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A HIERARCHICAL APPROACH TO THE MANAGEMENT OF CONSTRUCTION PROJECT RISK

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ABSTRACT

This thesis considers work undertaken in the area of the management of construction project risk.

The construction industry in Britain is undergoing a radical change; new markets are opening up as traditional ones close, and the nature of contracts are changing with the increasing popularity of design-build and the development of the Government's Private Finance Initiative. These changes have left many construction companies moving into markets in which they have little experience or entering into contracts which allocate risks to them which have previously been held by others. Since the traditional method of managing risks was by using the experience and judgment of managers, this has left many companies in a dangerous position, selecting projects with little knowledge of the risks the company is already exposed to, the extent to which the company wants the project, or the change that project will make to the risk profile.

An investigation into the formal approach to risk management, developed over the last few decades as a way of progressing from the purely experience based approach, concludes that although several of the techniques offer an improvement, the overall approach does not consider the company. Projects are treated as independent entities rather than temporary parts of the company's ongoing activities.

A system is produced which builds on the already identified organisational hierarchy of a company. Two risk models are produced, one for use at the project level, which considers the sources of uncertainty in the project, and one for use at the company level, which combines the uncertain impacts of the projects it is undertaking, those it is pursuing, and those which it expects will be available in the future.

The models have been tested and validated using data collected from projects in their tendering stage. The results of the tests are presented and the findings discussed.

Conclusions drawn from the work and recommendations for future work are presented.

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CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION

The construction industry in Britain is undergoing a radical change; new markets are opening up as traditional ones close, and the nature of contracts are changing with the increasing popularity of design-build and the development of the Government's Private Finance Initiative. These changes have left many construction companies moving into markets in which they have little experience or entering into contracts which allocate risks to them which have previously been held by other parties. These changes have left managers dealing with risks of which they have little experience. In this situation, the traditional method of risk management, which uses the experience and judgement of managers, has been found to be inadequate, and hence the need for a more scientific approach has arisen.

The main objectives of the research presented in this thesis are as follows:

- To investigate the nature of risk and uncertainty in a construction company arising from the projects it undertakes.
- To investigate the link between project and company risk.
- To assess the effectiveness of current methods and techniques employed to manage those risks.
- To determine whether a system can be produced which allows the effective management of risk arising from projects, whether to their own objectives or those of the company. This will include the following:

  a mechanism for assessing the uncertainty in a single project,

  a mechanism for assessing the uncertainty in a company undertaking several projects,

  a method for relating those uncertainties to the objectives of each level in order that the risks and opportunities can be managed effectively.

The remainder of this chapter contains a discussion of risk and uncertainty and their manifestation in a construction company. This allows the chapter to conclude with an investigation and appraisal of the traditional methods of managing project risk. This introduction leads to an understanding of the detailed requirements of a risk management system.

Chapter 2 presents a review of the literature relating to risk management, assessing the extent to which the more scientific approach which has developed over the last few decades allows the effective management of project risk. The conclusion of the review is that although the scientific approach addresses many of the deficiencies in the traditional approach it does not allow the effective management of the risk arising from projects.

Chapter 3 proposes a system which harnesses the hierarchical nature of a company to allow the risks to any level of the company arising from projects to be managed effectively. This system, in line with the organisational hierarchy and the tendering process, divides responsibility and detail between the project and the company, requiring a model for each level.

Chapter 4 present the project risk model which assesses the uncertainties affecting a single project. The effectiveness of the model is tested against its objectives in Chapter 5.

Chapter 6 presents the company risk model which assesses the uncertainties arising from all projects the company undertakes. The effectiveness of the model is tested against its objectives in Chapter 7.

Chapter 8 contains a discussion of issues relating to the system and the two risk model and the use of the system in practise. The wider applications of the model are also discussed. Chapter 9 presents an overview of the thesis, summarising the conclusions drawn. Chapter 10 suggests topics of further work required in this field

1.2 UNCERTAINTY, RISK, AND OPPORTUNITY

In order to fully understand a subject and assess the effectiveness of solutions to problems within it, a consistent set of definitions is required. In the subject of risk management, an understanding of the nature, origin, and the effect of risk is needed.

1.2.1 What Is Risk?

Risk is a term used in everyday life to describe the detrimental effects of uncertainty, or the act of gambling on the effects of uncertainty. Dictionary definitions of "risk" reflect this common usage, adding further definitions.

> Risk *n.* 1. the possibility of incurring misfortune or loss. 2. *Insurance.* chance of a loss or other event on which a claim may be filed. 3. at risk. vulnerable. 4. take or run a risk. to proceed in an action without regard to the possibility of danger involved ~vb (tr.) 5. to expose to danger or loss. 6. to act in spite of the possibility of (injury or loss)
>
> Collins Concise Dictionary Plus, 1989

In the above definitions, the word "possibility" is used three times. This is a reflection of the nature of risk, in that it arises out of the action of uncertainty. In the world we live there are many uncertainties, and yet it is the ones which can have a detrimental effect on our lives which we consider as risks. Inspection of definitions 5 and 6 may lead to the question, "Why?". Why do we expose ourselves or our belongings to danger or loss, or act in spite of the possibility of injury or loss? The logical answer must be that there is the possibility of gain or benefit, and that this can only be achieved if we place ourselves at risk. If risk is the downside of uncertainty, the opportunity or possibility of gain can be described as the upside. If it were possible we would seek only the opportunities which arise from uncertainty and avoid the risks. However, the two are usually linked in some way, and so we balance the risks we are exposed to with the opportunity which they bring. This balancing forms the basis of the decisions which we use to plan our future. The balance between the risks and the opportunities which we accept will be based on the perceived risks and opportunities, the opportunities we seek, and the risks we are prepared to accept.

The above discussion has concentrated on the common usage of risk and how it relates in everyday life to uncertainty and opportunity. In order to understand the subject of risk management in the context of the construction industry, the same terms must be defined within a more scientific framework.

1.2.2 Uncertainty

Uncertainty is inherent in the construction industry, perhaps to a greater extent than in other industries because of its interface with the Earth, whether from trying to control the natural elements, from trying to predict the state of the ground we want to build on, or from the variation in characteristics of the natural materials we use.

Uncertainty arises from the inability to accurately predict the outcome of future events. An event can be many things, ranging from, for example, the delivery of materials, to the cost of those materials, to the suitability of them, to the weather conditions when they are to be utilised. The uncertainty can manifest itself in the inability to predict if an event is going to occur and/or the effect if that event occurs. In the above example, the materials are going to cost money, there is no uncertainty about that, but there may be uncertainty about how much they cost. Alternatively, there is uncertainty about whether the material will be suitable for its purpose, and if it is not, the degree to which it is unsuitable.

The definition of uncertainty used in this thesis is as follows:

Uncertainty An event whose outcome cannot be accurately predicted.

From this definition, the degree of uncertainty comes from the accuracy of our prediction.

1.2.3 Risk

The subject of risk management has developed over the last few decades to bring together the many systems and techniques used in the management of risk. It is not surprising then that a great deal of the literature on the subject has offered definitions as to what it is that is to be managed.

As a starting point, the British Standards Institute, in BS 4778 (1979), provides the following definition:

> "The combined effect of the probability of occurrence of an undesirable event, and the magnitude of the event."
>
> British Standards Institute, 1979

This definition comprises several aspects of importance; that risk is an undesirable event, and that its magnitude and probability of occurrence should be taken into account. This qualitative approach, of multiplying the effect by the magnitude is also suggested in definitions given by Green (1982), RISKMAN (1994) (termed risk exposure rather than risk), and CIRIA (1994). These definitions place risk in a technical environment, allowing risk to be quantified.

A looser definition is that given by Bannister and Bawcutt (1981) who define risk as:

> "Potential variability in the future outcome (of a stated situation) due to uncertainty"
>
> Bannister and Bawcutt, 1981

One aspect of the above definition which is important is the potential for a desirable impact to be termed a risk. This concept that risk is the impact of uncertainty, whether beneficial or detrimental, is also supported by Drucker (1974), who effectively defines the net risk as the balance between the upside and the downside, and Al-Bahar and Crandall (1990) and Perry and Hayes (1985).

Another group of definitions attempt to differentiate between uncertainty and risk. For example, Gardenfors and Sahlin (1988) state the following:

> "Risk: When the decision maker has full information about the world, in that they 'know' the exact probabilities of the states of the world.
> Uncertainty: When the decision maker has no information about the states of the world and hence no probabilities."
>
> Gardenfors and Sahlin, 1988

This view is supported by Pilcher (1992).

The definitions above are not consistent, even though most talk about the same things: uncertainty, damage, loss, and the probability of it occurring. In order to allow understanding, the following definition will be used throughout this thesis, and can hopefully be applied to other work.

Risk An uncertain event whose outcomes can be detrimental to the attainment of the objectives.

The definition acknowledges that risk is a consequence of uncertainty and acts against the attainment of our objectives.

1.2.4 Opportunity

The upside of uncertainty, opportunity, unfortunately does not warrant discussion in many of the papers which offer a definition of risk. Perhaps if the subject had developed under the title "Uncertainty Management", the opportunity aspect would gain more attention. However, the more recent additions to the literature covering risk management acknowledge the importance of opportunity when assessing risk (Flanagan & Norman, 1993).

The definition of opportunity used in this thesis reflects the equal importance of opportunity and risk.

Opportunity An uncertain event whose outcomes can be beneficial to the attainment of the objectives.

The definitions of risk and opportunity presented classify all uncertainty which affects our objectives.

1.2.5 Riskiness

The above definitions of risk and opportunity classify the possible outcomes of an uncertainty into beneficial and detrimental. Using the definitions it is possible to determine whether an uncertainty is a risk, an opportunity, or both. An uncertainty can be both a risk and an opportunity if it has possible outcomes which would be beneficial and ones which would be detrimental. There is a need to classify the extent to which uncertainties are risks and opportunities to allow comparisons and decisions to be made regarding their acceptability. Definitions of risk which produce a numerical value do classify the risk; the higher the value the riskier the uncertainty. However, such definitions, that by British Standards Institute (1979) is an example, deal only with single outcomes of an uncertainty. There is a need to classify the riskiness of an uncertainty, taking into account all its possible outcomes. In this sense, a risk could be an uncertainty with more risky outcomes than opportunities. This classification is not a simple addition of the number of outcomes which are risks and those which are opportunities; the magnitude of each of those outcomes has to be taken into account.

A risk, therefore, has two meanings. It can be an undesirable outcome of an uncertainty, or an uncertainty with a balance between the risk and opportunity outcomes in favour of the risks. Obviously, an opportunity can be seen in a similar manner.

1.2.6 Risk, Perception and Affinity

The above definitions of risk and opportunity refer to the possible outcomes of uncertainties, which are future events. Although the assessments of the possible outcomes can be made with reference to past events, accurate historical data is usually unavailable in the construction industry because of its project based nature. Instead, people make the assessments of risk and opportunity based on their own past experience. The result of this is that two people with the same objectives can make different assessments of the risk and opportunity.

The difference in the assessments is a function of the past experience of the people and their affinity or aversity to risk. If a person enjoys risk, their view of the acceptable balance between risk and opportunity will have a greater proportion of risk to someone who is risk averse. Studies have been undertaken to investigate the relationship between risk and expected return, showing that high risk ventures generally have higher expected returns, and that troubled firms tend to take higher risks in a desperate attempt to restore profits (Marsh & Swanson, 1984). Higher risk, in this context, means the acceptable balance between the risks and the opportunities in the venture is more towards the risks than would be expected. In this case, the objective of survival can be seen to be of greater importance than with firms which are stable.

The level of risk which is considered acceptable is, therefore, a function of the interpretation of the data available and the relative importance of the objectives, both of which are controlled by the people involved.

1.3 TRADITIONAL APPROACH TO THE MANAGEMENT OF RISK FROM PROJECTS

1.3.1 Role of Managers in the Management of Risk

The role of managers as the controllers of risk is not new; it may be seen as one of the primary roles of managers. The traditional approach to managing the risk from projects has utilised the valuable assets of experience and judgement. Interestingly, the term "risk management" has only been in common use for the last few decades. This is because the term "risk management" refers to treating the risk management of risk as an explicit task. Traditionally, the management of risk, using experience and judgement, has not been separated from other functions of managers and so not warranted a title.

1.3.2 Importance of Tender Stage

Although the traditional approach has used experience and judgement, which have drawbacks, several of which will be discussed later in this section, the application of that experience has been targetted at the time in a project when most can be done to manage the risks it generates. This time is the tender stage. It is at this time that the company submits a bid for a project based on a set of contract conditions. The contract conditions determine which of the parties is responsible for the uncertainty and the tender price sets the objectives for the project from which the uncertainty the company is responsible for will be translated into risks and opportunities. As an example, a common clause used in many standard forms of construction contract is pertaining to the uncertainty regarding ground conditions and to what extent each party is responsible for the possible effects of that uncertainty. If the contractor accepts the uncertainty in the ground conditions and does not make any modification to the tender price to take this into account, the uncertainty in the ground conditions will be translated directly into risk to cost and ultimately profit. If the tender price had been modified to take the increased uncertainty into account, some of the uncertainty in the ground conditions would be translated to opportunity (i.e. the project would cost less if the ground conditions did not cause any problem), so limiting the extent of the risk.

1.3.3 Traditional Approach to Managing Risk at Tender Stage

The above discussion illustrates the importance of tender activities with respect to the management of risk arising from projects. The two impacts above, of committing the company to a set of contract conditions and a price for undertaking the project, have always been identified as of high importance. Although the tender finalisation, when the qualifications to the bid and the price are set by the company, are considered to be important, the approach taken contains little scientific content. The approach taken relies on the personnel developing the tender to bring to the management's attention areas of possible concern within the tender. Such areas might be related to the contract conditions or to direct cost. In the case of the contract conditions, a legal opinion is usually sought, acknowledging the limitation of the project team's expertise.

Having brought areas of concern to the attention of management, the price has to be set and any qualifications identified. Here, the managers employ their experience and judgement to assess the potential impact of the uncertainties, some of which may be purely opportunity. From that assessment a modification to the tender price may be made, to reflect the judgement of the managers regarding the level of risk exposure in the project.

The process by which the managers determine the modification to the price concentrates on the wider implications on the company, as well as those related directly to the project. These wider implications are extremely important and include

- the extent to which the company wants the project,
- the price which the market is expecting, and
- the risk the company is already exposed to from other projects.

The extent to which the company wants the project will be related to the amount of work the company is already committed to and any strategy it has for the future. The company is likely to have a target for the amount of work it wishes to take on at any time. This target may be set by it or the controlling company in relation to a strategic plan and the resources available to undertake the work. The level of risk the company is willing to accept (i.e. the price it is willing to undertake the project for) is likely to vary if the company is likely to meet its turnover target without the project or if it is struggling to meet that target.

The price which the market is expecting the tenders to be returned at will also be linked to the extent to which the company wants the project. If the company decides it wants the project, it must then decide how it is going to be awarded it. In this case, submitting a tender above the expected or budget price is likely not to achieve this objective.

The risk the company is already exposed to impacts the risk the managers are willing to accept on this project. If the company has recently been awarded projects which, in the managers' views, contained high degrees of risk, they may be looking to win some projects of lower risk to balance the risk exposure of the company. However, the managers have no way of knowing, using the traditional approach, the risk the company is already exposed to.

1.3.4 Deficiencies in the Traditional Approach

The above discussion has shown that there are many factors which impact the finalisation of a tender. The use of experience based judgement to assess the price to be submitted could be argued to be a successful approach. The continued existence of companies which use this approach may be used as evidence of that success. However, the judgement used to base the decisions is only valid when the experience used is relevant. In the construction industry, moving into a new market or operating in a changing market are likely to reduce the relevance of the vast experience of the management.

The reliance on experience which, in some cases, may not be relevant may be seen as the major deficiency in the traditional approach. This approach requires the management to make judgements of the extent to which the company wants the project, the price which is likely to win it, the risk the company is already exposed, and the risk this project would expose the company to if the tender was successful. Forming a judgement on the above issues results in decisions which are rarely documented as the managers consider so many aspects that it would be difficult to document them.

1.4 SUMMARY

This chapter has defined the objectives for the research presented in this thesis and introduced the subject of risk and its management. Definitions of uncertainty, risk, and opportunity have been discussed and a set which will be used throughout this thesis have been adopted. These definitions give equal weight to risk and opportunity, defining these as flowing from the action of uncertainty on our objectives.

Also as a means of understanding the subject, the traditional approach to the management of risk from projects was investigated. This concluded that it is an approach which, although it identifies the tender stage as the key stage for a project in terms of risk management, it relies on the judgement of management. This judgment can be based on irrelevant experience. Of the four aspects identified, it should be noted that only one related to the project itself, the others relating to the company and its other activities, and the market in which it operates.

Chapter 2 presents an investigation into the subject of formal risk management which has developed over the last few decades to overcome the deficiencies in the traditional approach.

CHAPTER 2

REVIEW OF FORMAL RISK MANAGEMENT APPROACH

2.1 INTRODUCTION

Chapter 1 introduced the subject of risk and uncertainty, investigating the methods by which risk has traditionally been managed in a construction organisation. One of the conclusions of that investigation was that a formal, scientific approach was needed. The subject of risk management has developed over the last few decades, bringing together many systems and techniques with the objective of doing just that. This chapter investigates the subject of risk management, judging its effectiveness in attaining its objectives.

The chapter begins by examining the definitions of risk management, and proceeds to investigate the process itself. The distinct stages of risk management are considered in turn. The chapter concludes with an overview of the subject with reference to the objectives of risk management defined in Chapter 1.

2.2 RISK MANAGEMENT

Chapter 1 began with a discussion of the many definitions of risk which have been proposed in the literature on risk management. The chapter concluded with a discussion of the methods by which risks have been managed traditionally. The objectives of that process could be inferred to be the assessment and management of various sources of uncertainty with reference to their potential impact on the attainment of the objectives. Although this could be taken as a definition, this chapter begins by examining the definitions of risk management given by others in literature on the subject.

There are many definitions of risk management, just as there are of risk, and, similarly to the definitions of risk, the definitions of risk management are also inconsistent. This inconsistency, and hence confusion, arises because of two aspects of the definitions. Firstly, as for risk, there are different definitions as to what risk management is, and secondly, different titles are sometimes given to a process which could be described as risk management.

As examples, the following definitions of risk management rely heavily on the definition of risk used by the author but do introduce many of the fundamentals of risk management.

> "A formal orderly process for systematically identifying, analysing, and responding to risk events throughout the life of a project to obtain an acceptable degree of risk elimination or control."
>
> Al-Bahar and Crandall, 1991

> "The identification, measurement, and economic control of risks that threaten the assets and earnings of a business or other enterprise."
>
> Bannister and Bawcutt, 1981

> "The aim is to identify, analyse, evaluate, and operate on risks. The company is converting uncertainty to risk."
>
> Flanagan and Norman, 1993

> "The whole complex process of decisions about risk: including risk estimation, risk evaluation and judgements on acceptability, taking into account public opinion."
>
> Royal Society, 1983

> "A technique aimed at controlling the level of risks and mitigating their effects."
>
> Toakley and Ling, 1991

The following definitions are of risk analysis but seem to refer to a similar process.

"Risk analysis is the qualitative identification and subjective assessment and then a quantitative analysis. Risk management involves the formulation of management responses to the main risks."

Association of Project Managers, 1992

"Risk analysis is the identification of uncertainties, estimation of the natures and magnitudes of the uncertainties, articulation of the impact of the uncertainties on the execution of the project, and formulation of a project plan, including appropriate contingency measures, which explicitly allows for the uncertainties."

Klein, Powell, and Chapman, 1994

The above definitions describe the subject of risk management, to which all the authors contribute work, in many different ways. Indeed, because there is no consistency in the definition of risk, this is compounded in the definitions of risk management. Taking the definition by Al-Bahar and Crandall, 1991, as an example, their definition of risk contains both the upside and downside of uncertainty, and this affects the interpretation of their definition of risk management. When Flanagan and Norman, 1993, describe the essence of the process as the conversion of uncertainty to risk, this can only be understood with reference to their definitions of risk and uncertainty.

There is also disagreement on the matter of what should be the focus of risk management within construction. Many of the definitions define it in terms of construction projects. As the investigation of Chapter 1 showed, although construction projects are the major source of risk, the risks are ultimately to the company undertaking them and even when considering a project many aspects are beyond that project being considered. When risk is viewed purely from a business perspective, as in Bannister and Bawcutt, 1981, the field of view is widened and risk management is defined in terms of a company and its operations. Indeed, Perry and Hayes, 1985, identify the benefit of understanding the cumulative effect of project risks but concede that this is not undertaken.

Many authors, rather than providing a definition of risk management, describe the process and, in doing so, definitions can be inferred. Risk management is described by many as a three stage process, entailing identification, analysis, and response (Perry and Hayes, 1985, Clark, Pledger, Needler, 1990, Bannister and Bawcutt, 1981, and Toakley and Lind, 1991). Al-Bahar and Crandall, 1991, add a fourth stage, referred to as system administration. The inclusion of this stage highlights the iterative nature of risk management, as it contains the monitoring of the risk management process. In responding to some risks, the effect of others can be changed or new risks produced or identified (Berny and Townsend, 1993). The iterative nature of risk management is easily illustrated using a flowchart, an example of which is shown in Figure 2.1.

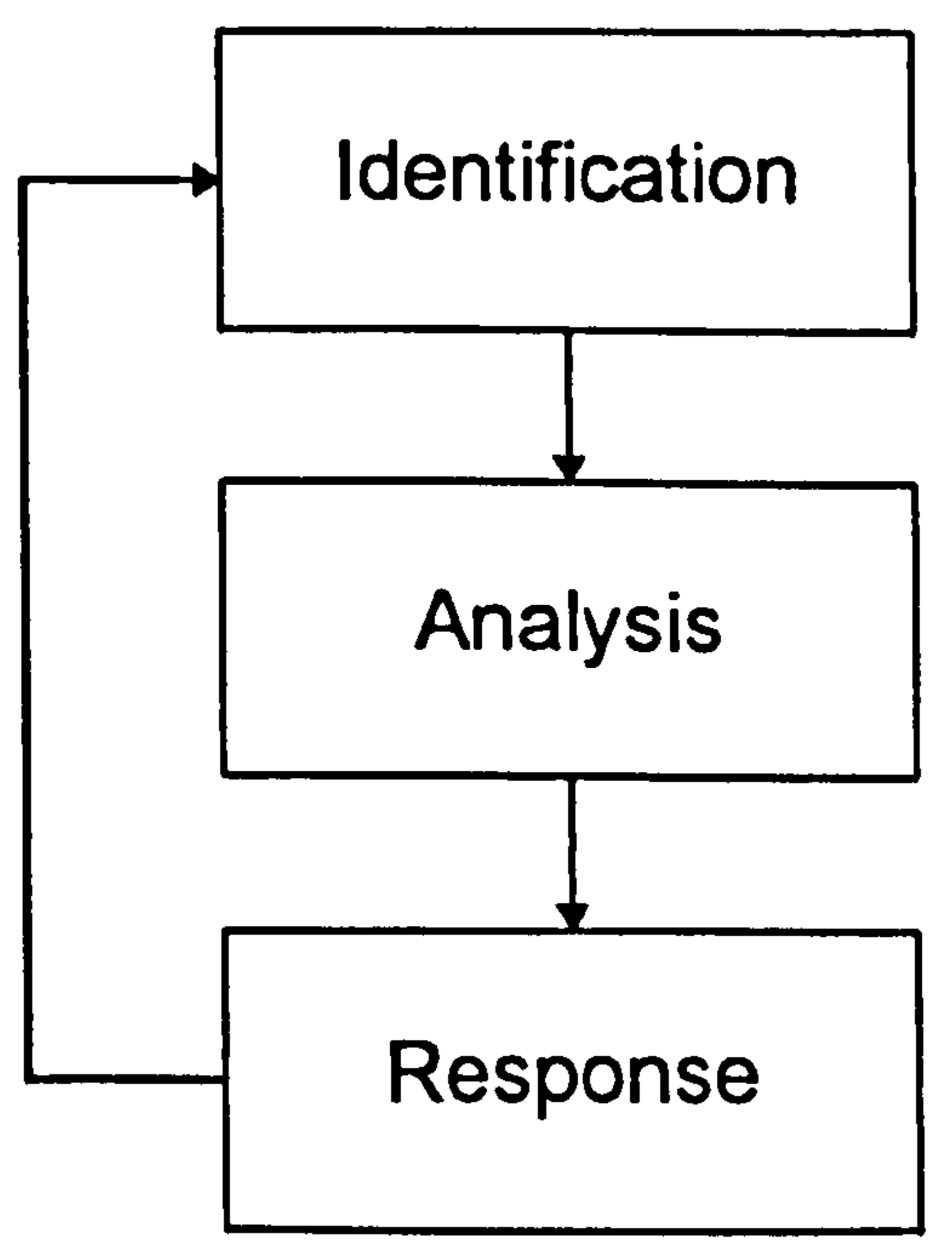

Figure 2.1 - Flow chart of the risk management process

Flanagan and Norman, 1993, include a further item into the process, referring to risk attitude, as "any decision about risk will be affected by the attitude of the person or organisation making the decision." This is an important element in decision making which the systematic and scientific nature of risk management is designed to control.

If lower costs are considered an opportunity, the objective of risk management is to minimise risk subject to cost constraints, as there is generally a negative correlation between risk and cost. Cooke and Pintér, 1989, define this as the risk problem. They also define the cost problem, as minimisation of cost subject to risk constraints. This further illustrates the link between risk and opportunity and shows that risk management should seek to control the balance between the two.

Although there is inconsistency between the definitions, there are similarities, as summarised below:

1 It is a formal process.

2. It employs systematic and scientific methods.

3. It aims to identify risks to an operation or business.

4. It evaluates the importance or impact of those risks on the operation or business.

5. It provides mechanisms to control the individual risks to provide an acceptable level of overall exposure.

6. It is not a one-off event.

For the purpose of this thesis, and hopefully for use in future work, risk management will be defined as follows.

> *Risk Management* - a continuous process by which the sources of uncertainties which could affect the objectives are systematically identified, their impact scientifically assessed, and their effect and likelihood managed to produce an acceptable balance between the risks and opportunities.

It should be noted that the definition is not specific to projects. The definition used is in terms of the effects of uncertainty on objectives, which, for a construction company, could be at a corporate or a project level.

The three main stages of risk identification, analysis, and response, will be investigated in turn, to determine their purpose and the techniques which have been developed to assist managers.

2.3 RISK IDENTIFICATION

2.3.1 Objectives

This stage of risk management is viewed by many as the most important, as the subsequent stages can only operate on the identified risks (Al-Bahar and Crandall, 1991). Clark, Pledger and Needler, 1990, go as far as to say "an identified risk is not a risk, it is a management problem." This suggests a difference between an identified risk and one which, although it exists, has not been identified.

The process of risk identification is defined by Al-Bahar and Crandall, 1991, as "the process of systematically and continuously identifying, categorising, and assessing the initial significance of risks associated with a construction project." Although the initial assessment of significance of risks could be considered a part of the analysis stage, it is placed here because of the need to limit the number of identified risks (Perry and Hayes, 1985, Berny and Townsend, 1993). In this way, pre-analysis can help to eliminate insignificant risks from the detailed analysis stage. Analysis can then be seen as a process of increasing complexity and sophistication, initially viewing risk independently, secondly in connection with other risks, and finally in the context of possible strategies (Thring, 1992).

2.3.2 Techniques

The process of risk identification relies on the knowledge, judgement, and experience of the people involved in the project or business. In order to assist these people, and to add a scientific base to the process, techniques have been developed. These techniques also help to control the bias, discussed earlier, arising from the subjective nature of the exercise and personal objectives.

The techniques can be divided into two categories; those designed to assist in the identification of risks and opportunities, and those designed to assist in determining the initial significance of those sources.

The following list, although not exhaustive, shows examples of the techniques available to assist in the identification stage.

- Checklists
- Brainstorming
- Cause-event-effect
- Prototype activities

The techniques applied to the pre-analysis stage include the following.

- Qualification
- Quantification
- Risk Mapping
- Classification

2.3.2.1 Checklists

Checklists are a popular method of identifying risks and opportunities. They are an effective method of relating past experience to present situations. The checklist will usually contain a list of the risks which commonly occur on projects or ventures of a similar type. Although this technique will not identify the risks specific to the venture under consideration, they do ensure that risks identified on other ventures, usually through experience, are considered (Al-Bahar and Crandall, 1987).

2.3.2.2 Brainstorming

The objective of this technique is to elicit information specific to the venture under consideration. The process requires a group of people involved in the venture, preferably with different expertise and perspectives, in order that the list of risk and opportunities reflects all aspects of the venture. The inclusion of a number of people in the exercise helps to control personal bias although this also introduces problems of an increased time requirement and a potentially riskier stance (Harrison, 1995). Although there is no ideal number of people which should form the group, it is considered that the effectiveness decreases when more than five people take part (CIRIA, 1994).

In order to focus the discussion, it is common to identify the risks and opportunities in a small number of categories, or to examine the project or venture with respect to time, studying each phase in turn (Thring, 1992) . Table 2.1 shows an example list of risk categories with typical risks.

Table 2.1 - Example of risk categories and typcial risks (after Al-Bahar & Crandall, 1991)

Risk Category	**Typical Risks**
Acts of God	Flood, earthquake, landslide, fire, wind, lightning
Physical	Damage to structure, damage to equipment, labour injuries, material and equipment fire or theft
Financial and economic	Inflation, availability of funds from client, exchange rate fluctuation, financial default of subcontractor, non-convertibility
Political and environmental	Changes in laws and regulations, war and civil disorder, requirements for permits and their approval, pollution and safety rules, expropriation, embargoes
Design	Incomplete design scope, defective design, errors and omissions, inadequate specifications, different site conditions
Construction related	Weather delays, labour disputes and strikes, labour productivity, different site conditions, defective work, design changes, equipment failures

2.3.2.3 Cause-Event-Effect

The previous two techniques have aimed to identify risks and opportunities by considering the possible sources themselves. This techniques approaches the problem from a different perspective by tracing the consequences back to discover the possible causes (Jardine Ins Brokers, 1987, Al-Bahar and Crandall, 1991, Flanagan and Norman, 1993).

This approach acknowledges that a single risk (the effect) can have many causes, each one contributing to the probability of occurrence.

2.3.2.4 Prototype activities

This technique, by Klein, Powell, and Chapman, 1994, for use on construction projects requires a prototype activity to be defined. The risks are then identified as variations from that prototype. The technique was produced to reduce the reliance on using the network of activities and allow the risk aspects of the project to be targetted. As will be discussed in the section on risk analysis, the network of activities has commonly been the target of analysis, but this suffers from several limitations. Firstly, a network of activities does not exist at all stages of a project, particularly at the stages where the major decisions concerning risks are made, and secondly, a project network can commonly contain upwards of a thousand activities. Considering each activity in isolation would be a time consuming task.

Prototype activities can therefore been developed to allow the key risk areas of a project to be identified by comparing actual activities with the prototype. The key feature of the prototype activity is that it does contain uncertainty, but at an acceptable level. In this way, rather than identifying every source of uncertainty, only those with above normal uncertainty are considered. This again reinforces the idea that the objective is to gain an acceptable level rather than to minimise risk.

The important aspect, then, is to identify the significant uncertainties rather than those which are accepted for the industry. Although this approach focuses the manager's attention of the aspects which make the project different to others, it may be that the industry accepted uncertainties still require attention. If, in this case, the prototype was defined with the usual level of uncertainty, some projects would have less uncertainty than the prototype, identifying an opportunity.

2.3.2.5 Risk Qualification

The first stage of any analysis is risk measurement, in which the possible effects of the identified risks and their likelihood of occurring are assigned. There are two methods of achieving this; qualification and quantification (Franke, 1987).

Risks contain two parts; their impact and the probability of that impact; many definitions of risk are based on these two characteristics. Qualification is used when the two parameters are described using words. For example, the impact might be described as low, moderate, or high, and the likelihood as probable, unlikely, etc. Words are used because of the difficulty in assigning actual values. Although such classifications are relatively easy to assign, their usefulness is limited.

2.3.2.6 Risk Quantification

In many cases it is possible to evaluate the impact of a risk in terms of cost or time, as these have commonly used units. Quantities such as quality cannot readily be quantified due to the lack of suitable units. In such cases, it is suggested that the effect is converted to an equivalent cost (Franke, 1987). However, in some cases this is not possible or advisable (Drucker, 1974).

The quantification of the probability of the risk occurring is often a more subjective task than that of the impact or effect. Ideally, the probability would be derived statistically from historical data, Unfortunately, historical data is generally not available, or is too sparse to make a confident statistical prediction. Consequently, in many cases, a subjective assessment is made, based on the historical data available and the experience and judgement of the people involved.

Following the qualification or quantification of the risks, pre-analysis can be performed. The following list contains examples of the techniques used for this task.

- Risk Mapping
- Risk Classification

2.3.2.7 Risk Mapping

This is perhaps the most common and simplest of the techniques. A risk map is a two dimensional graph; one axis representing the potential impact of a risk, and the other denoting the probability of occurrence. The graph is converted to a map by the placing of contours (or iso-risk curves); the contours further away from the origin denote high risk. Figure 2.3 shows an example risk map.

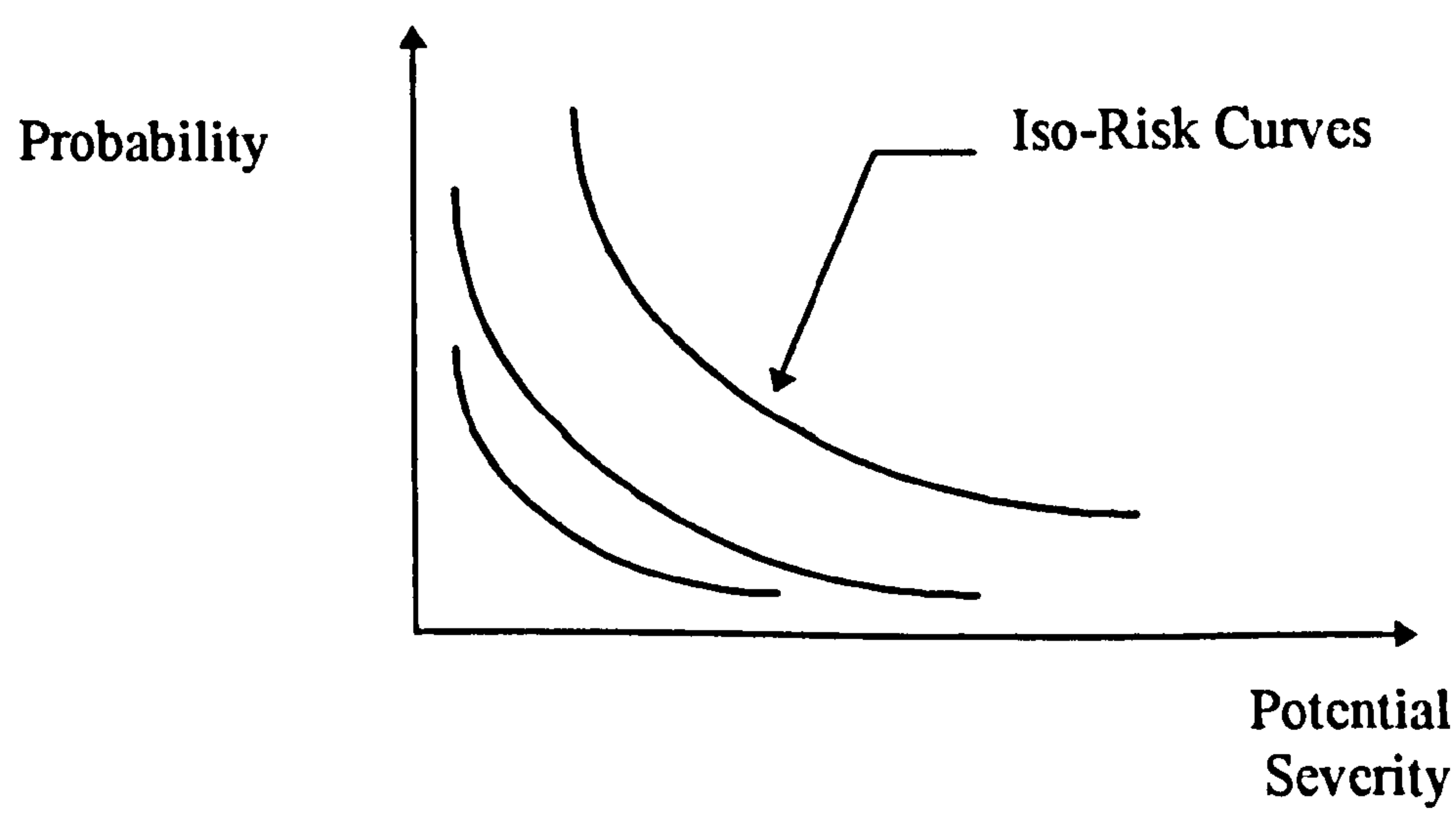

Figure 2.2 - Risk map (from Al-Bahar and Crandall, 1991)

The graph in Figure 2.2 shows the iso-risk curves, dividing the space into regions of equal risk.

The limitations of such a technique are that it is only applicable to event risks, i.e. risks which either occur with a pre-defined effect, or do not, and that it does not acknowledge the link between individual risk events, treating each as an independent event, both in terms of probability and effect.

2.3.2.8 Risk Classification

Risk classification has been developed to describe the nature of a risk, either in terms of its origin, consequence, or impact, etc. The risk classification can then be used in determining possible strategies to control each risk. Figure 2.3, below, shows a hierarchical classification, while Table 2.1 above showed a classification system based on the nature of the source alone.

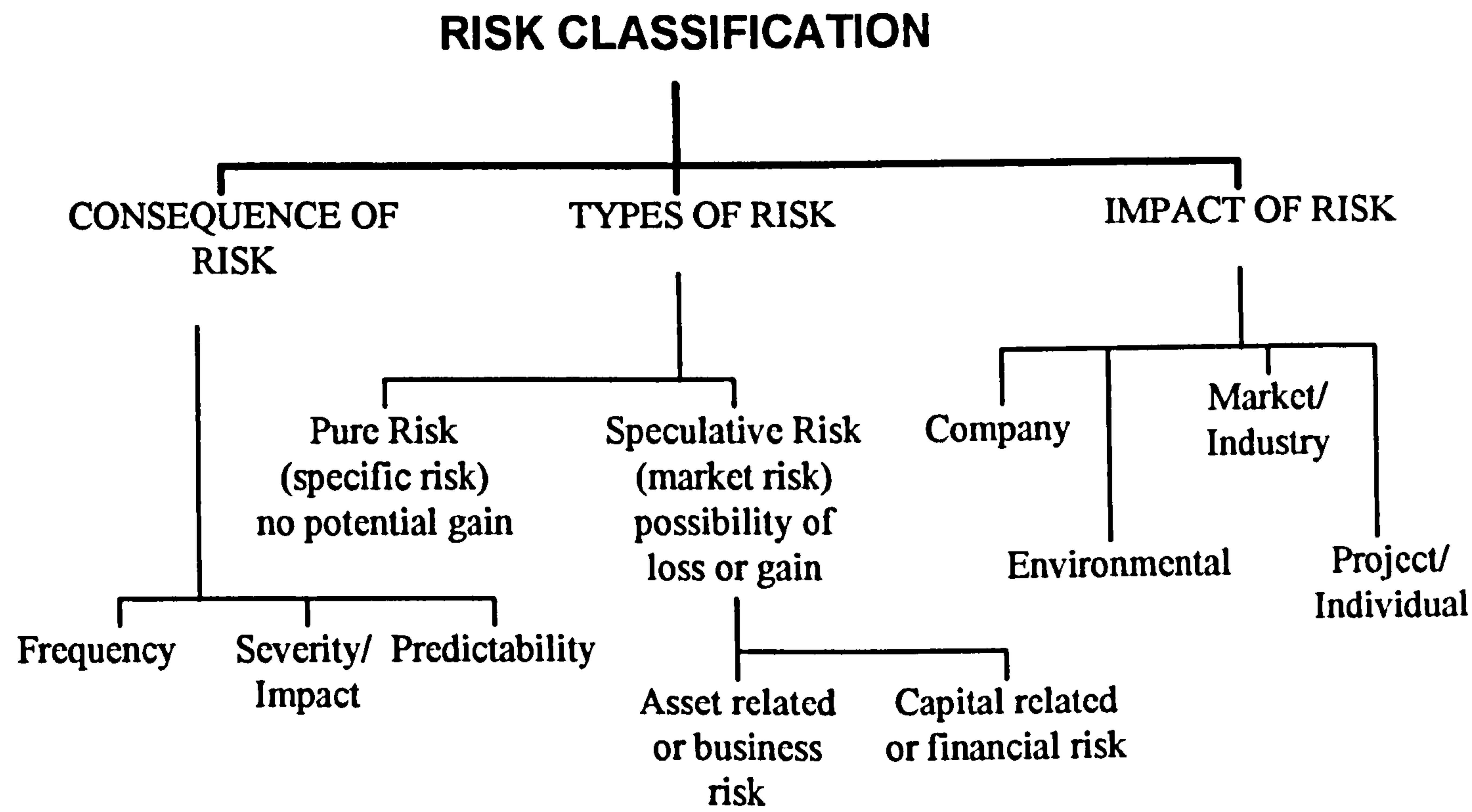

Figure 2.3 - Hierarchical classification system (from Flanagan and Norman, 1993)

As an extension of this, Williams, 1994, proposes a risk register which, acting as a database, combines information regarding the effect each risk may have and its probability, any actions which can be taken to control the risk, and the contractual status of the risk, i.e. the extent to which the risk can be transferred.

Effectively, the risk register brings together the results of risk quantification, mapping, and classification. The benefits of this are that it produces a summary of the identified risks and allows the links between them to be defined (Al-Bahar and Crandall, 1991).

2.4 RISK ANALYSIS

2.4.1 Objectives

The importance of risk analysis is stressed by Al-Bahar and Crandall, 1991, by describing it as "the vital link between systematic identification and rational management of significant [risks]." They go on to define it as a "process which incorporates uncertainty in a quantitative manner, using probability theory to evaluate the potential impact of risk". Other authors, namely Perry and Hayes, 1985, agree that the objective of risk analysis is to determine the combined effect of the identified sources of risk and opportunity and highlight those which make a significant contribution to that total. Banister and Bawcutt, 1981, expand on this by saying that risks are taken depending on "the size of the potential losses, in excess of gains over losses, and in the favourableness of the odds." This illustrates again that risks are accepted because of the opportunities they bring, based on the balance between the two.

For the purpose of this thesis, risk analysis will be defined as the process of evaluating the balance which exists between the risks and the opportunities, and identifying the sources to which that balance is sensitive. The balance between the risks and opportunities is the parameter against which decisions are made and as such it should be an output of the analysis stage. Further, in order to facilitate effective management action, the significance of individual sources of risk and opportunity is required.

