go bankrupt when you are only half way home, you have little recourse to cover your losses, and it will cost you another 300 minutes to get the rest of the way home.

There is now a growing tendency to analyse the risk on contracts, and apportion it to those parties best able to control it. This is just good business sense. You can stretch the analogy too far, but in Example 10.2 you could accept that the duration of the journey is client risk and award the job to the contractor that bids the lowest price per minute; or you could allow the contractor to bid a range of prices dependent on traffic densities, and measure the density to determine the price; or you could let the contractor choose the time of the journey, if you have that flexibility. There are a range of options for apportioning the risk rationally. Example 10.3 is an apocryphal story about risk sharing.

Neil Armstrong was being interviewed about the moon landing and was asked what was the most frightening moment; was it as the moon lander came down and might crash; or was it as he stepped off the ladder; or was it when they came to blast off from the moon and the rockets might not be powerful enough. No, he said, the most frightening moment was being on the launch pad at Cape Canaveral, and under him were 2000 components, every single one of which had been bought on minimum price tender! And one of them did fail in 1986.

Example 10.3 Risk sharing

LEGAL RISKS

There are three types of legal risk, risks under the criminal law, risks under the law of contract and risks under the law of tort. (The law of tort is the duty of reasonable care we all have to our fellow citizens. Even where we do not have a contract with somebody, we have a duty to behave responsibly and with reasonable care.) If an employee is killed in an accident at work, you can be prosecuted under the Health and Safety at Work Act or the CDM (Construction Design and Management) Regulations, and fined up to £2000 and sent to jail for two years. You can be sued by his or her estate under the contract of employment or under the law of tort. If a visitor to your site is killed, you can be prosecuted under the criminal law as above, or the law of tort, but you may have had no contract with the individual. This applies to the software industry as much as the engineering industry. There was a lot of conjectural discussion about the computer control system on Sizewell B Nuclear Power Station when it was commissioned. If a failure had occurred, (of which there was never any likelihood), the suppliers would have been liable, under all three sets of legal risks.

Under the criminal law there have been several attempts to bring charges of corporate manslaughter. One such was after the Zeebrugge disaster, although nothing ever came of it. I believe there has been one successful prosecution, although I cannot name the case, but I do know it is very difficult to prove. One person still has to be responsible for the decision that caused the accident, which will not be the case if the accident is due to a series of oversights, as was the case with the Zeebrugge or Bowbell disasters. The current Labour Government is proposing to introduce a charge of corporate killing, which could be based on a general culture of sloppiness and irresponsibility, rather than a single incorrect decision.

In the event of a charge, the case is judged on the basis of what any reasonable professional would have done in the circumstances. Examples 10.4 to 10.7 contain four cases, showing how this might apply. The law is not necessarily fair or logical, as Example 10.6 shows. It just tries to be precise.

Some years ago I was on a course where we were discussing the Health and Safety at Work Act, and one of the delegates said he was responsible for testing the control software for a jet fighter used by the Royal Air Force. He said that in a reasonable amount of time they could test 90 per cent of all the paths through the software, which would represent 99.9 per cent of all the occurrences. However, to test all the paths would take 100 years. His question was what would happen if there was a failure because the control system locked into a path that had not been tested but which had a fault. He was told that he would be judged by what any reasonable professional would have done, and because it was not sensible to test all the paths, he would not be held liable.

Example 10.4 Testing a computer control system

A woman who worked in an asbestos factory in the late 1930s developed asbestos related diseases in the 1980s. She sued her former employers claiming they had been negligent in the containment of asbestos in the factory. They had to be judged by the standards of the 1930s, not the 1980s, but were still judged to have been negligent.

Example 10.5 Seeking damages after 50 years

Children with stunted growth are fed a growth hormone. Up to 1980 this was made from extracts from the brains of dead people. From July 1978, the government knew this could cause CJD, the human equivalent of mad cow disease, but did not replace it with a synthetic alternative until 1980. The families of people who had suffered CJD sued the government. The courts ruled that anyone who had been fed the hormone for the first time on or after 1 July 1978 should receive compensation. Anyone who had received it on 30 June 1978 or earlier could not because the government could not have known there was a problem before then. There was one person who had received it for the first time on about 30 June 1978, and everyone said this is not fair – not fair but scrupulously exact. (The ruling was overturned by the Court of Appeal at the time of writing, and all people suffering CJD can now claim. People not suffering CJD, but who are at risk, want to claim now for the fear they have to live with.)

Example 10.6 The law is not fair, but scrupulously exact

It was suggested to Churchill in early 1945 that the allies might bomb the railway line leading to Auschwitz, and he said it was not worth the risk. People now react in horror that he could have said such a thing, but they are judging by 1990s standards. With the technology of 50 years ago, they were lucky to drop the bomb within two miles of the target. It saved more lives to use the pilot's life to shorten the war than to go on a fool's errand.

Example 10.7 Not judging by today's standards

Techniques for identifying risk

Various techniques can be used to help in the process of identifying risk. Five, which may be used solely or jointly are:

1. *Expert judgement* uses personal intuition and awareness. The use of checklists against the categories identified above can help.
2. *Plan decomposition* shows risks inherent in the interdependency of work. Any event which lies at the start or completion of many activities is a potential risk. These occur at bottlenecks in the network. When analysing the plan, you should also look at all external interfaces, such as external supply, for potential failure of third parties.
3. *Assumption analysis* is win/lose analysis, and focuses on events which might be detrimental, considering both events we want to occur but which may not, and events we do not want to occur but which may. Expert judgement is needed to foresee these events and check for completeness.
4. *Decision drivers* are influences which might determine whether or not certain events may occur, (inside and outside the project). Win/lose

analysis can be used to derive the list of decision drivers. It can be particularly damaging if decisions are made for the wrong reason: political vs technical; marketing vs technical; solution vs problem; short vs long term; new technology vs experience.

5. *Brainstorming* uses social interaction to enhance the above techniques.