The techniques employed in risk analysis can be categorised as those designed to determine the balance between the risks and opportunities, and those which aim to assess the significance of individual risks.

2.4.2 Determination of the balance between the risk and opportunity

The objective of the following techniques is to determine the combined effect of the individual sources of risk and opportunity. Of all the stages of risk management, this stage contains the vast majority of the available techniques. The techniques discussed here are:

- Expected Outcome Analysis
- PERT
- Monte Carlo Simulation
- Tolerance Analysis
- Analytical Hierarchy Process
- Event and Decision Trees
- Influence Diagrams

2.4.2.1 Expected Outcome Analysis

This is the simplest technique used and builds on the standard quantification technique of defining the probability and effect. Multiplying these two parameters gives the expected outcome for each uncertainty, and the sum of these gives the expected outcome for the project. The figure represents the average outcome of the uncertainties which, if added to the price of the project, would reflect the average price of the project.

Although this technique is quantifying the risk, giving a sum of money which can be added to the price, it does not really define the balance between the risks and the opportunities. Although the figure does show whether the average outcome is a risk or an opportunity, the range of possible outcomes is not evaluated, so not presenting the balance. To illustrate this, consider a list of items whose expected outcome was zero. The result gives no indication of how the risk and opportunity is distributed around the balancing point (of zero), or the likelihood and potential impact of the individual risks and opportunities. This highlights another problem in that this technique treats a risk with a relatively high probability of occurrence and moderate impact the same as one of low probability but catastrophic implications.

2.4.2.2 PERT

The Program Evaluation Review Technique, PERT, (Malcolm, Roseboon and Clark, 1959) is perhaps the first risk analysis technique, dating back to the late 1950's. The technique is based on the network of activities for a project, in which the activity durations are considered variable, rather than fixed, as they are in critical path analysis. The objective of the technique is to determine the probability of finishing the project by pre-defined dates. The range of possible durations for each activity is defined using a three point approximation based on the beta distribution. The three parameters are referred to as the optimistic, most likely, and pessimistic durations.

The mean and variance of each activity duration is evaluated using the properties of the beta distribution from the three parameters given. The analysis begins with the determination of the critical path using the most likely durations. The mean total duration is then the total of the mean duration of every activity in the critical path. Using the Central Limit Theorem (Wilson, 1972), the variance of that duration is the sum of the variances of the activity durations on the critical path. The resultant distribution has the characteristics of the normal distribution, an example of which is shown in Figure 2.4 in two formats.

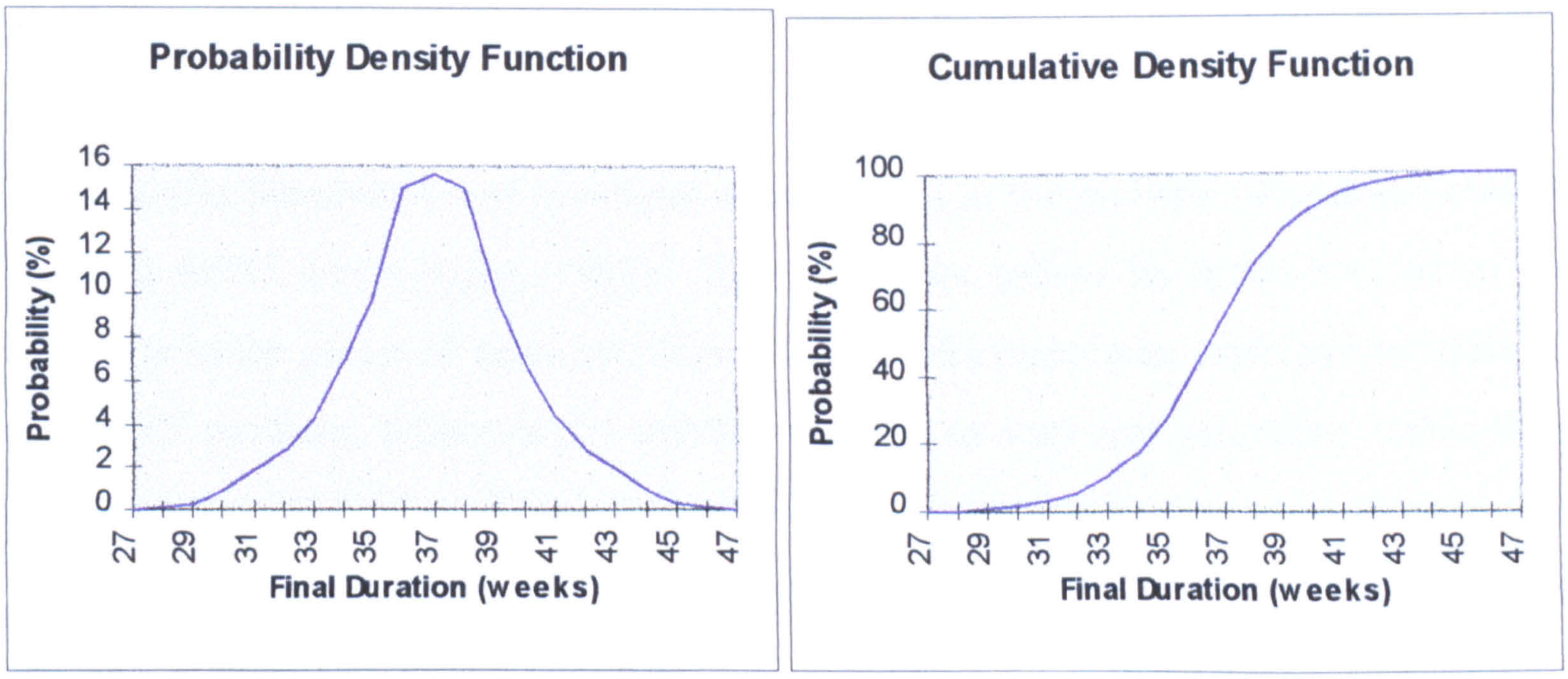

Figure 2.4 - Example output of PERT

Frequency distributions, such as those shown in Figure 2.4, are a common output of quantitative risk analysis techniques. The distribution on the left is a probability density function (pdf) in which the height of the graph represents the relative likelihood of that outcome. The peak of the graph shows the most likely result and is easily identifiable. An alternative method of presenting the distribution is the cumulative density function, as shown on the right. The height of the graph represents the probability of finishing before that date rather than on that date. This form of the distribution is particularly useful for determining the likelihood of meeting milestone dates.

In comparison to the Expected Outcome Analysis technique, PERT acknowledges that uncertainties can have a range of possible outcomes. Although PERT gives more information than a single point estimate, it does suffer from several problems and limitations. Perhaps the most obvious, as pointed out by the proposers of the technique, is that it produces optimistic forecasts because it does not allow for multiple critical paths. Multiple critical paths arise when the duration of a path parallel to the critical path can be in excess of the critical path duration. PERT produces an optimistic result because, in this case, it uses the shorter of the two paths.

Despite these limitations, PERT is still being applied and an important technique, especially in determining the distribution of costs, as this contains only one path (Aquino, 1992).

2.4.2.3 Monte Carlo Simulation

Monte Carlo Simulation was developed as a solution to the problem of multiple critical paths in PERT (Van Slyke, 1963). The technique gained its name because of its similarity to the games of chance in Monte Carlo. The technique, explained in terms of the PERT problem, allows every activity duration to vary and estimates, rather than evaluates, the distribution of project duration. It achieves this by simulating the project a number of times, each time randomly assigning durations for each activity in the whole network from the distributions defined.

A random number is converted to a duration by determining the duration for which the probability of that duration not being exceeded equals the random number. To illustrate this, consider the distribution in Figure 2.5, in which a value is selected from a triangular distribution using a random number of 57.

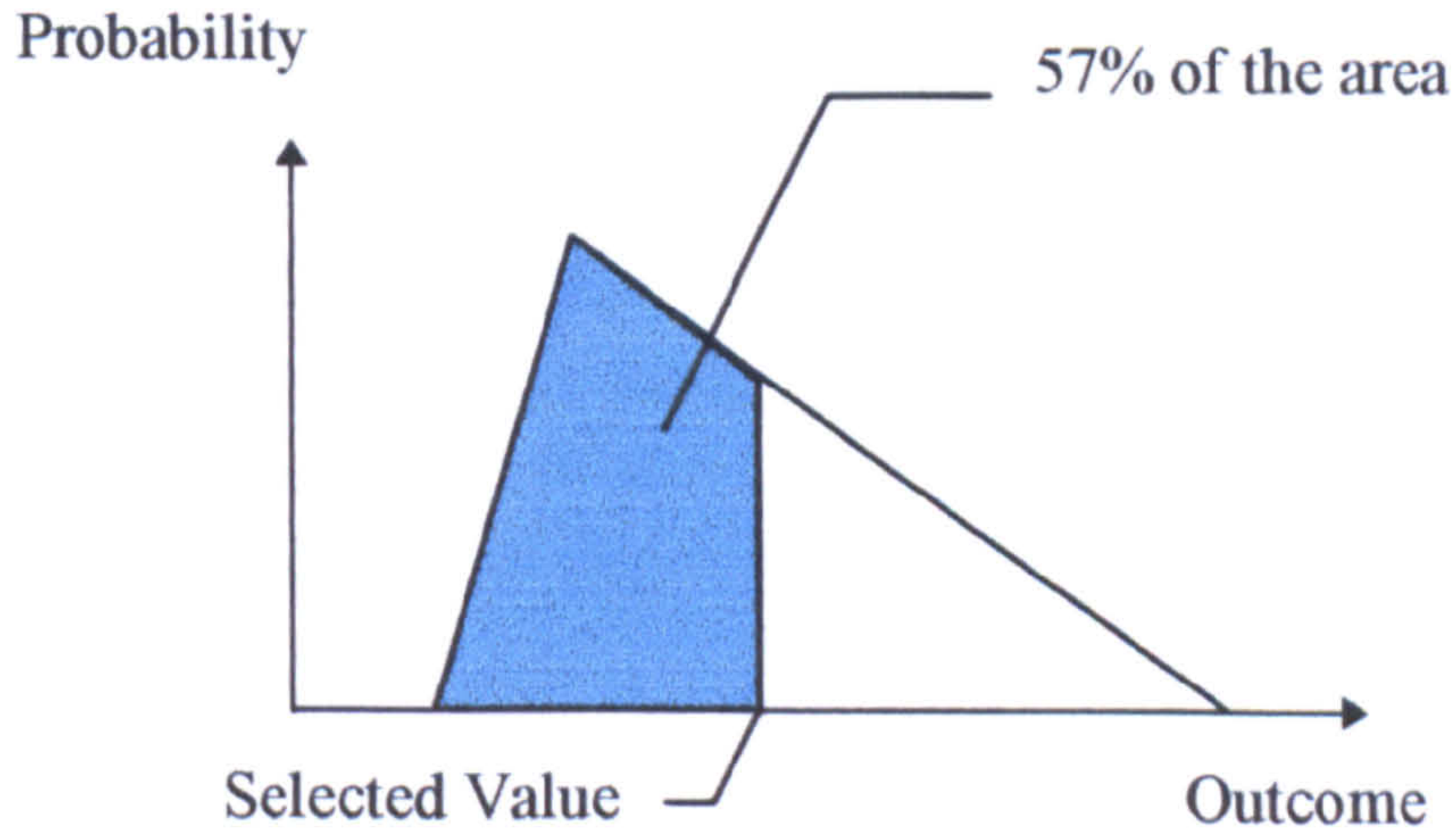

Figure 2.5 - Conversion of a random number to a value

The distribution of total duration is produced by compiling the results generated for each simulation.

Another benefit of Monte Carlo Simulation over PERT, in addition to solving the problem of multiple critical paths, is that it can be applied to any deterministic problem which contains variables, and, it allows distributions of any shape to be defined for those variables rather than limiting the user to the beta distribution. Although any distribution shape can be used, the most common are uniform, triangular, normal, Poisson, and beta, falling into categories of geometrical and statistical (Flanagan and Norman, 1993, Pouliquen, 1970).

One aspect of Monte Carlo simulation which requires examination is the generation of the random numbers used in the analysis. Since Monte Carlo simulation is undertaken on computers, there are two methods by which the numbers can be produced; a table of random numbers can be stored on the computer or the computer can generate the numbers internally. The computer generates the numbers by evaluating a function which, strictly speaking, cannot produce truly random numbers. The numbers produced by this method have been termed pseudo random numbers (Tocher, 1963).

Pseudo random numbers have become increasingly popular because the effort of storing true random numbers, produced by mechanical means, has become excessive due to the volume of random numbers required for some analyses. As an example, a Monte Carlo simulation of a 100 activity network would require 100 pairs of random numbers for every run of the simulator. A typical number of runs to perform is 1000, requiring 200,000 random numbers. Further numbers would be required if the analysis was to be repeated with a different set of random numbers.

Pseudo random number generators produce a random number by applying a function to the previous random number. For storage, pseudo random number generators require only the function and the seed value. The seed value is used as the initial number to be entered into the function. Using the same seed value will produce the same string of random numbers allowing variations in the model to be tested rather than also introducing variations in the random numbers used.

There are several forms of pseudo random numbers generators, although ones of congruential form are dominant (Pidd, 1993). The basic form of such a generator is shown below.

$$X_{i+1} = aX_i + c \pmod{m}$$

in which X is the string of random numbers
a, c, m are constants

Caution is suggested in using pseudo random number generators provided within software, unless that generator is fully specified and tested. The results of the tests performed on IBM's RANDU generator are often quoted, showing it to be far from suitable for random sampling (Morgan, 1984, Pidd, 1993).

In the above generator, although the constants are chosen through a thorough testing regime, one parameter which cannot be tested external to the simulation and yet has a significant impact on the solution is the number of runs of the simulator to perform. The ideal number is a function of the complexity of the problem and the desired accuracy of the result. The number of runs also impacts on the distribution produced; ideally, there should be at least 5 times as many observations as intervals (Flanagan and Norman, 1993), although this is no guarantee of an accurate estimate.

The major problem with Monte Carlo Simulation is that, although it is excellent at estimating the mean and standard deviation of the resultant distribution, it is very inaccurate at estimating the tail of the distribution, i.e. the unlikely extremes (Williams, 1994, Banister and Bawcutt, 1981) Despite this problem, Monte Carlo Simulation is one of the major analytical tools used in quantitative risk analysis.

Tolerance analysis, developed by Ilumoka, 1987, is a combination of PERT and Monte Carlo Simulation. However, the strength and applicability of Monte Carlo Simulation is that it is not limited to network analysis. Tolerance analysis is then an application of

Monte Carlo Simulation to PERT with an interactive element, which restricts the power of Monte Carlo Simulation.

2.4.2.4 The Analytical Hierarchy Process

The Analytical Hierarchy Process was developed by Saaty, 1980, and applied to the management of construction projects by Mustafa and Al-Bahar, 1991. The technique operates, unlike PERT, tolerance analysis, and the initial applications of Monte Carlo Simulation, directly on the classifications produced during the identification stage. This increases its applicability and flexibility. The objective of the technique is to produce a classification of the risk in the project.

The hierarchy in the example given is based on that shown in Table 2.1. The managers involved are asked to weight the relative importance of the categories (e.g. Acts of God, Physical, Financial/Economic) and then the risks in each category (e.g. flood, earthquake and fire in the case of Acts of God). The final weight for each risk is the product of its weight within the category and the weight of the category. As a final task, the risk weight is distributed amongst three risk categories, of low, medium, and high. The weights allocated to each risk category are summed to produce a measure of the total risk in the project. The reader is directed to the paper by Mustafa and Al-Bahar (1991) for examples.

It should be noted that the Analytical Hierarchy Process, unlike PERT and Monte Carlo simulation, determines the risk in the venture. The previous techniques evaluate the total uncertainty rather than the risk.

2.4.2.5 Event and Decision Trees

These techniques are particularly useful for projects or ventures which can be undertaken in many different ways, each one being termed a scenario. The different scenarios arise because of events or decisions. The result of an event or decision can be determined and, in the case of events, the probability that it will occur assigned. In order to aid understanding, the problem is presented graphically, in the form of a tree. The left hand side represents the start and the right hand side the final outcomes. The probability of a scenario is then the product of the probabilities of all the nodes in that path (Lind, 1988, Perry and Hayes, 1985).

Figure 2.6 shows a simple example of a decision tree. Each node is a decision for which, in this example, the cost and its probability of occurrence have been estimated. The decision to be made is which contract to tender for, knowing the cost of each, the relative probabilities of success, and the extremes of profit and loss from each.

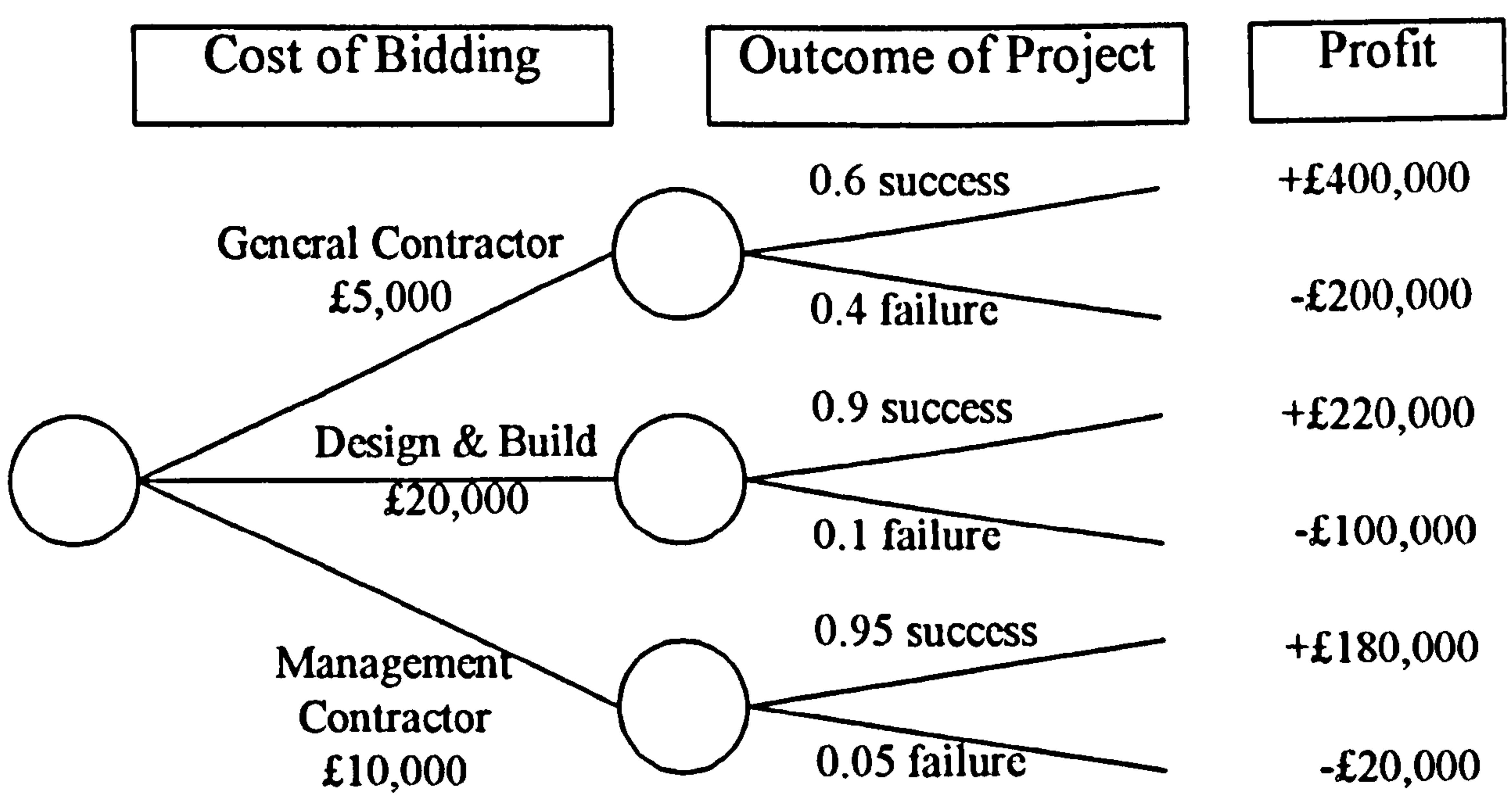

Figure 2.6 - Example Decision Tree (after Flanagan and Norman, 1993)

For each choice, the expected monetary value (EMV) can be calculated by summing the outcomes with their relative weights, or probabilities, which for the design build option is given by

$$EMV = -20,000 + 0.9*220,000 - 0.1*100,000 = 168,000$$

2.4.2.6 Influence Diagrams

Influence diagrams are an extension of decision and event trees. Whereas in the above the connections formed scenarios with no loops and each node had only one branch entering it, influence diagrams show the links between different risk events, leading to output states. In this case, each identified risk could be a node. Figure 2.7 shows an example influence diagram taken from Diekmann, 1992.

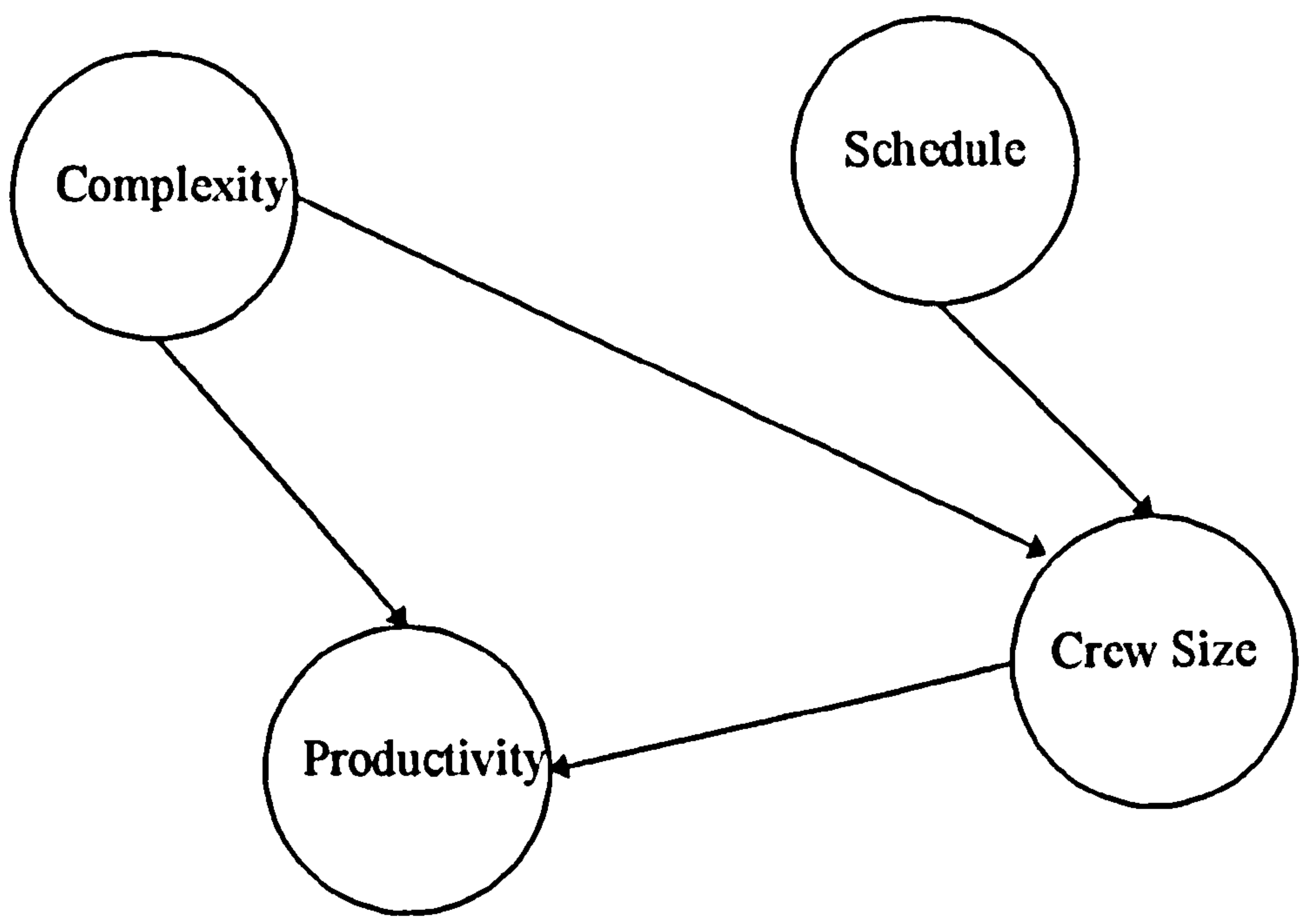

Figure 2.7 - Influence diagram (after Diekmann, 1992)

Arrows leading from one node to another illustrate an influence the former has over the value the latter one takes. A node with no arrows entering it is an input to the system. A node with no arrows leaving it is an end state. Referring to the diagram in Figure 2.7, crew size is influenced by both the schedule and the complexity, both of which are input states, and productivity is the output state.

The end states or outputs are evaluated by propagating the influence of the inputs throughout the network until the value of the end states is known.

2.4.3 Determination of the significance of individual risks

The second objective of risk analysis is to determine the significance of risks in order to highlight those for which management action would be beneficial. The following techniques have been developed to assist in this process.

2.4.3.1 Sensitivity Analysis

This technique is the most commonly used method for this purpose as it can be applied to problems of varying form and complexity. The principle of the technique is "to examine the sensitivity of the derived strategy to possible variations in the judgmental inputs" (Moore, 1983). The usual form of this analysis is to determine the percentage variation in the outcome of the project or venture caused by a percentage change in the variable under consideration. The most effective way of presenting the results of this analysis is graphically, an example of which is shown in Figure 2.8.

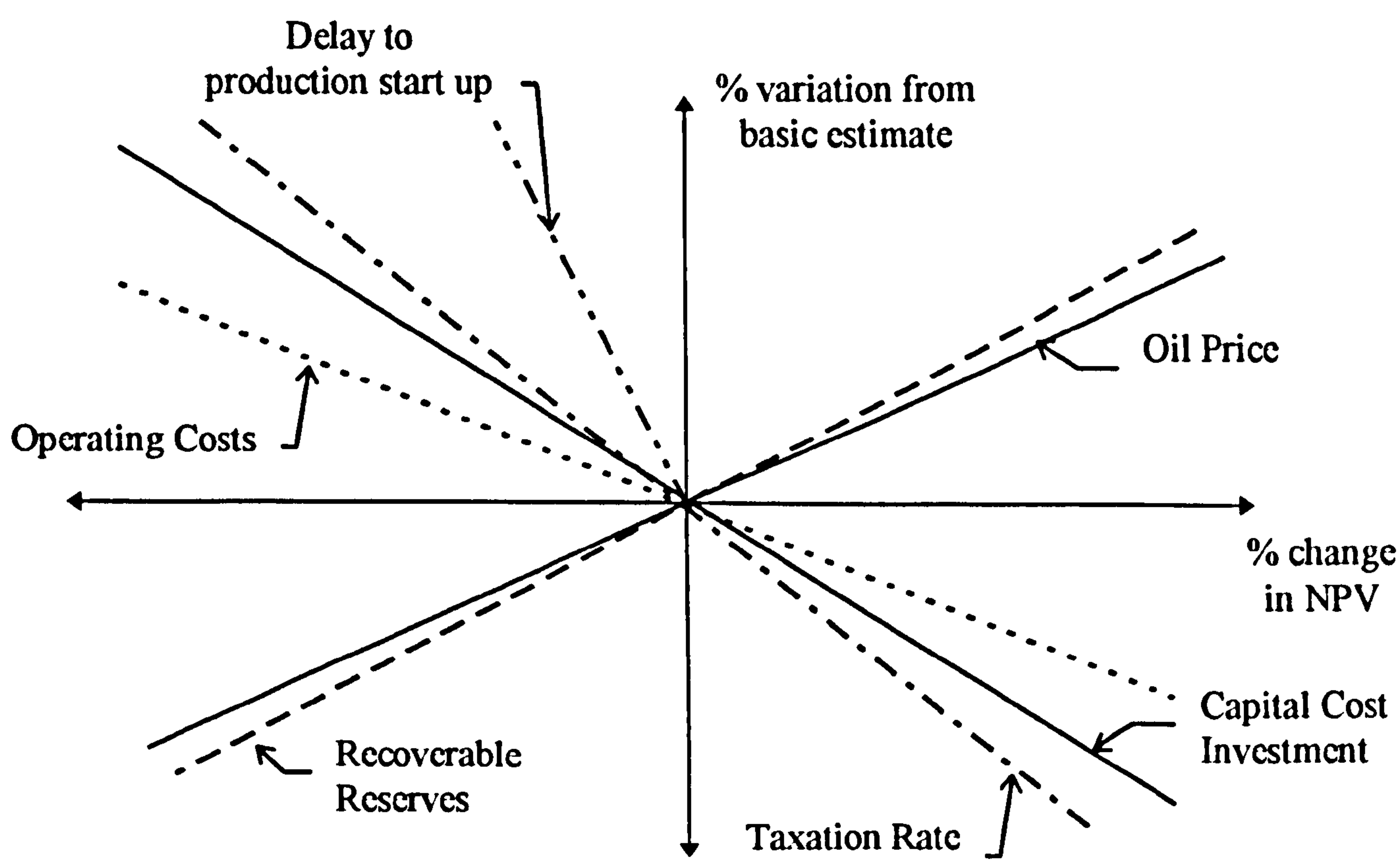

Figure 2.8 - Example result of sensitivity analysis (after Perry and Hayes, 1985)

The sensitivity of the project is a function of the gradient of the lines. For example, in Figure 2.8, the project is largely insensitive to "Delay in production start-up" when compared to "Oil price", as a similar percentage change in each caused significantly different effects on the net present value of the project. It should be noted that sensitivity analysis considers the opportunity in addition to the risk.

A problem, identified by Perry and Hayes, 1985, arises because of the relative expectation of the percentage changes. To illustrate this, consider the variables "Operating costs" and "Capital cost investment" in the graph of Figure 2.8. From the standard interpretation, it would appear that the project was more sensitive to "Operating costs". However, if a 10% change in "Capital cost investment" was more likely than a 5% change in "Operating costs", management should aim to control "Capital cost investment" before "Operating costs". To overcome this, Perry and Hayes added measures of probability to the lines. The result, when all points of equal probability are joined, is shown in Figure 2.9, and has become known as the spider diagram.

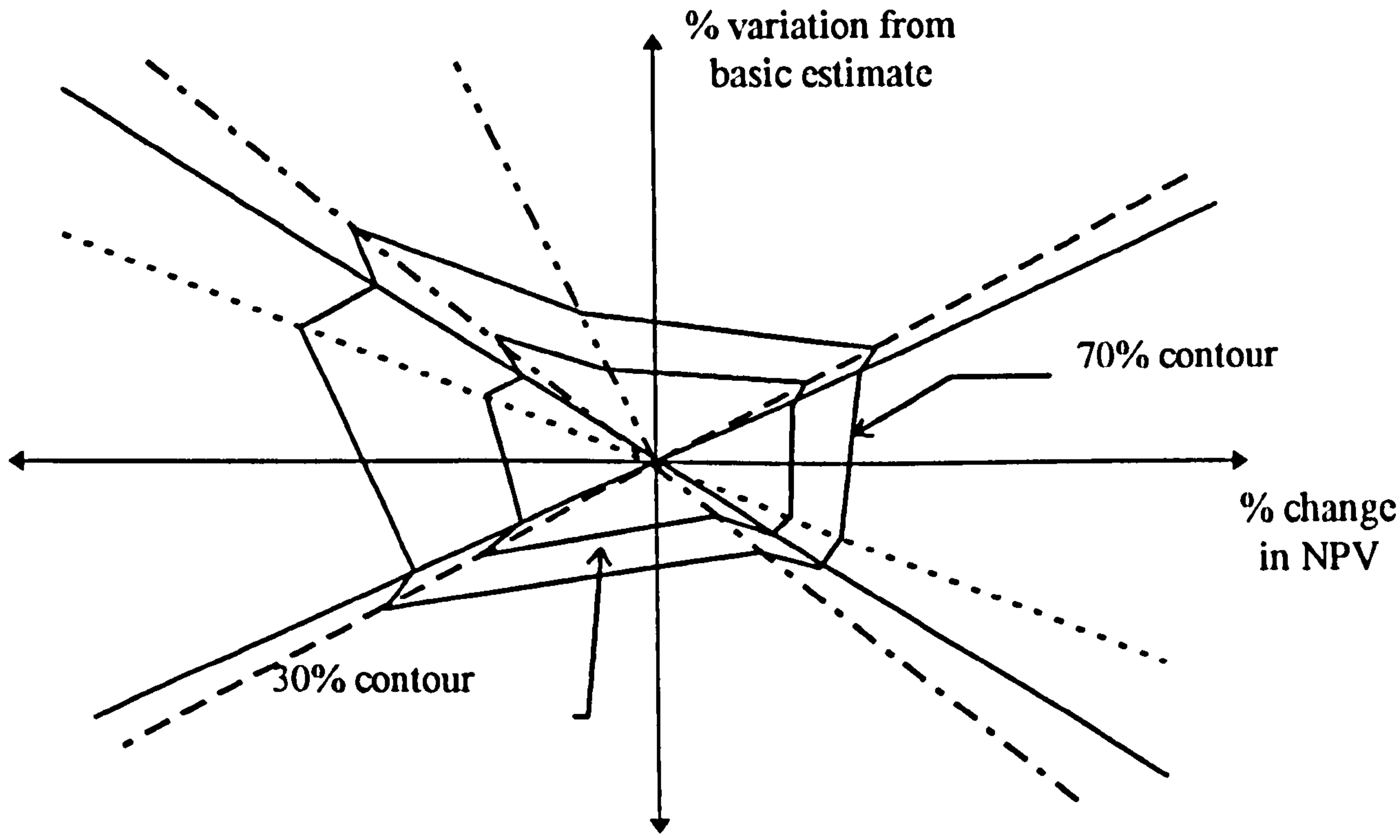

Figure 2.9 - Spider diagram (after Perry & Hayes, 1985)

Although sensitivity analysis is a commonly used technique, it does suffer from one major limitation. Sensitivity analysis allows only the variable under consideration to vary and yet is commonly used in conjunction with Monte Carlo Simulation which allows every variable to vary simultaneously (Flanagan and Norman, 1993).

2.4.3.2 Other techniques

Sensitivity analysis is a very applicable technique and as such has overshadowed any other techniques produced. Other techniques which assess the significance of risks, such risk mapping and classifications have been discussed elsewhere. They differ from sensitivity analysis in that they do not determine the sensitivity of the project, merely the magnitude of the risk.

2.4.4 Summary of Risk Analysis techniques

This section has described several techniques developed to determine the combined risk, usually in a project, and the sensitivity of the project to the individual risks. In reality, many of the techniques, sensitivity analysis included, determine only the uncertainty, leaving the assessment of the risk to the decision makers (Flanagan and Norman, 1993). As discussed in Chapter 1, uncertainty is generally objective while risk is usually a subjective assessment of the effects of the uncertainty.

2.5 RISK RESPONSE

2.5.1 Objectives

Risk response is generally a management action, in which decisions are made based on the results of the risk analysis. Its objective, as defined by Al-Bahar and Crandall, 1991, is "to remove as much as possible the potential impact and increase the control of risks."

It should be noted that the objective is not to eliminate risk. Hertz and Thomas, 1983, and Drucker, 1974, describe such an action as futile.

Risk response should bring together the results of the analysis techniques performed, showing both the balance between the risks and opportunities and the individual risks to which that balance is sensitive. This again shows the iterative nature of risk management, because, in order to evaluate the effectiveness of particular strategies, the project or venture should be re-analysed to reflect the proposed changes.

2.5.2 Mechanisms available for Risk Response

The mechanisms available generally arise out of common sense. The key strategies can be described as follows:

- avoidance
- reduction
- transfer
- retention
- share.

The above list has been compiled from the work of many different authors (including Al-Bahar and Crandall, 1991, Perry and Hayes, 1985, and Moore, 1983). Each possible strategy will be described in turn.

2.5.2.1 Risk Avoidance

This strategy is used for wholly unacceptable risks. In its most extreme form, when the total risk in the project or venture is unacceptable, risk avoidance requires the abandonment of the whole project or venture; this being the only way to completely avoid risk (and the potential opportunity). Usually, risk avoidance means changing the plan or strategy so that the area of unacceptable risk, identified possibly by sensitivity analysis, is avoided. For example, if the health risk from asbestos is considered unacceptable, a construction company can avoid this by never tendering for contracts which involve its use (Al-Bahar and Crandall, 1991).

2.5.2.2 Risk Reduction

Risk reduction is the most commonly used strategy, as it attempts to tilt the balance between the risks and opportunities without transferring the risks to other parties. Risks can be reduced in two ways: by reducing the probability that they occur, and by limiting the effects if they do. As in all risk response strategies, the objective is to tilt the balance in favour of the opportunities in an economic manner. Reducing risk can have two effects on opportunity. Firstly, because of the link between risk and opportunity, a reduction in risk usually triggers a reduction in opportunity. Secondly, the method by which the risk is reduced can require resources, which can be viewed as a reduction in opportunity. In selecting a reduction technique, the effect on opportunity should be considered.

2.5.2.3 Risk Transfer

When risk is passed to someone else, it carries with it a premium. Risks can be transfered either to other parties in the project or venture, or to third parties, i.e. insurance. In both cases, the risk is transfered at a cost. Design-build is an example of risk transfer, in which the client passes the risk of cost escalation arising from problems between the design and the construction to the contractor, who in turn charges the client more to cover the increased risk, but at a disproportionate amount (Ward, Chapman, and Curtis, 1991). However, in the case of design-build, it could be argued that if one party is responsible for both design and construction, they will be better able to manage the problems which develop between the two.

Perry and Hayes, 1985, suggest the client should consider the following factors when viewing to transfer risk:

1. the party which can best control the events which may lead to the risk occurring,
2. the party which can best control the risk if it occurs,
3. whether or not it is preferable for the client to retain an involvement in the control of the risk,
4. the party to carry the risk if it cannot be controlled,
5. whether the premium to be charged by the party to which the risk is allocated is likely to be reasonable and acceptable,
6. whether the party is likely to be able to sustain the consequences if the risk occurs,
7. whether, if the risk is transferred, it leads to the possibility of risks of a different nature being transferred back to the client.

Although the above considerations are based on common sense, in practise, the sixth consideration is largely ignored by contractors when transferring risk to subcontractors. As a means of ensuring the contractor or subcontractor is able to sustain the effects of a risk, bonds are often required. However, it follows that a company which can produce a bond is likely to be financially stable anyway.

2.5.2.4 Risk Retention

Risk are retained for several reasons, either

1. the attendant opportunities more than compensate for them, or
2. they are not wholly unacceptable and their reduction or transfer is not economically viable.

The usual method by which retained risks are controlled is a contingency fund. The fund is set at a limit which is expected to cover the risks to an acceptable degree.

2.5.2.5 Risk Sharing

Risk sharing can occur on two levels. It can exist between different parties to a project or venture or from the collaboration between different organisations in the form of a joint venture. In either form it requires co-operation and a sensible approach by both parties to risk response, usually taking on-board many of the considerations given in the list above.

Joint ventures have been increasingly popular over the last few years. They are usually required in the case of large projects considered too large for organisations acting independently; the Channel Tunnel, the Thames Barrier, and privately financed infrastructure projects are examples of this type. Joint ventures are also used to bring together expertise from two different areas. For example, a company wanting to work in a foreign country is wise to form a joint venture with a local company to gain experience of the market.

2.6 SUMMARY

The consensus, therefore, seems to be that risk management is a three stage process designed to assist management with respect to the exposure to uncertainty. The view is that in order that a risk can be managed, its potential impact must firstly be analysed and that cannot be done on a risk which has not been identified.

Although various techniques are available to assist management in each of the stages, one aspect which does not receive much consideration is the information or time available. For instance, the network based approaches of PERT and Tolerance Analysis require a network of activities which, especially during the tender stage, may not be available.

Of the literature referred to in this chapter, some are mentioned several times; namely Perry and Hayes (1985), Al-Bahar and Crandall (1991) and Flanagan and Norman (1993). This is because these sources discuss the process of risk management as a whole, rather than concentrating on one aspect. Risk analysis, of the individual aspects, warrants the most attention, perhaps because of its sometimes mathematical nature.

2.7 EFFECTIVENESS OF RISK MANAGEMENT SOLUTIONS

This chapter has investigated the subject of risk management, which has developed over the last few decades to provide a scientific method of managing risk, with particular reference to the construction industry. In concluding this chapter, this section places the risk management solutions in the context of the objectives of risk management.

To reiterate, the objective of risk management is to determine the balance between the risks and opportunities at any level in the organisational hierarchy and facilitate management action to tilt that balance in favour of the opportunities. The three stage process of risk identification, analysis, and response fulfils this objective as it promotes a systematic approach. Although the overall framework would lead to attainment of the objective, the techniques used within each stage might not lead to the successful completion of each stage.

2.7.1 Identification Techniques

Risk identification is perhaps the most important stage as only the risks which have been identified can be analysed and responded to. This is important for two reasons. Firstly, and this is the objective of the techniques, it is essential that the key risks are identified. Secondly, and more importantly, the correct risks have to be identified. This requires that the risks identified are to the true objectives of the venture; if the objectives are ill-defined, the risks to the true objectives will not be identified.

The majority of risk management applications are targeted at projects, which, as major sources of risk and opportunity to a company, seems a logical approach. However, the projects are treated as independent entities, rather than as temporary parts of a company's ongoing activities. If each project is viewed independently of its role in the company, the objectives for each project will be identical (maximise profit and minimise duration). However, some projects are undertaken with other objectives, such as breaking into a new market or filling a hole in the order book. In these cases, although the objectives might be the same, the acceptability criteria will be different. If a project is undertaken to fill a hole in the order book, the objective might not be to complete the project as quickly as possible, as this could leave a further hole in the order book.

Every project must, therefore, be viewed as unique and having a particular role in the company, defining its objectives as such. A major criticism of the current applications of risk management is that projects are not treated as this and so the objectives to which the risks are identified are not the true objectives.

Once a set of objectives has been defined, the risks and opportunities to those objectives are identified. Unfortunately, due to the confusion over the definition of risk and the title of the subject, in many cases only the risks, the detrimental consequences of uncertainty, are identified. The techniques produced do, however, provide a scientific means of identifying the risks, for example through the use of brainstorming and checklists. Unfortunately, the task of identification is still difficult as in some cases the objectives are defined in such a way that does not readily allow risks to be identified. A common objective of this type might be to make more than a predefined level of profit. Identifying all the uncertainties which affect the attainment of this objective can be confusing. In this case it would be better to define a measure of the project which reflected the objective, then identify the uncertainties which could affect that measure. In this example, the cash flow of the project would be used to determine the final profit margin, and so to use the cash flow as the measure of the project would seem sensible. Identifying uncertainties in the cash flow is an easier task than identifying those which affect the attainment of a predefined level of profit or higher.

In addition, the use of a measure to reflect objectives reduces confusion when several objectives are dealing with a similar quantity. For example, in addition to the profit objective, there might be set by the company a maximum level of debt which the project could reach throughout its duration. In this case, both objectives are concerned with the profitability of the project and so there will be common risks and opportunities, which can cause confusion in the identification. Since the cash flow reflects both the objectives, by identifying the uncertainties in the cash flow, the uncertainties to both objectives are identified.

Returning to the objectives of the venture, many of the applications of risk management assume profit and time are the objectives; the above discussion shows that the cash flow of the project can be used to reflect many of the objectives for undertaking a project. However, in many cases, the objectives cannot be reflected by the cash flow and so further measures are required. For example, if the objective of undertaking a project was to attract future work by impressing the client, minimising the number claims and disputes, producing a product of high quality, and improving the image of the company as a whole, the cash flow of the project would not reflect these objectives. In this case measures such as client satisfaction and quality might be used. Many of the applications ignore objectives of this nature, presumably because they are concerned with the role of the project within the company and so can be in conflict with the cash flow based objectives, and because the measures cannot easily be assigned units.

In conclusion, the risk identification stage must be targeted at the true objectives of the venture, although to aid the process measures can be defined which reflect those objectives. The process must also not neglect non-financial objectives. Although their identification and quantification are rather abstract, they are of equal importance to the financial objectives.

2.7.2 Analysis Techniques

There are many components of this stage. The identified risks and opportunities are quantified, analysed to determine the balance between the risks and the opportunities, and the significance of individual sources determined. The method of quantification and the analysis techniques used are dependent on each other, and both are restricted by the information available. If risk management is to be applicable at all levels of the company hierarchy, the analysis techniques must acknowledge that the level of detail of information will vary with time and be flexible to these changes. Some of the techniques, particularly the network based solutions, require an excessive amount of information, often including obviously insignificant risks and opportunities into the analysis. Such data might not be available at all times and the analysis could take an excessive amount of time to perform.

The most applicable analysis techniques are Monte Carlo simulation, to determine the balance between the risks and the opportunities, and sensitivity analysis, to determine the significance of individual sources of risk and opportunity. These two techniques are closely related (Flanagan and Norman, 1992) and in combination work effectively to achieve the analysis objectives of risk management. However, as discussed in section 2.4.3.1, sensitivity analysis is univariate and the effect of this in a problem where variables are expected to vary simultaneously requires investigation.

2.7.3 Response Techniques

The response techniques, as they are based on common sense, when applied in combination offer effective means of managing the risks and opportunities to produce an acceptable balance between the two. It should be stressed, however, that response is not the end of the risk management process as responses to some risks and opportunities can change the probabilities or effects of others, and the risks and opportunities will change with time, and for both reasons the process continues.

2.8 CONCLUSIONS

This chapter has considered a risk management approach to the analysis of projects at an early stage in their life cycle. It is by no means the only technique which a manager might find useful and several researchers have suggested others. For example, Couzens et al (1996) and Tah et al (1993) consider the use of decision support systems and fuzzy sets for tender adjudication; Leech (1982) and Glautier & Underdown (1991) describe the use of cash flow analysis at various stages of projects; Pidd (1989) and Tocher (1963) suggest that simulation might be useful. Indeed, since the technique applied throughout the rest of this work is Monte Carlo Simulation, it is important that this technique is understood. The remainder of this thesis relies heavily on an understanding of cash flows and the reader is referred to Leech (1982) and Glautier & Underdown (1991) for a treatment of the topic.

This chapter has presented a review of risk management as a subject which has developed over the last few decades to provide a more scientific approach. Risk management was found to be a three stage process of risk identification, analysis, and response. Each stage was investigated in turn. Finally, having investigated the subject, it was examined with reference to the objectives of risk management set out in Chapter 1. This showed that although the system and some of the techniques were applicable to the problem defined in Chapter 1, the target of the process and particularly the identification stage are unsuitable.

CHAPTER 3

A HIERARCHICAL APPROACH TO THE MANAGEMENT OF PROJECT RISK

3.1 INTRODUCTION

Chapter 1 introduced the objectives for the research presented in this thesis. The first of these objectives was to investigate the link between project and company risk. The chapter proceeded with a discussion of uncertainty, risk and opportunity, setting definitions for use throughout this thesis. The chapter concluded with a discussion of the traditional approach to the management of risk from projects within a construction company. This investigation concluded that the majority of the main aspects which are considered at the tender stage of a project are not related to the project itself. The reliance on experience was identified as a major deficiency in the traditional approach.

Chapter 2 presented an investigation into the formal subject of risk management with respect to construction projects, with the objective of assessing whether this formal approach allows the effective management of risk. The appraisal concluded that although many of the techniques developed helped inject a scientific base into the experience led judgements, they contained the following deficiencies:

- They are largely project based,
- They concentrate on the risk the project would contribute to the company and not the other issues, external to the project, which are considered when assessing a tender,
- They sometimes require information which is not available at tender stage,
- They concentrate on risk, rather than giving equal importance to risk and opportunity.

This chapter concludes the investigation into the link between project and company risk by applying the definitions set out in Chapter 1 to the objectives of a company and a project. Having concluded the investigation, the requirements of an effective risk management system for tender stage are presented. From these requirements a system is proposed which is based on the conclusions of the investigation into the link between project and company risk and the deficiencies in the traditional and formal risk management approaches already identified.

3.2 HIERARCHY OF OBJECTIVES AND STRATEGIES WITHIN A COMPANY

3.2.1 Definitions of Risk and Opportunity

Chapter 1 introduced the subject of risk management with a discussion of the nature of risk and its origins. From this discussion, which identified many different definitions of risk, definitions of uncertainty, risk, and opportunity were formulated. The definitions of risk and opportunity related the uncertainty which surrounds us to our objectives. In this way, risk became the detrimental impact of that uncertainty on our objectives, while opportunity became the beneficial impact. The definitions, therefore, relate the sometimes constant uncertainty to our objectives. In this way, two people or organisations exposed to the same uncertainty would be exposed to different risks and opportunities if their objectives were different.

The definitions have two aspects which require further investigation if an effective system for the management of risk is to be produced: the uncertainty which may impact on us and the objectives on which it will act. For a construction project at tender stage, this requires that we know the objectives for undertaking the project and the sources of uncertainty which could affect the attainment of those objectives.

3.2.2 Objectives of a Company

A construction organisation has, or should have, purposes or missions. These might be, for example, to enhance the quality of life through the built environment, employ people, and to give shareholders an acceptable return on their investments. The organisation then has objectives, or goals, which are the ends towards which activity is aimed. The ultimate objectives might be longevity, being considered the best in the business, and the continued growth of the company. Strategies are produced which it is hoped are the means by which the objectives will be attained. Examples of these are turnover, profit, and market share targets. These principles are fundamental to the management of an organisation, further discussion of which can be found in standard management texts, such as Weinrich and Koontz, 1993, and Mullins, 1993.

3.2.3 Hierarchy of objectives and strategies

Operating a company on a set of strategies based on the ultimate objectives is a difficult, if not impossible, task. As a result, the strategies are passed to people lower in the organisation, who view these as their objectives. Just as strategies were produced to attain the ultimate objectives, strategies are produced to assist in the attainment of these sub-objectives. These sub-strategies are passed to people still lower in the organisation and the process continues. As a result, a hierarchy of objectives and strategies is produced. Figure 3.10 shows a hierarchy of objectives taken from Weihrich & Koontz, 1993, which demonstrates the increasing detail and verifiable nature of the objectives as they proceed down the hierarchy.

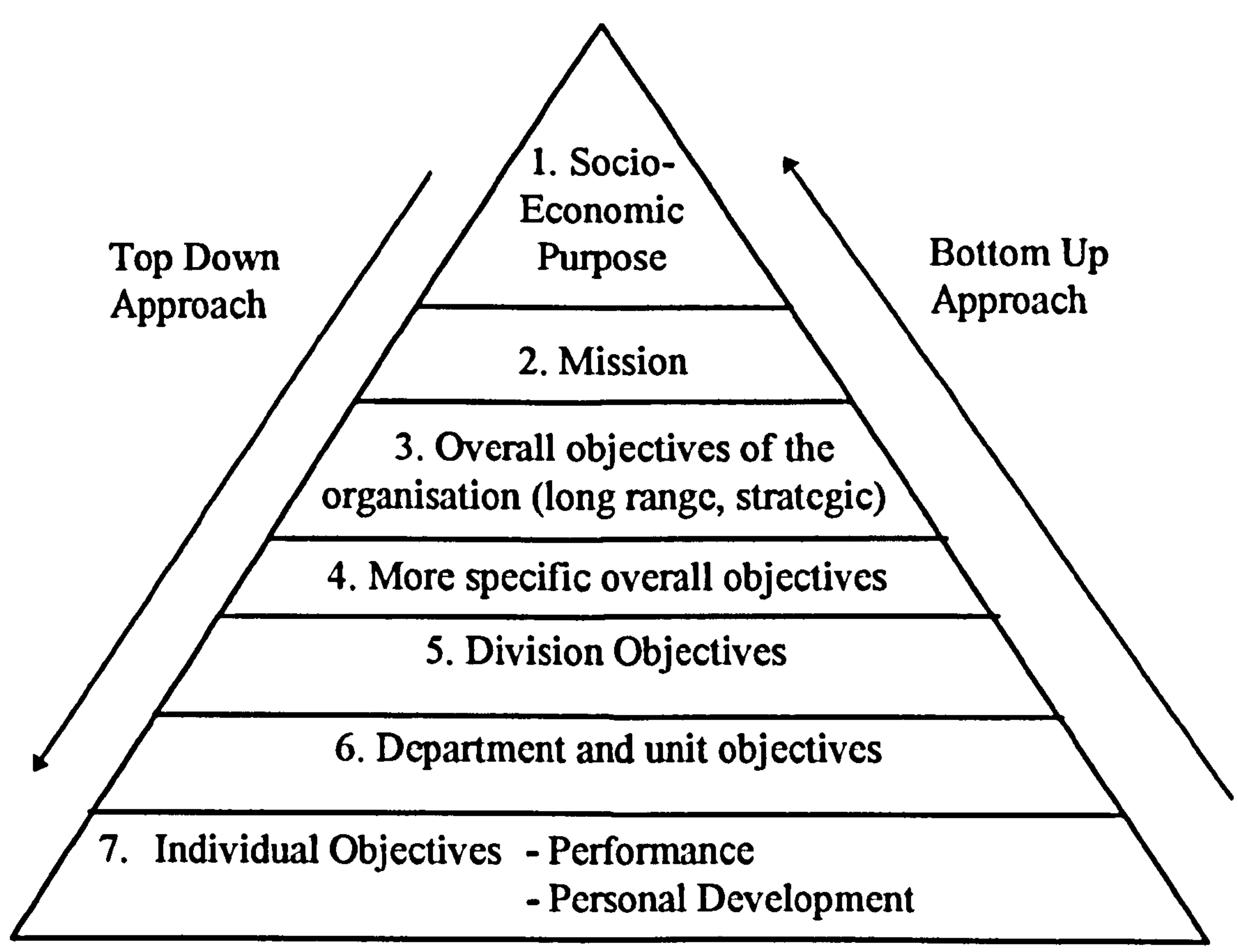

Figure 3.10 - Relationship of objectives and the organisational hierarchy

The increasing detail and verifiable nature of the objectives nearer the bottom of the hierarchy is also reflected in the change of measures used to assess performance. At the top of the hierarchy, financial measures such as cash flow, turnover, profit, and ratios are important, but these are used in conjunction with measures such as quality and image. Such non-financial measures reflect the long term objectives which managers higher up the hierarchy are seeking to attain, yet these measures are less quantifiable. Lower down the hierarchy, the objectives become shorter term and more quantifiable, and this is reflected in the use of purely financial measures, such as the cash flow.

The diagram of Figure 3.10 has arrows marked for a top-down and a bottom-up approach to the setting of objectives. In the top-down approach the managers set the objectives for sub-ordinates, while in the bottom-up approach the sub-ordinates set their own objectives and notify managers of these. Whichever method is superior, communication must pass in both directions if the strategies at the bottom of the hierarchy are to be consistent with the objectives at the top.

Mullins (1993) points out that at every level of the hierarchy there are people, and people set their objectives for professional and personal reasons. The result of this is a potential distortion of the objectives as they pass from level to level. As an example, if a manager is given a strategy that his/her operation should make X% profit, a manager who is keen to be promoted and is looking to dazzle his/her superior may set the objective of profit target a little above X%. A manager who is seeking security may set the objective at X%. In the first case, the professional and personal objectives are not consistent and hence can lead to increased risk for the company as a result of someone's personal objectives. In the second case, the professional and personal objectives are consistent and hence the risk in the company is not increased. If the impact of personal objectives is linked to the subjective assessment of risk and opportunity, the effects on the company are compounded.

Communication is therefore essential if the distortion of the objectives between levels is to be minimised. Indeed, decision making at one level uses data from lower levels and passes data up to higher levels. In turn, the level acts on data passed to it from the higher levels and passes data to lower levels to be acted upon. This flow of information can be used to monitor the objectives and strategies of each level.

3.3 HIERARCHY OF RISKS AND OPPORTUNITIES WITHIN A COMPANY

3.3.1 Applying the Definitions of Risk and Opportunity to the Hierarchy of Objectives

The definitions of risk and opportunity set out in Chapter 1 are based on the impact of uncertainty on our objectives. Applying the definitions to the hierarchy of objectives and strategies which exists in an organisation produces a hierarchy of risks and opportunities. Since the objectives in the hierarchy are linked, the risks and opportunities may also be linked. For instance, some levels in the hierarchy exist for organisational purposes, for example dividing the building division between regional and major projects operations. The objectives for the regional businesses and major projects will be of a similar nature to those of the building business, representing targets for turnover and profit which should combine to fulfil the target for the business. In this case, moving from one level to the next has not changed the nature of the level, the targets have simply been divided to, it is believed, attain the targets more effectively. Therefore the risks and opportunities to the lower level can be readily related to the higher level.

Further down the hierarchy, the levels comprise projects rather than more organisational businesses. For example, the regional business may organise itself between traditional work and design-build contracts, with each of these businesses undertaking projects to fulfil their targets rather than passing them on as strategies for lower businesses. At this low level in the hierarchy the uncertainties begin to become more tangible. For example, the uncertainties may relate to the direct cost of an item within a single project whereas further up the hierarchy, the uncertainty relates to the final cost of the project or the performance of a business unit.

Within the context of risk management, the hierarchy also acts as an effective filter, allowing each level to consider the uncertainty to varying levels of detail. Using the hierarchy, the chief executive does not need to consider the uncertainty regarding the cost of or duration of every item in every project. Even the managing director of a business unit may not want to consider such detail, except when an individual risk or opportunity is deemed significant. The managing director will be more concerned with the combined effect, firstly with each project and then for the business unit. At the next level up the hierarchy, the uncertainty in the business units will be required, possibly with information regarding the contribution of individual projects. In this way, the hierarchical approach limits the amount of information each level has to consider in order to effectively manage the risks and opportunities.

3.3.2 Possible Conflicts Between the Risks and Opportunities at Different Levels

The above discussion has illustrated how the objectives of the organisation cascade down the various organisational levels, ultimately being fulfilled by projects. One assumption which has been made is that the objectives, and hence perception of risks and opportunities, are consistent between levels. However, this is not necessarily true, since the objectives can change in nature between levels and because individuals have an impact on the setting of the objectives, sometimes distorting the objectives for personal reasons.

The change in nature between levels occurs most noticeably between the organisational and project levels as it is between these levels that turnover is removed from the objectives (as the project is undertaken to contribute to that turnover) and relate more to profit. Since the company usually has objectives which extend beyond the end of the particular project, its objectives for a project may not be just to return profit, but could include pleasing the client (to hopefully produce future work with the same client), promoting the good name of the company, and raising the reputation of the company. The objectives which extend beyond the project may conflict with that of generating profit. For example, there may be an opportunity to claim against the client which, if successful would increase the profit for the project but could risk the attainment of the other objectives. This is an example of an uncertainty impacting several objectives and producing both risks and opportunities.

In an organisation which has effective communication between levels, the above conflict could be managed as the project team would be aware of the objectives for the project and could consult the management of the higher level regarding possible conflicts between objectives. However, as mentioned earlier, since people are involved at each level, the project team may see the profit objective as being more important than the other objectives and so decide to seek the opportunity to attain that objective at the expense of the others.

3.4 OBJECTIVES FOR UNDERTAKING A PROJECT

The above discussion began with the identification of the ultimate objectives of a construction company and followed those as they cascaded down the company hierarchy. Although there may be many levels to that hierarchy, is it ultimately projects which are undertaken to fulfill the targets. So, although projects exist towards the bottom of the hierarchy, they impact the whole of it. If the objectives have not been distorted between levels, the projects are undertaken to fulfil the ultimate objectives of the company.

The operating business, therefore, undertakes projects to fulfill its targets, which will be based on the targets set by the level higher up the hierarchy. Targets for profit will be only one aspect of the targets the business is seeking to fulfil. As the discussion regarding the possible conflict between objectives suggested, a project is likely to be undertaken for several reasons, in which case it would be set various objectives. In this case, the profit it produced would be only one of these.

In practice, it is the operating businesses which decide which projects to pursue and the price which the company will undertake the work for. As the discussion in Chapter 1 identified, regarding the traditional approach to risk management, it is at tender stage that the uncertainties for which the company is responsible are decided and the objectives for the project are set (translating those uncertainties into risks and opportunities). That discussion identified four aspects which are considered when deciding whether a project should be pursued:

- the extent to which the company wants the project,
- the price which the market is expecting,
- the risk the company is already exposed to from other projects, and
- the risk and opportunity which would be contributed by the project under consideration.

The approaches described in Chapter 2, relating to the management of risk from projects, treated projects as independent entities rather than the means by which the company seeks to attain its objectives. This approach ignores three of the above aspects of importance. It should be noted that many of those objectives extent beyond the life of individual projects and so any study should look at the wider implications of a project if it is to effectively manage the risks and opportunities.

This discussion has identified many possible objectives for undertaking a project. Many of these will be passed to the project team as targets, for example profit, cashflow, image, quality, potential for further work, safety record, and environmental performance.

3.5 SOURCES OF UNCERTAINTY AFFECTING THE OBJECTIVES FOR UNDERTAKING A PROJECT

The uncertainty to which a project is exposed and the objectives on which it acts will vary with time. Even during the tender period, they will change. Before the tender has been submitted, the uncertainty regarding the possible success of the tender will have a significant impact on the company. At this stage it does not know how much work it will be undertaking in the future or for what price and cost.

Once the tender has been submitted, the uncertainty regarding turnover has largely been removed, particularly in the case of fixed price contracts. If the tender is unsuccessful, this removal of uncertainty may increase the risk to not attaining the target for turnover.

Such an effect may have an impact on the approach taken for subsequent tenders. If the tender is successful, the company is nearer fulfilling its turnover target, unless it is already committed to more work that it wants, in which case it creates other uncertainties, regarding the ability of the company to undertake the work. Although the turnover uncertainty has largely been removed by the tender being successful, the company has exposed itself to uncertainty regarding the cost of the work it has been contracted to undertake.

This uncertainty could be project specific or more global in nature. Examples of project specific uncertainties are the ground conditions and the compliance with the specifications. Global uncertainties are generally linked to the economy, for example inflation. The global uncertainties are likely to impact more that one project and so will be of more importance to the business unit than the project specific uncertainties, which will be expected to be managed by the project teams.

3.6 REQUIREMENTS OF A SYSTEM FOR THE MANAGEMENT OF RISK AT TENDER STAGE

The investigation into the traditional approach to the management of risk from projects, presented in Chapter 1, although identifying that tender stage is the most important stage of a project regarding risk management, concluded that the approach was flawed because it relied almost exclusively on the experience and judgement of managers. The validity of such judgement reduces when the experience on which it is based loses its relevance. In addition, to expect people to effectively address all the issues, which the above discussion has shown are complex, is asking a lot of managers without offering any analysis tools.

The investigation into the more formal approach to risk management presented in Chapter 2 concluded that, although many of the techniques were effective for the task they were designed, the approaches generally treated projects as independent entities and did not consider the reasons for undertaking projects, concentrating almost exclusively on profit. Additionally, many of the techniques considered only the final outcome of the project and did not consider the events which lead to that end point. Probably due to the name under which the approaches are described, many target only risk and do not acknowledge the equal importance of opportunity (or the upside of uncertainty, depending on the definition used), particularly that risks are often accepted because of the opportunities to which they are linked.

In order for a system for managing the risk from projects at tender stage to be effective, it must, therefore, consider the following points.

- Projects are undertaken to fulfil the objectives of the company.
- Profit is not the only objective for undertaking a project.
- Opportunity is of equal importance to risk.
- A tender has a finite duration and limited available information and resources.
- Each level in the hierarchy should only have to consider a manageable quantity of information.
- Due to the need to communicate between levels, the results produced at any level must be readily communicable to the higher level.

3.7 PROPOSED SYSTEM FOR THE EFFECTIVE MANAGEMENT OF RISKS AT TENDER STAGE

3.7.1 Fundamentals of the System

The system is based on the organisational hierarchy which exists within companies. Two distinct levels are identified at tender stage, each with their own set of objectives and hence risks and opportunities. One is termed the company level, which corresponds to the business unit which will undertake the project. The other is termed the project level, reflecting the view of the project team. By separating these two levels, the objectives for undertaking a project can also be separated. This allows the company's objectives to be considered explicitly, whilst not confusing them with those of the project team.

Considering the hierarchical approach, as described earlier, it allows information to be analysed at one level and passed as a result to the higher level. This approach is important as it allows the company level to view each project, and the one under consideration, as single sources of uncertainty, not confusing the issue with lists of the actual sources of uncertainty which each project team will need if they are to be managed.

In order that each project can be viewed as a single source of uncertainty, techniques are required which will allow the project to combine the various uncertainties identified. At the company level, a similar approach is required to then combine the uncertainty from each project to determine the exposure of the company.

3.7.2 Differences Between the Models Required at Project and Company Levels

Although both models seek to combine the sources of uncertainty to determine the combined effect, there are various differences between the two levels which results in different models being required. Three such differences are listed below.

- The project model will have a finite duration whereas the company model will continue for as long as the study requires.
- The company model can readily identify the sources of uncertainty, all of which are already quantified, whereas the project model will be combining a variety of uncertainties, the identification and quantification of which will be a major task.
- The project team will be concerned with the final outcome whereas the company will be concerned with the result in every time period.

3.7.3 The Company Risk Model

The model for use at the company level will contain all the projects the company is, or is seeking to, undertake. It will be against the combined uncertainty that the company can assess the extent to which it wants a particular project and the price it is willing to undertake it for. To model those two objectives, identified in Chapter 1 as the major considerations of a company at tender stage, the model will be based on the cash flow of the company. The model will therefore reflect both the uncertainty in the turnover and the profit, as combinations of the various projects it is undertaking. In order that the risks to the objectives can be effectively managed, the model will allow the current state of the company to be assessed (to determine the current exposure to risk) and allow individual projects to be assessed (to determine the extent to which they change that exposure). The means by which these objectives are fulfilled is described in Chapter 6. The model is tested in Chapter 7, to determine the extent to which it fulfills these objectives.

3.7.4 The Project Risk Model

The project risk model must produce the output required by the company risk model, namely the uncertainty in the cashflow of the project. This requires that the various sources of uncertainty in the cashflow are identified, quantified, and combined. The techniques which will be used to achieve this will be taken from those described in Chapter 2. In addition to providing output for the company risk model, the project team will also seek to determine the level of risk inherent in the project and assess the difference various approaches have on that uncertainty. For this purpose, the communication and reporting aspects of the model are as important as those of the company risk model. The model is presented in Chapter 4 and tested to assess its performance against its objectives in Chapter 5. The project risk model is presented and tested before the company risk model as the former acts as input to the latter and limitations in the project risk model will have to be accommodated in the company risk model.

3.7.5 Combined Use of the Models

The company risk model is designed to operate continuously at the company level. This would initially require all the projects to be analysed and input, to enable the current risk profile to be determined. Subsequently, when a tender is being reviewed the project team will use the project risk model to assess the risk and opportunity in the project to their perceived objectives and present this to the company level. The results of the project risk model will be input to the initialised company risk model and the impact of the project determined. This will enable the extent to which the company wants the project to be determined, in addition to the price it is willing to undertake it for.

3.8 SUMMARY

This chapter has discussed further the conclusions of both the investigation into the traditional approach to risk management and the more formal scientific approach. From this discussion the requirements of a system were developed. The proposed system for the effective management of risk at tender stage was then presented, aimed at addressing all the objectives for undertaking a project. The project and company risk models which are required for this system were briefly introduced. The project risk model will be presented and tested in Chapters 4 and 5 respectively. A similar approach will be taken for the company risk model in Chapter 6 and 7.

CHAPTER 4

THE PROJECT RISK MODEL

4.1 INTRODUCTION

The previous chapter introduced the concept of a hierarchical approach to risk management within a construction company. Part of that hierarchy is the analysis and management of risk at the project level to allow information to be passed to the higher company level. This chapter presents the project risk model, the methodology and techniques applied to identification, analysis and response described through an example project.

The chapter begins with a discussion of the objectives of and basic inputs to the model, and progresses towards the identification techniques used and their output. The quantification and the analysis of the identified risks and opportunities are then addressed, the chapter concluding with the presentation of the risk and opportunity classification system.

4.2 OBJECTIVES OF THE MODEL

The objectives of the model are to combine the various sources of uncertainty in a project's cash flow to produce a single input to the company risk model, and to assess the combined uncertainty with respect to the objectives for undertaking the project.

4.2.1 Inputs to the model

The model is based on the uncertainties in the project cash flow. To define the cash flow, in its most basic form, requires the start date, duration, cost, and tender value for the project. At tender stage, the value is unknown and so an estimate of cost is used to which the typical overhead and profit mark-up are added. These parameters define the base cash flow, assuming the worth of the project is uniformly distributed throughout the project. Table 4.1 shows the parameters for the example project, which is a small private sector design build project.

Table 4.1 - Basic data for example project

Start Date	1/2/95
Duration	11 months
Cost	£3.025m
Tender Value	£3.225m

The information presented in Table 4.1 represents the minimum required to allow a cash flow to be created. In this case, a uniform distribution of cost and value is assumed although this might not be representative of the envisaged cash flow of the project.

The uncertainties which will be identified will be quantified in terms of their impact on the base cash flow. The base cash flow used should, therefore, be as representative as possible of the expected cash flow. If a detailed cash flow has been produced during the production of the estimate, the values in each month should be used as input to the model.

In practise, it is very rare that a detailed cash flow exists when the risk model is to be produced. In this case, the accuracy of the cash flows can be increased by defining phases within the project. Each phase will last for a proportion of the duration and account for a proportion of the cost and value. For the example project, three phases have been identified, relating to design, construction, and commissioning. The duration and cost of each phase is shown in Table 4.2.

Table 4.2 - Phasing details of example project

Phase	**Cost (£k)**		**Duration (months)**	
Design	227	(7.5%)	1	(9.1%)
Construction	2,723	(90%)	9.5	(86.4%)
Commissioning	75	(2.5%)	0.5	(4.5%)

If the value is assumed to follow the cost, the phases in Table 4.2 produce the cash flow produced in Figure 4.1 below. If the value of the project in any time period is not directly related to the cost of the work undertaken in that time period, the s-curve for value can be defined independently of the cost.

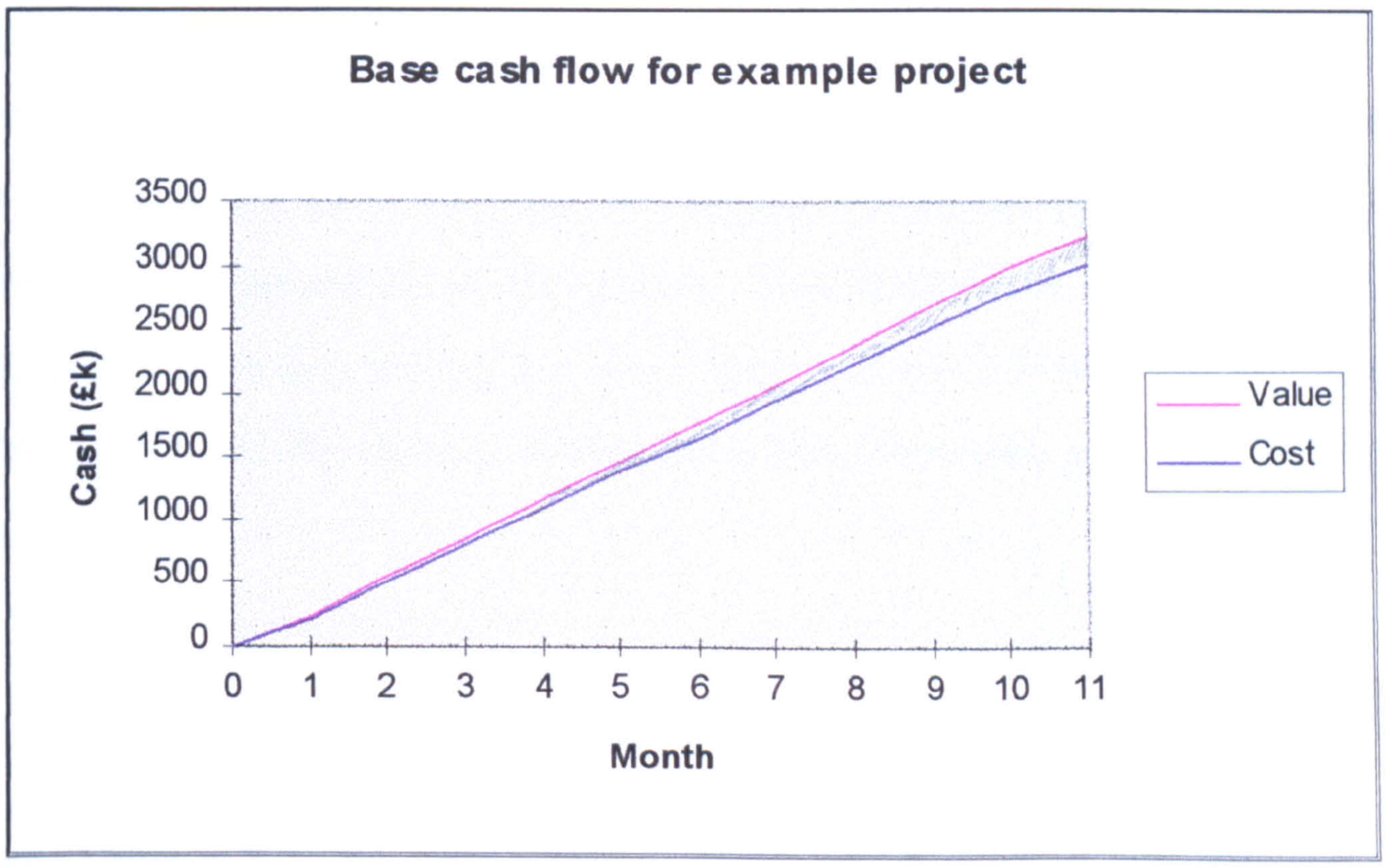

Figure 4.1 - Base cash flow for example project

4.3 SOURCES OF UNCERTAINTY IN THE BASE CASH FLOW

Although project risk management usually looks to the final outcome of the project as a measure of performance, the company will be concerned with the performance of the project throughout its duration. A company will want to know the cash flow of the project in addition to its final outcome to assess its financing needs with relation to the requirements of other projects. So, although the project team will want to know the combined effect of uncertainties on the final profit of the project, the project risk model considers the uncertainties with reference to their timing in addition to their impact.

4.3.1 Risk Factors

The identified uncertainties which can affect the cash flow are here termed risk factors. A risk factor is defined by its chance of occurrence and then its effect on the cash flow if it does occur. By defining a risk factor in terms of its effect on the cash flow, a single risk factor can affect both the cost and duration of the project so removing the confusion of a risk which has several effects on the project.

4.4 IDENTIFICATION TECHNIQUES

Identification is arguably the most important step in risk management, as only identified risks can be analysed and subsequently managed. The business unit requires confidence that the single source of uncertainty the project risk model produces is an accurate assessment of the uncertainty in the project. This confidence can only be gained by applying a structured approach to the identification of risk factors. For this reason, the use of two techniques described in Section 2.3.2 are encouraged: structured brainstorming and checklists.

4.4.1 Structured Brainstorming

Brainstorming sessions promote the discussion of the issues within the project in an open forum. An open forum is essential if the views of all those involved are to be heard and developed, as it offers a mechanism to control the strongest personalities in the group.

The objective of such a session is to produce a list of the sources of uncertainty in the project. Although the project risk model will only contain those which can have an impact on the cash flow, other uncertainties should also be considered. These uncertainties usually relate to the contract and the liability of the company in the event that the project fails. Although uncertainties of these types do not directly impact the cash flow of the project because of their severity, they should be identified and dealt with accordingly, usually with reference to the legal and commercial departments.

Since the nature of the sources of uncertainty in the project is diverse, representatives of all aspects of the project team should participate. By involving those responsible for estimating, programming and commercial aspects, the areas relating to direct price, duration and global issues will be represented.

In addition to ensuring all aspects of the project team are represented, a structured approach is required to ensure all aspects of the project are investigated. A tendency in sessions which do not follow a structured agenda, is that the discussions can centre on one, albeit important, issue which has already been identified and ignore other aspects of the project which may also contain uncertainties. A structured approach can be implemented by the session being controlled by someone not directly part of the project team. The role of an independent facilitator then is to ensure that all aspects of the project are considered and the project team do not consider only the aspects of the project they have previously identified and perceive as important.

Another measure to ensure all aspects of the project are investigated is to have a list of areas which have to be addressed. Typical aspects for discussion are:

- site
- client
- design
- subcontractors
- construction methods/materials
- suppliers

Although such topics are very broad in scope, they do cover the main aspects of the project. The approach described does not allow previous experience to be transferred between projects, other than through the individual's experiences. For this reason, the use of checklists is also advised.

4.4.2 Checklists

The six topics listed above form a starting point for a checklist in that they represent areas which have to be addressed. The level of detail is such that they do not allow experience to be represented and so should only act as a starting point.

The next stage in the development of a checklist would be to discuss the issues which are important in each area. Such an approach means that for the first project, the production of the checklist and the brainstorming of risk factors occur simultaneously. The "Site" category might include items such as:

- What are the ground conditions?
- Is the foundation flexible to accommodate variable ground conditions?
- Has the issue of landfill tax been considered?
- At what level is the water table and what would be its effects if it changed?
- What activities would be affected by inclement weather and what could be done to overcome those effects?

Through the use of checklists, the experiences on other projects can be readily applied to all projects, regardless of the teams working on them. The deficiency in the usual approach to experience is that it is held with the individuals rather than communicated to others as a matter of course.

4.4.3 Outcome of Identification Session

A typical identification session, incorporating structured brainstorming and checklists, could last several hours and would produce a list of sources of uncertainty in the project cash flow. Each item would be described, stating what the source of uncertainty was, and how and when it could affect the project. It should be noted that since the objective was to identify uncertainties, regardless of their potential impact, opportunity is given equal importance to risk.

Although many items will be discussed during the session, only a small proportion of them will be considered to be important. The items which have been discarded should not be ignored as there are usually two reasons why they have been discarded. Firstly, the team might consider that they are not relevant to this project or that their potential effects are negligible compared to the majority of other items being identified. Secondly, they may have already been managed or are to be managed from within the tender. In both these cases, a record should be kept in order that the items can be added to the checklist to enable future projects to benefit. As discussed earlier, other items will have been identified which are of more concern to the company than the project team (such as contract conditions) which will be dealt with by the relevant department.

Table 4.3 contains a list of the risk factors identified for the example project with a description of the uncertainty and the timing of any effects in terms of the phases defined earlier.

Table 4.3 - Identified risk factors for the example project

No	Risk Factor	Description	Phase or Date
1	Client Attitude	The client is expected to have a significant impact on the project. Additional resources may have to be assigned to the project to manage this input.	1,2
2	Variations	The high degree of involvement by the client is likely to force variations which should be profitable.	2
3	Design Development & Coordination	The development of the design could produce savings or losses if packages are not coordinated.	1,2
4	Bills of Quantities	The submitted price was based on a BoQ, which may have contained inaccuracies	1,2,3
5	Design Programme	Delays in the design would have a direct impact on the performance of the project.	1
6	Buildability	Buildability is an issue in any design build project	2
7	Building Regulations	The project is susceptible to changes in building regulations.	1,2,3
8	Specialist Subcontractor Procurement	The prices on which the tender will be based may not be achievable.	1
9	Domestic Subcontractor Procurement	The prices on which the tender will be based may not be achievable.	1
10	Winter Working	Due to the complexity of the roof, completion is close to the start of the winter season which may require winter working.	10/96-End
11	Cash Flow	Management of the cash flow throughout the project could provide cash which the business unit can utilise.	1,2,3
12	Curved Roof Buildability	The most challenging aspect of the project is the curved roof.	2

One risk factor which warrants further explanation is Risk Factor 11, Cash Flow. The cash flow of the project, as discussed earlier, is a significant factor for the company as it could provide cash for other operations or require cash for the project to be undertaken. Therefore, the management of the cash flow is regarded as a significant part of the management of the project. Although the cash flow is the focus of the project risk model, at the time the model is created, it can itself be a risk factor in the event that the cash flow is not managed effectively.

To illustrate the timing of the risk factors, Figure 4.2 plots them in bar chart form.

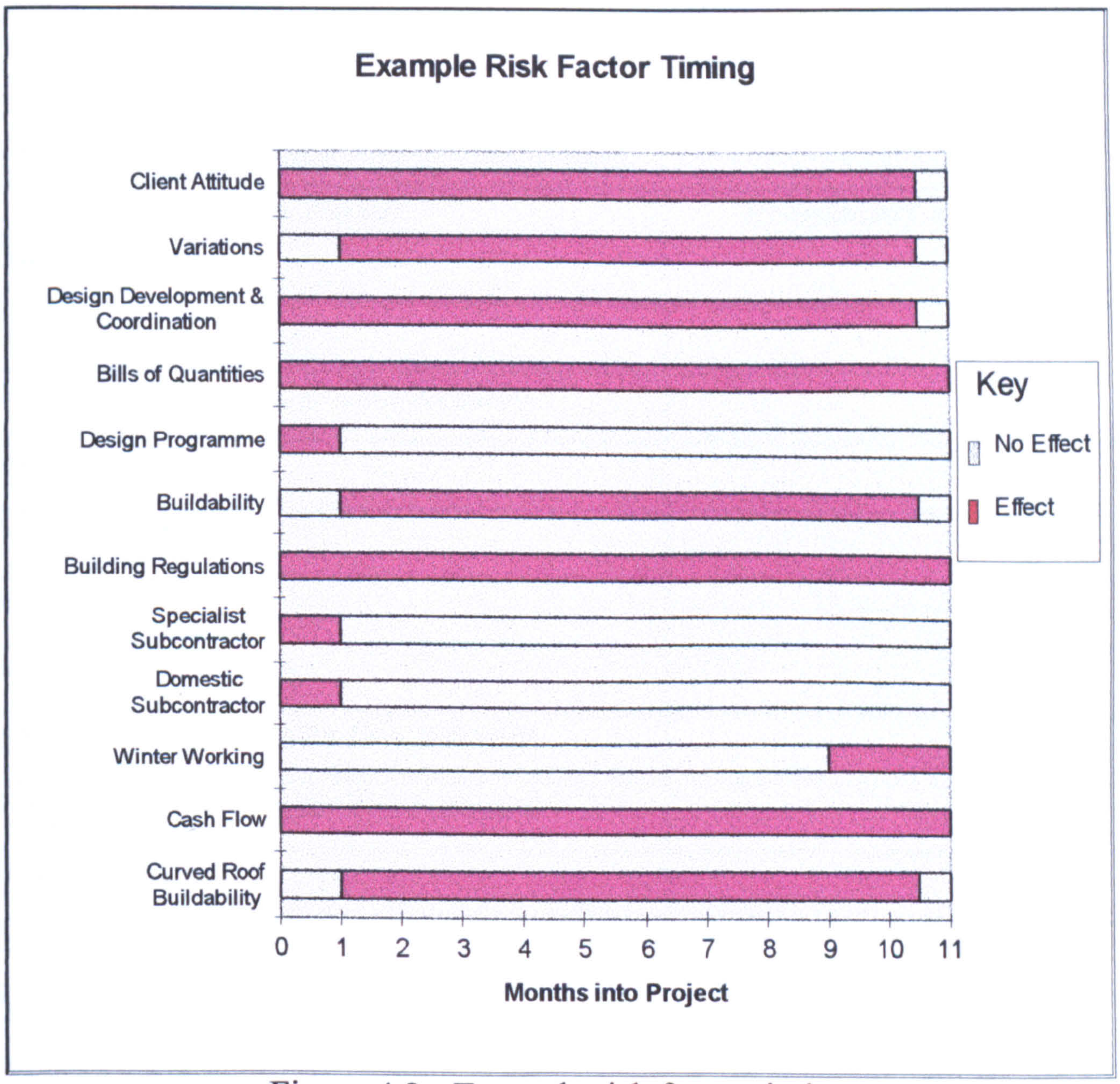

Figure 4.2 - Example risk factor timing

4.5 RISK QUANTIFICATION

A risk factor is fully defined by the probability that it occurs and the effects on the project's cash flow if it does.

The probability of occurrence can very rarely be defined using historical data; even risk factors which exist on the majority of projects will be affected by the nature of the project and local conditions. Subjective assessments are therefore used to determine, between the members of the project team, the probability of occurrence. This is a task which benefits from representatives of the whole project team being present as it limits the effects of bias. Additionally, once several risk factors have been assessed, the probabilities of occurrence can be compared, testing the logic used.

For the continuing example, Table 4.4 shows the probability of occurrence for each risk factor.

Table 4.4 - Risk Factor Probability of Occurrence

No	Risk Factor	Probability of Occurrence
1	Client Attitude	100%
2	Variations	100%
3	Design Development & Coordination	100%
4	Bills of Quantities	100%
5	Design Programme	100%
6	Buildability	100%
7	Building Regulations	100%
8	Specialist Subcontractor Procurement	100%
9	Domestic Subcontractor Procurement	100%
10	Winter Working	40%
11	Cash Flow	100%
12	Curved Roof Buildability	50%

It should noted that only two risk factors have been assessed at less than 100%, i.e. all the other risk factors will happen, the only uncertainty being what their effects will be.