Expecting the unexpected

Good project managers learn to be risk aware, to expect failure where they least expect it. This is known as *Sod's law* or *Murphy's law*, sometimes stated as: *if something can go wrong it will; if something can't go wrong, it still will!*

The value of this attitude is that if you expect things to go wrong, you will be on your guard for problems, and will be able to respond quickly to them. The failures may be ones you had predicted, or ones you least expect. If you anticipate problems, and plan appropriate contingency, you will not be disrupted when those problems occur. If the unexpected then also occurs, you will be able to focus your management effort into the areas that might now cause greatest disruption (Example 10.8). This attitude of expecting risks and being ready to respond is sometimes known as *risk thinking*. To some people it comes naturally; others require structured, logical processes of risk identification and analysis to support their response.

In 1983, I managed an area of work on the overhaul of an ammonia plant. We were uprating the steam system, and this required us to run a line between the 50 bar and 30 bar steam mains as shown in Figure 10.1. On the overhaul, we just had to make break-ins into the two mains at each end of the line. These consisted of T-sections, together with an isolation valve. The new line would be run between the two valves once the plant was back on line. The break-in to the 30 bar main was simple. We made an 8 in × 6 in T-section in advance of the overhaul. In the overhaul we just had to cut the line, weld in the T-section, and install the isolation valve. The other break-in, however, carried greater risk. It was to be made in a 12 in line just downstream from the main isolation valve, separating the plant main from the factory main. This valve had not been closed in 12 years, and so we did not know if it would shut tight. If it did not, the job would be more difficult, or even impossible. We put considerable effort into drawing up contingency plans in the event of a partial or full leak of the valve. In the event it shut like a dream. However, when we offered up the T-section at the other end, we found it had been made 6 in × 6 in instead of 8 in × 6 in. We therefore had to make a new T-section in a hurry, and an 8 in pipe of the right pressure rating was not immediately available. That particular job almost extended the duration of the overhaul. However, the time spent planning the other job was not wasted. I knew that so well, I could leave it to run itself and focus my attention on procuring 8 in pipe.

Example 10.8 Expecting the unexpected

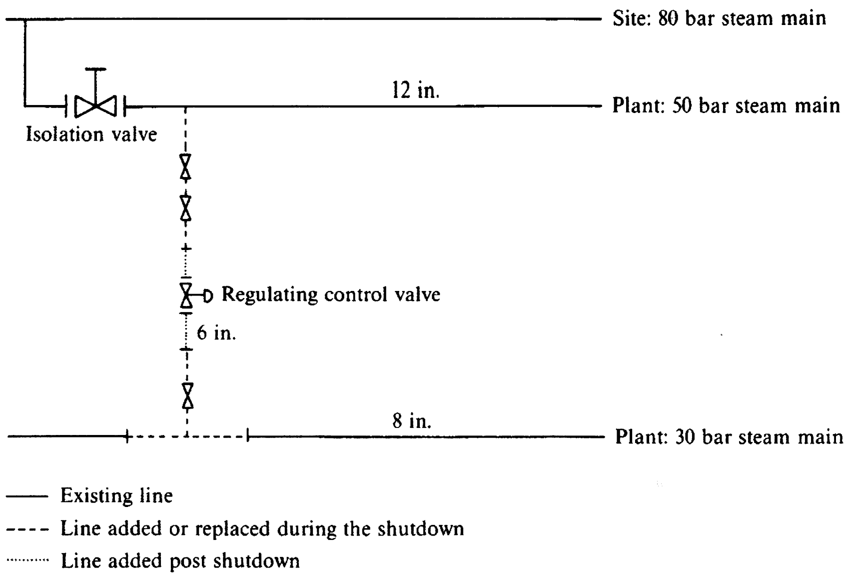

Figure 10.1 Break-ins to the steam mains of an ammonia plant

10.3 Assessing risk

Having identified possible source of risk to the project, we need to calculate their impact on the project. First we calculate the impact of individual risks, and then determine their combined impact.

The impact of a single risk

The impact of a risk factor depends on its likelihood of occurring and the consequence if it does occur:

Impact of risk = (Likelihood of risk) * (Consequence of risk)

To illustrate this concept, consider the question of whether buildings in the British Isles have earthquake protection. The answer is very few do. Multi-storey office blocks in London do not. The consequence of an earthquake in London of force 7 on the Richter Scale would be severe loss of life. However, the probability of such an earthquake is so small, virtually zero, that it is considered unnecessary to take precautions. However, one type of building which does have earthquake protection is a nuclear power station. The likelihood of an earthquake has not changed, but the consequence is now unacceptably high. The consequence of an earthquake of force 7 in the Heysham area would be that Liverpool is uninhabitable for 10 000 years (or that at least is the public perception). Perhaps we should include the public perception when assessing the consequence of the risk (Example 10.9). Indeed, the assessment of risk is highly irrational (Example 10.10), and so the impact of risk needs to be amended as:

Impact of risk
= (Likelihood of risk) * (Consequence of risk) * (Public perception)

Perhaps the consequence of an earthquake under a nuclear power station would not be as severe as suggested, but the public perception is that it would. In the 1980s, the civil design consultants, Ove Arup and Partners, put considerable effort into designing and testing railway wagons for transporting low level nuclear waste around the country. There were some highly publicized experiments in which a locomotive was slammed into a wagon at 100 miles per hour. In this case, the likelihood of an accident which would result in a release of radiation was small, and the consequence was also small, no immediate deaths, perhaps one or two additional cancer cases resulting in early death several years later. However, this is a highly emotive public issue, and hence the need for indestructible wagons. On the other hand, quite lethal chemicals are transported around in relatively flimsy wagons. In the early 1980s, I worked close to a railway line, along which, twice a day, passed a train towing two wagons filled with cyanide gas. The consequence of a crash involving a leak in the centre of a city would be instant death to thousands of people, but this is not a public issue. A thousand instant deaths from cyanide gas seems to be more acceptable than two lingering deaths from radiation induced cancer.