There are many ways in which the uncertain effects can be defined but again, since accurate historical data rarely exists, statistical based distributions can not be readily defined. To overcome this problem, a limited number of easily defined distribution shapes are used. These shapes will be demonstrated using one of the risk factors defined for the example project.

4.5.1 Event Distribution

The simplest distribution to define, and understand, is termed the "Event" as an event either happens or it doesn't. To define such a distribution requires the probability of the event occurring and its effect if it does. Using Risk Factor 10, Winter Working, as an example, the probability that some protection would be required might be assessed at 60%, based on the experience and perception of the project team. If protection is required, the assessment might be that it would cost £35,000. The cost effect is that by which the cost of the project would increase. If some protection had already been allowed within the estimate, the effect would be the cost of the additional protection over that already allowed for. If this risk factor could result in the duration of the project changing, the change would also be defined. For this example, the additional protection is being provided to reduce the risk of the weather impacting on the completion date. The distribution for cost which this information defines is shown in Figure 4.3 below.

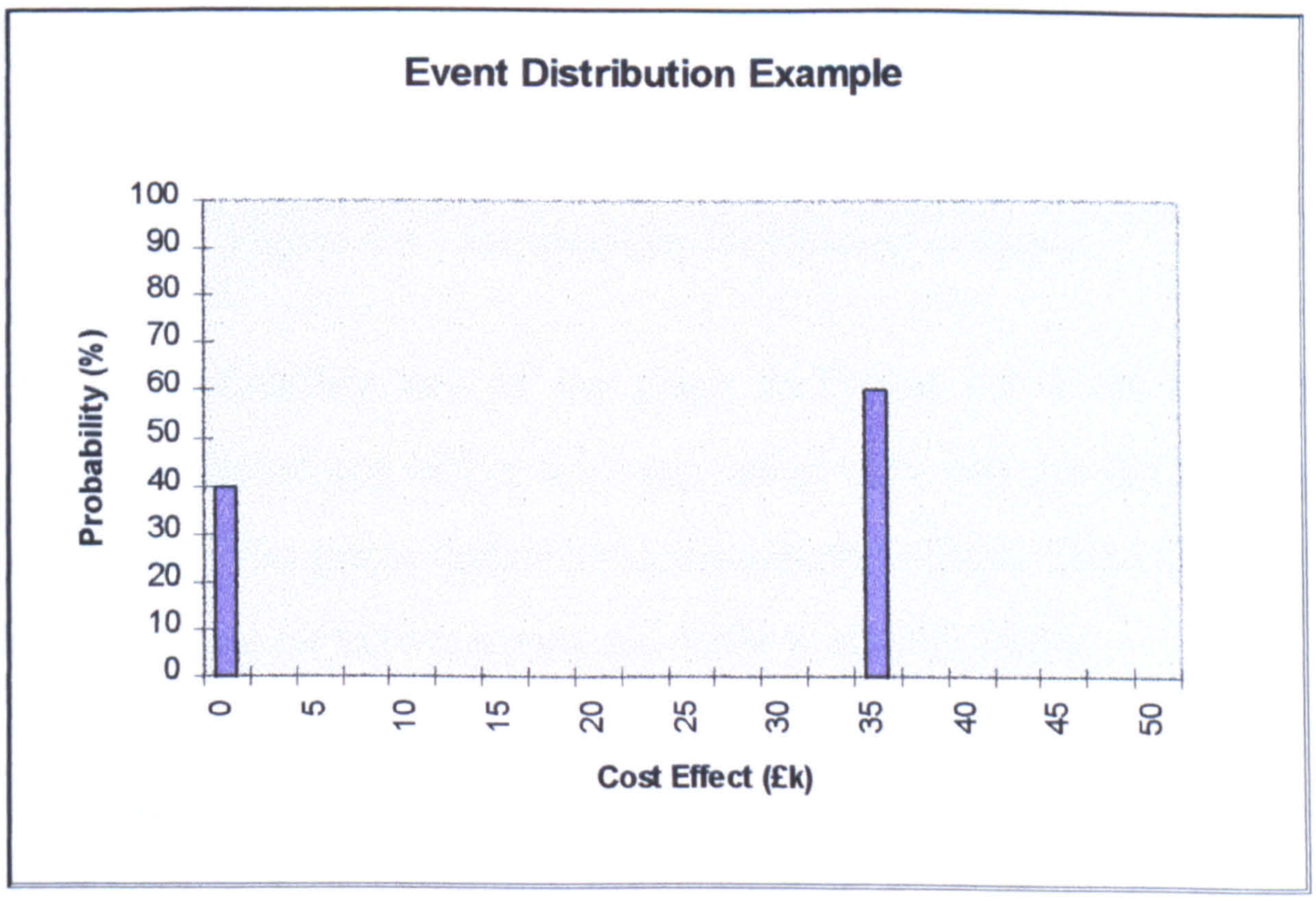

Figure 4.3 - Event distribution example

The graph shows a 40% chance of there being no effect on cost, leaving a 60% chance that the cost will be £35k.

4.5.2 Rectangular Distribution

Continuing with the above example, there might have been a difference of opinion amongst the project team as to the cost of protection because of uncertainty regarding how much protection would be required. In this instance, the cost of protection might be thought to be anything up to £50k, with every value being equally likely. This defines a rectangular distribution, as shown in Figure 4.4 below.

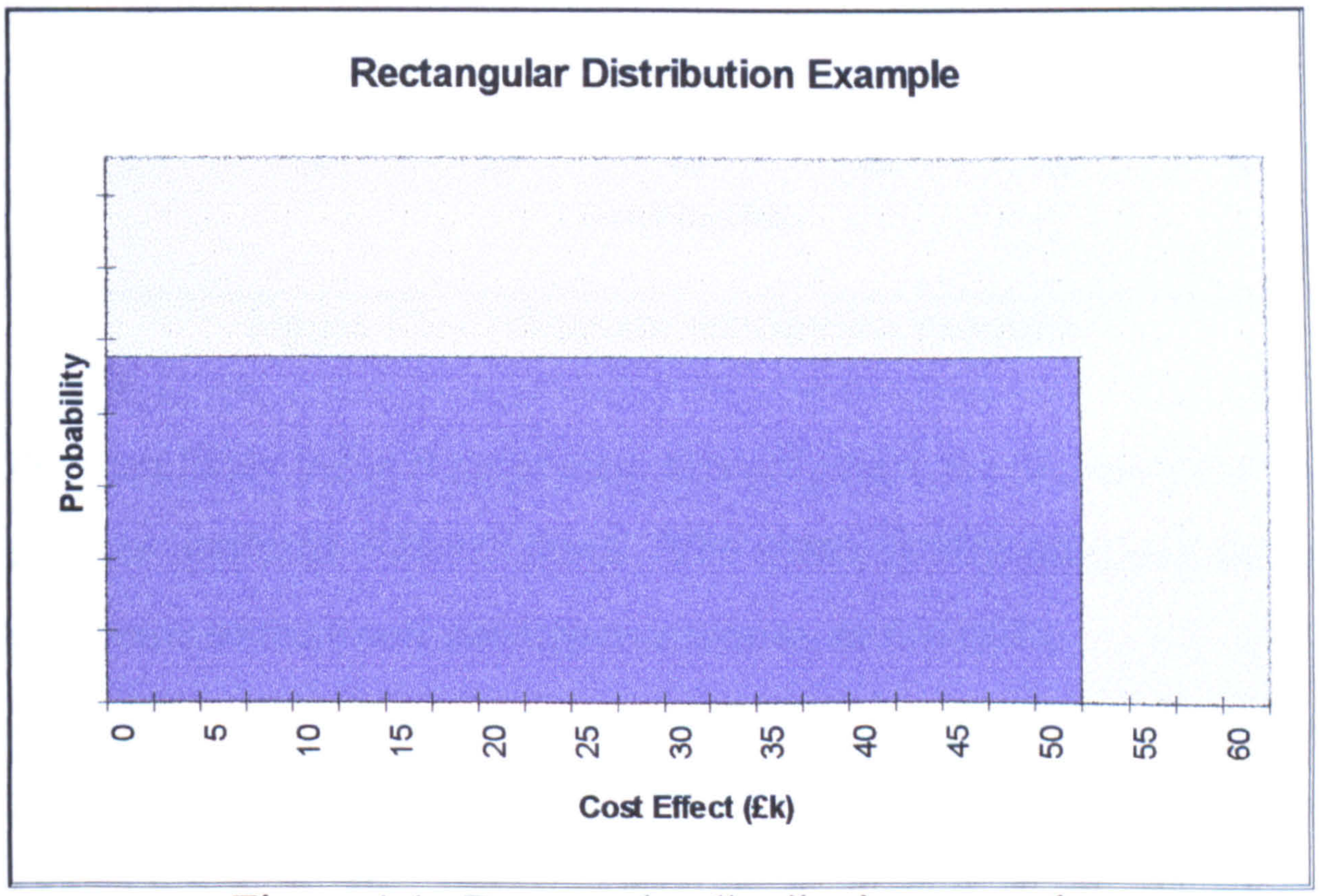

Figure 4.4 - Rectangular distribution example

The scale for the probability axis of the graph in Figure 4.4 is not marked. This is because the probability of any effect has been set at 60% and not the probability of an individual outcome. The graph therefore represents the effects if the risk factor occurs, showing that each outcome between zero and £50k is equally likely.

4.5.3 Triangular Distribution

The discussion regarding the amount of protection required might have concluded that although it could cost between zero and £50,000, it was more likely to be nearer zero than the upper extreme. This defines a triangular distribution with a lower extreme of zero, a most likely outcome of zero, and an upper extreme of £50,000. The shape of the distribution is shown in Figure 4.5 below.

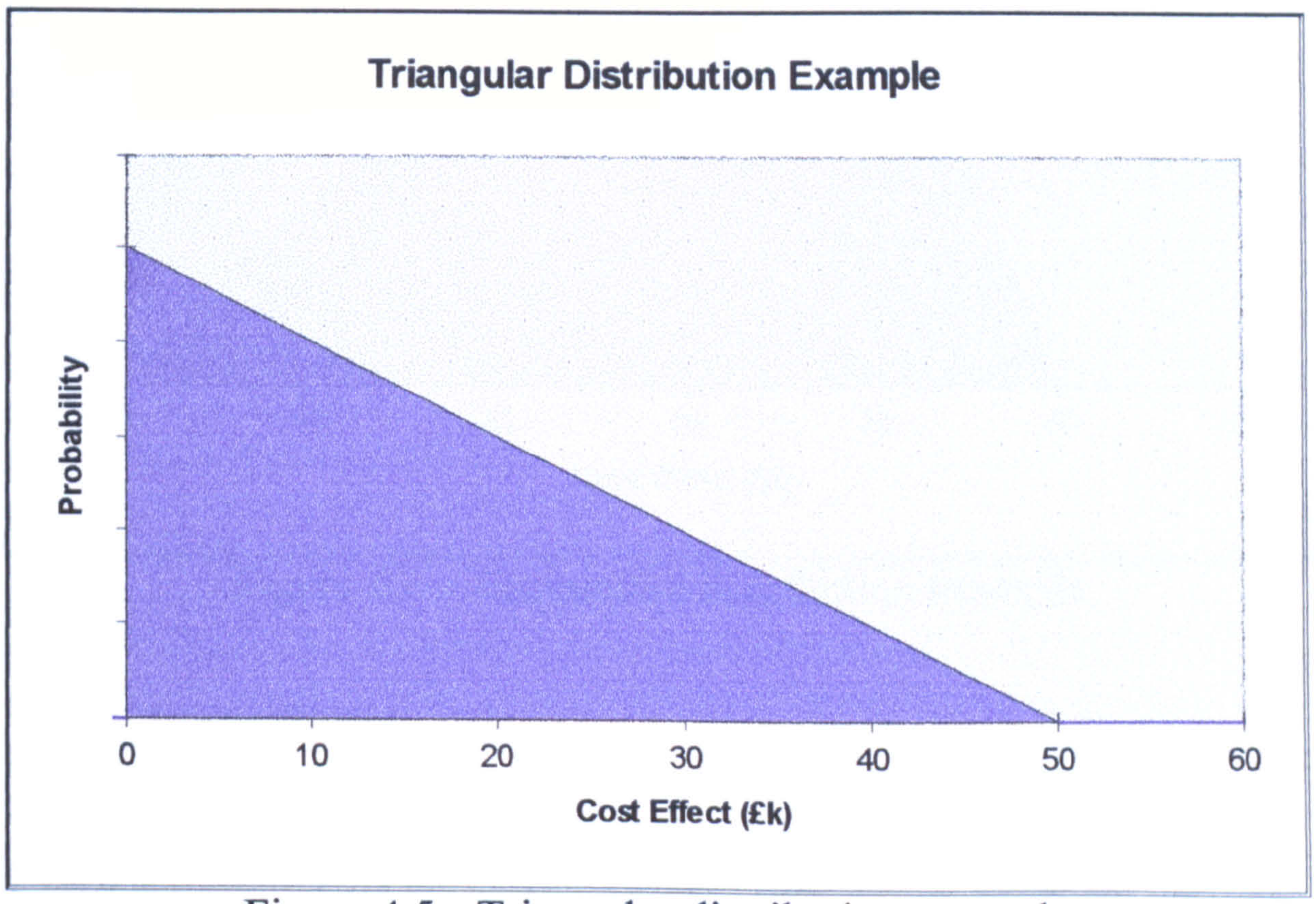

Figure 4.5 - Triangular distribution example

Although the most likely value is set at zero, this only fixes the highest point on the graph and should not be confused with the mean. The mean, in this case, will be one third of the difference between the lower and upper extremes, at £16.667k.

4.5.4 Trapezoidal Distribution

If it was felt that rather than there being a most likely outcome there was a most likely range, as in the rectangular distribution, but then there was an ever decreasing chance of the effect being outside this range, a trapezoidal distribution should be used. In the continuing example, it might be felt that although the cost of protection could range from zero to £50,000, it was more likely to be between £25,000 and £40,000. These parameters define the distribution shown in Figure 4.6 below.

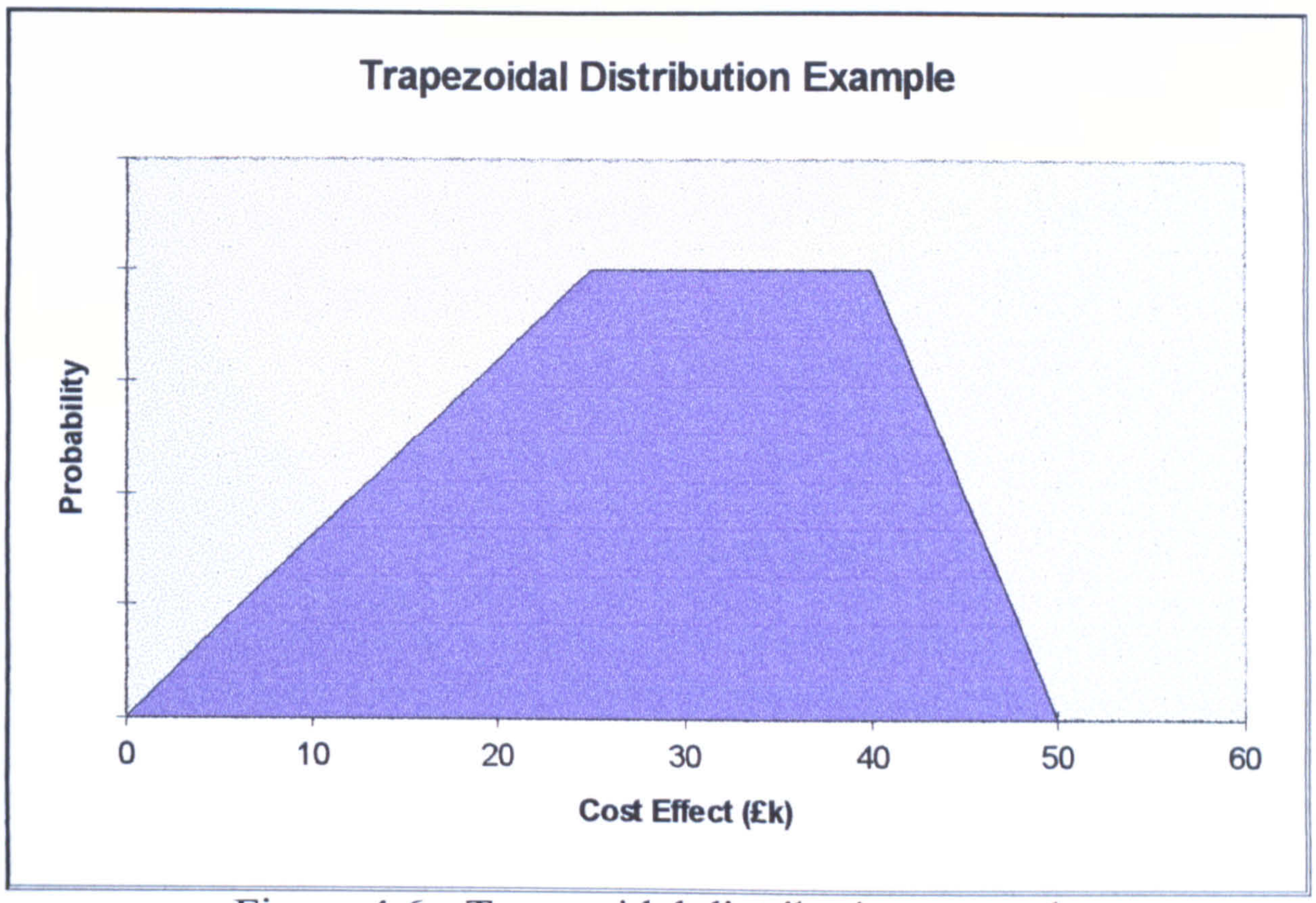

Figure 4.6 - Trapezoidal distribution example

4.5.5 Dual Range Distribution

The above distributions will be sufficient to define the majority of the effects of uncertainties on the project. However, the shapes all define the uncertainty over an expected range. In some cases, there may be the need to define a catastrophic effect beyond the expected range. In this case, the triangular distribution can usually define the expected range, but there is a slight probability that the outcome may be higher than the upper extreme defined. Following the continuing example, if full protection is required, for which there is a 10% chance, the cost could be anything up to £150,000, although the triangular distribution defined earlier adequately represents the uncertainty for the expected range. These parameters define the distribution shown in Figure 4.7 below.

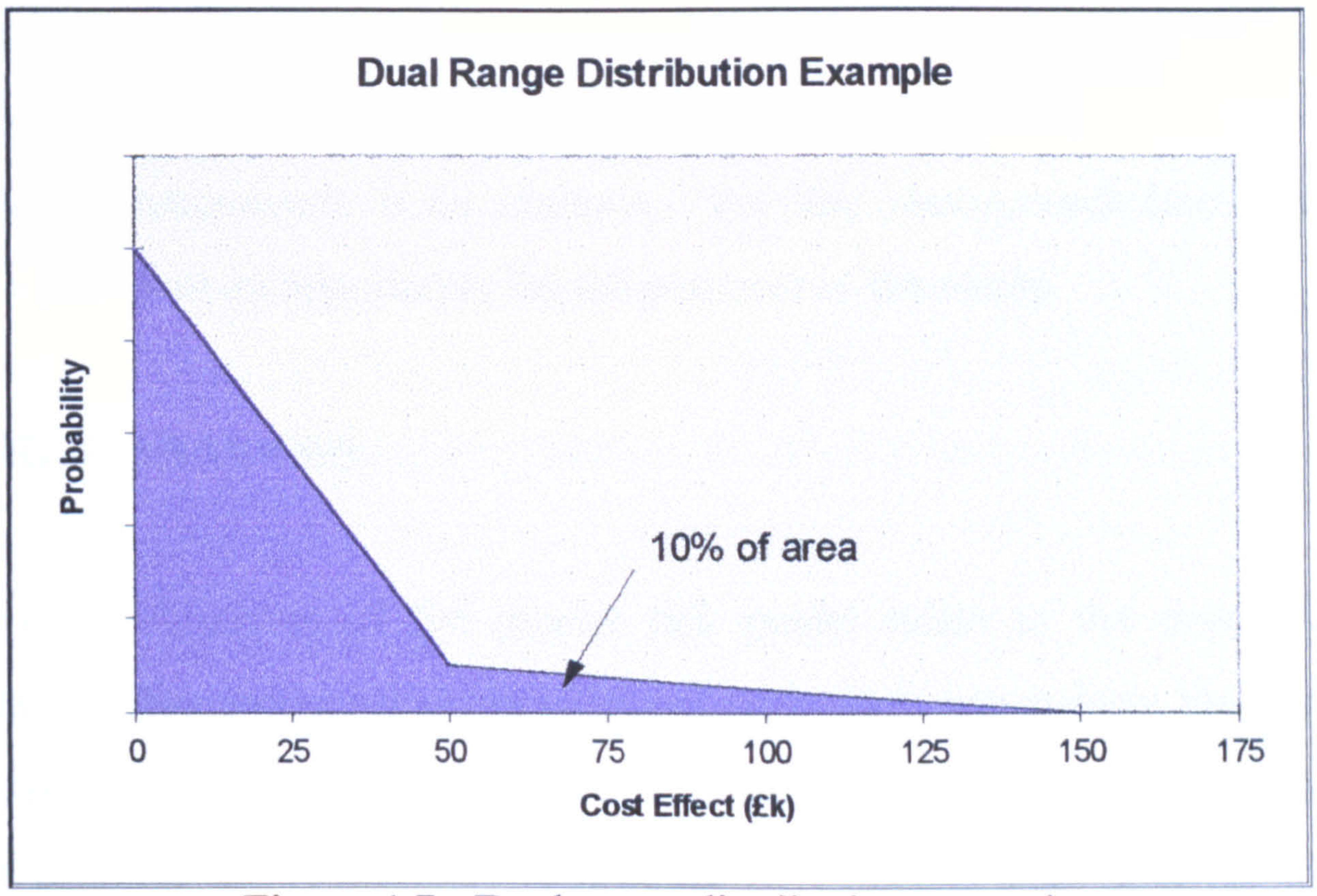

Figure 4.7 - Dual range distribution example

4.5.6 Timing of Effects

Since it is the effects of uncertainty on the cash flow that are being investigated, rather than just the final outcome of the project, the timing of the risk factors is important. Figure 4.2 showed the timing of the example risk factors in bar chart form based on the phases in which the effects would occur. In practise, it may not be possible to define precisely when a risk factor will occur because just as its effects might be uncertain, its timing may be uncertain. In this case, the start and end of the risk factor's effects can be defined using distributions rather than fixed dates. Continuing with the example of protection due to adverse weather, the requirement may start anytime up to a month before the date previously assumed, although the most likely date is still the start of October.

4.5.7 Quantifying Opportunity

Although the term Risk Factor is used, there is no distinction between risk or opportunity in the quantifications. An uncertainty might be described as a risk if it increases cost and duration, and conversely an opportunity if it reduces cost and duration. In the example, risk factor 10, Winter Working, is an example of a pure risk as if it occurs it will always be to the detriment of the project. Conversely, risk factor 11, Cash Flow, is an example of a pure opportunity. This distinction cannot be made in the case where the effects range from being beneficial to detrimental, of which risk factor 9, Domestic Subcontractor Procurement, is an example. For this reason, each uncertainty is not classified as a risk or an opportunity for the purposes of the model.

4.6 RISK ANALYSIS

The two main objectives of the project risk model relate to the evaluation of the uncertainty to either produce a single source of uncertainty to represent the project in the company risk model or to allow the project to be classified. The objective of the analysis is then to combine the risk factors to produce an uncertain cash flow for the project. Monte Carlo Simulation is an ideal technique for this task as it was specifically developed to offer a means of estimating the combined effect of many distributions.

4.6.1 Monte Carlo Simulation

Monte Carlo simulation, as discussed in Section 2.4.2.3, is a sampling technique used to evaluate a function which contains uncertain variables. In the previous applications of the technique in project risk analysis, only the final duration or cost has been required and so the function to be evaluated has not been necessarily complex. The cash flow of the project is the function to be evaluated within this model, which increases the complexity although the principle remains the same. Each stage of the process is described in detail below, with reference to the example project.

4.6.2 Evaluation of the Base Cash Flow

The first stage of each run is to evaluate the base cash flow which the risk factor effects will be added to or subtracted from. If, however, all the uncertainty was defined using risk factors, the base cash flow would be identical on each run and so would be evaluated once for the entire simulation.

4.6.2.1 Start Date

If the start date of the project is uncertain, a value is selected from the distribution defined. In the example project, although the basic parameters set the start date at 1 February, 1995, it may be felt that the project would actually start on site anytime during February. This defines a rectangular distribution. The start date is then selected randomly from the distribution defined.

Although the actual start date may have little implication on the project, it is likely to be important to the business unit. The start date fixes the base cash flow and the risk factors for which dates were specified in time, the remainder usually being defined in terms of durations from the start date.

4.6.2.2 Total cost, value, and duration

If general uncertainty has been defined, the cost, value, and duration of the base cash flow must be selected from their distributions. For the example project, all the uncertainty in these parameters has been defined using the risk factors. In this case the cost, value, and duration and the phase durations, taken from Table 4.1, are used to complete the definition of the base cash flow. The total values are used to scale the relative costs and durations for each phase selected earlier.

If phases or monthly values have been defined and general uncertainty exists, the phases and monthly values reflect the proportions rather than the actual values. For example, if the general uncertainty defined allowed the base cost to increase by 20%, the cost for each phase could also increase by 20%. Similarly, the amount defined for each month could increase by 20%.

4.6.3 Risk Factor Effects

4.6.3.1 Risk factor occurrence

The risk factor effects will be added to or subtracted from the base cash flow. The first stage of this process is to determine which risk factors occur for the run of the simulation being evaluated. For each risk factor, the probability that the factor occurs has been defined (see Table 4.4). If the random number generated is less that the probability of occurrence the risk factor occurs. For the example project, only risk factors 10, and 12 have probabilities of occurrence other than 100% defined for them. Risk factor 10, Winter Working, at 40%, has been used in the example throughout, and risk factor 12, Curved Roof Buildability, has been assessed at 50% chance of occurrence. For the other risk factors, the uncertainty is not related to whether they occur or not but to the effects when they do.

The remainder of the discussion of risk factor effects applies only to those which occur on the run of the simulator being evaluated.

4.6.3.2 Risk factor start and end dates

The project risk model is not purely seeking to determine the uncertainty in the final outcome of the project and so the timing of the risk factor effects is important. The start and end dates of the effects for each risk factor were defined, either as finite dates or distributions. For those defined as a distribution, the start date is selected at random.

The end of the risk factor effects is defined as a date, rather than defining a duration for the effect. A similar process is performed to select the end date of the effect for those risk factors where a distribution is defined.

For both start and end of the risk factor effects, dates are not always necessary. In the case of the start date, several of the risk factors start at the start of the project. If the start of the project was uncertain it would be difficult to specify distributions for the start of those risk factor effects so they always coincided with the start of the project. In this case, and where the end of the risk factor coincides with the completion of the project, the model fixes the risk factor to the start or end of the project; once the project start and end dates have been determined, the timing of these risk factors is evaluated.

4.6.3.3 Risk factor duration effects

Unlike the cost and value effects, the duration effects affect the whole cash flow, rather than over the period of the risk factor. If a duration effect has been defined, the effect on the project for the run under consideration is selected from the distribution and added to the project duration. Having repeated this for all the risk factors which occur, the base cash flow is amended to take into account the new duration of the project. In the case of risk factor effects linked to the end of the project, their end dates are amended accordingly.

4.6.3.4 Risk factor cost and value effects

If a duration effect has been selected, and if a relationship between cost, value, and duration is required, the same random number is used to select the financial effects. If no duration effect has been selected, or a relationship is not required, random numbers are generated with which the effects are selected. It is assumed there is a relationship between cost and value, and so the same random number is used for cost and value, regardless of whether a relationship with time is assumed.

The effect selected is the total for that risk factor and is distributed uniformly between the start and end dates of the risk factor. Repeating this process for all the risk factors which occur on the run produces the final cash flow for the project for that run.

4.6.4 Storage of Results

The results of each run of the simulator can be, and are, stored in several ways. The following information is recorded:

- The cash flow in its entirety.
- The final duration, cost, and value, and hence profit.

The cash flow is used as an input to the company risk model as it gives, at the end of the simulation, a collection of possible cash flows for the project. It can also be used to produce frequency distributions of the cash flow in each time period. The final duration, cost, value, and hence profits are stored separately because they give measures of the overall performance of the project. A frequency distribution can be produced for each parameter showing more information than the cash flow frequency distributions, since the project may finish in different time periods between runs of the simulator.

4.7 INTERPRETATION OF RESULTS

4.7.1 Uncertain Cash Flow

The main objective of the project risk model is to combine the various sources of uncertainty in the project's cash flow into a single source. The collection of possible cash flows for the project will act as this input to the company risk model.

The cash flows can be viewed in several ways. The first is to plot all the cash flows on the same axis. Figure 4.8, below, plots the cost of the example project for the first 100 runs of the 2000 run simulation. Graphs of value and profit can also be plotted.

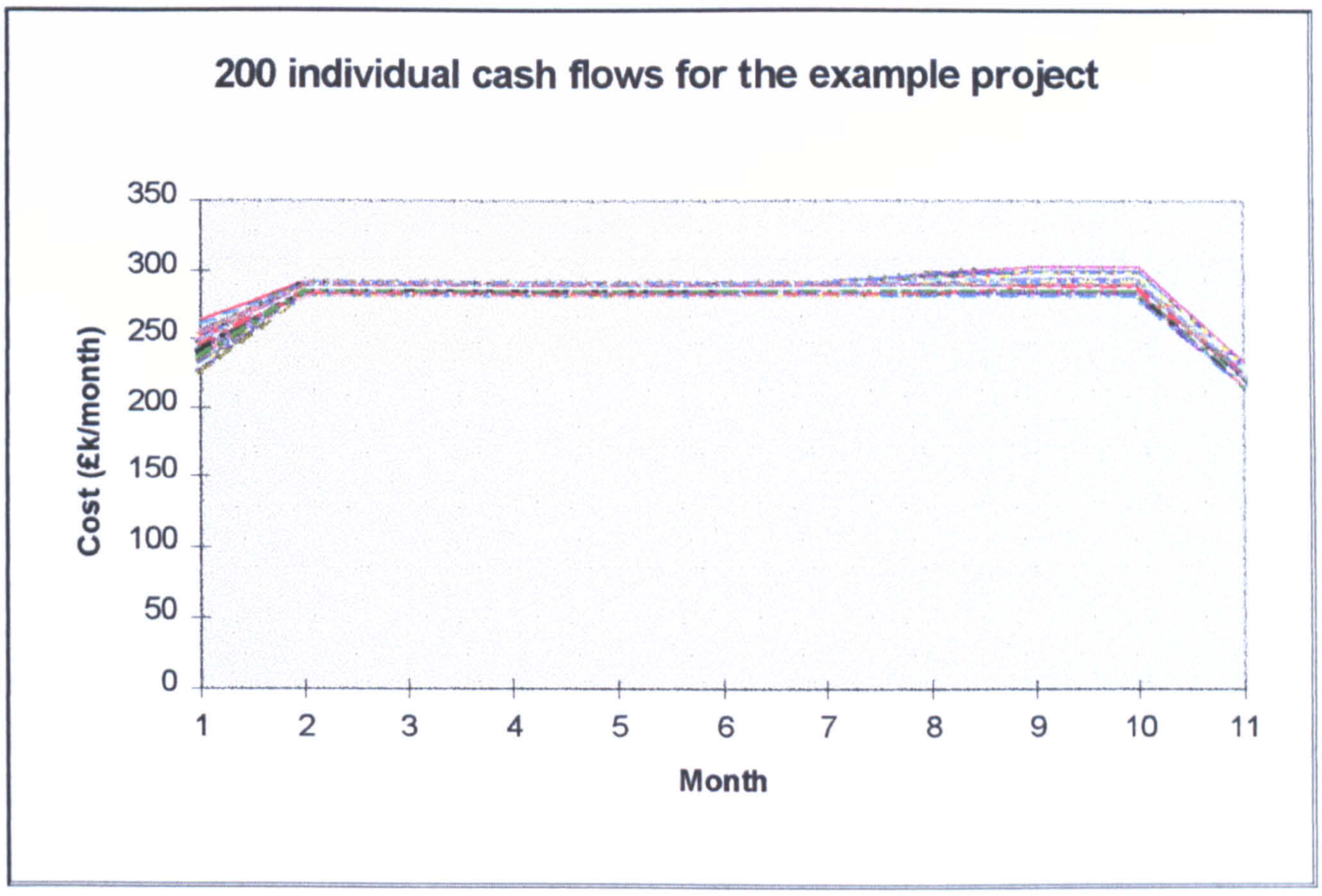

Figure 4.8 - 200 individual cash flows for the example project

Plotting each cash flow individually illustrates the bounds of the possible cash flow in each time period. Unfortunately, due to the overlap of many of the cash flows, the graph does not offer any information as to the likelihood of values between the two bounds. The second method of presenting the cash flows is an attempt to overcome this. Frequency distributions are constructed for the cash flow in each month, showing in detail how the values in any particular month are distributed. An example of this for the profit in one month of the example project is shown in Figure 4.9 below. The graph is constructed using £5k intervals and shows that the higher costs are less likely than the lower costs.

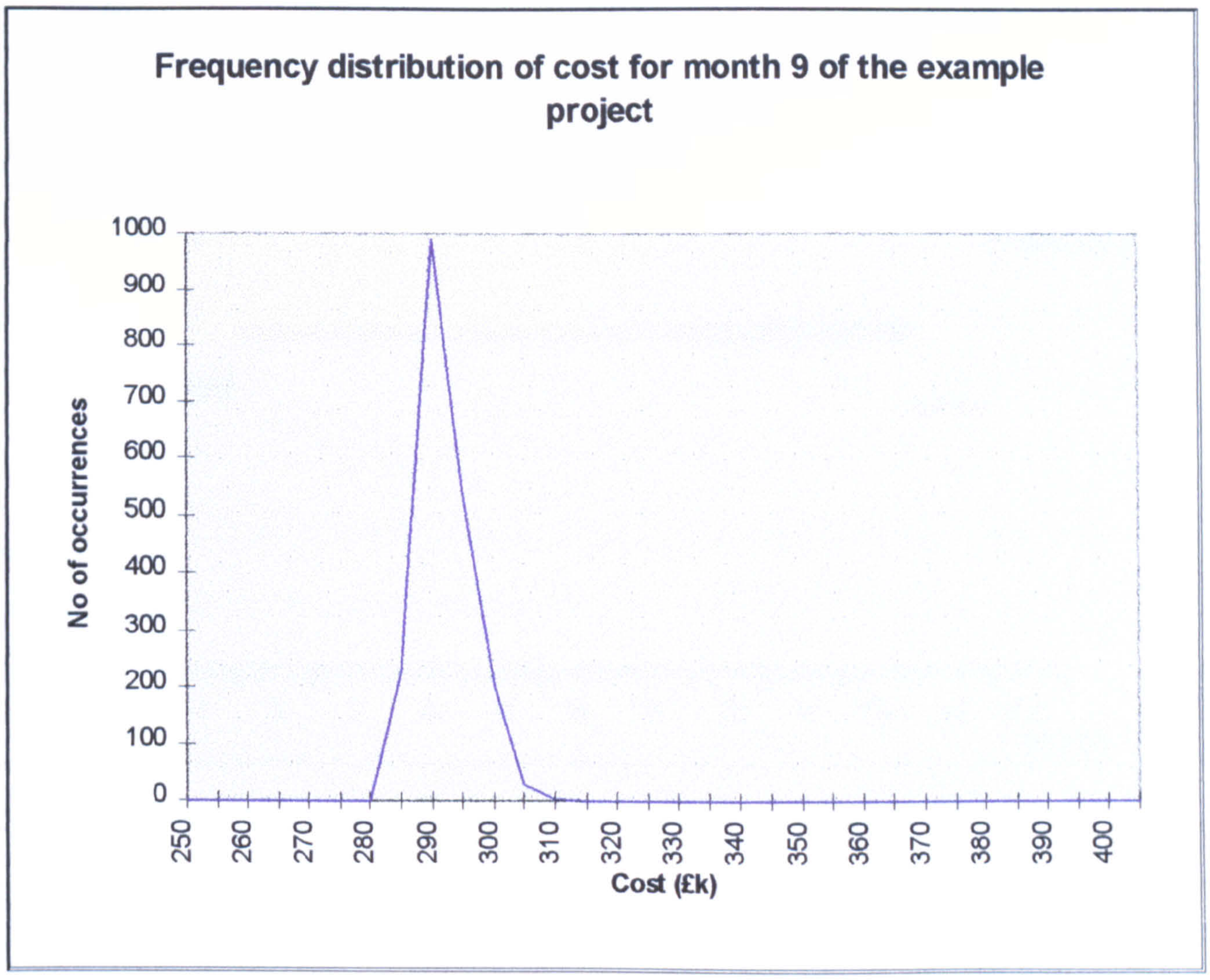

Figure 4.9 - Frequency distribution of cost in month 9 of the example project

Although such a method of presentation illustrates the distribution of the values between the two bounds, inspecting the distribution for each month in turn is a time consuming task which does not readily allow the trend from month to month to be analysed. The third method of presentation plots all the frequency distributions of monthly cashflow side by side. Rather than plotting this as a 3D graph, which would have problems with peaks hiding the detail of subsequent months, colour is used to represent the height of the graph, or in this case, the probability of the cash flow actually being in a particular interval. This form of presentation is shown in Figure 4.10, again using the results of the analysis of the example project.

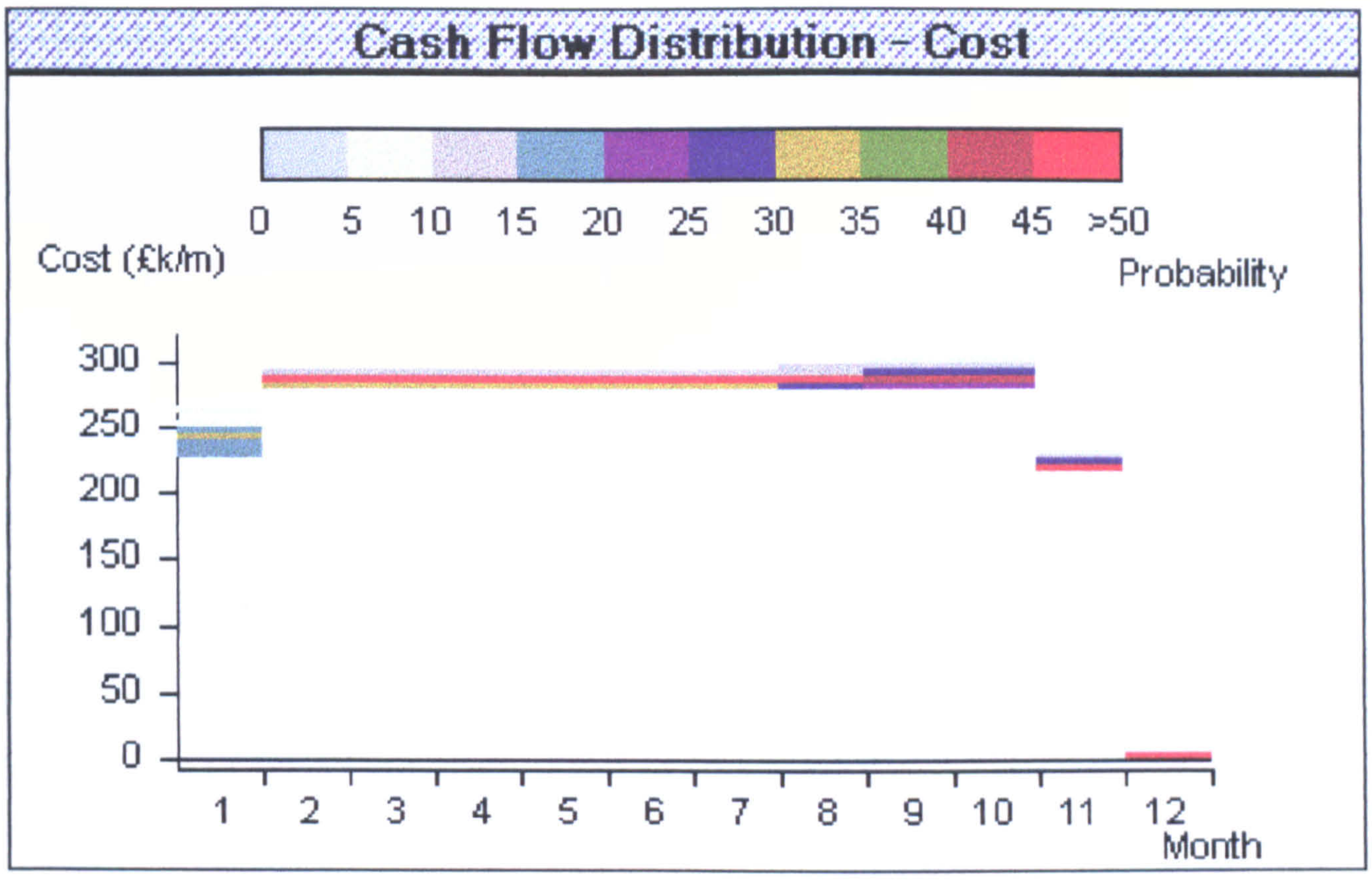

Figure 4.10 - Distribution of monthly cost for example project

The distributions show the greatest uncertainty to be in the first month and the last 4 months of the project. The knowledge of the uncertainty in month 9 gained from the distribution in Figure 4.9 is confirmed with the colour getting lighter as the cost increases. Although this graph does not offer as much information about the uncertainty in month 9 as the graph in Figure 4.9, it does offer information about the uncertainty in all months at the same time.

4.7.2 Distributions of Final Outcome

A further objective of the project risk model, when applied to the project being tendered for, is to give an assessment of the uncertainty in the project to act as a basis for decisions regarding the tender price. In addition, if analysis is performed while the tender is being produced, it may show that the project contains an excessive amount of uncertainty and allow the approach taken for the project to be changed to control that uncertainty. For example, different materials may be used, or the order in which elements are constructed may be changed. Such actions may, in addition to reducing uncertainty, increase cost. The need to have a detailed analysis of the uncertainty is therefore essential if such decisions and the submitted tender price are to be made with confidence.

In order that such action can be taken, a means of presenting the uncertainty is required. This must be in such a form that it can be readily communicated and allow comparison with the results of an analysis using the different approach.

The distributions of final outcome for cost, value, profit, and duration can be produced while the analysis is being performed. Although they only illustrate the uncertainty in the final outcome of the project, since the project has not been added to the company risk model at this stage, it is on this information that the project will be assessed. Figure 4.11 and Figure 4.12 show the distributions of cost and profit for the example project (no uncertainty exists in the value or duration of the project).