Example 10.9 Public perception of risk

A classic example of the irrational perception of risk is the BSE scare. First the public behaved irrationally. The number of deaths from new form CJD, which may, just may, be caused by BSE is running at 5 per year, about the same number that die from allergic reaction to peanuts. The BBC went down to the local supermarket to interview an average shopper, smoking a cigarette, with a trolley load of beer, and a car with bald tyres in the car park. 'Are you eating beef?' asked the BBC. 'No', said the shopper, 'it's too dangerous.'

The public seem to have come to their senses, but at the time of writing the government is behaving irrationally. They have just made the selling of a T-bone steak a crime as heinous as the selling of crack cocaine, because it is expected to kill one person every 20 years. The Agriculture Minister appears on the TV and says he is concerned about public health! If he were concerned about public health, he would ban peanuts before a T-bone steak.

Example 10.10 The irrational assessment of risk.

Table 10.1 Scaling risk factors

Level	*Numeric*	*Likelihood (%)*	*Consequence*	*Perception*
High	3	50	P/2	National issue
Medium	2	5	P/20	Local issue
Low	1	0.5	P/200	Company issue
Negligible	0	0.05	P/2000	Not an issue

It used to be common to work out the formulae above numerically. Figures would be chosen for likelihood, consequence and perception, and diligently multiplied together to produce a hit parade of the risks on the project. Perhaps each of likelihood, consequence and perception could be rated high, medium, low or negligible, or on a scale of 0 to 3 (Table 10.1). For each risk you can add the numerics, (effectively adding the logarithms of the numbers), to judge each risk on a scale of 0 to 9. This is silly for two reasons. First, to say a risk of level 6 is worse than one of level 5 and better than one of level 7 is meaningless because the conclusions drawn from the data are more accurate than the estimates on which it is based. Second, it says that the following two risks are the same, one that has a likelihood of 50 per cent but risks 0.5 per cent of the project cost is the same as one with likelihood 0.5 per cent and risks 50 per cent of the project cost. In fact the latter is worse, as it has a much higher spread of potential out-turns. You have to ask which is more important, the expected value of the risk or its predictability, and the latter is probably of more concern.[6]

What is now suggested is to apply the concepts qualitatively rather quantitatively.[7] You still assign to risk parameters a range of values such as those in Table 10.1. You might even have more than three parameters describing your risks. You then produce a table of your risks and their parameters, as Table 10.2, and qualitatively assess the risks. Furthermore, each risk is assessed on a scale with the same number of levels as that assigned to the parameters. In effect, you judge each risk to be high, medium, low or negligible. This avoids somewhat spurious conclusions. Van der Merwe used this approach to remove 10 per cent from the amount Eskom, the Electricity Supply Commission of South Africa, spent annually on the security of its substations.[7]

Combining the impact of several risks

It is a rare project which has only a single source of risk, so to determine the total impact of risk on a project, the elements must be combined. If we

Table 10.2 Qualitative risk assessment

Risk	*Parameter 1*	*Parameter 2*	*Parameter 3*	*Parameter 4*	*Impact*
R1	High	Medium	High	High	High
R2	Medium	High	Medium	Low	Medium
R3	Low	Low	Medium	Low	Low

include all possible sources of risk into the model, it will become impossibly complicated, and so we limit our attention to the significant few, the 20 per cent which have 80 per cent of the impact. The work breakdown structure is a key tool in this integration of the risk. In practice there are two approaches:

- a top-down approach, in which key risk factors are identified and assessed at a high level of work breakdown, and managed out of the project
- a bottom-up approach, in which risks are identified at a low level of work breakdown, and an appropriate contingency made to allow for the risk.

THE TOP-DOWN APPROACH

The top-down approach can provide the manager with checklists of potential risk factors based on previous experience, and can help them to determine their relative importance. Furthermore, by identifying the controlling relationships at a high level, it enables the project manager to find ways of eliminating the most severe risks from their projects.[1] The approach is to take a component breakdown for the project, and evolve it down to the integrative level with about 20 elements of the breakdown. The component breakdown chosen will depend on what it is that is expected to create risk. It can be the PBS, WBS, OBS, CBS, or *bill of materials* (BOM), for the facility. You then identify the risk associated with each component, and, critically, the links between the risks: if one risk occurs, does it make another more or less likely. You then concentrate on either eliminating the risk associated with each component, or breaking the links between the risks. If you are successful in breaking the links, you can isolate each risk in the breakdown structure. The reason for limiting yourself to 20 components is that, if you have a sheet of paper describing each risk and each link, you would have 420 sheets of paper. If there are 30 components, you have 930 sheets.

Two tools introduced previously which provide a clear, visual representation of the PBS, WBS and OBS to an appropriate level are the milestone plan (Section 5.4) and the responsibility chart (Section 6.4). The milestone plan shows the PBS at the strategic level. An interesting outcome of using the milestone plan is you can sometimes find that there is a risk link between two milestones where you have not shown a logic link. This can happen, for instance, where at an early milestone you make certain design assumptions. At a later milestone you find that you cannot meet the design assumptions, and so all milestones dependent on those assumptions are invalid. There is such a link between milestones A2 and O5 in Figure 5.4, for instance. Both assume we know sites 1 and 2, and if that is the case, they are not linked. However, if at A2 it proves impossible to use the chosen sites, then O5 is affected. The responsibility chart shows the OBS, PBS and WBS at the strategic level on one document. It also shows how these are influenced by one element of the CBS, the work content, and by the time scale. It is therefore a very powerful document for top-down risk analysis.

I illustrate the top-down approach with a simple four-work-package project to build a warehouse (Figure 10.2). Assuming end-to-start dependencies only, the duration of the project is seven months. It might be possible to fast track the project by overlapping work packages. However, let us assume that that is impossible on the path A–C–D: it is not possible to buy the steel until the design is finished; and all the steel will arrive at once, so erection cannot begin until the steel has arrived. It is possible to start work on the site, B, before the design is finished, but there is no need, because the duration will be determined by the delivery of the steel.

Now let us consider the risks. Let us assume that the project will start at the beginning of September, after the summer vacation. The risks are as follows:

1. The design of the building may take more or less than three months. From previous experience we may be able to say it will take two, three or four months with the following probabilities:

   - 2 months: 25 per cent
   - 3 months: 50 per cent
   - 4 months: 25 per cent

   Hence it may be finished as early as the end of October, or may stretch to the end of December.
2. The site cannot be prepared if there is snow on the ground. Snow occurs in four months of the year with the following probabilities:

   - December: 25 per cent
   - January: 25 per cent
   - February: 50 per cent
   - March: 25 per cent

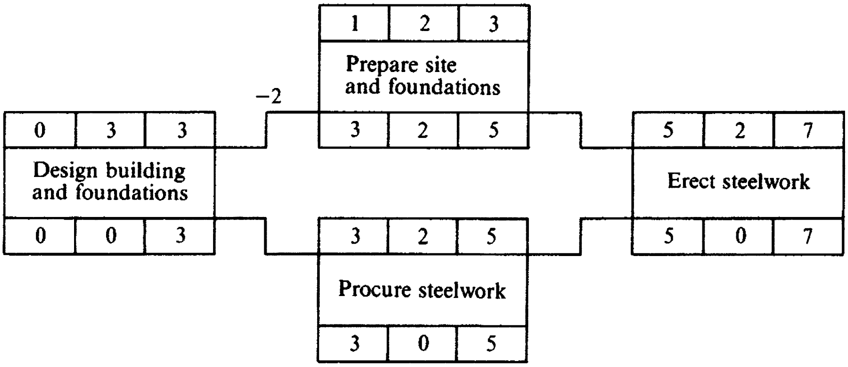

Figure 10.2 Simple precedence network for constructing a warehouse

The duration of this work is dependent on when it starts. If it starts in October, it will take only two months; if it starts in November, it will have the following range of durations (Figure 10.3):

- – 2 months: 75 per cent
- – 3 months: 19 per cent
- – 4 months: 3 per cent
- – 5 months: 2 per cent
- – 6 months: 1 per cent

There will be similar lists if the work were to start in December or January, but with the probabilities weighted towards longer durations. In some circumstances the preparation of the site will become critical. Now it may be worth while to try to fast track the design of the foundations. If the design could be completed by the end of September, we could eliminate this risk entirely. If it is finished by the end of October, there is a 75 per cent chance of the work being finished on time. If the start of this work is delayed to December, there is only a 50 per cent chance. The choice will depend on the cost of fast tracking the design of the foundations. There will be additional financial charges if this work is completed early, it is unlikely that the cost of the design will be greater *per se*, but there is a risk of rework. In the event, you may actually make the decision on the day, depending on how the design of the steelwork is progressing, and other factors below.

3. There may be two possible suppliers of steelwork: the more expensive one can deliver in one month or two months with equal probability; and the cheaper in two months or three months also with equal probability.

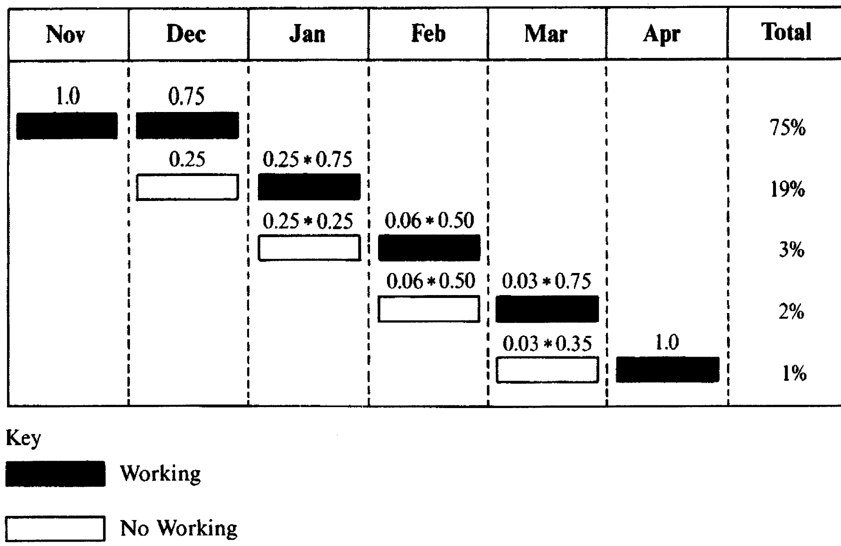

Figure 10.3 Calculating the duration of work package B with November start

The delivery time therefore has the following distribution:

- 1 month: 25 per cent
- 2 months: 50 per cent
- 3 months: 25 per cent

This appears the same as the design. However, the power of the top-down approach is that you can decide what to do on the day, when you know how long the design has taken and how you are progressing with the foundations. To understand this we need to address the fourth risk.

4. This is that the steelwork cannot be erected if there are strong winds, and these occur with the following probability:

- February: 25 per cent
- March: 50 per cent

The duration of this work will also depend on when it starts, as with preparing the site. However, what we can see is that, if the design work finishes at the end of October, it will be better to use the more expensive supplier. There will then be a 50 per cent chance that erection can begin in December and finish in January without any delay, or a 50 per cent chance that it will begin in January, in which case it will finish in February with a 75 per cent chance. This is, of course, dependent on the foundations being ready, and so if it looks as though the steelwork design will be completed early, it will be worth while fast tracking the foundations. On the other hand, if the design takes four months, it would be better to use the cheaper supplier, and just plan to start erecting the steelwork in April, saving on extra cost of the foundations and on having erection fitters stood idle.

This simple case shows that the top-down approach allows you to analyse the interrelationships between elements of risk, and take management decisions based on that analysis and the actual out-turn. Following a top-down approach, you are able to develop additional detail in some areas. In the example above, for instance, you could break the design into a lower level of work breakdown to find out how to fast track the design. Section 4.4 differentiated between fast track and fast build, and it is fast build we should use here to reduce the risk. That requires the design to be broken into smaller packages of work, subject to strict design parameters at the top level.