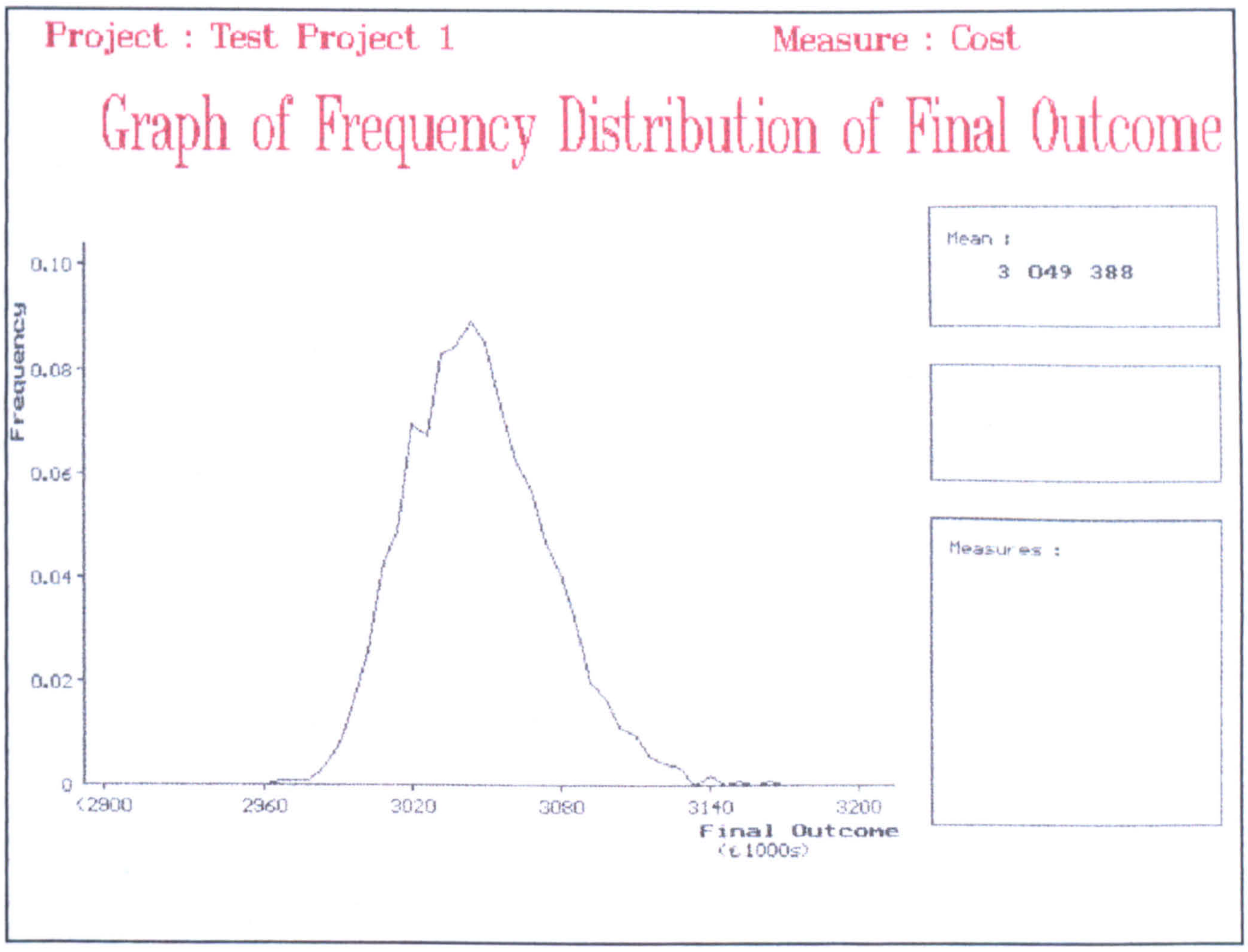

Figure 4.11 - Frequency distribution of total cost for example project

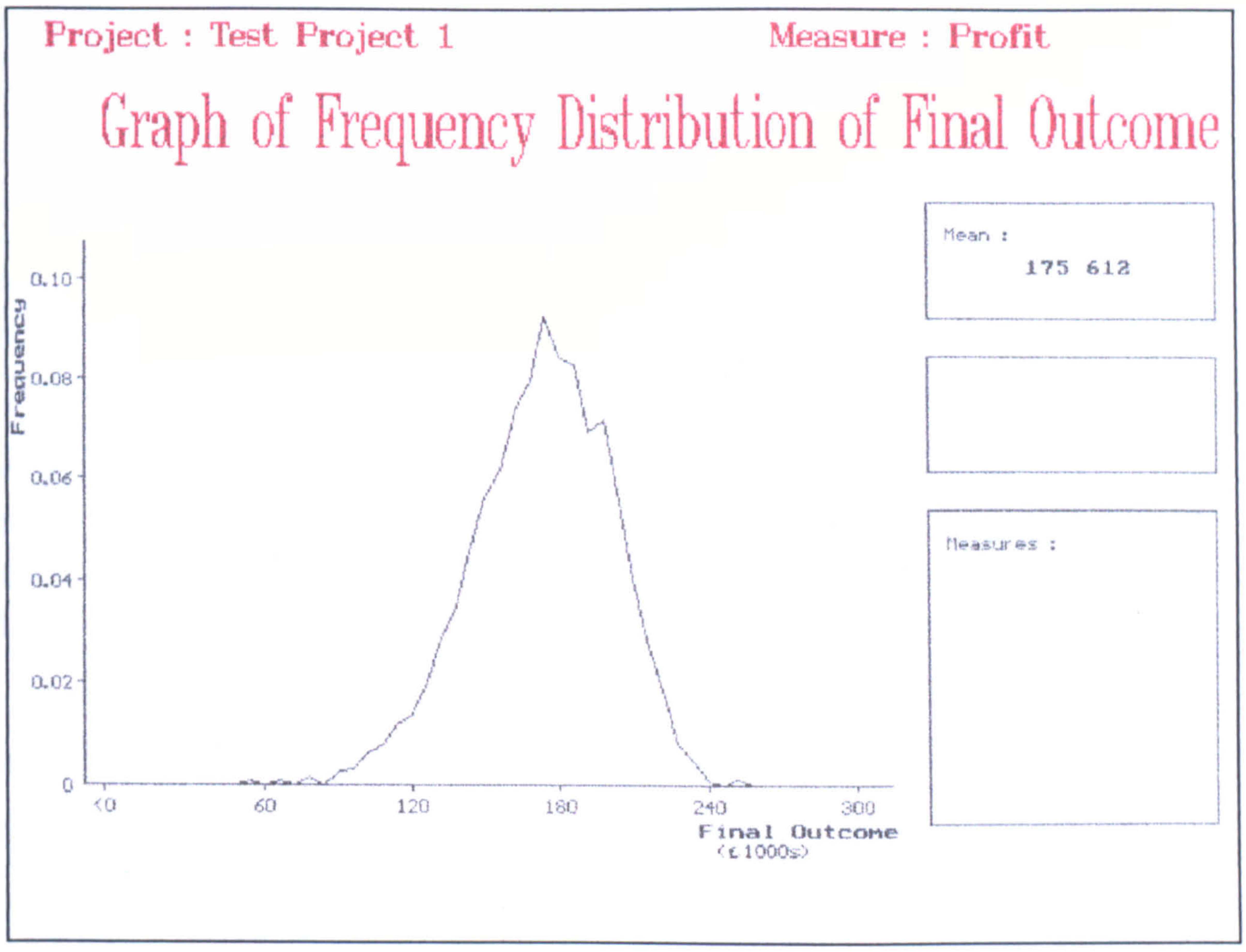

Figure 4.12 - Frequency distribution of final profit for example project

From the distributions, statistical measures can be evaluated which quantify the uncertainty. Such measures are required in order that comparisons can be made and the results communicated. Of the many parameters which can be evaluated from a frequency distribution, the measures which are required are those which reflect the likely outcome, the range of possible values, and the distribution of values between the two. The parameters in Table 4.5 reflect the desired measures, showing their values for the example project.

Table 4.5 - Statistical results for the example project

Statistic	Cost	Value	Profit	Duration
Mean	3 049 388	3 225 000	175 612	11.000
Standard Deviation	27 757	0	27 757	0.000
Best Case	2 968 803	3 225 000	256 197	11.000
Worse Case	3 166 275	3 225 000	58 725	11.000
Theoretical Best Case	2 920 000	3 225 000	305 000	11.000
Theoretical Worst Case	3 248 000	3 225 000	-23 000	11.000

The best and worst case produced within the simulation and theoretical extremes are presented to illustrate the difference between the two. The theoretical extremes are the outcomes if all the risks occur with their maximum impact with none of the opportunities and if all the opportunities occur with their maximum impact with none of the risks. These define the limits beyond which the outcomes cannot fall. However, these extremes, due to the compounding of sometimes unlikely uncertainties are extremely unlikely to occur. The extremes produced by the simulation offer are more likely range of outcomes for the project.

In any project it is accepted that there is a significant amount of risk and if all those risks occur the project is likely to lose to the company money. When deciding the tender price, it is the likelihood of risks occurring which are important and so more importance is given to the likely range given by the simulation rather than the theoretical maximum.

4.8 RISK AND OPPORTUNITY CLASSIFICATION

Although the statistical measures offer parameters against which other projects and variations on the one under consideration can be compared and a means of communicating the results, they only reflect the uncertainty in the project and require all the results to be presented to be meaningful. In order to relate the uncertainty to the desired outcome of the project, and offer a single result for the purpose of communication and comparison, the resultant uncertainty is classified for risk and opportunity.

The purpose of the classification system is to relate the uncertainty to the objectives of the project; in order to allow the communication of the result however, it must do so in a manner which can be readily understood to people not directly connected with the project. In order that this is achieved, the classification system must be calibrated using projects with which the teams are familiar, enabling the classification to reflect their views of the project.

Although ideally a single classification would be produced for the uncertainty against the objective for profit, say producing a result on a scale of 0 to 10, it is not possible to reflect the balance between the risks and the opportunities and the magnitude of them using a single number. For example, a high risk and high opportunity project would be considered different to a project of low risk and low opportunity and yet a single classification would not be able to distinguish between the two if it was based on the balance between the risks and opportunity. For this reason, a classification is produced for the risk and one for the opportunity, allowing both the magnitude of each and the balance between the two to be communicated.

4.8.1 Objectives against which the uncertainty is classified

Although at tender stage the project may not have clear targets for profit, an assessment of risk and opportunity can be made against the standard rules of the business unit, which might include an addition to cost relating to overheads and profit. For the purpose of classification, a risk is an outcome of the project which would cause the project to make less profit than its target, while an opportunity would result in a profit greater than its target. The cut-off point between risk and opportunity is here called the threshold level, denoting the threshold between risk and opportunity.

The threshold level can be set at various values, three of which are:

- the cut-off between absolute profit and loss,
- the level at which the project only makes its contribution to overheads,

- the level at which the project returns its target margin, representing both overhead and pure profit.

If further objectives, in addition to that for profit, where applied to projects, the risk and opportunity to these objectives would also be classified.

4.8.2 Classification Functions

Since the objective for profit is based on the final profit, it is the distribution of final outcome which is considered when classifying the risk and opportunity. If objectives for the profit at stages in the project had been defined, the distributions at those stages would also be used. For example, an objective might be that the project should not operate a negative cash flow, for which the distribution of cash flow at all stages of the project would be assessed.

When viewing the distribution of final profit with reference to the target, or threshold level, several aspects are considered. These are the most likely outcome, the range of profit, and the probability of being above or below the threshold. In order to produce the single classifications for risk and opportunity, functions are applied to each aspect and the results of these are then combined to produce the classification. The functions are combined in proportions which reflect their assumed importance. The functions applied to each aspect are detailed below in Table 4.6.

Table 4.6 - Functions for risk and opportunity classifications

Parameter	Risk	Opportunity
Likely Outcome	$\frac{\text{Threshold} - \text{MeanProfit}}{\text{MeanValue}}$	$\frac{\text{MeanProfit} - \text{Threshold}}{\text{MeanValue}}$
Extreme	$\frac{\text{Threshold} - \text{MinimumProfit}}{\text{MeanValue}}$	$\frac{\text{MaximumProfit} - \text{Threshold}}{\text{MeanValue}}$
Probability	$\sqrt{100 * \left(\frac{\text{No of Outcomes Below Threshold}}{\text{Total No of Runs}}\right)}$	$\sqrt{100 * \left(\frac{\text{No of Outcomes Above Threshold}}{\text{Total No of Runs}}\right)}$

Combining these components produces the functions for risk and opportunity shown below.

Risk = $c_1.k_1$.fn(Mean Profit) + $c_2.k_2$.fn(Minimum Profit) + $c_3.k_3$.fn.(Probability of Loss)

Opportunity = $c_4.k_4$.fn(Mean Profit) + $c_5.k_5$.fn(Maximum Profit) + $c_6.k_6$.fn(Probability of Profit)

The first set of constants, $c_{1\text{-}6}$, are used to combine the components in proportions which reflect the relative importance given to each aspect. The second set of constants, $k_{1\text{-}6}$, are used to scale the outcome of each component to produce an outcome of between 0 and 10, controlling the sensitivity of the functions. By limiting the outcome of a single function to between 0 and 10, and setting the constants $c_{1\text{-}3}$ and $c_{4\text{-}6}$ so they sum to 1.0 gives classifications for risk and opportunity between 0 and 10.

4.8.3 Controlling the sensitivity of each function component

The intention is to have each component produce a result between 0 and 10, by the use of constants $k_{1\text{-}6}$ which can then be combined to give a total classification between 0 and 10. The component relating to the probability will always produce a result between 0 and 10, since it evaluates the square root of a percentage. However, the components relating to the mean and extreme profit do not have such a naturally restricted range. In order to ensure that the components always produce a result between 0 and 10, a limit must be defined. If no limit was defined, the constant would have to be set to enable any foreseeable result to produce an output between 0 and 10. This would produce a function which was largely insensitive to minor changes. Consequently, a limit is defined, above which the function will return its maximum. The lower the limit is set, the more sensitive the function is to results close to the threshold level. Obviously, if the limit is set too low, the function may be too sensitive, producing a maximum result too often.

For the most likely outcome, as a starting point, it might be felt that if the expected profit is greater than 10% different to the target profit (expressed as a percentage of the contract value) then the maximum result should be returned. To produce a result between 0 and

10, the output of the function, as shown in Table 4.6, is therefore multiplied by 100. Then, the output of the function is limited at 10; if the mean profit is greater than 10% different than the target, the function would produce a result greater than 10 which is then constrained at 10.

For the extreme outcome function, it might be felt that if the extreme profit is greater than 20% different to the target that the function should return the maximum result. In order to produce a result between 0 and 10, the output of the function is multiplied by 50. Similarly, the output of the function is then limited at 10.

The probability function, assessing the chance of making a profit or a loss, is automatically limited to a result between 0 and 10. The square root of the percentage chance of profit or loss is evaluated, rather than simply dividing the result by 10, to increase the sensitivity of the function over the lower range of probability.

Applying the above functions, with the suggested constants, to the example project produces the results shown in Table 4.7 below, using a threshold level of zero.

Table 4.7 - Component classifications for example project

	Risk	**Opportunity**
Mean	0.0	5.45
Extreme	0.0	3.97
Probability	0.0	10.00

4.8.4 Producing a single classification

Having scaled the outcome of each individual function, these are combined in varying proportions. The constants, c_{1-6}, are selected to give increased weight in the classification to the aspects which are considered of greater importance when assessing the risk and opportunity.

It might be felt that the most important aspect is the most likely outcome, followed by the extreme outcome, with the probability of making a profit or loss of least importance of the three aspects being considered. One combination of constants might be as shown in Table 4.8, which are then applied to the results of the example project showing the total classifications.

Table 4.8 - Component weights and resulting risk and opportunity classifications

Aspect	**Weight**	**Risk**		**Opportunity**	
		Original	Weighted	Original	Weighted
Most Likely (k_1 & k_4)	0.5	0.0	0.0	5.45	2.725
Extreme (k_2 & k_5)	0.3	0.0	0.0	3.97	1.191
Probability (k_3 & k_6)	0.2	0.0	0.0	10.00	2.000
		Total	**0.0**	**Total**	**5.916**

For the example project, since it always makes a profit, setting the threshold value at zero produces a risk classification of zero. The opportunity classification, of nearly 6, suggests a project of moderate opportunity, since the classification is scaled between 0 and 10. If the threshold level was set at the expected margin of £200k, which includes overhead contributions and profit, the results are as shown in Table 4.9.

Table 4.9 - Risk and opportunity classifications for a threshold value of £200k

	Risk	**Opportunity**
Mean	7.56	0.0
Extreme	2.19	0.87
Probability	8.95	4.47
Classification	**6.228**	**1.155**

As the results in Table 4.9 show, setting the threshold value at the expected margin and not the cut-off between absolute profit and loss changes the classifications considerably. The risk classification, at 6.2, suggests a project of moderate risk, which is confirmed by the inspection of the numerical results (Table 4.5). The opportunity classification, at 1.2, suggests a project of low opportunity, and this again is consistent with a project which is expected to make less than the target profit.

Setting the threshold value at the two different levels has illustrated that risk and opportunity are relative to the objectives. The uncertainty which was classified was identical in both cases and yet the results were significantly different.

4.9 SUMMARY

This chapter has introduced the project model and described its components and use. An example application has been used throughout the chapter to illustrate the mechanics of the model and to present typical output. The next chapter tests the model with a selection of projects, investigating the extent to which the model attains its objectives.

CHAPTER 5

TESTING THE PROJECT RISK MODEL

5.1 INTRODUCTION

This chapter investigates to what extent the project risk model can attain its objectives of modelling the uncertainties in individual projects. There are two aspects to this process. As stated previously in Section 2.3.1, only identified risks can be actively managed, and so the identification process requires investigation, as does the methodology for quantifying the effects of the identified risk factors. This first aspect is concerned with the input to the model. The second aspect concentrates on the output of the model and how it is produced and interpreted. Within the Monte Carlo Simulator, there are several parameters which must be set, perhaps the most important of which is the number of runs to perform. In addition to this, once the uncertainty has been analysed, the ability of the risk and opportunity classifications described in Section 4.8 to represent that uncertainty needs to be investigated.

The chapter proceeds by listing the types of projects the model was tested on and then investigates the input to the model, looking at the number of risk factors identified and the ability of managers to describe their uncertain effects using the distribution shapes offered. The chapter then progresses by investigating key parameters of the Monte Carlo Simulator and the effectiveness of the risk and opportunity classification system.

5.2 TEST PROJECTS

The model was tested on projects of various type, value, and complexity. A sub-objective of the tests was to determine the types of projects the model was applicable to and, perhaps more importantly, the ones it was not. The projects were both civil engineering (roads, water, tunnelling) and building based (including special purpose buildings), reflecting both traditional contracting and design-build. The value of the projects ranged from £1.5m to £105m, reflecting a large percentage of major projects in the categories of civil engineering and building. A small project has been classified as having a value of less than £10m, a medium project being between £10m and £25m, and a large project having a value greater than £25m. The method of procurement has been classified as either traditional contracting or design and build.

The projects were tested as they were being tendered for with input from the project teams. The implication of this is that the results presented here reflect what can be expected in practice rather than some idealised case.

The details of the projects tested are listed in Table 5.1, showing a brief description, the approximate value, duration, and start date. The identity of the projects has been disguised to protect commercial interests, although the details presented elsewhere in this chapter are representative of the actual projects as they were assessed at tender stage.

Table 5.1 - List of test project characteristics

Project Number	Description	Value (£m)	Duration (months)	Start Date
1	Small D&B Building	3.2	11.0	2/95
2	Medium D&B Special Purpose	15.0	15.0	5/96
3	Large Traditional Building	39.5	14.25	4/95
4	Large D&B Building	46.0	15.5	2/97
5	Large D&B Building	75.0	32.0	1/97
6	Large Traditional Building	103.6	18.0	8/96
7	Small Traditional Road	1.7	9.7	3/95
8	Small Traditional Road	2.3	13.0	10/96
9	Small Traditional Road	3.9	13.0	8/95
10	Small Traditional Road	5.2	12.25	5/95
11	Medium D&B Road	11.1	4.75	1/96
12	Medium Traditional Road	23.8	22.0	1/95
13	Small Traditional Tunnelling	9.6	24.0	1/96
14	Medium Traditional Tunnelling	24.0	42.0	7/95
15	Large D&B Water	46.0	43.0	8/96

5.3 RISK FACTOR IDENTIFICATION

The uncertainties in each project were identified using the techniques of checklists and structured brainstorming as suggested in Section 4.4. A facilitated workshop was used, to which all members of the particular project team were invited. Since the projects were to be analysed within their tender period, the timing of each workshop was largely controlled by the other tender period activities. Since the model was tested within a commercial atmosphere, the varying level of detailed information available at different stages in the tender was evident, reinforcing the need for a model which concentrates on the key factors rather than, in the case of network models, requiring a high level of detail in order to operate.

5.3.1 Number of Risk Factors Identified

The brainstorming sessions did not aim to identify a predetermined number of risk factors, or make an assessment of when too many had been identified. The brainstorming ended when the project team had discussed all aspects of the project and felt that the list generated contained all the sources of uncertainty they could perceive. The list on some occasions contained items which were all readily translated to risk factors and became inputs to the model. In other instance, particularly on larger projects (numbers 3, 5, 6 as examples) the list contained many items for which mechanisms to manage the risk or opportunity were developed during the workshop or would be dealt with in the course of preparing the tender, such as contractual issues. In these cases, all items were not translated into risk factors and used as input to the model. Table 5.2 shows the number of risk factors identified for each test project.

Table 5.2 - Number of risk factors identified for the test projects

Project Number	No of Risk Factors Identified
1	12
2	23
3	19
4	14
5	9
6	15
7	9
8	5
9	10
10	18
11	13
12	14
13	9
14	12
15	8

The number of risk factors identified ranges from 5 to 23, with a fairly even distribution between these two extremes. The reason the number of risk factors varies so much is more a function of the view of the managers than a function of the identification process since the number of risk factors to be identified was not specified. If, for Test Project 8, the five risk factors identified satisfy the managers that they describe the key sources of risk to the project, then fixing a minimum number of risk factors which should be identified will only detract from the important aspects of the project described in the five identified previously. One aspect of the project which could influence the number of risk factors identified is the contract value. Figure 5.1 shows the number of risk factors identified plotted against contract value in order that this relationship can be investigated.

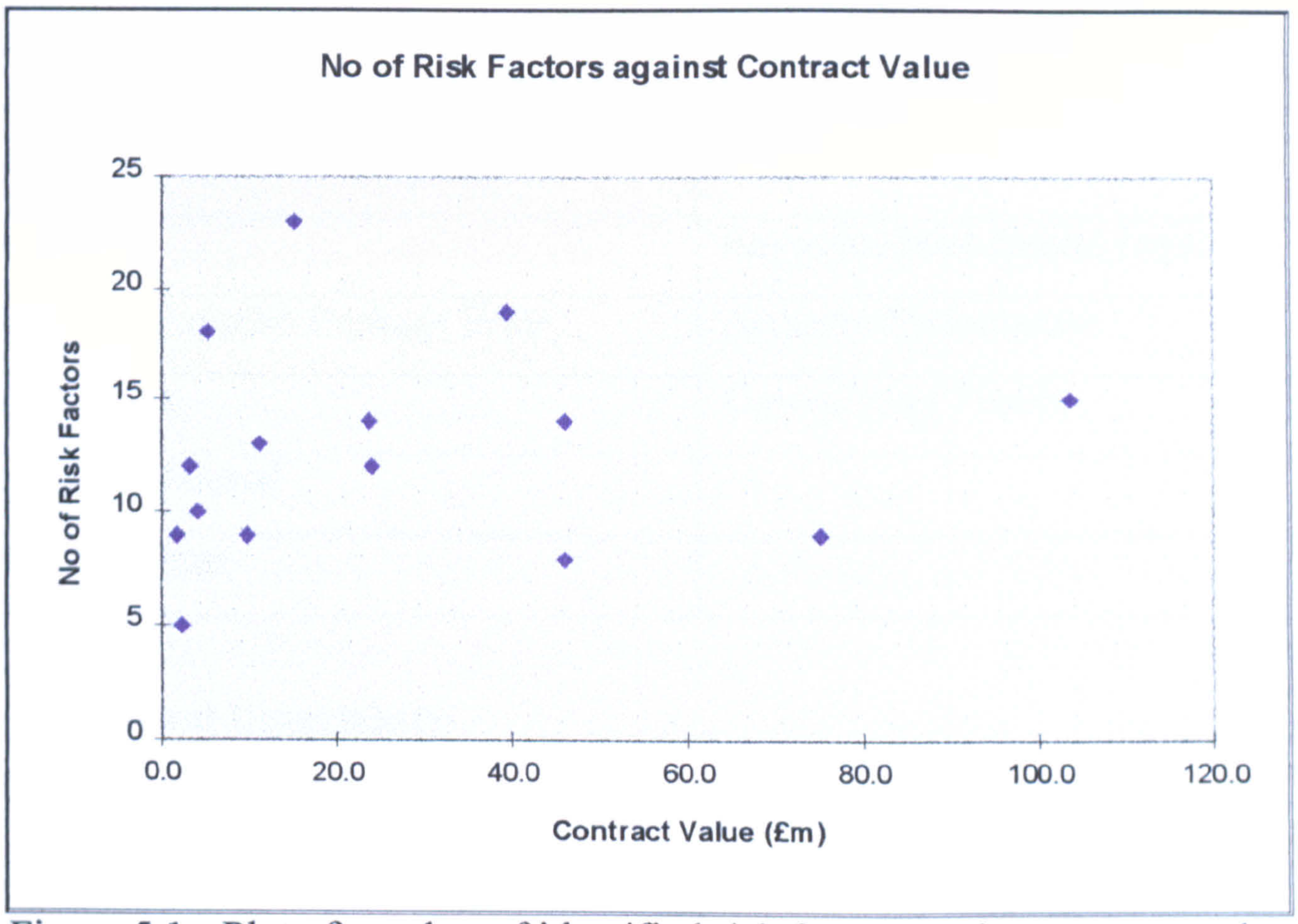

Figure 5.1 - Plot of number of identified risk factors against contract value

The number of risk factors identified appears to be independent of the size of the project. The reason for this is that the project teams are asked to identify the key sources of uncertainty in the project cash flow, with no reference to the magnitude of the effect. If the teams were asked to identify all uncertainties which could have an effect above a specific value, then the number identified would be expected to be correlated with the size of the project.

One situation in which the number identified may be proportional to the contract value is where a project team familiar with projects of a modest value are faced with a significantly larger project. In this case the team may well identify uncertainties with a similar magnitude to previous projects, so identifying more than usual.

5.3.2 Risk Factor Descriptions

The risk factors identified included those relating directly to the categories discussed, and which in time would form part of checklists used on subsequent projects, such as material price, inflation assumptions, subcontractor performance. In addition, several risk factors were identified which were obviously project specific. Examples of both types are shown in Table 5.3.

Table 5.3 - Example risk factors

General Risk Factors (examples)	**Project Specific Risk Factors**
Inflation	Environmental control required
Subcontractor/Supplier Package Price	Acoustic Performance
Weather Effects	Curved Roof Profile
Suitability of Material	
Ground Conditions	

5.3.3 General Uncertainty

General uncertainty in cost, value, or duration, is allowed within the model to enable uncertainty in those measures to be modelled if it is felt that the uncertainty is not adequately dealt with by the risk factors. For all projects, the teams felt that the risk factors identified would adequately model the major sources of uncertainty in direct cost and value and so general uncertainty was not used on those measures. For duration, eight of the projects included general uncertainty in the duration of the project. The different treatment of cost and duration suggests that the project teams felt they have more control of direct cost than they do of duration. The result of this is that the project teams tended to identify more risk factors which could affect cost than they do for duration and then felt that the remaining uncertainty in duration has to be included elsewhere. Although general uncertainty was defined for eight out of the fifteen projects, this could also have been dealt with by defining a risk factor dealing with programme and possible delays. This approach was taken for one project, showing that the model need not allow general uncertainty to be defined separately from the risk factors. However, since separating risk factors from the general uncertainty might help with presentation, such an approach may be beneficial.

5.4 RISK FACTOR QUANTIFICATION

5.4.1 Probability of Occurrence

The second stage of producing the input to the model is to quantify the effects of the risk factors which begins with assigning a probability of occurrence. Although dealing with probabilities was unfamiliar to some members of the project teams, the approach is more appropriate than translating descriptions into probabilities within the model. The experience of the tests has been that managers found the concept of probabilities relatively easy to understand. It must be remembered that the probabilities given are subjective assessments and perhaps more vague than the effects, since the effects can often be related to actual costs whereas the probabilities, because of the lack of historical data, cannot be readily explained. The subjective nature is controlled, to some extent, by forcing the project team, rather than an individual, to assign the probabilities.

5.4.2 Risk Factor Timing

The definition of the effects of the risk factor on the cash flow if it does occur is a more complex task than defining the probability that it does. The first stage is to define when during the project the risk factor occurs and the effects if it does. Although any date can be specified, the most common approach which was used is to allocate risk factors to the phases defined in the base cash flow, if such phases have been defined. Commonly, projects can be divided into design/start-up, construction, and commissioning/handover phases. By allocating risk factor effects to phases, the team can avoid debate on the actual timing of a risk which may distract the team from the task at hand. Obviously, in some instances, the dates between which a risk factor would occur are known and are not adequately represented by the phase dates, for example weather effects, and so the actual dates are used.

Using the approach of allocating risk factor effects to phases, which several projects teams adopted, particularly on projects with long durations, individual risk factors are not limited to a single phase of the project. A risk factor can start at the start of construction and continue until handover is complete. Indeed, this approach can be extended to define a risk factor whose effects begin at the start of the project and continue for its whole duration.

One limitation which was identified on one of the test projects, is the inability to assign the risk factor effects to two non-adjacent phases. There are two situations in which this could be required. One is where the risk factor affects two periods and the effect on each is the same. This situation can arise where work is expected to ceased for a period but no management action can be taken to modify the risk factor's effect in the period when work recommences. In this case, the model could be extended to allow a single risk factor to impact over two time periods. In the second situation, the effect in the second period is different to that in the first. This situation could arise when management action can be taken in response to the effects in the first period. In this case, a risk factor could be used to define each period but the model would then treat them as independent. Further issues of risk factor independence are discussed in Section 10.2.1.

Although the facility to define an uncertain timing for the effects was provided in the model, fixed dates were normally used by the teams. The view of the project teams was that it was the actual effects which deserved their effort, rather than the possible uncertainty in the timing of those effects. Although such an approach, in conjunction with defining the effects based on the phases of the project, may affect the result which is used as input to the company model, the effect should not be significant because the actual dates were defined if it was felt that the phase approach was not satisfactory.

Allowing such approximations in the input data is not ideal, however, since the projects were tested in their tender period, there are several reasons why the above approach was allowed. Firstly, the demands on the time of the project team limited the duration of a risk quantification session and so the objective was to ensure that all risk factors were considered, to whatever degree of accuracy was possible, rather than addressing as many risk factors as possible to the highest degree of accuracy. Secondly, the variation in the accuracy of the information available at tender stage meant that the approximations were in some cases as much as the project teams knew.

5.4.3 Risk Factor Effects

The definition of the effect of the risk factors on cost, value, and duration is based on several shapes, as described in Section 4.5. The shapes are used as they can easily translate the views of the managers into a distribution, starting with the range of possible effects and then describing how the effects are distributed between those two extremes. Table 5.4 shows the distribution types used for each project.

Table 5.4 - Distribution types used for each project

Project Number	No of Risk Factors	Event	Rectangular	Triangular	Trapezoidal	Dual Range
1	12	0	0	12	0	0
2	23	0	0	21	0	2
3	19	1	0	15	0	3
4	14	1	0	7	0	6
5	9	1	1	3	0	4
6	15	0	0	9	2	4
7	9	2	7	0	0	0
8	5	4	0	1	0	0
9	10	5	5	0	0	0
10	18	10	0	8	0	0
11	13	1	2	10	0	0
12	14	3	3	7	1	0
13	9	5	3	1	0	0
14	12	2	0	9	1	0
15	8	2	0	6	0	0
Total	190	37	21	109	4	19
Percentage	**100%**	**20%**	**11%**	**57%**	**2%**	**10%**

The values in Table 5.4 show that the triangular distribution is the most popular. This is not surprising, as the triangular distribution approximates the normal distribution, which describes many naturally occurring uncertainties. The triangular distribution is in some ways more flexible as it can readily represent skewed distributions. The views of managers, as reflected in the figures presented in Table 5.4, are that the triangular distribution can be used to define most of the effects of the uncertainties, although the other shapes are necessary in some instances.

The process of selecting the shape of the distribution was not a task in itself. The task was to describe the uncertainty and from that select the shape which best modelled the effects.

5.5 MONTE CARLO SIMULATION

The objective of the analysis is to combine the various sources of uncertainty in the project cash flow to allow the possible cash flows to be used as input to the company risk model, and to allow the uncertainty to be classified for risk and opportunity. The performance of the model will be tested against each aspect of this objective. The accuracy of the input to the company risk model can be tested without reference to that model by ensuring that the distributions generated are representative of the true uncertainty in the project. Since the distributions produced are an approximation of the true uncertainty, statistical tests can be applied to investigate this. Although the projects were tested during their tender period, when the time was not available for the calibration of the classification system, discussions with the project teams post-tender allowed the assessment of the classification system. The classification system, being an integral component of the system, will be tested also.

Within the Monte Carlo simulator there are several parameters which need to be fixed prior to simulation which will have an impact on the results of the analysis. Although the minimum number of runs of the simulator required to produce a satisfactory answer is extremely important, the first aspect which needs considering is the choice of random number generator itself.

5.5.1 Random Number Generator

Since computers cannot produce true random numbers, and the quantity of numbers required makes storing a list of random numbers difficult, pseudo random numbers are used within the project risk model. Although there are many different types of pseudo random number generator, as discussed in Section 2.4.2.3, not all are suitable for this application. Following the tests performed by Dudewitz and Kennedy (1981), a multiplicative congruential pseudo random number generator is used within the model. The parameters of the generator are as suggested by Dudewitz and Kennedy, 1981, making the generator of the form:

$$X_{i+1} = 663608941.X_i \mod 4294967296$$

5.5.2 Seed Value

The string of random numbers is produced by applying the function defined above to the previous random number. In order to begin the sequence, an initial value must be provided, this being known as the seed value. Although the choice of seed value should not be critical, published random numbers often suggest suitable choices, or list those seed values which do not produce an acceptable string of random numbers.

The choice of seed value does become more important for short run simulations as the string of random numbers generated will not produce a representative sample.

Within the tests performed, as in practice, it is common to investigate the effect a change to a risk factor has on the result. In this instance, if a different seed value was used for the second, comparison analysis, the different random numbers would produce a different result for each risk factor, producing a different, although equally valid, result. If the same seed value is used to begin each analysis, the results can be readily compared as the difference between the two will be a consequence of the changes made to the model rather than the random numbers used to sample from the model. This approach is only useful if a risk factor has been modified; if a new risk factor is added or one removed from the model, the number of random numbers required for each run of the simulator will be different, resulting in the random numbers used in the second and subsequent runs of the second analysis being different to those of the original.

5.5.3 Number of Runs Performed

Since Monte Carlo Simulation is a sampling technique, the more runs performed, the more representative of the true result the distribution produced will be. Unfortunately, the number of runs is directly proportional to the time taken to perform the analysis, and as described earlier the time available to undertake such analyses in practice is limited due to the time restrictions of the tender process. The number of runs which should be performed will therefore be a balance between the time allowed to undertaken the analysis and the desired accuracy.

To determine the number of runs required, the accuracy of the result has been evaluated for increasing numbers of runs to investigate the performance of the model.

5.5.3.1 Required Output of the Analysis

One objective of the model is that it allows the various sources of uncertainty in the project to be combined to produce a single source for input to the company risk model. A sub-objective is that the model classifies the final outcome of the project for risk and opportunity to allow comparison with other projects and the result to be easily communicated.

The input to the company risk model will be of a higher required accuracy due to its use in its raw form, rather than the classification system which may require a lower accuracy distribution. As a result, the statistics of the distributions will be examined rather than the results of the classification system. Although the company risk model uses the distributions for each time period as input, the final profit of the project will be used for the tests as this produces a meaningful statistic and is also used as input to the risk and opportunity classification system.

5.5.3.2 Objective of the Test

Although the distribution of the final outcome has been selected as the focus of the tests, the method by which the accuracy of the distribution is to be assessed has to be determined. There are several aspects of the distribution which are of concern; although the mean gives a measure of the expected outcome, the way in which the other outcomes are distributed around that mean is of equal, if not greater, importance. One statistical measure which combines both the mean and standard deviation is the confidence limit of the mean. This test produces a limit within which the true mean lies with a given confidence. The test derives from the Central Limit Theorem (Wilson, 1972), which assumes that the resultant distribution tends towards a normal distribution. Working to a confidence limit of 95% (i.e. we want to be 95% confident that the true mean is within the limit defined), the limit, δ, is given by the equation below.

$$\delta = 1.96\left(\frac{\sigma}{\sqrt{n}}\right)$$

where 1.96 is taken from a standard normal distribution table for a 95% limit, σ is the sample standard deviation, and n is the number of runs performed.

The true mean, μ, then would lie between the limits,

$$\bar{x} - \delta < \mu < \bar{x} + \delta$$

where $\bar{x}$ is the sample mean.

For the example project used in Chapter 4, Test Project Number 1, the values of $\bar{x}$, σ, and δ for increasing values of n are shown in Table 5.5.

Table 5.5 - Mean, sigma and delta for the test project 1 for various numbers of runs

No of Runs	$\bar{\mu}$	σ	δ
100	176.944	29.260	5.73496
200	175.627	28.197	3.907905
300	176.162	28.322	3.204936
400	175.974	28.980	2.84004
500	176.292	28.693	2.515052
600	176.410	28.295	2.264072
700	176.617	27.942	2.069972
800	176.822	27.69	1.918819
900	176.182	27.601	1.803265
1000	175.62	27.906	1.729632
1100	175.613	27.804	1.643111
1200	175.446	27.754	1.57033
1300	175.377	27.648	1.502962
1400	175.323	27.859	1.459344
1500	175.588	27.833	1.408544
1600	175.655	27.81	1.36269
1700	175.536	27.756	1.319436
1800	175.730	27.887	1.288314
1900	175.543	27.865	1.252963
2000	175.612	27.757	1.216504
2100	175.56	27.828	1.190223
2200	175.548	27.893	1.165574
2300	175.456	27.864	1.138769
2400	175.251	27.969	1.118993
2500	175.000	28.238	1.10693
2600	174.951	28.326	1.088816
2700	175.001	28.322	1.068312
2800	175.021	28.27	1.047135
2900	175.045	28.284	1.029433
3000	175.072	28.185	1.008587
3100	175.091	28.213	0.993172
3200	175.083	28.181	0.976422
3300	175.338	28.207	0.962401
3400	175.501	28.231	0.948949
3500	175.624	28.202	0.934334
3600	175.532	28.207	0.921429
3700	175.548	28.242	0.910019
3800	175.492	28.202	0.896694
3900	175.477	28.174	0.884244
4000	175.526	28.155	0.872532
4100	175.439	28.21	0.86351
4200	175.494	28.207	0.853077
4300	175.439	28.234	0.843906
4400	175.389	28.169	0.832341
4500	175.396	28.191	0.823683
4600	175.389	28.138	0.813149
4700	175.396	28.102	0.803423
4800	175.32	28.135	0.795944
4900	175.219	28.085	0.78638
5000	175.247	28.125	0.779585

The above shows that as the number of runs increases, the value of delta (the confidence limit) decreases, suggesting that the distribution is becoming increasingly representative of the true distribution. This is illustrated in Figure 5.2 which plots the mean and the confidence limit for increasing numbers of runs.

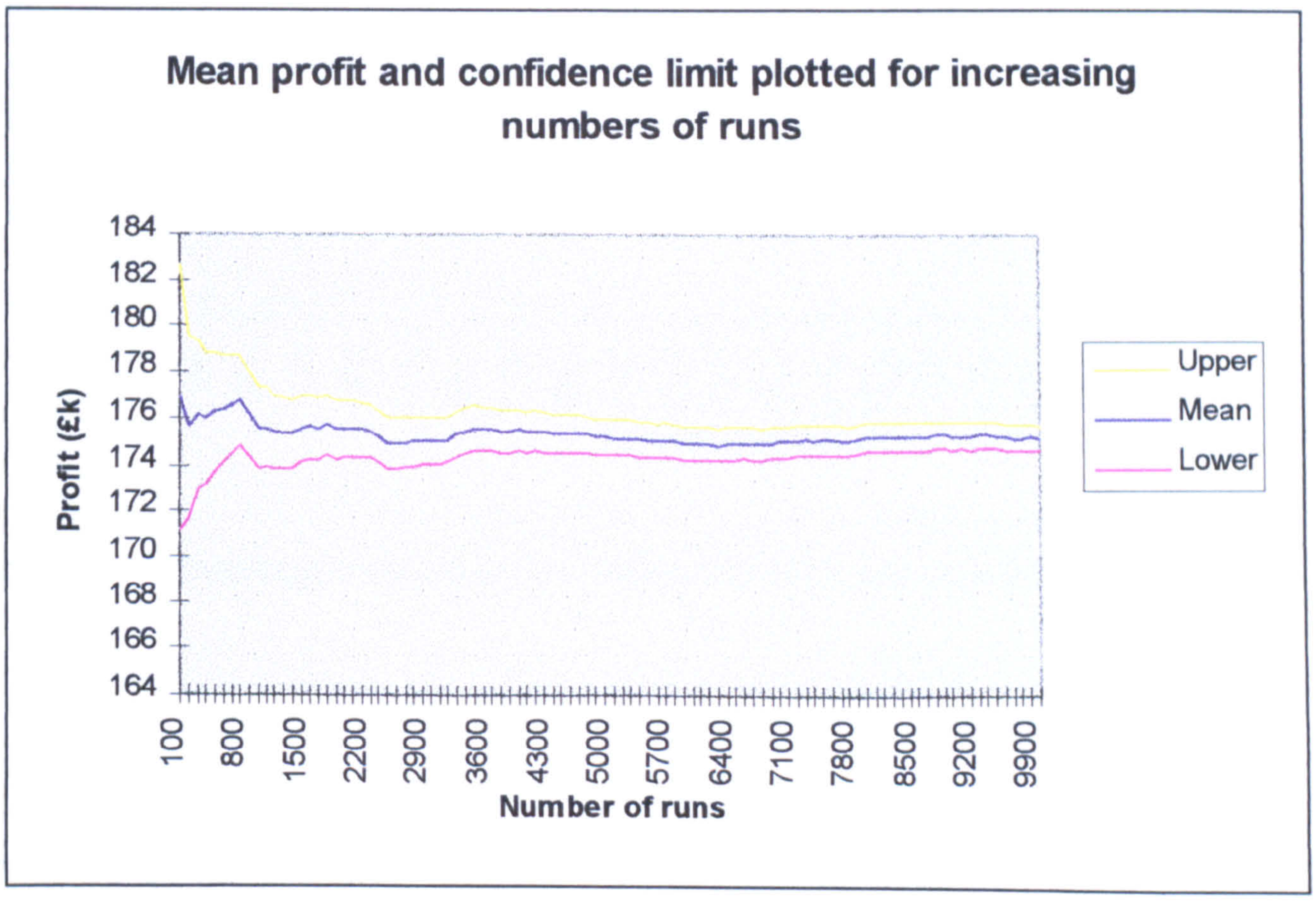

Figure 5.2 - Mean profit and confidence limit plotted for increasing numbers of runs

Since the accuracy of the distribution produced will increase with the number of runs performed, the confidence limit will continue to reduce. The objective of the test is not to minimise delta, but to determine how many runs are required for the distribution to be of acceptable accuracy. Since it is expected that the rate of decrease in the confidence limit should be continuously reducing, the number of runs required to produce a result of the required accuracy can be gained by performing as many as is required so the rate of decrease is lower than a significant amount. The change in the confidence limit for increasing numbers of runs is plotted in Figure 5.3.

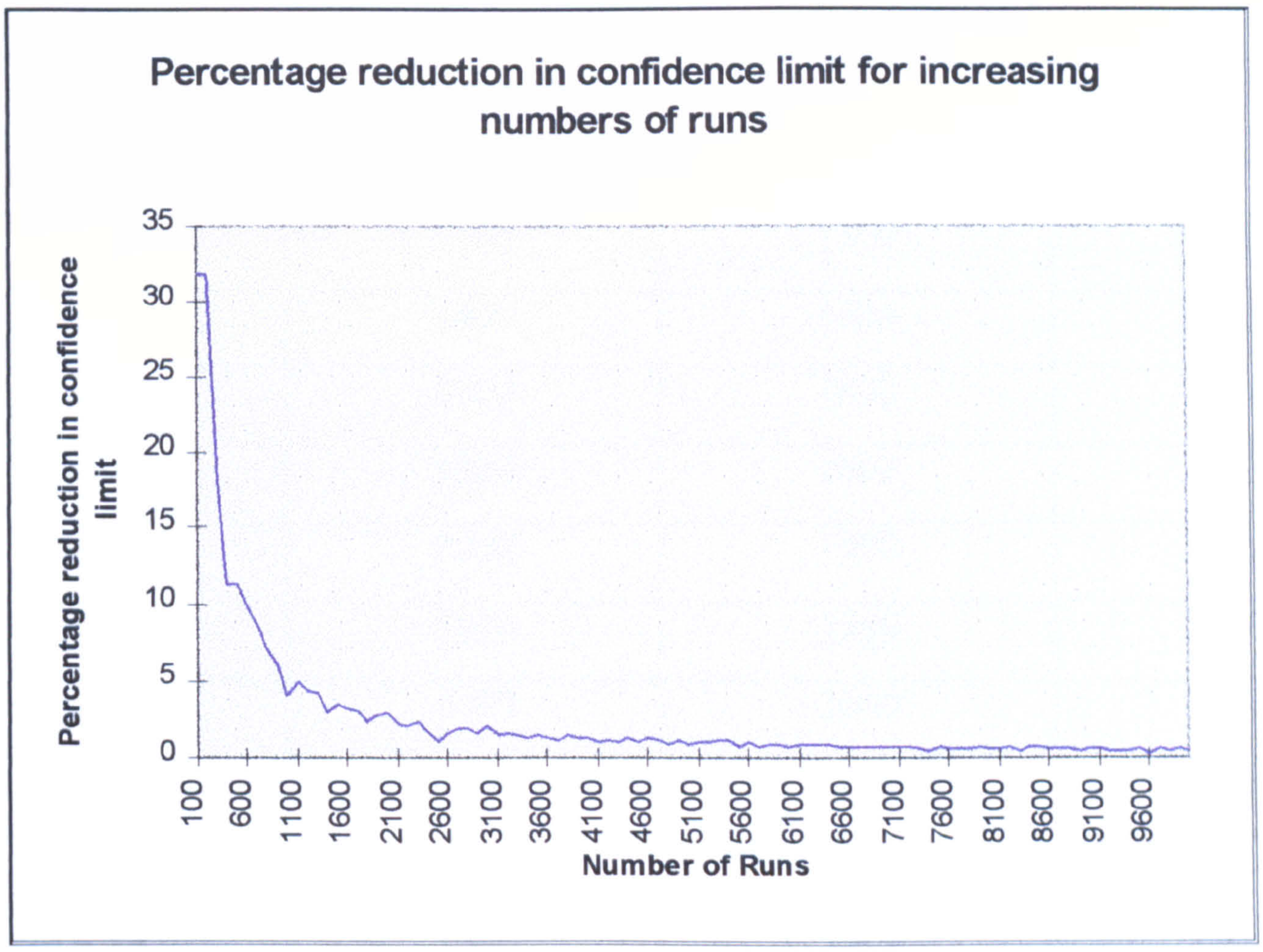

Figure 5.3 - Percentage reduction in confidence limit for increasing numbers of runs

Figure 5.3 shows the percentage change in the confidence limit decreases rapidly over the first 1000 runs, with the rate of decrease slowing over the subsequent 500 runs, with the decrease per 100 runs being greater than 4% before 1300 runs, greater than 3% until 1700 runs, and greater than 2% until 2300 runs have been performed.

Viewing the mean and confidence limits shown in Figure 5.2 shows the mean begins to settle down after 1500 runs. The results in Figure 5.3 show that at this point the reduction in the confidence limit has reduced to between 3% and 4% per 100 runs. From this project the general rule of performing as many runs as necessary to produce a decrease in the confidence limit of less than 3% per additional 100 runs performed could be formulated. The validity of this rule will be tested against the other 14 test projects, the results of which are presented in Table 5.6.

Table 5.6 - Number of runs required to produce a reduction in the confidence limit

Test Project	Number of Runs for Reduction in Confidence Limit		
	<4 %	<3%	<2%
Test 1	1300	1700	2300
Test 2	1400	1900	3000
Test 3	1500	1800	2900
Test 4	1300	1600	2700
Test 5	1700	1900	3200
Test 6	1800	1900	3200
Test 7	1400	2000	2700
Test 8	1400	1600	3000
Test 9	1400	1800	2900
Test 10	1400	1900	3200
Test 11	1500	2000	2600
Test 12	1200	1900	2800
Test 13	1200	1800	2700
Test 14	1300	1700	2600
Test 15	1400	1700	2400

The results in Table 5.6 show that although the number of runs to produce a decrease of less than 4% in the confidence limit is not consistent across projects, the number of runs for a change less than 3% is fairly consistent at around or just less than 2000. It is expected that the number of runs required to produce a representative result is dependent on the number of random variables, or risk factors, and the range of possible values for each one. The above shows that, although the distribution produced is not representative for the first few hundred runs, at around 2000 runs, irrespective of the number of risk factors, the distribution begins to be representative of the true distribution. The reason for this is, although the number of and the uncertainty defined for each risk factor contribute to the uncertainty in the resultant distribution, the test is looking at the ability to predict that distribution and the percentage, rather than absolute, gains in accuracy with an increase in the number of runs performed. Consequently, the model will be set to perform 2000 runs of the simulator.

5.6 OUTPUT OF THE MODEL

Having set the inputs to the model and the parameters required to perform the analysis, the results of the model can be investigated. The results will be viewed firstly to assess their use as input to the company risk model, and then to assess the performance of the risk and opportunity classification system.

5.6.1 Cashflow Uncertainty

The company risk model requires the various sources of uncertainty in a project to be combined and reflected in the cashflow. The company risk model views each project as an uncertain contribution to its cashflow.

After performing 2000 runs of the Monte Carlo Simulator on a project, the results can be stored in several ways. For each run, the effects of the risk factors are selected at random to produce a single possible cashflow for the project. The simplest method of storing the results is to record each cash flow as it is produced. Each cashflow would be stored as a start month, number of months, and then the cost and value for each of those months.

The drawback of this approach, in addition to the amount of storage space needed, is that it can only produce as many cash flows for input to the company risk model as were generated originally, and that when it is viewed in graph form, as demonstrated in the previous chapter (see Figure 4.8), although the extremes are immediately identifiable, the relative likelihood of any outcome between the those two is not obvious.

Producing a distribution of outcomes in each time period, as is done for the final outcome, does allow the probability of outcomes between the two extremes to be determined. An example of the output in this form was also given in the previous chapter (see Figure 4.9).

Storing the results in distribution form, in addition to being more informative when viewed graphically and more space efficient, allows more cash flows to be produced from it than were used to create it by using Monte Carlo Simulation. However, this approach has the drawback that the distribution in each time period would be viewed as independent of the distributions in other time periods. The result is that the cash flows produced would not necessarily be representative of the true cashflows the project might produce.

The conclusion to be drawn from this is that, since presenting the results in distribution form is preferable to individual cashflows, and the reverse is true for storage and input to the company risk model, both methods should be employed.

5.6.2 Distributions of Final Outcome

At the project level, although the cashflow contributions to the business unit are important, the performance of the project will be assessed by examining its final position with respect to the targets set for each project. While the Monte Carlo Simulation is being performed, distributions are produced of the final cost, value, profit, and duration for the project. These are created by defining the interval size to which the results are to be differentiated. Presented in Figure 5.4 is the frequency distribution of final profit for Test Project 1 using an interval size of £6k. The interval size is set knowing there are 50 intervals and the range required is £3m.

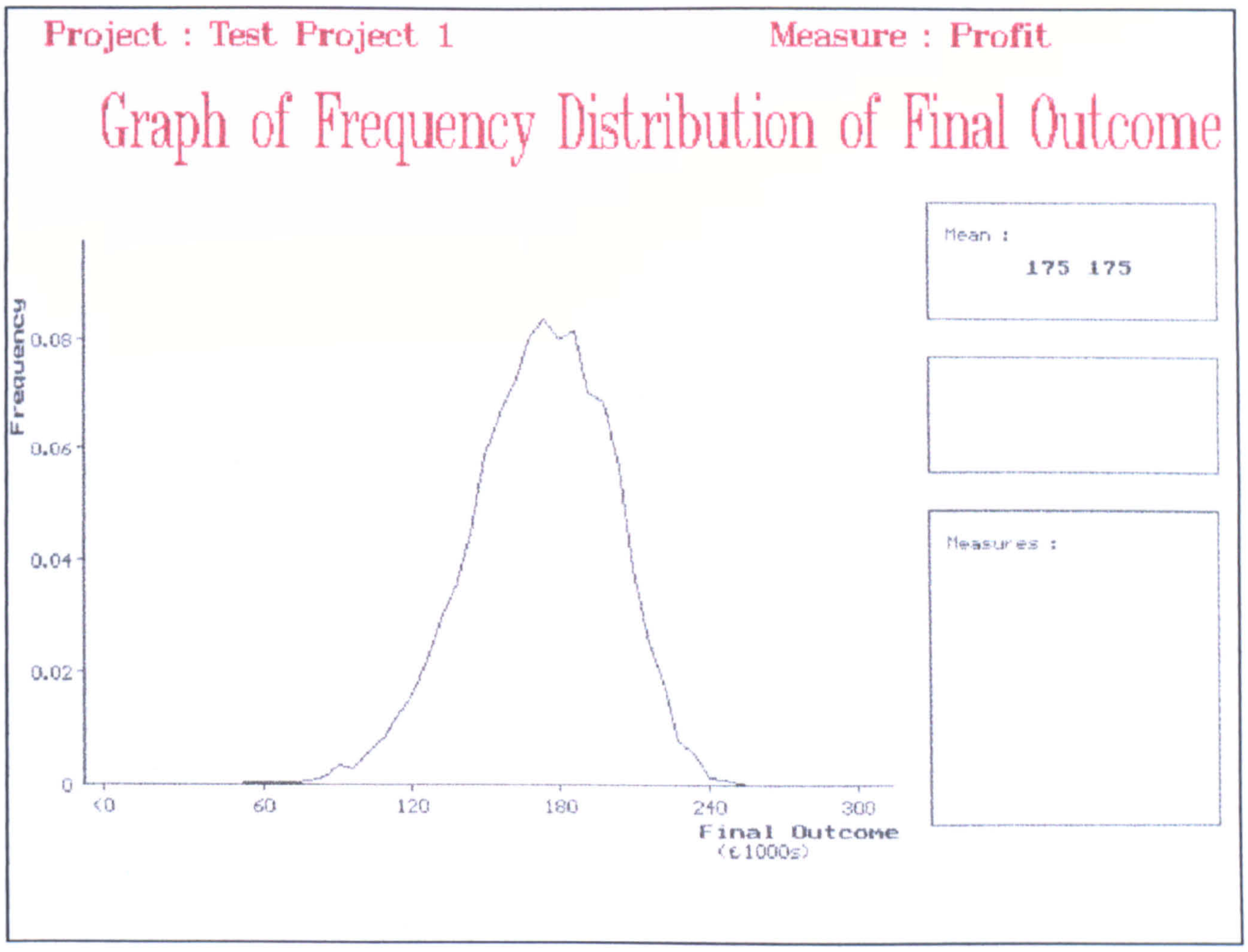

Figure 5.4 - Frequency distribution of final profit for Test Project 1

The graph in Figure 5.4 shows not only the range of possible profits for the project but the relative likelihood of any profit between those two and the most likely outcome. Similar distributions are produced for cost, value, and duration.

5.7 RISK AND OPPORTUNITY CLASSIFICATION SYSTEM

When assessing the performance of the project against its profit target, the target can be plotted on the graph of frequency distribution of final profit, with all outcomes to the right of the line being regarded as opportunities, as the profit target has been exceeded, and all those to the left being risks as the target has not been attained. In order to improve the communication of the risk and opportunity in the project, the classification system views the outcomes described above to produce a single number for risk and one for opportunity, ranging from 0 to 10, reflecting negligible to extreme.

5.7.1 Results for All Test Projects

In Section 4.8, the functions for the classification system were defined. The sensitivity and relative importance of each parameter were set in order to reflect the views of the managers involved, and so the weights suggested in that Chapter, with the mean being more important than the extreme, which is in turn more important than the probability, will be tested to assess whether they produce meaningful results when a project is modified.

Table 5.7 shows the mean, minimum, and maximum profits for each project and the probability of making a profit (setting the threshold level at zero). It is against these results that the classifications will be made.

Table 5.7 - Profit results for test projects used as input to classification system

Project	Mean Profit	Minimum Profit	Maximum Profit	Prob of Profit
Test 1	174,983	67,725	248,186	100.0%
Test 2	1,009,225	-351,094	1,706,600	99.5%
Test 3	324,225	-1,147,643	1,307,250	80.9%
Test 4	3,614,571	2,253,420	4,568,219	100.0%
Test 5	7,674,575	4,324,581	8,959,082	100.0%
Test 6	7,211,637	1,455,134	9,476,221	100.0%
Test 7	34,815	5,937	69,136	100.0%
Test 8	127,176	98,194	136,510	100.0%
Test 9	312,348	227,909	392,799	100.0%
Test 10	129,805	67,915	195,199	100.0%
Test 11	198,367	-271,981	553,268	94.4%
Test 12	-614,841	-1,287,205	51,659	0.015%
Test 13	416,676	-260,201	1,084,505	90.9%
Test 14	1,612,416	320,795	2,897,433	100.0%
Test 15	311,358	-1,045,339	1,425,950	80.3%

The results in Table 5.7 show that all but one of the projects (Project 12) are expected to make a profit, with only six of the projects ever making a loss. The result of this, setting the threshold at zero, is that only six of the projects will return a risk classification greater than zero.

Table 5.8 shows the contributions of mean, extreme, and probability for the risk and opportunity of each test project, resulting in the risk and opportunity classification shown using the proportions 5:3:2 as set out in the previous chapter.

Table 5.8 - Mean, extreme and probability contributions to risk and opportunity classifications

Project		Mean	Extreme	Prob	Classification
Test 1	Risk	0.0	0.0	0.0	0.0
	Opp	5.4	3.9	10.0	5.9
Test 2	Risk	0.0	1.1	0.7	0.5
	Opp	6.3	5.3	10.0	6.7
Test 3	Risk	0.0	1.1	4.4	1.3
	Opp	0.8	1.7	9.0	2.7
Test 4	Risk	0.0	0.0	0.0	0.0
	Opp	7.9	5.0	10.0	7.4
Test 5	Risk	0.0	0.0	0.0	0.0
	Opp	10.0	6.0	10.0	8.8
Test 6	Risk	0.0	0.0	0.0	0.0
	Opp	7.0	4.6	10.0	6.9
Test 7	Risk	0.0	0.0	0.0	0.0
	Opp	2.0	2.0	10.0	3.6
Test 8	Risk	0.0	0.0	0.0	0.0
	Opp	5.6	3.0	10.0	5.7
Test 9	Risk	0.0	0.0	0.0	0.0
	Opp	8.0	5.0	10.0	7.5
Test 10	Risk	0.0	0.0	0.0	0.0
	Opp	2.5	1.9	10.0	3.8
Test 11	Risk	0.0	1.2	2.4	0.8
	Opp	1.8	2.5	9.7	3.6
Test 12	Risk	2.6	2.7	10.0	4.1
	Opp	0.0	0.0	0.4	0.1
Test 13	Risk	0.0	1.4	3.0	1.0
	Opp	4.4	5.7	9.5	5.8
Test 14	Risk	0.0	0.0	0.0	0.0
	Opp	6.6	6.0	10.0	7.1
Test 15	Risk	0.0	1.1	4.4	1.2
	Opp	0.7	1.6	9.0	2.6

The risk and opportunity classifications are plotted in Figure 5.5, showing that the classifications are distinguishing between projects for risk and opportunity and yet are not excessively sensitive. For clarity, the opportunity classification is plotted above the line, while the risk classification, to reflect its negative impact, is plotted as a negative value below the line. This form of presentation allows the difference between the risk and opportunity classifications to be readily determined.

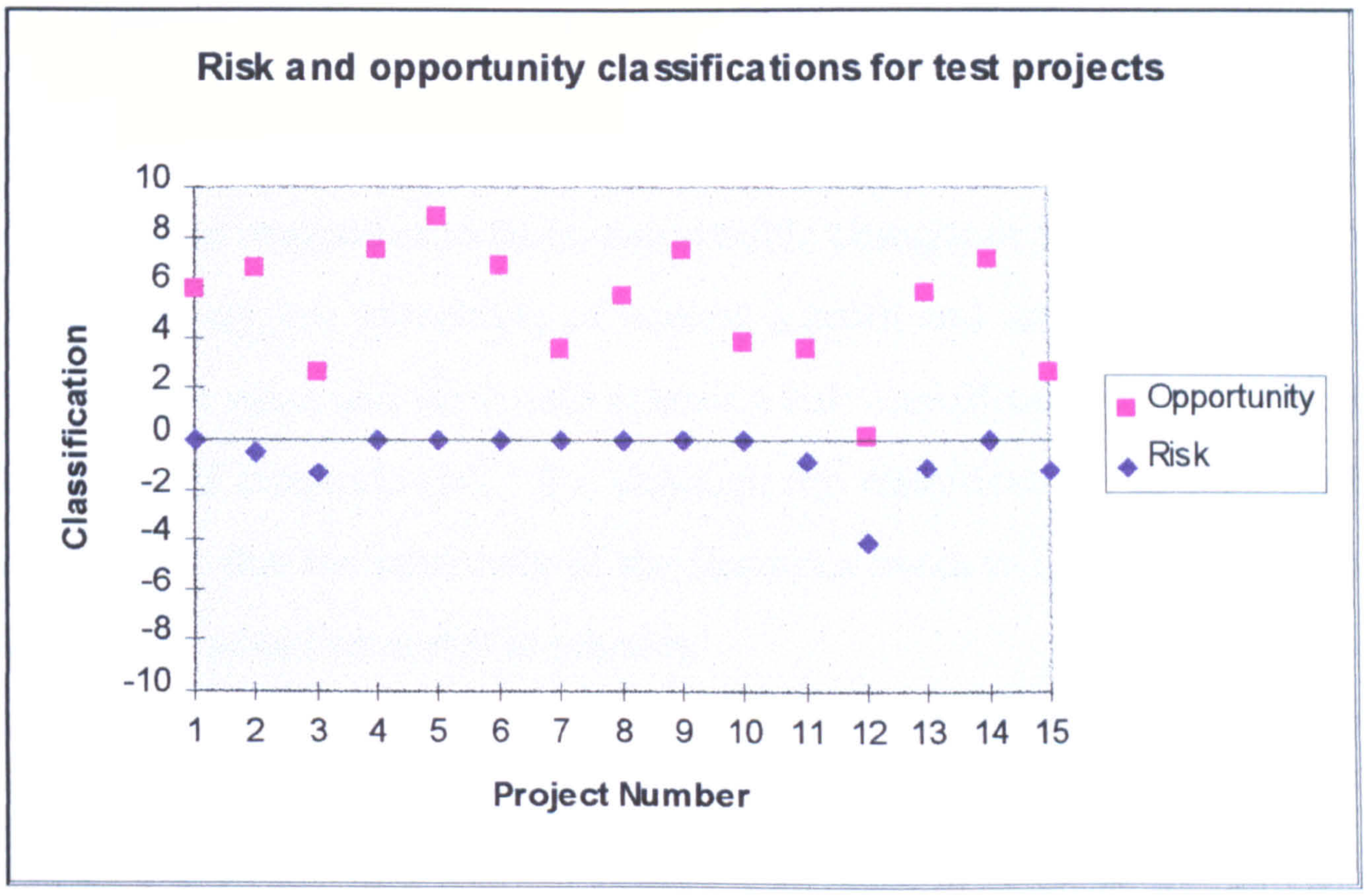

Figure 5.5 - Risk and opportunity classifications for test projects

In order to assess the extent to which the classifications reflect the uncertainty in the projects, Table 5.9 shows the range of profit for each project, expressed as a percentage of the contract value, and the risk and opportunity classifications.

Table 5.9 - Profit characteristics expressed as percentage of contract value and risk and opportunity classifications

Project	Mean Profit	Minimum Profit	Maximum Profit	Risk	Opportunity
1	5.4	2.1	7.7	0.0	5.9
2	6.3	-2.2	10.7	0.5	6.7
3	0.8	-2.9	3.3	1.3	2.7
4	7.9	4.9	9.9	0.0	7.4
5	10.2	5.8	11.9	0.0	8.8
6	7.0	1.4	9.1	0.0	6.9
7	2.0	0.3	4.0	0.0	3.6
8	5.5	4.3	6.0	0.0	5.7
9	8.0	5.8	10.1	0.0	7.5
10	2.5	1.3	3.7	0.0	3.8
11	1.8	-2.5	5.0	0.8	3.6
12	-2.6	-5.4	0.2	4.1	0.1
13	4.3	-2.7	11.3	1.1	5.8

14	6.6	1.3	11.9	0.0	7.1
15	0.7	-2.3	3.1	1.2	2.6

Inspection of the results shown in Table 5.9 shows that the greater the range of possible profits, when expressed as a percentage of the contract value, the greater the risk and/or opportunity classifications. However, one observation which can be made is that the classifications seem insensitive to quite considerable changes in the results. For example, Project 12 has a very low probability of making a profit and can lose the company over 5% of the contract value and yet it only returns a risk classification of 4.1, which should reflect a project of moderate risk. So, although the classifications distinguish between projects, it may be that the sensitivity of the functions needs to be increased in order that the classifications would be useful in practice.

5.7.2 Classification Sensitivity

The sensitivity of the functions is controlled by, for each component (mean, extreme, and probability) setting the range over which the function will be sensitive and then scaling the output back to an answer between 0 and 10. In the example so far, the mean profit has been limited to ±10% of the contract value, and the extreme limit has been set at twice that. In order to increase the sensitivity of the classifications, either or both of these values can be changed. To illustrate this, the sensitivity of the function can be increased by reducing the range to ±5% for the mean component and ±10% for the extreme components. The resulting classifications are as shown in Table 5.10 below.

Table 5.10 - Increased sensitivity risk and opportunity classifications

Project Number	Risk	Opportunity
1	0.0	9.3
2	0.8	10.0
3	1.7	3.6
4	0.0	10.0
5	0.0	10.0
6	0.0	9.7
7	0.0	5.2
8	0.0	8.8
9	0.0	10.0
10	0.0	5.6

11	1.2	5.2
12	6.2	0.1
13	1.4	9.3
14	0.0	10.0
15	1.6	3.4

Figure 5.6 shows the increased sensitivity risk and opportunity classifications plotted in a similar manner to Figure 5.5, with risk plotted as negative values to reinforce the negative impact of risk.

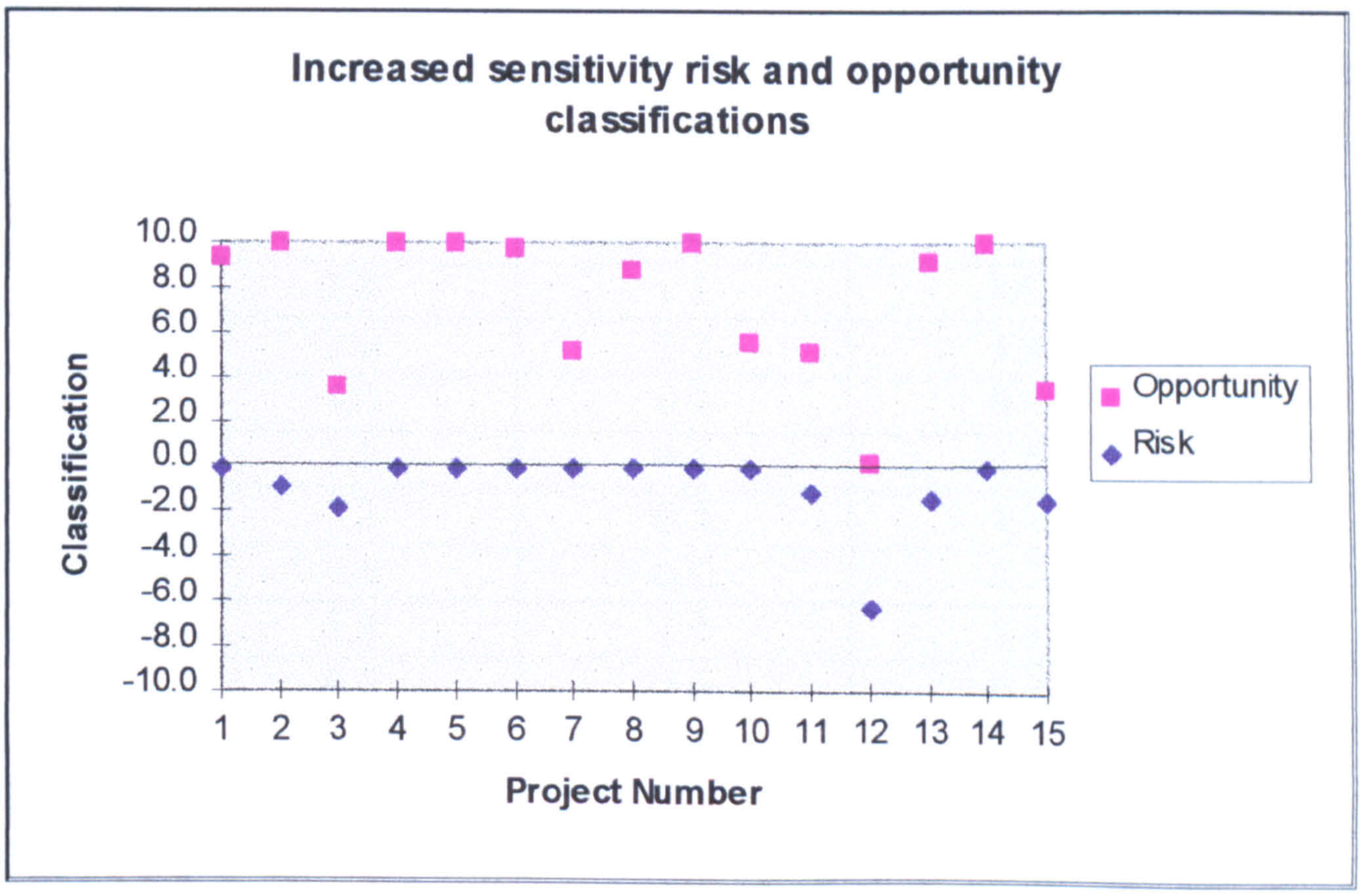

Figure 5.6 - Increased risk and opportunity classifications

Comparing the original with the increased sensitivity classifications, the maximum risk classification has increased from 4.1 to 6.2 and the maximum opportunity classification has increased from 8.8 to 10.0, with the maximum opportunity being returned for five of the projects. Whether this has made the classifications, especially the opportunity, too sensitive is a matter for the managers. One aspect which perhaps is affecting the analysis is that the projects tested are from various sectors and of a wide range of contract values. For example, a £100m design-build development might be expected to produce a higher return (in terms of percentages) than a £5m traditionally procured road project. The different expectation across the sectors and project sizes suggests the calibration of the classifications must be sector specific.

5.7.3 Impact of threshold level on classifications

As demonstrated in Section 4.8.4, the threshold level between risk and opportunity has a significant impact on the classifications. In that section, the threshold level was increased, from zero, to the expected level of profit. If a similar approach is taken with the other test projects, the classifications presented in Table 5.11 are produced if both the original and sensitive classifications are used.

Table 5.11 - Risk and opportunity classifications using expected profit as the threshold level

Project Number	Original Risk	Original Sensitivity	Sensitive Risk	Sensitive Opportunity
1	2.8	1.1	3.8	1.3
2	2.6	2.2	3.9	2.8
3	4.3	0.0	6.6	0.0
4	3.2	0.6	4.5	0.7
5	3.3	0.5	4.7	0.6
6	4.4	0.0	6.7	0.0
7	1.8	1.6	2.1	1.9
8	0.2	2.6	0.3	3.3
9	0.0	4.4	0.0	6.7
10	0.0	3.3	0.0	4.7
11	5.0	0.0	8.0	0.0
12	3.0	1.1	4.1	1.3
13	7.1	0.2	10.0	0.3
14	3.6	1.4	5.5	1.9
15	2.4	1.4	3.1	1.7

The output of the classifications using the original functions, setting the threshold at zero and the expected profit, are plotted below in Figure 5.7, again with risk plotted as a negative result.

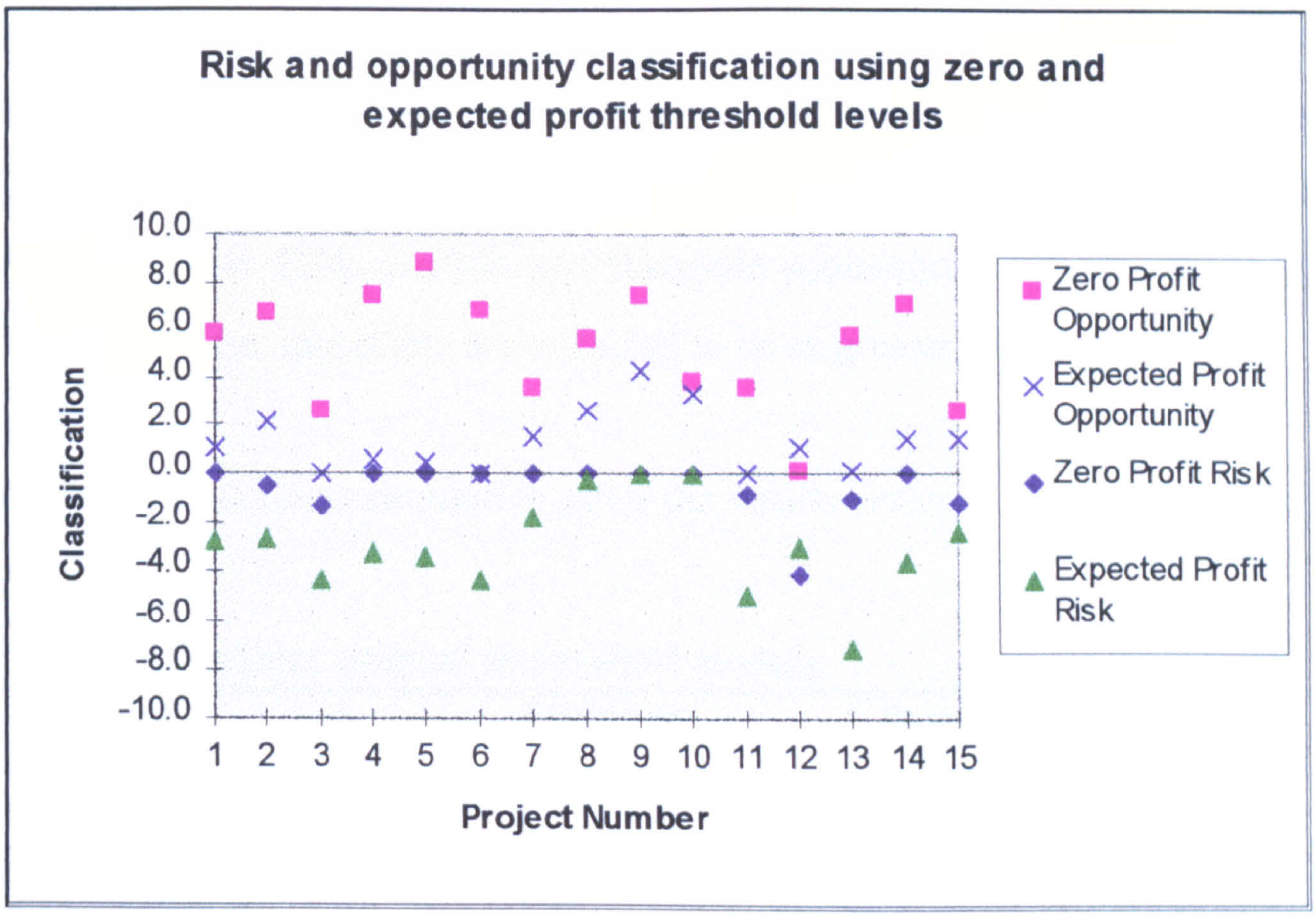

Figure 5.7 - Risk and opportunity classifications using zero and expected profit threshold levels

The above comparison shows that the threshold level has a significant impact on the output of the classifications. In the majority of cases, the classifications when the expected profit is used as the threshold level are significantly different to those produced when zero profit is used. In all but one project the use of the expected profit has reduced the opportunity classification and increased the risk classification. In Project 12 the opposite happened as this project was expected to make a loss.

5.7.4 Use of the classifications within a tender appraisal

Having demonstrated that the classification system does classify the risk and opportunity in the final profit of a project, albeit with modifications to the sensitivity, one further aspect requires examination. The project risk model, of which the classification system is part, is designed to assist in a tender appraisal. The extent to which the classification system can assist in the process will be examined.

Referring back to Test Project 1, if the results produced so far relate to an analysis undertaken during the period in which the tender was being produced, examination of the results by the managers may allow decisions to be made which affect the project. For example, the managers' view might be that general inflation and an anticipated increase in workload could increase the subcontract prices. In the model, this could be reflected by increasing the worst case effects on cost for the specialist subcontractor procurement to be increased from £10k to £50k and domestic subcontractor procurement increased from £10k to £25k (as specialists are expected to be in greater demand).

Rerunning the Monte Carlo simulation gives the results presented in Table 5.12 below.

Table 5.12 - Results from original and revised models

Statistic	Original	Increased Subcontract Costs
Mean Profit	175 612	157 037
Minimum Profit	58 725	27 461
Maximum Profit	256 197	251 276
Risk	0.0	0.0
Opportunity	5.9	5.6

The results in Table 5.12 show that, as expected, increasing the worst case for two risk factors reduces all three profit statistics. The reduction of the opportunity classification, from 5.9 to 5.6 shows that the system is reflecting the reduction in opportunity if the risk in the subcontract prices increases. Continuing with the example, since the uncertainty in the subcontract prices has increased the uncertainty in the final profit, the management might consider entering partnering arrangements with the key subcontractors. Such arrangements would reduce the uncertainty in the total subcontract price but at a premium. The increased expected cost could be modeled in two ways.

The first way is to include the partnering premium in the estimated cost, leaving only the remaining uncertainty in the risk factor effects. The second way, since the risk factor has a 100% chance of occurring, is to increase the best case, i.e. the lower effect on cost, to the price of the premium and the upper effect on cost to be the worst case including the cost of the premium.

The view of the managers might be that entering into partnering arrangements with the key subcontractors would bring the uncertainty back to that previously envisaged, albeit at a cost of £20k. Rerunning the Monte Carlo simulation with these amendments produces the results shown in Table 5.13 below.

Table 5.13 - Results of partnering arrangement analysis compared to increased uncertainty

Statistic	Increased Subcontract Costs	Partnering Arrangement
Mean Profit	157 037	155 612
Minimum Profit	27 461	38 725
Maximum Profit	251 276	236 197
Risk	0.0	0.0
Opportunity	5.6	5.5

It appears from the results in Table 5.13 that the partnering deal decreases rather than increases the opportunity to the business. Although the uncertainty has reduced, the price which was paid for that reduction (which reduced the mean profit) was too high. If the premium paid for the reduction was lower, at only £10k, rerunning the analysis gives an opportunity classification on 5.7, reflecting an increase in opportunity. This analysis illustrates the trade between risk and opportunity with an increase in costs being traded for a reduction in uncertainty. If the increase is too high, the trade does not give good value for money in that it does not increase the overall opportunity to the business. The opportunity classifications take into account the expected outcome as well the best case. In this example, if the premium were £15k, the opportunity classification returned would be the same as analysis without the partnering agreement, showing the balance between the fixed increase in cost and the uncertain greater increase.

5.8 SUMMARY

This chapter has tested the project risk model against its objectives of combining the sources of uncertainty in the project cash flow to act as input to the company risk model and to allow the project to be classified for risk and opportunity in its own right to assist the appraisal of the project at tender.

The following chapter presents the company risk model, describing it in terms of its objectives and how it links with the project risk model.

CHAPTER 6

THE COMPANY RISK MODEL

6.1 INTRODUCTION

Chapter 3 introduced the concept of a hierarchical system for managing risk, in which each level of the organisation views its operations as single sources of uncertainty. Relating the resultant uncertainty to the objectives of that level produces the risks and the opportunities the level is exposed to. The chapter proceeded to show that even if only projects were to be considered, a system of this type was needed to allow the risks from the projects to the business unit undertaking them to be managed; assessing projects in isolation does not reflect the risks to the business unit which will ultimately undertake them. In order to maintain the hierarchical approach, Chapter 5 presented the project risk model, which allows the sources of uncertainty in an individual project to be modelled, resulting in the combined uncertainty in the project. This combined project uncertainty is then used as input to the model presented in this chapter, in addition to giving an understanding of the project which is useful for tendering purposes.

This chapter begins with a discussion of the objectives of the model, before presenting the model, with a discussion of the components and input to it. The chapter concludes with a description of the risk and opportunity classification used.

Throughout this chapter, as a means of demonstrating the use of the model in terms of its input and output, an example business unit will be used. This will be introduced in Section 6.4, and developed throughout the remainder of the chapter. Detailed testing of the model is presented in Chapter 7, in which the example will be expanded.

6.2 OBJECTIVES OF THE MODEL

As discussed in Chapter 3, projects are not independent entities and so to gain an understanding of the risks they produce, they must be viewed firstly in conjunction with the other activities of the business unit, and secondly against the objectives of the business. The model must therefore allow the uncertainties from individual projects to be combined in order that the uncertainty the business unit is exposed to can be assessed against its objectives. The discussion in Section 3.3.1 identified the two common business unit objectives of turnover and profit. In terms of risks and opportunities, while profit can have risk and opportunity, turnover has the risk that the target is not achieved and the risk that the target is exceeded. Having combined the various sources of uncertainty from projects, the resultant must be classified for risk and opportunity against the objectives of the business unit.

6.3 THE MODEL

6.3.1 Business Unit Cash Flow

The two objectives of the model listed above, of combining the sources of uncertainty and then classifying that uncertainty against the business unit objectives, are attained by studying the cash flow of the business unit, as the projects which comprise the business can be represented as contributions, albeit uncertain, to that cash flow. It is therefore the uncertainty in the cash flow which is evaluated, rather than the uncertainty relating directly to the objectives. This approach was used for the project risk model, as it is better to produce one measure which can be used to reflect multiple objectives. In this case, the cash flow can be used to reflect both profit and turnover targets, which will be evaluated for each time period.

For the example company, which will be used throughout the chapter, the target turnover is £60m, with a desired profit of 3% on that turnover. These targets are used to determine which projects should be pursued, in addition to assessing the risk and opportunity in the resultant company.

The model incorporates Monte Carlo Simulation, in that it produces a finite number of possible cash flows for the company which are representative samples of the true cash flow. The same number of runs as performed in the project risk model will be undertaken as the testing of that model showed that 2000 runs was the minimum required to produce a result of acceptable accuracy (Section 5.5.5).

6.3.2 Study Duration

The duration of the project risk model was not an issue; the model continues to the completion of the project, especially as it is against the final outcome that many of the objectives are attached. For the business unit, the objectives will be placed on each time period, reflecting short, medium, and long term objectives for the business. The duration of the company risk model should be sufficient to allow the objectives to be assessed. In most cases, with a company which is being wound up being an exception, the company will be expected to continue operating beyond the end of the study. For the example business unit, the study duration will be five years, starting from January 1995.

The five year study period will be evaluated monthly as this will provide adequate accuracy. If the study was divided into shorter periods of time, the input to the model would also have to be evaluated to that time scale if accuracy was to be gained. If a longer period was used, the level of detail of the information provided by the model would become less useful.

6.4 COMPONENTS OF THE MODEL

Projects which have relevance to the model can exist in three states; projects being undertaken, those being pursued, and those which the company knows little about but expects to exist in the future. From the company's perspective, in line with the hierarchical approach, all projects will be considered as uncertain cash flows. The sources of uncertainty in those cashflows will be considered at lower levels in the hierarchy. The project cash flows will be added together to produce the cash flow of the business unit. The inclusion of uncertainty in the cash flows means that, as discussed in Section 4.6.3.4, to maintain dependence between income and expenditure and across time periods, the model will produce a series of possible cash flows for the company. The alternative would be to produce only distributions of the values in each time period.

Before the treatment of projects of each kind is discussed, the technical aspects of modelling the uncertainty in the cash flows of projects will be considered.

6.4.1 Projects Modelled Using the Project Risk Model

Since the cash flow of the company model will be evaluated on a monthly basis, the model requires the contribution to the cash flow from the project for each month. The project risk model, since it was developed to model projects both to combine the various sources of uncertainty in a project and to assist the project team in tendering, produces as output the possible cash flows for the project which were produced during Monte Carlo Simulation. Each cash flow is stored as a series of monthly incomes and expenditures.