INFLUENCE DIAGRAMS

Influence diagrams are tools, derived from systems dynamics, that can assist a top-down analysis. They show how risks influence one another; some risks reinforce others (+), and some reduce others (−). Figure 10.4 is an example of an influence diagram. The power of the technique is to identify loops of influence. 'Vicious cycles' have an even (or zero) number of negative influences, and 'stable cycles' an odd number. In Figure 10.4, loop ADEKLIBA is vicious, and loop ADEGHJIBA is stable. In a 'vicious cycle' an externally imposed influence can be amplified indefinitely.

THE BOTTOM-UP APPROACH

The bottom-up approach analyses risk at a low level.[8] It can identify several critical paths, and calculate a range of outcomes for cost and duration, to enable the project manager to allow appropriate contingency. However, it is essentially a negative approach to risk, as it assumes that risk elements are beyond the control of managers. It does nothing to help the manager to quantify or convey information for developing an appropriate management response to reducing or eliminating risk.

The approach develops a detailed project model, at a low level of breakdown. Variable durations and/or costs are assigned to work elements, as in the above example. However, at a low level it is not possible to calculate the various outcomes manually, as they were above. Instead, we perform a *Monte Carlo* analysis. The project model is analysed many times; 100 to

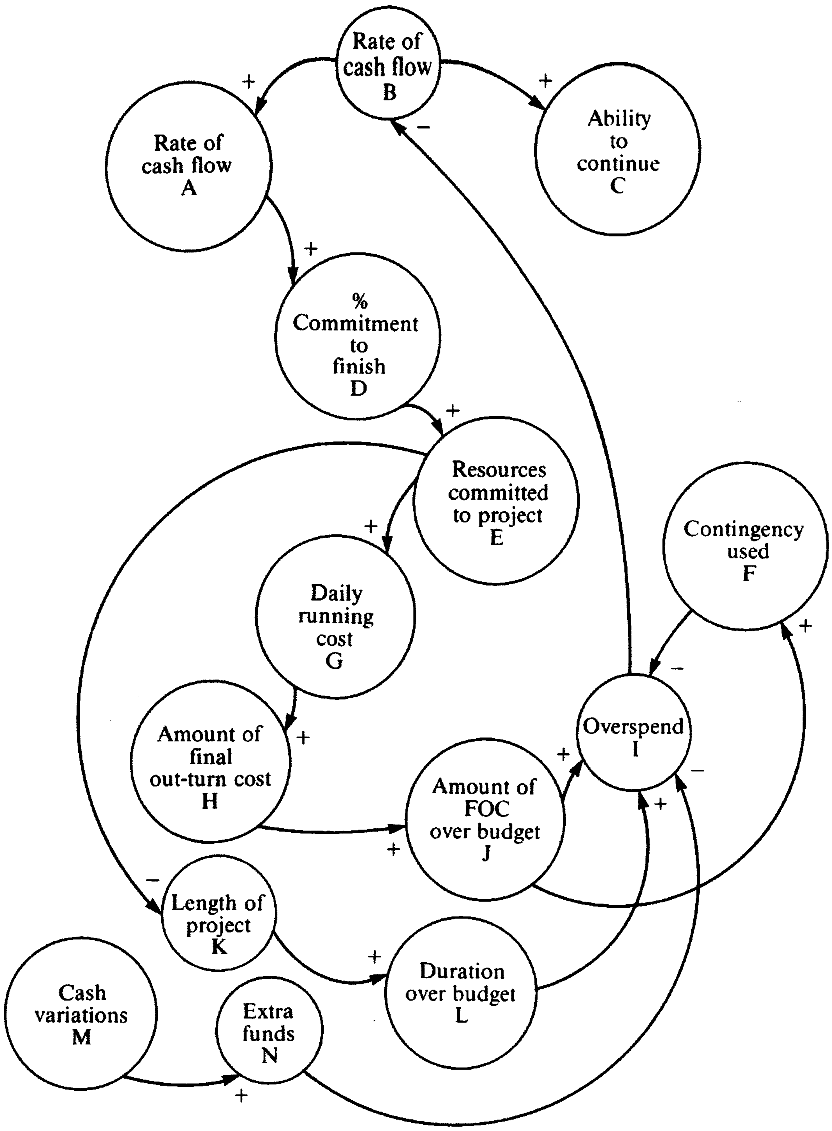

Figure 10.4 Influence diagram

10 000 is typical, depending on the size of the model. Each time, a random number is drawn for each parameter for which there is a range of values, and a value selected accordingly. (This makes the simplifying assumption that the risk elements are unrelated, which may not be the case – see Figure 10.4.) The cost and duration are then calculated using those values, and a range of possible outcomes calculated for the project. Effectively, the project is sampled however many times the analysis is performed. The results of the Monte Carlo analysis are presented as a probability distribution for time, cost, or both. This may be a simple or cumulative distribution. Figure 10.5 shows both distributions for the duration of the warehouse project. For this simple example, the critical path may go through either A–B–D or A–C–D, and the duration can be anything from 6 to 11 months. The likelihood that either or both of the routes will be where the critical paths is:

A–B–D	52 per cent
Both	24 per cent
A–C–D	24 per cent

With a project this small, it is just possible to calculate these numbers by hand: it took me an hour. With anything larger, the figures have to be determined using a Monte Carlo analysis. For the project, the median outcome is 8 months, (half the time the duration will be this or less), and that 90 per cent of the time, the duration will be less than nine months. The most likely duration (the mode) is nine months. If a nine-month duration is acceptable, we may accept these figures. If not, we would need to shorten the project. The critical path shows that the most useful effort may be put

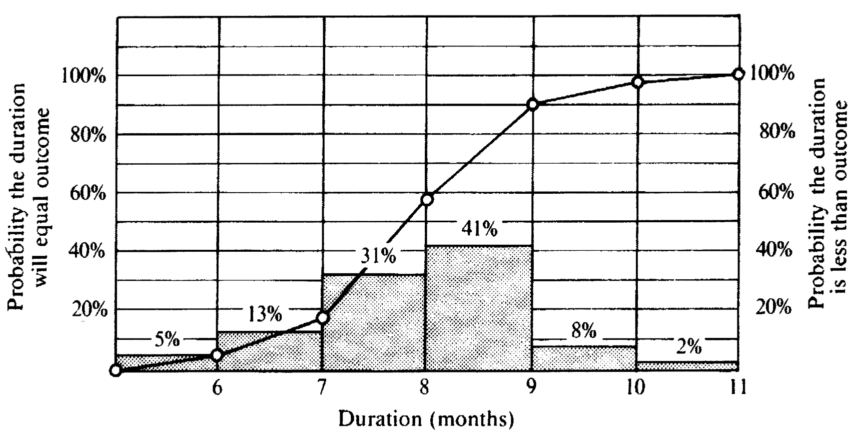

Figure 10.5 Simple and cumulative probability distributions for the duration of the project to build a warehouse

into shortening A–B–D, and that may suggest fast tracking the design of the foundations. However, from this we do not see the effect of the two suppliers. That can only be analysed by the top-down approach.

The owner's view of risk

The quantitative methods described produce a value for the project. However, the true value of the project is not the figure calculated by the project team, using these methods. It is the value the owner puts on the project, and that reflects his or her perception of the risk, and to a certain extent the public's perception as well (if the owner is concerned about public opinion – Example 10.11).

In the early 1980s, NIREX proposed storing medium-level nuclear waste in a redundant mine under ICI's factory at Billingham. It may have been one of the safest proposals for storing such waste. The project would cost ICI nothing (but see Example 10.12), but earn them an income; an attractive project with *no* risk attached. However, ICI would not allow the project to proceed because that was not the way the local community viewed it, and ICI was concerned about local opinion. The ironic thing was ICI used to operate one of the country's largest private nuclear sources on the Billingham site.

Example 10.11 The owner's perception of risk

It is almost certainly incorrect to say that the project described in Example 10.11 would have 'cost ICI nothing'. It was causing a loss of goodwill in the local community, and so the 'cost' was whatever value the company put on that goodwill. Clearly they did not think that 'cost' was worth the returns.

This is part of a wider viewpoint that is gaining credence. The environment itself has a value, and if a project we undertake reduces that value, we should take that into account when assessing the value of a project. In the case described in Example 10.11, that loss of value had a monetary impact in that house prices were falling in Billingham. The cost of the project would therefore not have been borne by ICI, but by the local community.

In this case the loss in value was caused by a fear of anything nuclear. A case in which the environment suffered a real loss in value is the Adriatic coast of Italy. Algae blooms reduced its ability to earn tourist revenues. Economic activity up the Po Valley had caused the blooms. However, the people who received the benefit of that activity did not pay the price. The solution is an environment tax. That can be levied in Italy in the latter case, but should Switzerland pay a tax to Germany for the water flowing down the Rhine? The answer to that question is beyond the scope of this book.

Example 10.12 The value of project opinion and the environment

Communicating the risk analysis

The ultimate purpose of the risk model is to communicate the analysis to all the parties involved:

- to the owner for them to assess its value
- to the champion, so that they can give their support and commitment to the project
- to the project manager so that they can develop their project strategy and perform what-if analysis
- to the integrators, to enable them to manage the risks during implementation
- to people joining the project at a later time, so that they know what assumptions have been made
- to the users, so that they know the commitments they are making.

To be an effective communication tool, the model must be simple, robust, adaptable and complete. Achieving this requires considerable effort. Structuring the model in order to achieve these requirements can take more than half of the total effort of risk analysis.

10.4 Reducing risk

Having identified and assessed the risk, you are in a position to consider ways of reducing it. There are three basic approaches:[9]

- *avoidance*: having identified the risk, you replan to eliminate it
- *deflection*: you try to pass the risk on to someone else
- *contingency*: you take no action in advance of the deviations occurring, other than to draw up contingency plans should they occur.

Pym and Wideman[9] use an analogy of a man being shot at. He can take cover to avoid the bullets; he can deflect or divert the bullets in another direction, allowing them to hit someone else; or he can allow them to hit him, and plan to repair the damage, and hope he has time to do so.

Avoidance

I showed above on the warehouse project, how to avoid the risk of snow holding up the preparation of the foundations by starting the work early enough, so that it is finished before the snow comes. Under avoidance, you change the plan to reduce the risk or eliminate it entirely.

Deflection

There are three ways of deflecting risk:

– *through insurance*: by which it is passed on to a third party
– *through bonding*: by which a security is held against the risk
– *through the contract*: by which it is passed between owner, contractor and subcontractors.

INSURANCE
A third party accepts an insurable risk (Section 10.2) for the payment of a premium, which reflects the impact of the risk, the likelihood combined with the consequence.

BONDING
One or both parties to a contract deposit money into a secure account so that if they or either party defaults the aggrieved party can take the bond in compensation. This is a way of transferring the risk of one party defaulting to that organization.

CONTRACT
Through contracts, the risk is shared between owner, contractor and subcontractors. There are two common principles of contracts:

1. *Risk is assigned to that party most able and best motivated to control it*: There is no point passing risk on to a contractor or subcontractor if they have neither the power nor motivation to control it. The Institution of Civil Engineers is currently revising their standard forms of contract around this principle.[10] There are four styles of contract for different approaches to sharing risk. The selection of an appropriate style will be part of the owner's contract strategies, but is beyond the scope of this book.[11]
2. *Risk is shared with subcontractors if it is within their sphere of control*: To achieve this, back-to-back contracts are used; the clauses in the contract between owner and contractor are included in that between contractor and subcontractors. I have come across instances where the contractor feels squashed between two giants, and accepts quite severe clauses from the owner to win the work, but believes that the subcontractors will not accept them because they do not need the work. This often happens to contractors on defence or public sector projects. The way to avoid this is to try to get the subcontractors to make their contracts directly with the owner, and use the owner's power to pull the supplier into line. The supplier may not need the business from the contractor, but may have a better respect for the owner.