If the Company Risk Model was evaluating the cash flow on a quarterly basis, the three months of the project's cash flow comprising that quarter would be summed to produce the input to the model.

6.4.2 Created Projects

The project risk model was designed specifically to fit into the Company Risk Model and so should be used to model all projects the company is undertaking or pursuing. It is recognised that in some instances the model will, or can not be used to analyse the uncertainty in a project. Such instances include

- when time does not allow a detailed analysis, and
- when the data available does not support a detailed analysis.

To allow all projects, regardless of whether they can or have been analysed using the project risk model, to be included in the company risk model, a simplified representation of a project is used. This takes all aspects of the project risk model except the risk factors, since they represent the time consuming analysis which requires detailed knowledge, and concentrates on the general uncertainty in the cashflow parameters.

Hence, to define a project the following parameters are required:

- Project start date
- Contract duration
- Contract value
- Anticipated profit margin

Uncertainty can be defined for any or all of the above parameters using a single distribution, as used in the project risk model (i.e. Event, Rectangular, Triangular, Trapezoidal, or Dual Range). The distinction between this representation and the project risk model is this model defines the profit margin whereas the project risk model defined the cost of the project and the profit margin was derived from that and the impact of the risk factors. The different approach used in the simplified model ensures that the value of the project and the profit margin are independent. If a distribution of cost was defined instead, and cost and value were selected independently, the result is unlikely to reflect the actual mechanics of the project since an increase in the value of a project is usually matched to some extent by an increase in cost. If the cost and value distributions were dependent, by using the same random number, the profit margin on the project would never change, which does not adequately model the expected mechanics of the project. Hence, by defining the profit margin and contract value, and using these to calculate the cost, the project can be adequately modelled.

The cash flows for the project are produced by performing Monte Carlo Simulation, selecting the start date, duration, value, and profit margin, and distributing the cost and value uniformly throughout the duration of the project.

6.5 PROJECTS BEING UNDERTAKEN

The main characteristic of these projects is that their cash flows will always be a part of the company's. In this sense, the title is not strictly true, as projects which are not currently being undertaken but which the company will definitely be undertaking sometime in the future would be part of this collection.

Adding these to the company cash flows requires producing the same number of cash flows as used in the model and adding the contribution in each time period to that already in the company.

Continuing the example business unit, Table 6.14 shows a list of roads projects, taken from those tested in Chapter 6, which will be deemed to be part of a market and currently being undertaken by the business unit. The predictions of profit are taken from the analysis using the project risk model. Test Project 8 is not contained in the list of projects being undertaken due to its start of October 1996, but will be included in the list of projects being pursued.

Table 6.14 - Projects modelled using PRM and undertaken by the example company

Test Name	Start Date	Duration (months)	Value (£m)	Lowest Profit (£k)	Mean Profit (£k)	Maximum Profit (£k)
Test 7	3/1995	9.7	1.6	3.8	34.8	65.1
Test 9	8/1995	13.0	3.9	221.7	313.8	389.4
Test 10	5/1995	12.5	5.2	64.9	129.5	191.6
Test 11	11/1995	4.75	11.1	(217.5)	198.6	592.1
Test 12	1/1995	22.0	23.0	(1332.6)	(609.2)	123.2

To demonstrate how projects can be modelled without using the project risk model, Table 6.15 introduces five projects which the example company is also undertaking. For each project, triangular distributions are assumed for each uncertain parameter. For each distribution, the first value corresponds to the lowest outcome, the middle value corresponds to the most likely outcome, while the third represents the maximum outcome.

Test Name	Start Date	Duration (months)	Contract Value (£m)	Profit Margin (%)
Created 1	1/7/1994	9.0, 9.25, 10.0	9.6	-1.0, 4.0, 7.5
Created 2	15/1/1995	10.0, 10.0, 10.5	12.2	2.0, 3.5, 5.5
Created 3	8/10/1994	9.25, 9.5, 10.0	7.3	1.5, 5.0, 8.5
Created 4	1/4/1995	5.5, 5.75, 6.75	4.2	-2.0, 3.2, 5.5
Created 5	15/1/1995	8.0, 8.0, 9.5	6.0	0.0, 5.5, 6.5

Adding the cash flows of the projects described in Table 6.14 and Table 6.15 together, creates the cash flows for the business unit. Turnover is plotted in Figure 6.1 and profit in Figure 6.2 below. As described in Chapter 4.7.1, rather than plotting each of the 2000 cashflows individually, although that is how they are stored, they are presented in frequency distribution form. A frequency distribution is created for each month of the study. In the graphs, colour is used to represent the probability of each outcome in each month.

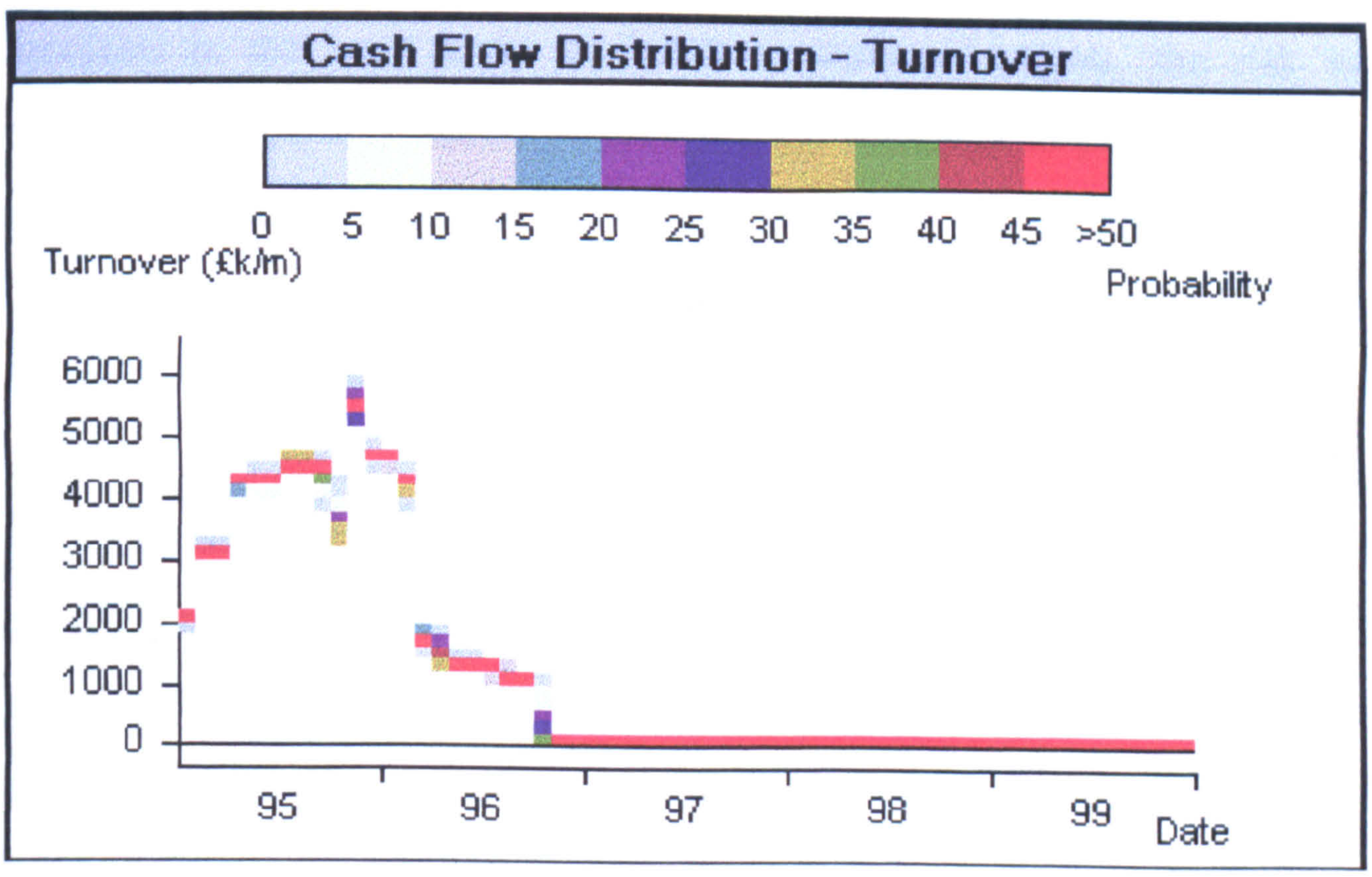

Figure 6.1 - Turnover Uncertainty with Projects Currently Being Undertaken

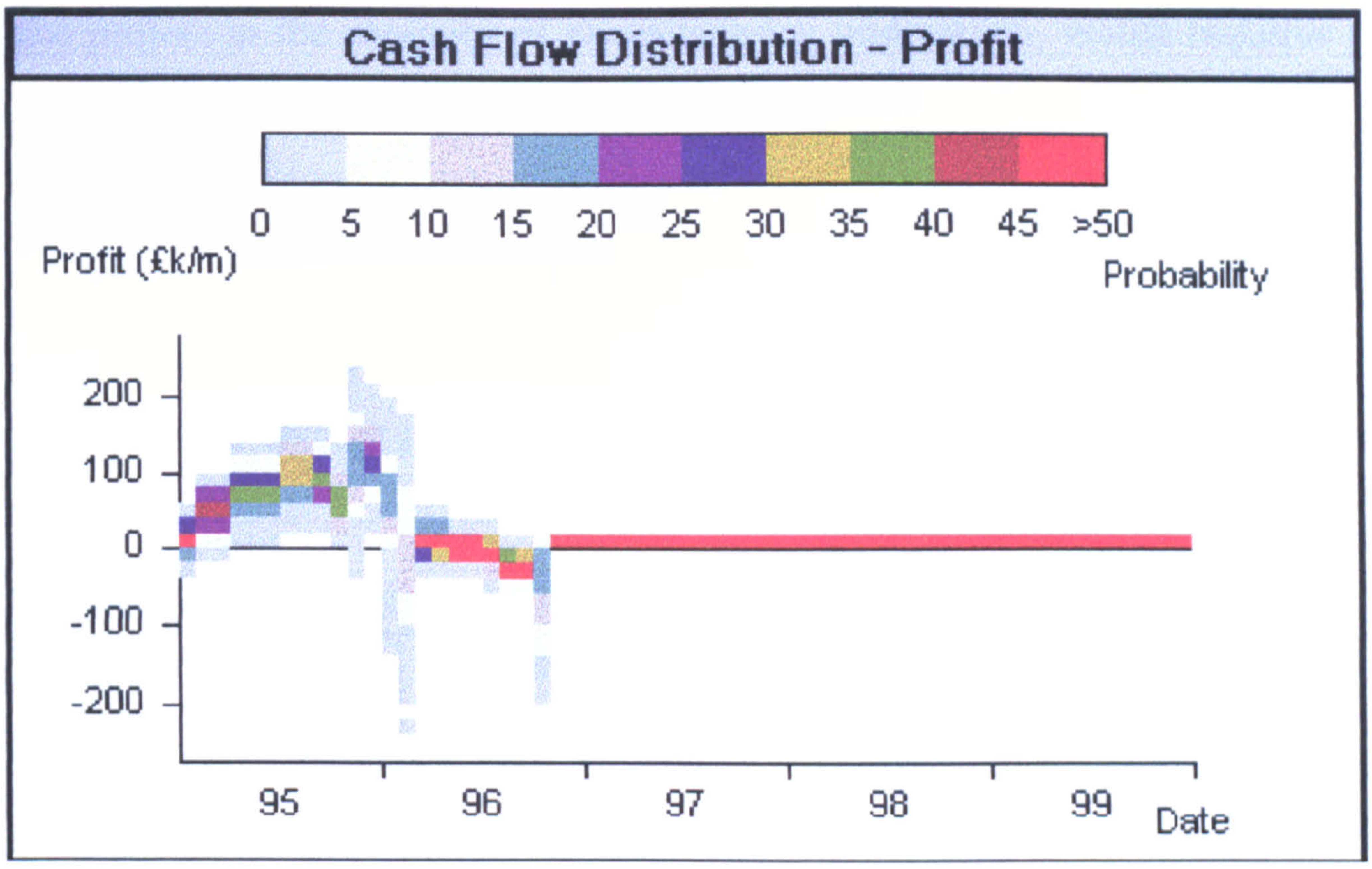

Figure 6.2 - Profit Uncertainty with Projects Currently Being Undertaken

Figure 6.1 shows the turnover reduces as the projects the company is undertaking reach their conclusion. In addition, the turnover for most of 1995 and the first quarter of 1996 appears to be close to the target of £5m per month. As a result of this the company should not be pursuing projects to start in the very near future. If the company did require projects in the near future to fulfill its turnover targets, the risk would be increased because there may not be projects for the company to pursue or the company may not be successful in the tenders it submits.

6.6 PROJECTS BEING PURSUED

The approach taken to include projects which the business is actively pursuing is similar to that for projects it is undertaking, except for each one an assessment of the probability of being awarded the contract is required. For example, if the assessment was made that the company is 75% likely to be awarded a particular contract, the Monte Carlo Simulation would test the success of the tender on each run to determine if the project cashflow was to be included. Although this means that it was not necessary to generate all 2000 runs for the project, as only 75% of them will be used, whether using the project risk model or not, this should not be taken into account as the probability of success could change as the tender proceeds. In some cases the contract could be awarded, placing the project in the category of projects being undertaken, which requires all 2000 runs.

Table 6.3 details the project tested previously in Chapter 5 which, for the example company, falls into the category of projects being tendered for, following the same format as Table 6.14, except an extra column is required for the probability of success.

Table 6.16 - Project modelled in the PRM being pursued

Test Name	Start Date	Duration (months)	Value (£m)	Lowest Profit (£k)	Mean Profit (£k)	Maximum Profit (£k)	Probability of Success
Test 8	10/96	13.0	2.0	103.0	127.2	136.5	75%

Table 6.17 contains the projects the example company is pursuing which have not been modelled using the project risk model, using a similar format to that used in Table 6.15, except for the extra column for probability of success. The start date specified is the expected and earliest start date, the second figure given is the maximum delay to the expected start date, in months.

Table 6.17 - Projects defined within the CRM being pursued

Test Name	Start Date	Duration (months)	Contract Value (£m)	Profit Margin (%)	Probability of Success
Pursued 1	8/8/95, 1	5.0, 5.0, 5.25	4.5, 4.6, 4.8	-1, 3, 7.5	90
Pursued 2	1/1/96, 0.5	8.0, 8.25, 9.0	5.2, 5.2, 5.5	0, 4, 6.5	25
Pursued 3	1/2/96, 0	6.0, 6.0, 6.5	1.9, 2.0, 2.1	2, 5, 7.5	70
Pursued 4	22/4/96, 1	12.75, 12.75, 13.5	7.9, 7.9, 8.5	3, 4, 7.5	50
Pursued 5	15/5/96, 1	16.25, 17.75, 20.25	8.0, 8.2, 8.5	-5, 6, 9.5	80
Pursued 6	15/6/96,0.5	19.25, 19.5, 20.5	17.5, 17.8, 18.5	-1, 4, 7.3	10
Pursued 7	1/7/96,0.75	6.0, 6.0, 6.75	5.2, 5.2, 5.3	0, 3, 8	40
Pursued 8	1/10/96,1	7.0, 7.25, 7.75	6.25, 6.5, 6.75	1, 4, 6	25
Pursued 9	1/11/96,1.5	9.0, 9.0, 10.5	4.2, 4.4, 4.8	-1, 4, 8.5	25

Combining the cash flows of the projects listed above together produces the turnover result shown in Figure 6.3 and the profit result shown in Figure 6.4.

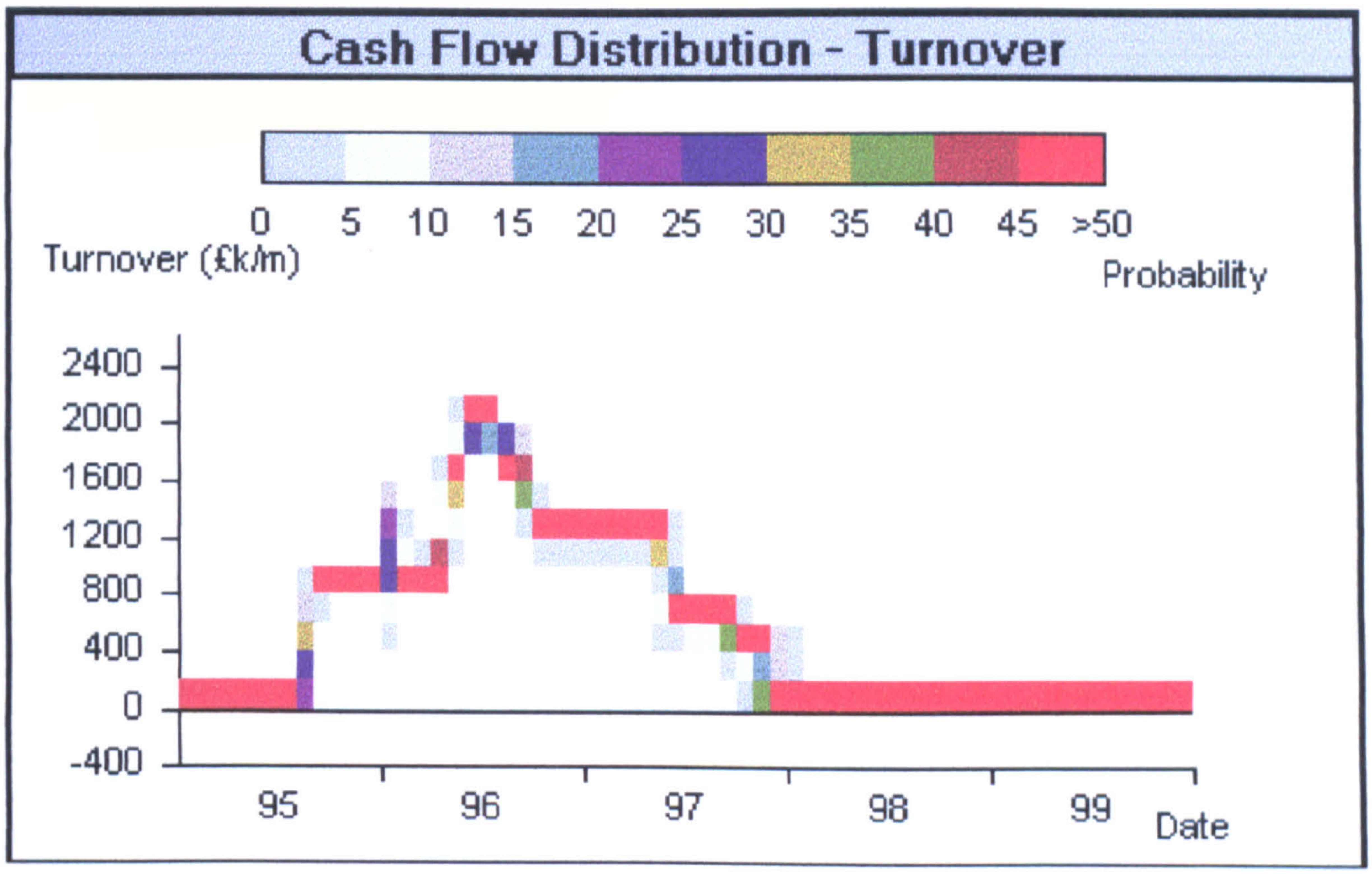

Figure 6.3 - Uncertain Turnover from Pursued Projects

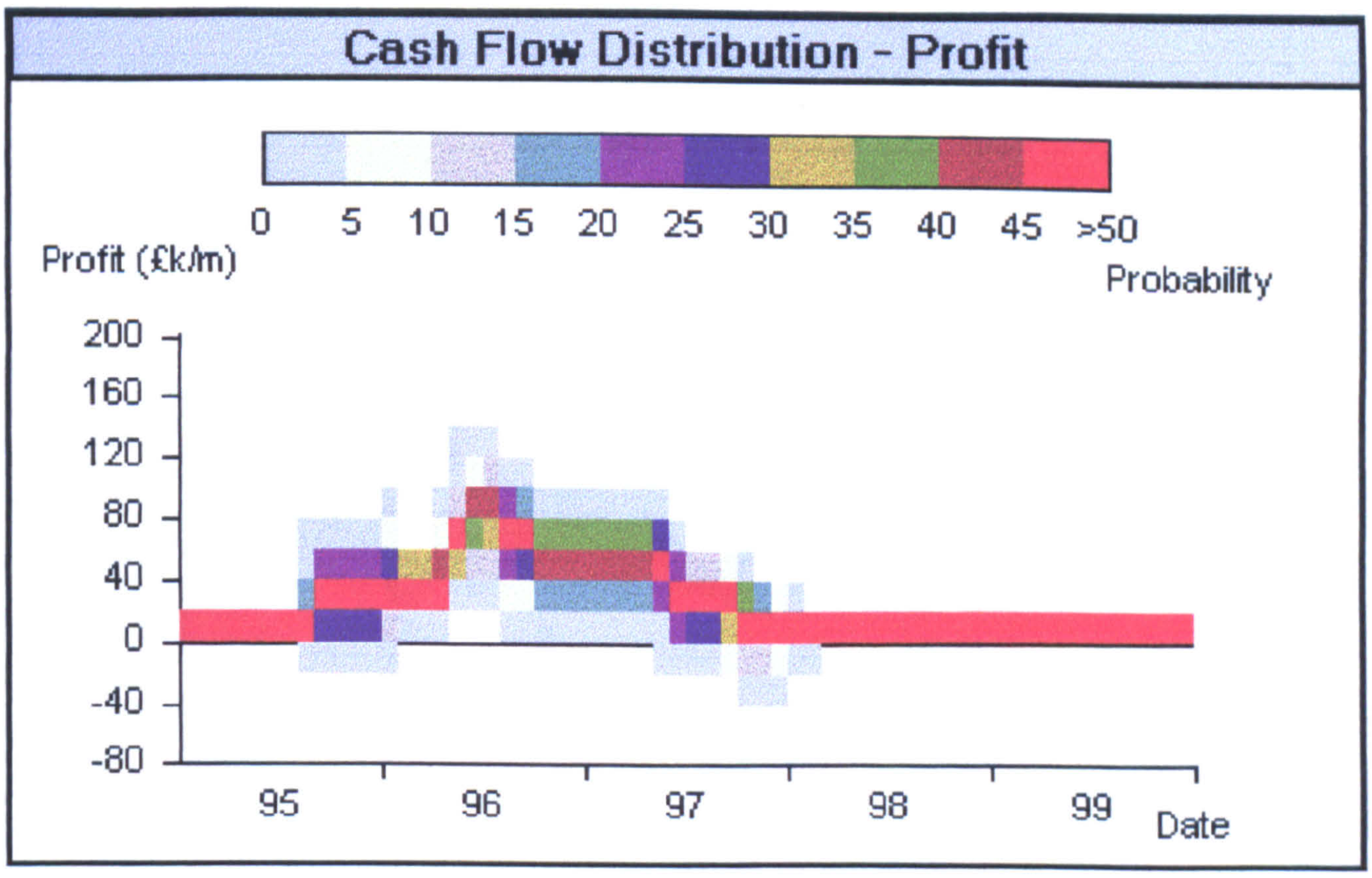

Figure 6.4 - Uncertain Profit from Pursued Projects

The distributions above show the turnover contribution at the start of 1996 settling down at around a quarter of the target for the business unit and then, just as Figure 6.1 does earlier, gradually decreasing in the final quarter of 1997. Figure 6.5 and Figure 6.6 show the combined results for turnover and profit for projects being undertaken and those being pursued by the example business unit.

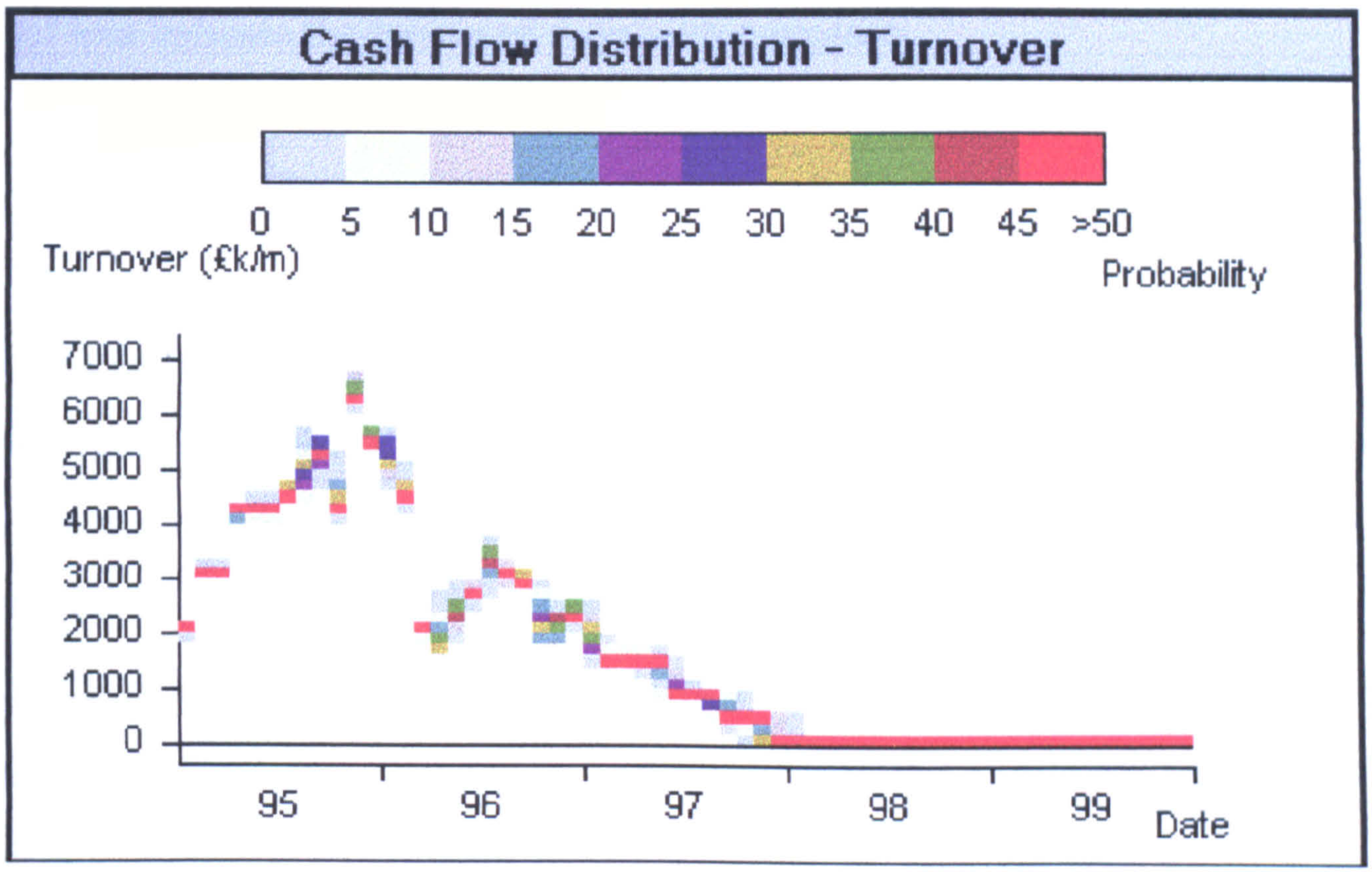

Figure 6.5 - Uncertain Turnover from Projects Being Pursued and Undertaken

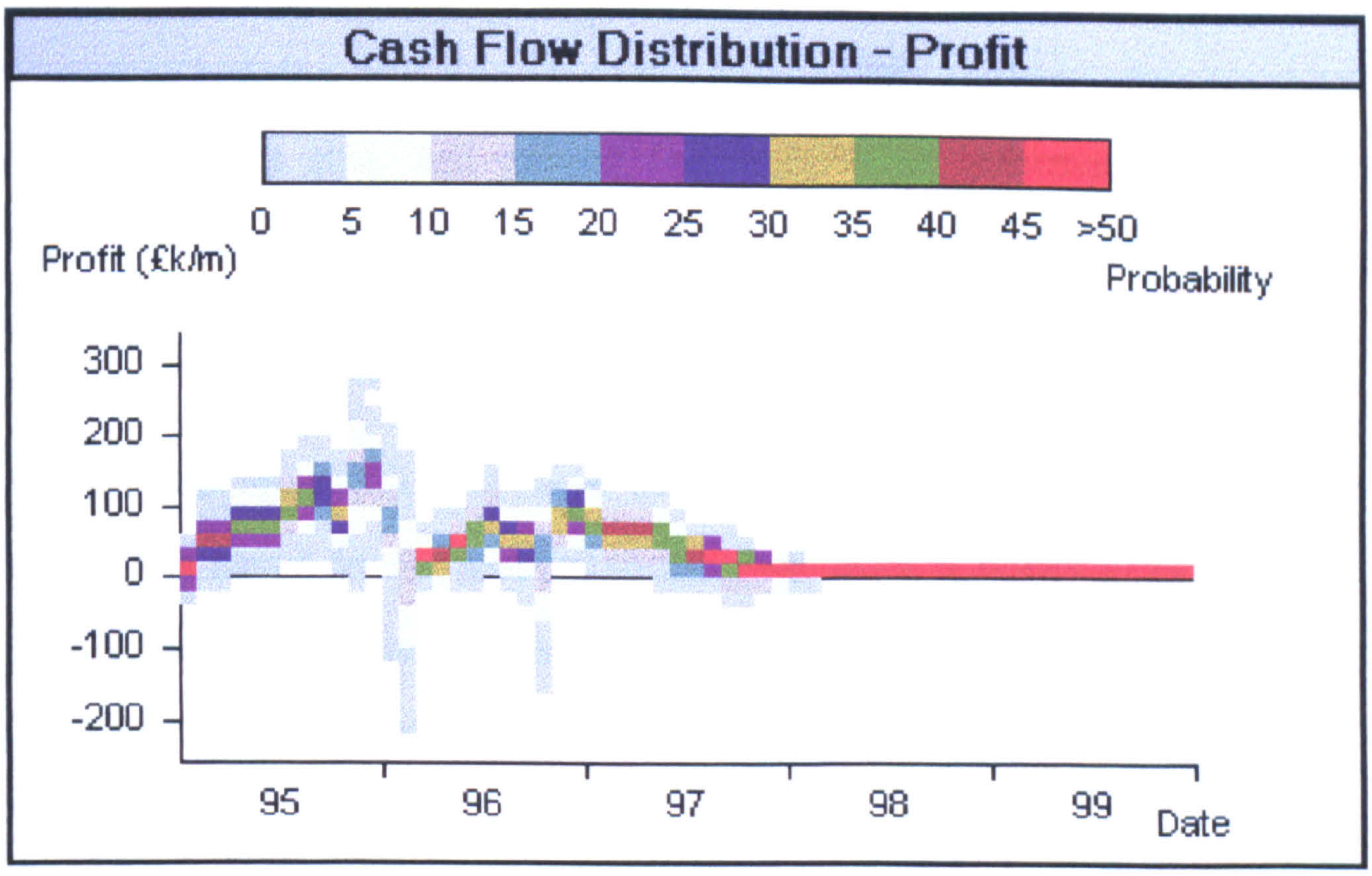

Figure 6.6 - Uncertain Profit from Projects Being Pursued and Undertaken

The distribution in Figure 6.5 shows the turnover increasing over the first half og 1995 to the target and decreasing to zero at the end of 1997. The turnover rapidly decreases at the start of 1996 before recovering to the trend. This indicates a period in which projects currently under construction and completed and not replaced by projects being pursued.

The distribution in Figure 6.6 shows the profit increasing over the first half of 1995 and the gradually decreasing to zero over the subsequent two and a half years. The two periods of loss indicate the timing of risks within projects.

6.7 MARKET PROJECTIONS

Considering only the projects being undertaken and being pursued, the uncertainty in later time periods is not representative of that perceived by managers as it does not include the contributions of projects they expect to exist in the later years. If the cash flow shown in Figures 6.5 is classified for turnover risk, the risk will increase dramatically as the current projects reach their conclusions. The expectation of future projects comes from the knowledge and experience the managers have in particular markets, although this knowledge is not essential as analyses of various markets are published periodically in the construction press, such as Construction News and Contracts Journal. These analyses show a breakdown of each sector of the UK construction industry, such as housing, building, and civil engineering markets, showing the trends in market value, project size, and project location. This information can be used, in conjunction with the knowledge of the managers, to create projects which could be available in the future.

Additional projects are required to show what might happen to the company when all the projects it knows about do not amount to the total work it hopes to be undertaking. In order to build this into the model, two aspects require definition; the market from which the projects are taken, and the tendering strategy used to select those projects.

6.7.1 Market Definitions

A market can be defined by the total value of work within it in any one time period, and the characteristics of the projects which make up that work. For example, the market from which the projects in the example business unit originate may have an annual value at present of £750m. A different market value can be defined for each year of the study, allowing scenarios to be modelled. The effects of inflation are neglected from the study, although they could be included by inflating the market value and the contract value of projects within it accordingly. In that case the amount of work the business unit is seeking to undertake would also have to be inflated.

6.7.1.1 Project Characteristics

The projects in the market are defined by the seasonality of start date, duration, contract value, and profit margin. The profit margin will be based on the company's experience rather than any industry-wide data.

For each parameter, distributions can be defined, again for each time period. For project start date, the relative probability of a project starting in each month can be defined, allowing seasonality to be modelled. Profit margin is defined using three triangular distributions, one for the expected profit margin, one for the risk, and one for the opportunity. Figure 6.7 shows how the distribution of profit is created at random from the distribution defined.

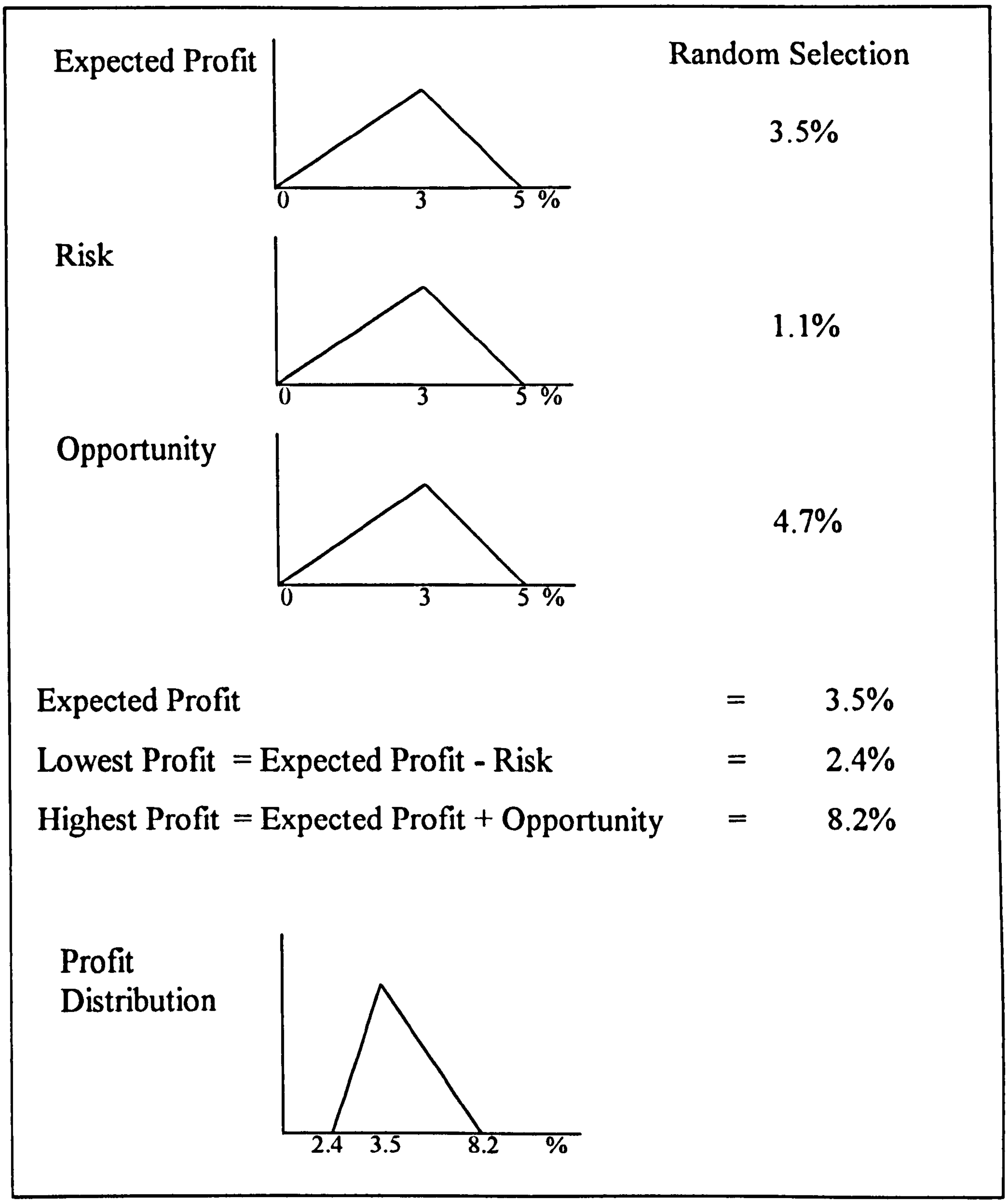

Figure 6.7 - Creation of a profit distribution

The distributions of contract value and duration are linked by defining a triangular distribution of contract value and for each parameter in that distribution (minimum, most likely, maximum) defining a triangular distribution for the duration of a project of that value. This concept is illustrated in Figure 6.8 below.

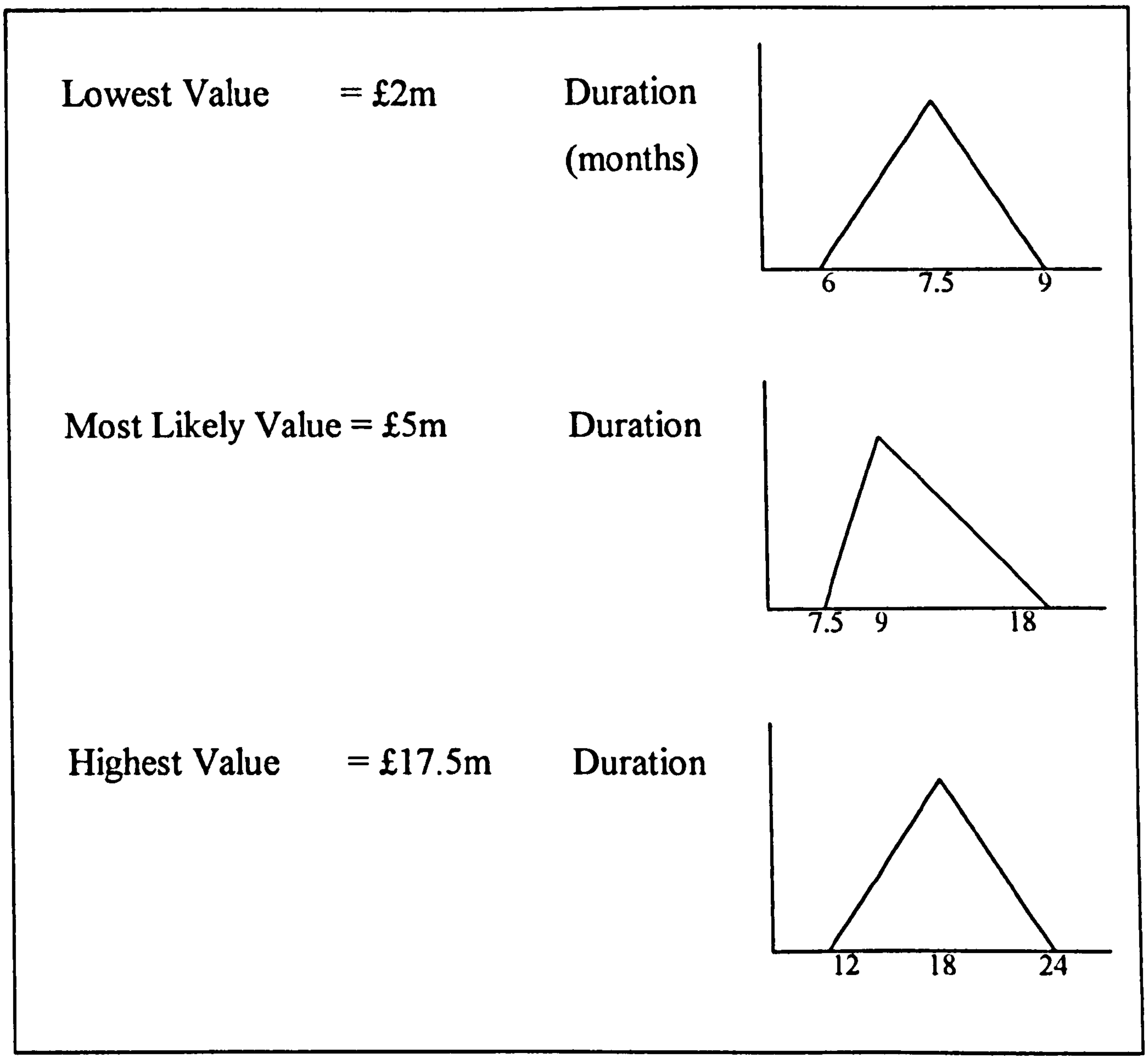

Figure 6.8 - Duration definition based on Contract Value distribution

To generate projects, the start date, profit margin, and contract value are selected at random from their distributions. The contract value is used to create a distribution of duration from which the project duration is then selected. Referring to the example shown in Figure 6.8, if the contract value selected is £4m, 66% between the minimum and most likely contract values, the same proportion is used to determine the minimum, most likely, and maximum durations, interpolating between the distributions of duration defined for the minimum and most likely contract values. It is then from this distribution that the actual duration for the project is selected at random. The distribution created has the parameters of minimum 7 months, most likely 8.5 months, and maximum 12 months.

The information required to fully define the example market definition, in addition to the profit and duration distribution shown in Figure 6.7 and Figure 6.8 respectively, are the market size, set at £750m in each year, the start dates, assumed uniform throughout the year, and the value distribution, defined as a triangular distribution with minimum of £2.5m, most likely of £5m, and maximum of £17.5m.

6.7.1.2 Generating a Market

Having defined a market, by its size and the characteristics of the projects within it, it is generated by, for each year, creating projects at random until the size of the market has been exceeded. For each project the start date, duration, contract value, and distribution of profit margin are stored. Table 6.18 shows a sample of the projects generated for the first year of the example market (1995).