Contingency
The third response to risk is to make an allowance for it, to add a contingency. You can add an allowance to any one of the five system objectives, but typically there are two main approaches:

- make an allowance by increasing the time and/or cost budgets
- plan to change the scope, by drawing up contingency plans should the identified risks occur.

TIME AND/OR COST

You can either add the allowance as a blanket figure, calculated through a bottom-up approach as above, or you can add it work element by work element. Either way, the project manager should maintain at least two estimates, as described in Sections 8.5 and 9.2. These are the raw estimate without contingency, and the estimate with contingency. The former, called the 'baseline', is communicated to the project team for them to work to, and the latter to the owner, for them to provide money and resources. The project manager may also maintain two further estimates, the most likely out-turn, the figure to which they are working, and the current estimate, which is the baseline with some contingency already consumed. The reason for giving the project team the baseline or current estimate as the figure to work to is they will seldom come in under the estimate, and will consume contingency if it is given to them. The reason for communicating the estimate with contingency to the owner is that they want to budget for the maximum likely time and cost.

CONTINGENCY PLANS

These are alternative methods of achieving the milestones, to be used in different circumstances. Contingency plans can be of three types:

1. *Purely after the event*: are plans which are drawn up but enacted only if the risk occurs.
2. *After the event with essential prior action*: are also drawn up and enacted only if the risk occurs. However, some preparation work must be done, such as procurement of long lead items.
3. *Prior action which mitigates the after the event action*: is where a contingency plan is drawn up, but the design of the facility or work methods changed to reduce the cost of implementing the contingency plan. The upfront cost may be increased to reduce the impact of the risk.

The alternative plans may or may not cost more money to implement, though presumably if they cost less it would be better to follow them in the first place. In Example 10.8, we drew up alternative plans should the valve shut tight, shut partially, and not shut at all. The latter plans each would have cost more than the first, which is the one we followed, although the second would have only been marginally more expensive.

It is better to plan to eliminate the risk than to plan how to overcome it, and it is better to plan how to overcome it than to increase the cost and extend the duration to pay for it.

TRIMAGI COMMUNICATIONS BV
RISK ITEM TRACKING FORM PAGE 1 OF 2

PROJECT: CODE
WORK PACKAGE CODE
ACTIVITY CODE
RISK NUMBER: RISK IDENTIFIER

NATURE OF RISK
SOURCE: EU/EP/IT/IN/L TYPE: BUSINESS/INSURABLE
CATEGORY CONTRACTUAL/MANAGEMENT/TECHNICAL/PERSONNEL

DESCRIPTION:

IMPACT DATE: LIKELIHOOD LOW/MEDIUM/HIGH

SUBSIDIARY RISKS
ACTIVITY RISK IDENTIFIER
ACTIVITY RISK IDENTIFIER

RISK IMPACT
SEVERITY: VL/L/M/H/VH SEVERITY SCORE ....../5
LIKELIHOOD SCORE ...../3 RISK SCORE SS * LS = .../15

IMPACT AREA
SCHEDULE:
COST:
PERFORMANCE:

RISK MONITORING

MONTH													
RANK													

Figure 10.6 Risk item tracking form

TRIMAGI COMMUNICATIONS BV
RISK ITEM TRACKING FORM — **PAGE 2 OF 2**

CORRECTIVE ACTION — PROPOSED/APPROVED
DESCRIPTION:

RISK REDUCTION COST
RESPONSIBLE MANAGER
REVISED DATE — LIKELIHOOD — LOW/MEDIUM/HIGH

START DATE: — CLOSURE DATE:

REVISED IMPACT

SEVERITY:	VL/L/M/H/VH	SEVERITY SCORE		....../5
LIKELIHOOD SCORE	...../3	RISK SCORE	SS * LS =	...../15

IMPACT AREA
SCHEDULE:
COST:
PERFORMANCE:

MONTH	ACTION TAKEN	NEXT ACTION	BY WHOM

ISSUE: — DATE: — AUTHOR — APPROVED

Figure 10.6 (*continued*)

10.5 Controlling risk

Having identified ways of reducing risk, you can implement a plan to control the reduction. Figure 7.2, shows four basic steps in control:

- draw up a plan
- monitor progress against the plan
- calculate variances
- take action to overcome variances.

THE RISK MANAGEMENT PLAN

The risk management plan identifies the risks associated with a project, the means by which they have been assessed, and the strategy for their reduction. A risk item tracking form (Figure 10.6) provides a framework for recording the relevant information for each risk. The form, which may be held in a spreadsheet or computer database, describes:

- *why* the risk is significant
- *what* is to be done to reduce it
- *when* the risk will have its impact on the project
- *who* is responsible for resolving the risk
- *how* the reduction will be achieved and how much it will cost.

I have already said that the risk varies throughout the life cycle of the project, and hence the priorities for risk reduction will change. Having each risk recorded on a separate sheet of paper, or recorded in a computer database, allows them to be sorted into appropriate order each month.

MONITORING RISK

The risks are then monitored on a regular basis (weekly, fortnightly, monthly, or at other predetermined intervals) to determine how far each risk has actually been reduced. At each review, the risk tracking forms are sorted into their order of current importance. A list of the most significant lists, usually the 'top-ten', is produced, giving rank this period, rank last period and periods on the list. Figure 10.7 contains an example of a report.

RISK REASSESSMENT

Reassessment should be carried out whenever new risks are identified in the course of risk monitoring. In addition there should be explicit reassessment at key milestones in the project, and at transition between stages. The launch meetings for subsequent stages, Chapter 13, are ideal media for this reassessment. All the above techniques are used for reassessment. It is always easier to improve on an existing plan, but there is the disadvantage that new risks may be ignored.

10.6 The PRAM and SCERT methodologies

The top-down approach to project risk management has now been codified into the project risk analysis and management (PRAM) methodology.[2,3] In this section, the PRAM methodology is summarized to

TRIMAGI COMMUNICATIONS BV
MONTHLY TOP RISK ITEM REPORT

PROJECT: CRMO RATIONALIZATION PROJECT **MANAGER: RODNEY TURNER**
WORK AREA: TECHNOLOGY **DATE: 26 FEBRUARY 199X**

RANK THIS MONTH	RANK LAST MONTH	MONTHS ON LIST	RISK ITEM	POTENTIAL CONSEQUENCE	RISK RESOLUTION PROGRESS
1	4	2	Replacement for team leader for MIS software development team	Lack of expertise in team. Delay in code production, with likelihood of lower quality - less reliable operation even after testing	Chosen replacement unavailable
2	6	2	Requested changes to user-interface	Now realized may impact h/w-s/w interface definition. If not cleared up at next week's user evaluation of prototype, will delay delivery date	User evaluation of latest prototype set for next week - attendance of some key users still to be confirmed
3	2	5	Resolution of network diagnostic software problems	Delay in completion of software detailed design and coding	New version of diagnostics appears to clear most problems but still to be fully checked
4	3	6	Availability of work-stations for main test phase	Lack of sufficient workstations will restrict progress on testing	Delay in deliveries being discussed with supplier
5	5	3	Testbed interface definitions	If not finalized by end of next month, will delay availability of testbed	Delayed items now being worked on. Review meeting scheduled
6	1	3	Tighter fault tolerance requirements impact on performance	Performance problems could require change to h/w-s/w architecture with major impact on cost and schedule	Latest prototype demonstrates performance within specification
7	—	1	Delay in specification of network data transmission	Could delay availability of hardware subsystems for integration	Meeting scheduled to consider alternatives
8	8	4	Tech author required	Insufficient time for programming staff to produce quality manuals	Requirement with agency
—	7	4	CM assistant required	Inadequate effort for rising CM workload with resulting costly errors	CM assistant joined team full-time
—	9	4	Re-usable database software uncertainties	Potential increase in estimates of coding effort	Uncertainties resolved in latest prototype

Figure 10.7 Monthly top-ten risk items report

show specifically how it achieves the concepts outlined in this chapter. The technique while new, is derived from a previous technique called the synergistic, combinatorial evaluation and review technique (SCERT) which was well documented.[1,11] However, after a decade of further research, the technique has been enhanced, and given a more user-friendly name.

The SCERT methodology (Table 10.3) has three stages and each with two phases.[1,11] The PRAM methodology is now a nine-stage process of risk management (Table 10.4).

Table 10.3 The SCERT methodology

Section	*Stage*	*Phase*	*Action*
Identify, 10.2	Qualitative	Scope	Component breakdown Identify risks Identify responses
Identify, 10.2	Qualitative	Structure	Risks response links Prioritize links
Assess, 10.3	Quantitative	Individual risks	Decide what to quantify Quantify uncertainty
Assess, 10.3	Quantitative	Combine risks	Combine risks
Reduce, 10.4	Manage	Plan response	Identify responses needs Plan responses
Manage, 10.6	Manage	Monitor	Monitor and control

Table 10.4 The PRAM Methodology

Section	*Stage*
	Define project
As part of project strategy	Focus PRAM
Identify, 10.2	Identify risks
Identify, 10.2	Structure risk
Reduce, 10.4	Allocate ownership
Assess, 10.3	Estimate risks
Assess, 10.3	Evaluate estimates
Reduce, 10.4	Plan responses
Manage, 10.5	Manage risk

10.7 Summary

1. There are five steps in risk management:
   - identify sources of risk
   - determine impact of individual risks
   - assess overall impact of risks
   - determine how the risk can be reduced
   - control the identified risks.
2. There are two types of risk:
   - business risk
   - insurable risk.
3. There are five sources of risk:
   - external – unpredictable
   - external – predictable
   - internal – technical
   - internal – non-technical
   - legal.
4. Techniques for identifying risks include:
   - expert judgement
   - plan decomposition
   - assumption analysis
   - decision drivers analysis
   - group brainstorming.
5. The impact of individual risks is a product of the likelihood they will occur, the consequence if they do occur, and the public perception of that consequence.
6. In assessing the combined effect of several risks, you can use:
   - a top-down approach, a management decision making tool
   - a bottom-up approach, and Monte Carlo analysis
   - influence diagrams.
7. There are three ways of reducing risk:
   - avoidance
   - deflection
   - contingency.
8. Contracts should be drawn up with the policy that risk should be assigned to the party best able and best motivated to control it.
9. There are four steps in controlling risk:
   - draw up a risk management plan consisting of Risk Item Tracking Forms
   - monitor progress against the top ten risks
   - reassess risks at regular intervals, and at key milestones or stage transition
   - take action to overcome any divergence from the plan.

10. The PRAM methodology identifies nine stages of risk management:
    - define and focus
    - identify and structure
    - allocate
    - estimate and evaluate
    - plan and manage.

References

1. Cooper, D.F. and Chapman, C.B., *Risk Analysis for Large Projects: Models, methods and cases*, Wiley, 1987.
2. Chapman, C.B. and Ward, S.C., *Project Risk Management: Processes, techniques and insights*, Wiley, 1997.
3. Simon, P., Hillson, D. and Newland, K., *Project Risk Analysis and Management Guide*, Association for Project Management, 1997.
4. CCTA, *PRINCE 2: Project Management for Business*, The Stationery Office, 1996.
5. Kähkönen, K. and Aarto, K.A. (eds), *Managing Risks in Projects*, Wiley, 1997.
6. Williams, T.M., 'The two dimensionality of project risk', *International Journal of Project Management*, **14** (3), June 1996.
7. Turner, J.R., Editorial, *International Journal of Project Management*, **14** (3), June 1996.
8. Hertz, D.B. and Thomas, H., *Risk Analysis and its Applications*, Wiley, 1983.
9. Pym, D.V. and Wideman, R.M., 'Risk management', in *The Revised Project Management Body of Knowledge*, Project Management Institute, 1987.
10. Institution of Civil Engineers, *The New Engineering Contract*, 2nd edn, ICE, 1995.
11. Turner, J.R. (ed), *The Commercial Project Manager*, McGraw-Hill, 1995.