Table 6.18 - First 20 projects generated for the first year of the example market

No	Start Date	Duration (months)	Value (£m)	Minimum Profit (%)	Most Likely Profit (%)	Maximum Profit (%)
1	12/05/95	14.6	12.4	2.2	4.2	8.2
2	27/12/95	12.5	8.3	1.0	4.0	7.0
3	07/07/95	14.4	12.5	-0.6	2.4	5.4
4	05/07/95	14.7	9.9	2.6	4.6	7.6
5	07/05/95	10.7	4.1	2.2	4.2	6.2
6	02/04/95	14.5	4.8	-2.4	1.6	3.6
7	17/05/95	15.5	7.5	-1.4	1.6	3.6
8	15/12/95	9.7	5.2	1.1	3.1	6.1
9	01/01/95	17.2	11.6	-0.6	2.4	5.4
10	04/11/95	14.6	5.6	1.9	2.9	5.9
11	20/05/95	11.3	8.3	-1.1	2.9	6.9
12	03/06/95	15.2	12.0	1.0	4.0	8.0
13	30/11/95	10.5	7.3	1.7	3.7	5.7
14	07/07/95	16.5	7.0	0.6	3.6	5.6
15	26/12/95	16.4	5.7	1.2	4.2	7.2
16	15/05/95	9.6	5.3	0.2	4.2	6.2
17	04/03/95	9.0	4.0	0.1	4.1	5.1
18	09/10/95	13.1	7.2	-2.1	0.9	3.9
19	05/07/95	15.6	6.2	2.0	3.0	5.0
20	25/12/95	17.8	6.6	-2.7	0.3	2.3

6.7.2 Tendering Strategies

The market defines the projects which are available each year, the tendering strategy of the business unit decides which of these are to be pursued. The choice of projects to pursue is made firstly on the volume of work required to fulfill the unit's turnover targets and then on the extent to which the projects fit criteria for project size, duration, and expected return. In order that the company pursues sufficient work for it to fulfill its turnover target, a success rate is defined by which the target turnover is scaled to give the total which will be pursued. Table 6.19 shows a possible tendering strategy for the example business unit, showing the criteria to be used to select projects.

Table 6.19 - Tendering strategy for example business unit

Parameter	Minimum	Maximum
Profit	0%	-
Contract Value	2m	15m
Duration	6 months	18 months
Target Turnover	60m	-
Success Rate	30%	-

6.7.3 Applying Tendering Strategies

The tendering strategy is applied to the market to determine the projects actually undertaken by the business unit, allowing the complete cash flows to be produced. For each year a target turnover is defined. The available projects are assessed, in turn, until sufficient have been selected to fulfil that target. Each project is defined by its contract value, and so if it is selected, its turnover contribution for each year must be subtracted from the target. If the target was defined by value of work to be started in each year, rather than the turnover, the contract value would be subtracted, although this would not link directly to the turnover objectives against which projects are selected. Additionally, if the year was assessed as a whole, it is possible, using the simple rules, to select a large number of projects which start in the later months of the year to fulfil the turnover target of one year which would produce far too much work in the following year. To overcome this, the projects are assessed on a quarterly, rather than yearly, basis. For the first quarter in the example, the projects available are shown in Table 6.20, in which the number relates to the sequence in which it was generated; the other projects relate to the remaining quarters of the year In total 88 projects were generated, of which 22 started in the first quarter of the year.

Table 6.20 - Projects available in the first quarter

No	Start Date	Duration (months)	Value (£m)	Minimum Profit (%)	Most Likely Profit (%)	Maximum Profit (%)
9	1/1/1995	17.2	11.6	-0.6	2.4	5.4
17	4/3/1995	9.0	4.0	0.1	4.1	5.1
24	5/1/1995	13.5	6.4	1.9	3.9	6.9
27	30/1/1995	11.8	9.3	-1.4	1.6	4.6
28	29/2/1995	10.5	6.7	1.8	4.8	6.8
30	30/2/1995	17.7	13.1	-0.1	3.9	5.9
34	24/1/1995	11.2	8.6	1.0	3.0	5.0
35	13/2/1995	14.1	10.8	-1.9	1.1	5.1
37	13/2/1995	13.8	8.8	-1.6	3.4	5.4
39	13/2/1995	11.4	7.6	2.2	3.2	6.2
43	7/1/1995	14.3	5.8	0.3	3.3	4.3
45	2/2/1995	11.9	10.3	0.9	2.9	5.9
47	1/1/1995	18.5	11.8	-1.0	2.0	6.0
48	28/3/1995	8.4	4.1	-2.0	1.0	5.0
51	6/1/995	16.5	9.2	-0.9	3.1	6.1
57	12/2/1995	11.6	12.0	-0.2	2.8	5.8
58	24/2/1995	12.7	13.7	0.4	2.4	4.4
63	26/3/1995	13.9	4.5	-1.0	3.0	7.0
68	1/2/1995	17.1	12.4	0.4	3.4	5.4
75	25/3/1995	14.6	8.4	-0.2	1.8	5.8
77	26/3/1995	9.7	6.0	-05	3.5	7.5
79	9/2/1995	16.9	9.5	0.3	3.3	7.3

The target for the work to tender for in the first quarter is £50m (£15m divided by 30%). Assessing each project in turn, Project 9 is accepted as it fulfills all the tendering strategy criteria and so the target is reduced by the proportion of the project undertaken in the first quarter, which relates to 3 months at (11.6m / 17.2 months) per month, giving a turnover contribution of 2.0m in the first quarter. This reduces the new target for the first quarter to 48.0m. The same calculation is repeated for the remaining months of the project, reducing the target in quarters 2, 3, 4, and 5. The next project in the list, Project 17, is also accepted as it meets the tender strategy requirements, further reducing the target by 0.4m.

If this process was repeated for all available projects, only Project 46 would be rejected due to unacceptability and the turnover target for the quarter would not be fulfilled, only being reduced to £28.2m. However, since projects which start in the first quarter on average contribute twice as much to the second quarter of the year, the target for the second quarter will be reduced to only £5.3m. This target can be fulfilled by the first eight projects available in the second quarter. As a consequence of this approach the turnover targets for the third and fourth quarters are zero. If this approach was taken within the model, the distribution of turnover shown in Figure 6.9 would be produced.

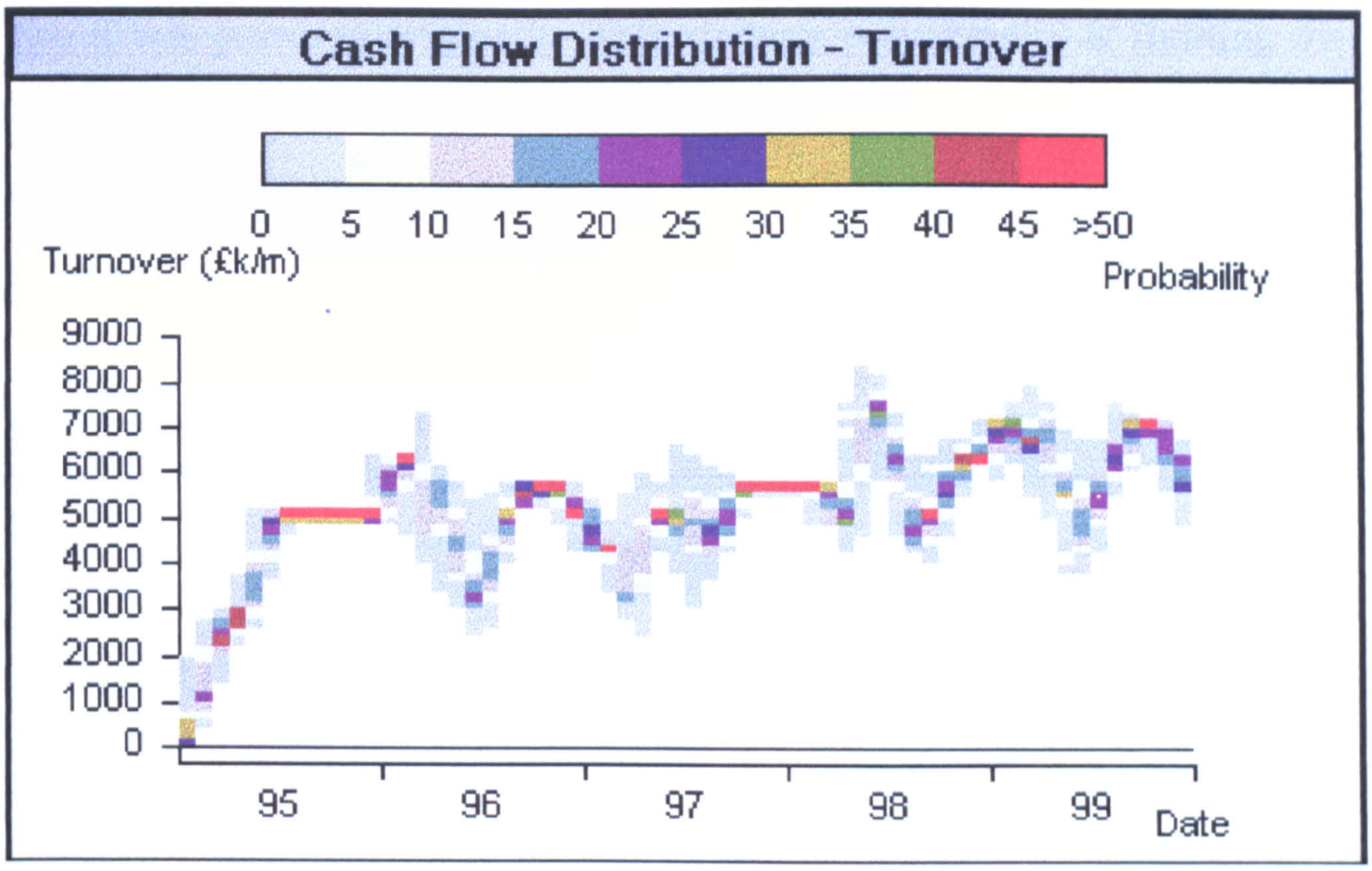

Figure 6.9 - Turnover from generated projects

The graph shows the turnover of the business unit increasing rapidly from zero over the first half of 1995 to the target of £5m per month and then remaining static for the second half. This is a direct result of the turnover requirement for the whole year being tendered for in predominantly the first three months. This situation is not representative of the actual tendering strategy of a company; a company would try to tender for work throughout the year, rather than having its tendering department working for only three months of the year and being idle for the last six. Over the later years of the study, a cyclic effect occurs as the tendering effort continues to be variable within a year.

In order to model the tendering effort, the capacity of the tendering department can be included in the selection process. A tendering department can only bid for a finite volume of work and so a limit is applied to the combined contract value of work being tendered for in any one quarter. The contract value is used, rather than the turnover produced, as a project worth £10m over one year will involve a similar amount of work to one of the same value of two years duration. Once the tendering limit has been reached, all projects remaining in that quarter are rejected.

For the example business unit, the target turnover is £60m and so it might be that the tendering department cannot produce tenders for more than four times this value of work. This strategy limits the business unit, in the first quarter, to eight tenders, rather than the twenty two it was pursuing originally. This strategy is successful at limiting the volume of work pursued in any one time period, although the graph in Figure 6.10 shows that this does not overcome the problem that the turnover in the third quarter of the first year is made up entirely of projects started in the first two quarters.

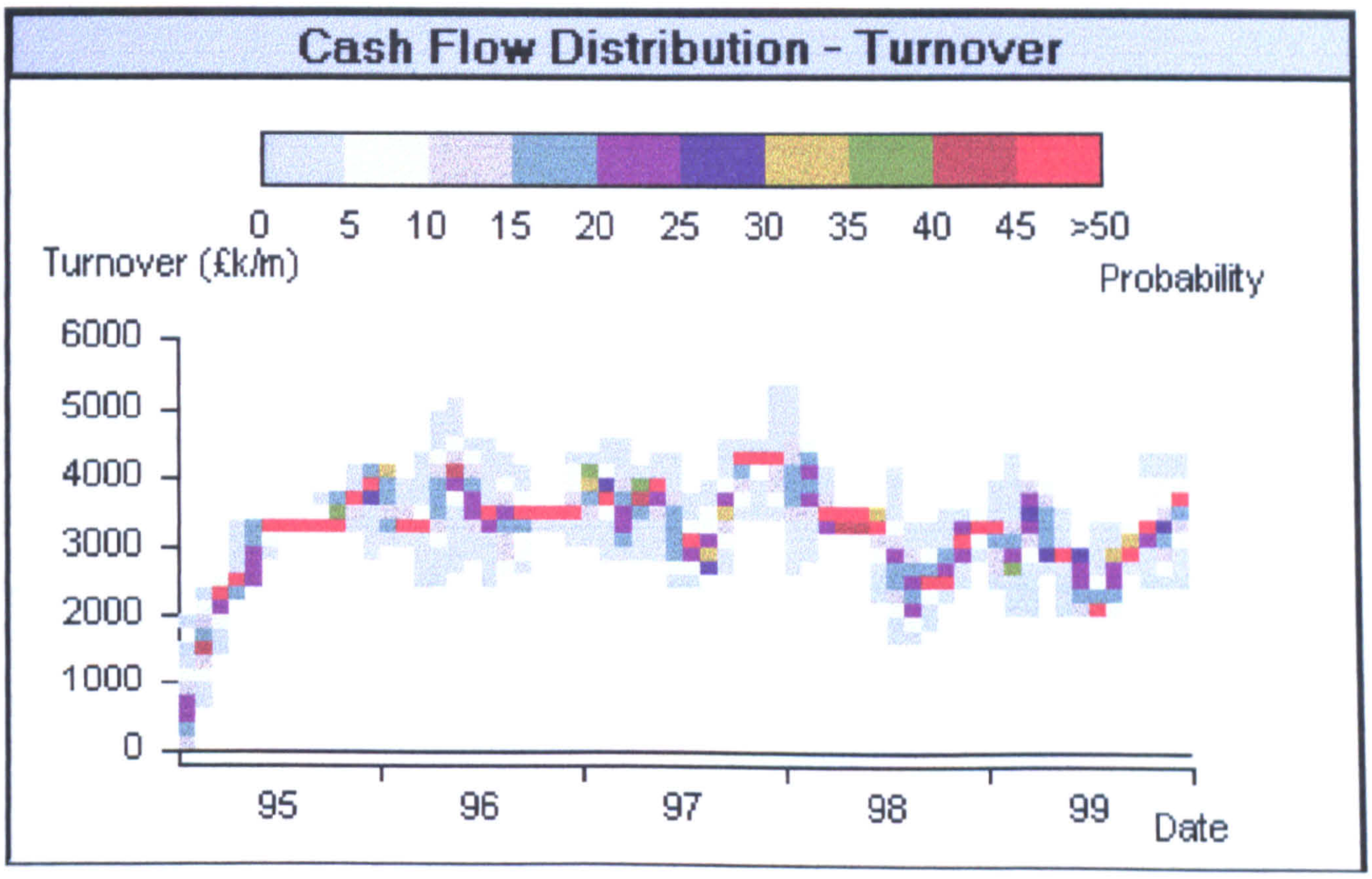

Figure 6.10 - Turnover from generated projects using constrained tendering

The graph of Figure 6.10 does show, when compared to Figure 6.9, the unconstrained tendering policy, that the strategy regulates the tendering process once the company has been established. This is illustrated by the fewer regions in which the turnover has little uncertainty.

The problem of the first year is produced because the company is being established in that year, rather than the business unit already having a workload it started in 1993 and 1994. If in fact the business unit was being established, it would be unrealistic to set its turnover target at full from the first quarter onward. In this case, the turnover would be expected to be increased gradually, reaching the target possibly in 1996 or 1997.

6.7.4 Project Selection

Although the tendering strategy used to produce the distribution shown in Figure 6.10 produces a more realistic approach to tendering, the result shows the turnover varying over the duration of the study but not considerably in any single time period. The reason for this is that the tendering strategy will always consider the available projects in the same order and hence will always choose the same projects. This approach will produce a similar turnover for each run of the model which is effectively only showing one possible result of the tendering strategy.

In order to correct this and produce a model of the company which shows the possible outcomes of the tendering strategy, the available projects should be reviewed in a different order each run. Shuffling the projects in this manner, rather than generating a different set of projects each run, produces the distribution of turnover shown in Figure 6.11 below.

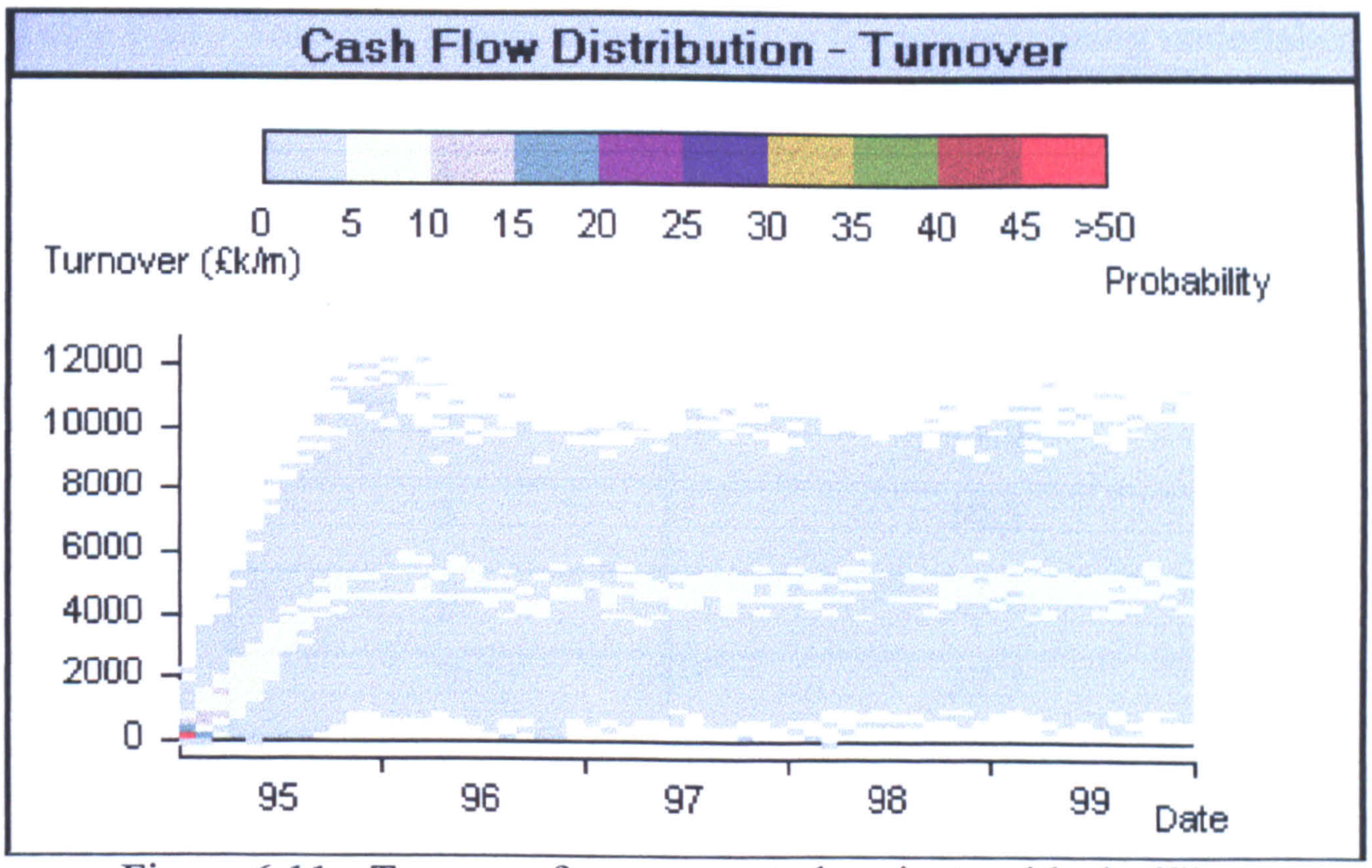

Figure 6.11 - Turnover from generated projects with shuffling

Generating a different set of projects would produce a similar result and yet would increase the analysis time.

6.7.5 Including known projects in the market

Projects which are currently being undertaken or already being pursued should be taken into account when selecting the projects to tender for. Indeed, the market projection was included in the company risk model to produce projects which the company could pursue once those it already knew about were exhausted.

6.7.5.1 Projects currently being undertaken

Projects which are currently being undertaken reduce the tender target, from the target turnover, in the months in which they operate. For each project, the proportion of its turnover in each quarter is used to reduce the tender target to be achieved from other projects. The remaining target is then divided by the tender success rate to give the turnover required from tendered projects. The tender targets for each quarter, once the projects in Table 6.14 are taken into account, are shown in Table 6.21.

Table 6.21 - Turnover targets after reduction for projects being undertaken

Quarter	Tender Target (£m)
1	14.4
2	1.4
3	8.0
4	11.0
5	10.5
6	34.6
7	37.7
8	43.5
9 - 20	50.0

The cash flows of the projects are included using the process set out in Section 6.5, effectively adding the projects automatically to the list of those being tendered for and with a 100% probability of being accepted.

6.7.5.2 Projects currently being pursued

Projects which the business unit is pursuing are included by making an assessment of the probability of award. The turnover requirement from generated projects in each quarter is then reduced by the turnover contribution of each project. The probability of success replaces the standard success rate for generated projects. Table 6.22 shows the turnover requirements from generated projects once the contribution of projects being pursued and those already being undertaken are modelled.

Table 6.22 - Turnover targets after reduction for projects being undertaken and pursued

Quarter	Tender Target (£m)
1	14.4
2	1.4
3	8.0
4	8.7
5	0.0
6	12.4
7	3.2
8	1.1
9	14.4
10	22.8
11	32.9
12	38.1
13	47.0
14 - 20	50.0

Generating the market using the targets shown in Table 6.22 produces the distributions of turnover and profit for the business unit as shown in Figure 6.12 and Figure 6.13 respectively.

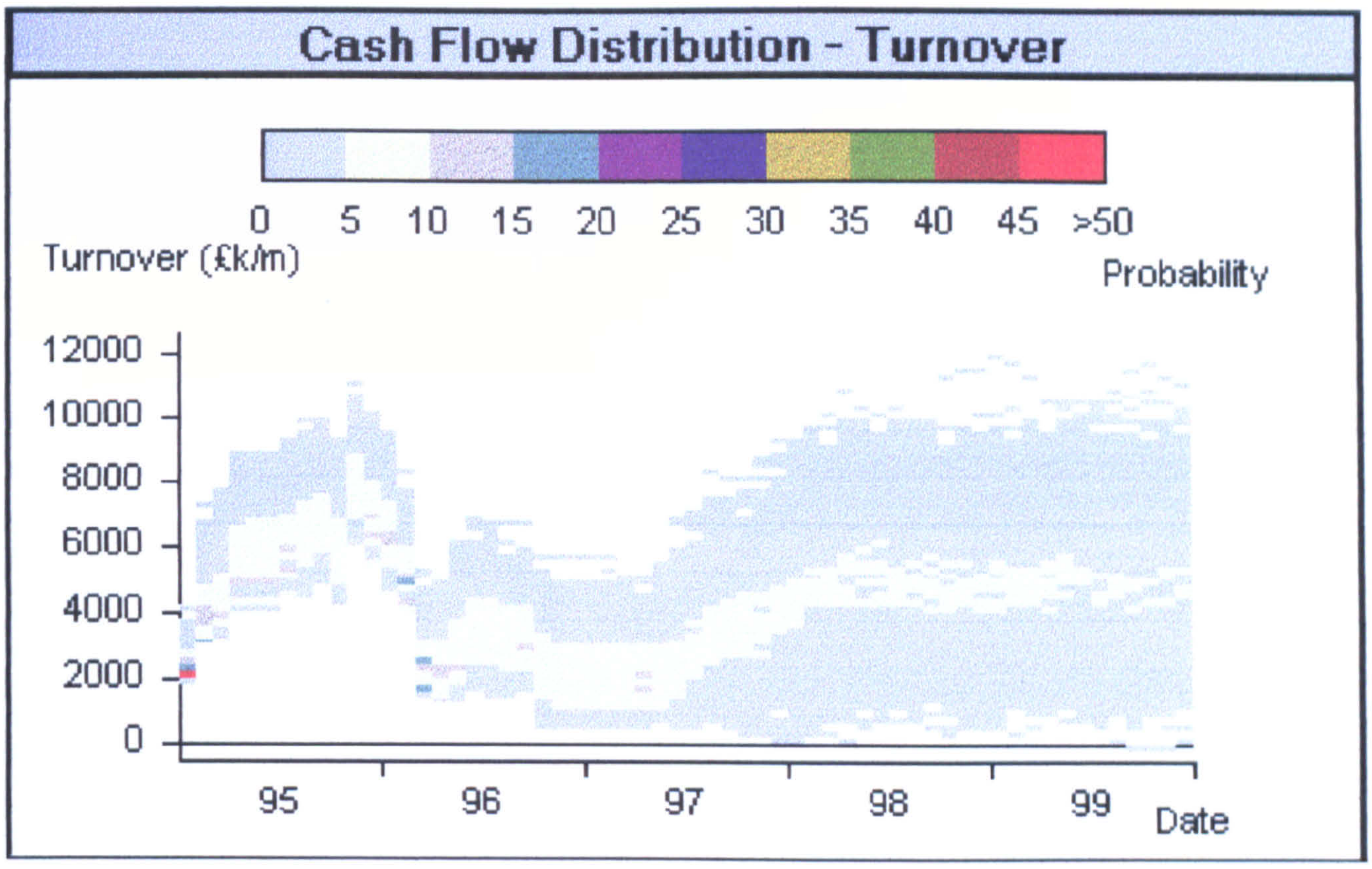

Figure 6.12 - Turnover combining undertaken, pursued, and generated projects

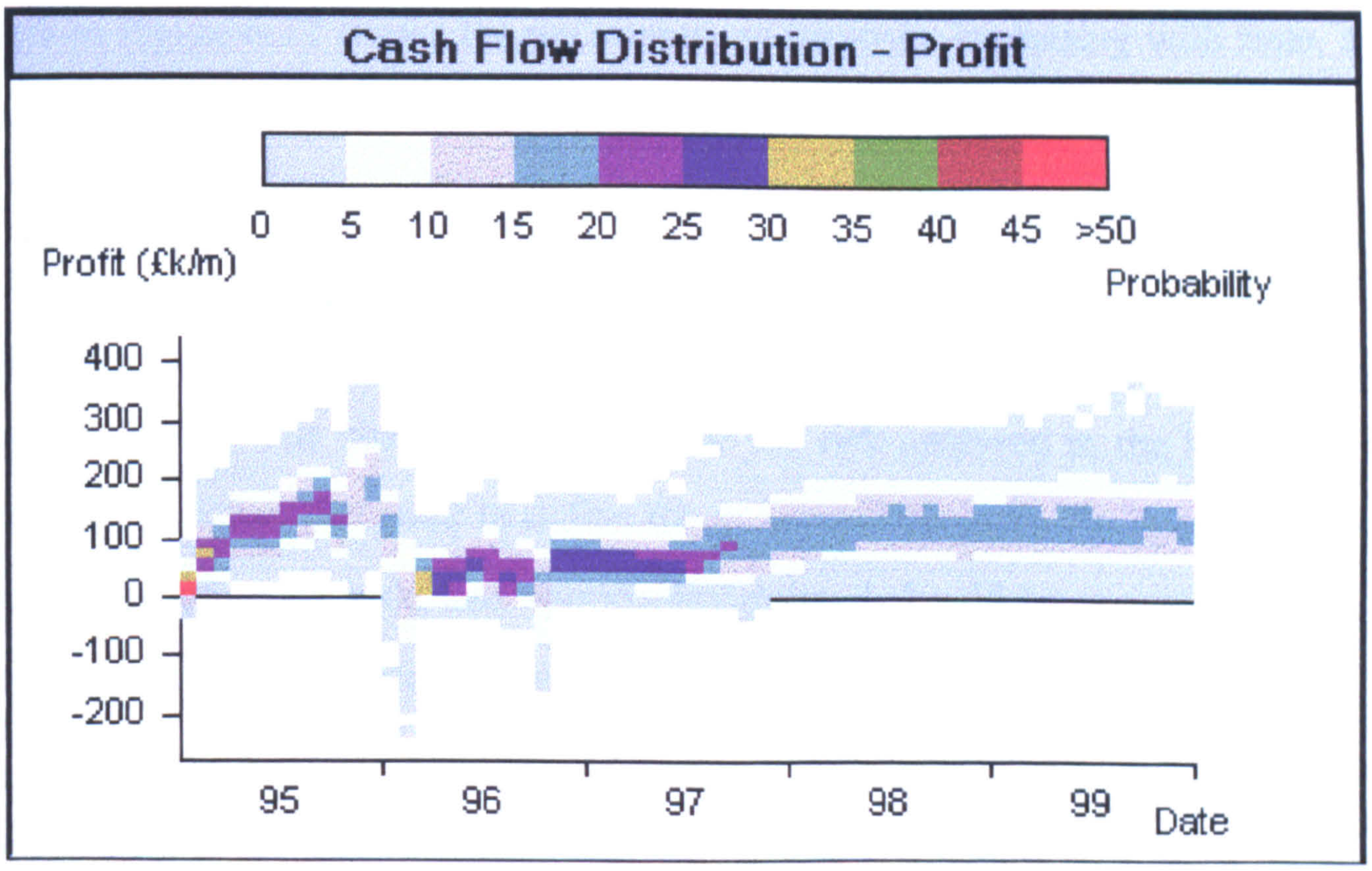

Figure 6.13 - Profit combining undertaken, pursued, and generated projects

Additionally, Figure 6.14 shows the profit uncertainty in terms of the percentage of the turnover rather than as a financial value.

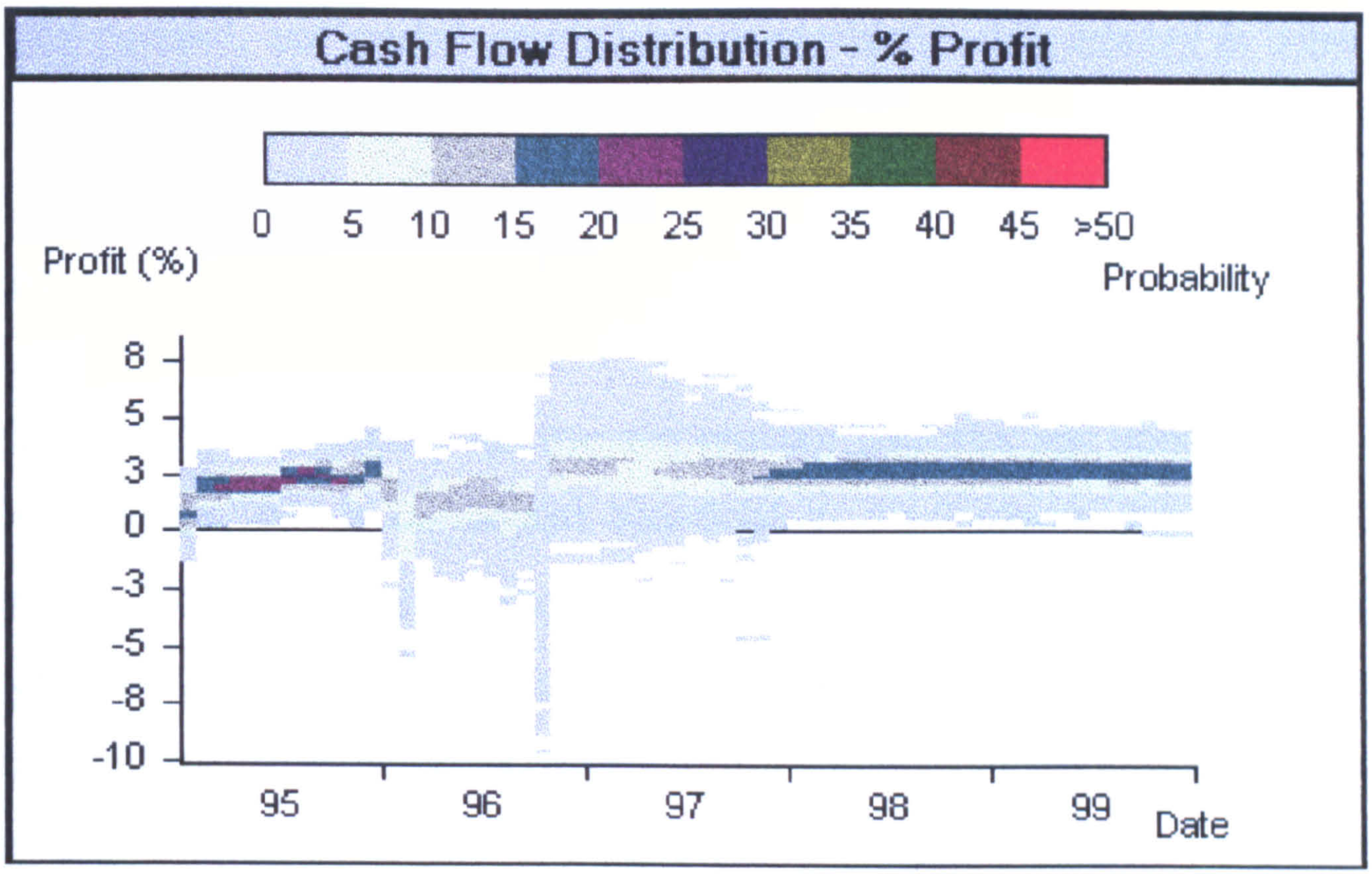

Figure 6.14 - Profit Distribution (as a percentage) for combined projects and market

The graph in Figure 6.12 shows the uncertainty in turnover increasing with time, as would be expected. The turnover is more stable in the later years, arising from the mix of randomly generated projects as opposed to the specific projects under consideration in the earlier years. The profit uncertainty depicted in Figure 6.13 and Figure 6.14 show the uncertainty decreasing with time. It is expected that the uncertainty should be in line with the turnover graph. The change arises because the risk analysed in the known projects is sometimes greater than that used to define the generated projects. In light of such a result, the distributions of profit, risk, and opportunity defined should be reviewed to ensure they as accurately as possible reflect the potential outcome of projects.

It should also be noted that the tendering strategy allows any project which was expected to make a profit to be selected while the objectives of the business unit are to make 3% profit. This has resulted in the expected profit in the final year of the study being slightly lower than target. The effects of changes to the tendering strategy will be tested in Chapter 7.

6.8 RISK AND OPPORTUNITY CLASSIFICATIONS

The graphs in Figure 6.12, Figure 6.13 and Figure 6.14 show the uncertainty in the turnover and profit of the business unit when the projects currently being undertaken, those being pursued, and market projections are combined. Uncertainty is converted to risk and opportunity when it is viewed with respect to the objectives. For the example business unit, the objectives are for a turnover of £60m and a profit of 3% on that turnover (£1.8m per year if the turnover is achieved).

As discussed earlier, the profit objective can produce both risk and opportunity, as if the target is exceeded, this is considered beneficial to the business unit. However, for turnover, any deviation from the target is considered a risk, albeit in a different manner. If the target is not reached, spare capacity will be available in the company, reflected in an inefficient business. If the target is exceeded, the resources of the business will either be stretched beyond their capacity or more resources will be required, again decreasing the efficiency of the business. The classifications required, since each outcome is distinct, are the risk to profit, the opportunity for profit, the risk from below turnover, and the risk from above turnover.

6.8.1 Profit Risk and Opportunity

The method of classifying profit risk and opportunity is similar to that used for the project risk model. When the distributions are examined, each time period is viewed to assess the mean outcome and the extremes in relation to the target. Additionally, the probability of making more or less profit than desired is considered. These three components, as also applied to the project risk model, reflect the elements of interest in the distributions for managers. The components and the functions used to evaluate them are shown in Table 6.23.

Table 6.23 - Profit Risk and Opportunity Classification Components

Component	Component Function
Mean Risk	$100\left(\frac{\text{Mean} - \text{ProfitTarget}}{\text{TurnoverTarget}}\right)$
Extreme Risk	$100\left(\frac{\text{Maximum} - \text{ProfitTarget}}{\text{TurnoverTarget}}\right)$
Probability Risk	$\sqrt{100\left(\frac{\text{Number above ProfitTarget}}{\text{Number of Cashflows}}\right)}$

Component	Component Function
Mean Opportunity	$100\left(\frac{\text{ProfitTarget - Mean}}{\text{TurnoverTarget}}\right)$
Extreme Opportunity	$100\left(\frac{\text{ProfitTarget - Minimum}}{\text{TurnoverTarget}}\right)$
Probability Opportunity	$\sqrt{100\left(\frac{\text{Number below ProfitTarget}}{\text{Number of Cashflows}}\right)}$

The classification function which combines the components contains two sets of constants for each component. Firstly, each component is scaled to produce a result between 0 and 10, where 10 is deemed the upper extreme for the component. For mean profit risk and opportunity, if the mean is greater than 10% away from the target, the extreme of 10 is returned. Hence the function does not require scaling. The extreme profit risk and opportunity functions return an extreme result of 10 when the extreme is more than 20% away from the target. To produce this result, the functions require dividing by 2. For the probability functions, which produce a result between 0 and 10, an extreme result should be returned when all the outcomes are above or below the target, and hence no adjustment is required. This approach was also taken within the project risk model (Section 4.8.3)

The second constant is used to combine the components in proportion to their importance. For instance, the mean component is possibly the most important, with the extreme component being more important than the probability. The proportions might be 5:3:2, so producing a final classification for each between 0 and 10. The calculation for the first year of the study for profit risk is shown in Table 6.24, based on a target profit of £150k per month.

Table 6.24 - Profit Risk Classification Calculation

Month	Minimum	Mean	Maximum	Prob Less than Mean	Mean Function	Extreme Function	Prob Function	Total
1	-35.929	-3.609	37.162	100	3.1	1.9	10.0	4.1
2	-16.663	20.373	68.961	100	2.6	1.7	10.0	3.8
3	-16.663	20.373	68.961	100	2.6	1.7	10.0	3.8
4	-3.931	45.151	96.450	100	2.1	1.5	10.0	3.5
5	-4.158	45.636	97.064	100	2.1	1.5	10.0	3.5
6	-4.158	45.636	97.064	100	2.1	1.5	10.0	3.5
7	17.854	70.019	124.814	100	1.6	1.3	10.0	3.2
8	17.854	70.019	124.814	100	1.6	1.3	10.0	3.2
9	17.854	68.533	124.814	100	1.6	1.3	10.0	3.2
10	12.567	56.447	113.106	100	1.9	1.4	10.0	3.3
11	-31.511	109.380	224.918	88	0.8	1.8	9.4	2.8
12	17.339	129.288	232.670	84	0.4	1.3	9.2	2.4

The results of the functions, on a scale of 0 to 10, show the probability function produces the highest result. However, because the relative importance of the functions are taken into account to produce the total risk classification, the effect of the probability function is reduced. The profit risk and opportunity classifications for the whole duration of the study are presented graphically in Figure 6.15. The output of the opportunity function is plotted as a positive number between 0 and 10, while the output of the risk function is plotted below the zero line, between 0 and -10, reflecting its negative impact on the business.

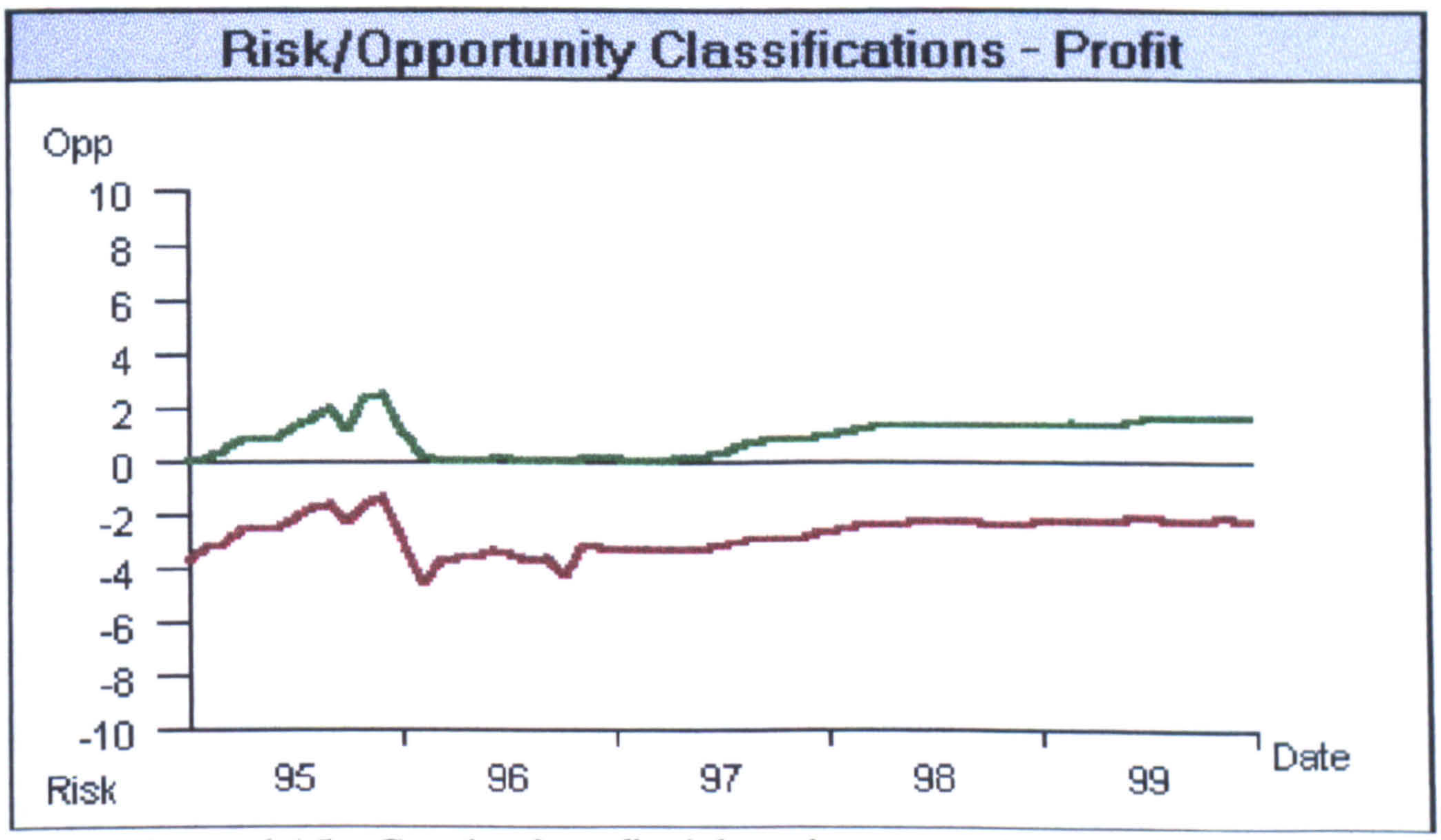

Figure 6.15 - Graph of profit risk and opportunity classifications

The graph shows the risk gradually decreasing throughout the study, with a slight but significant increase at the end of 1995. The opportunity for most of the study is lower than the risk, with the exception coming towards the end, when most of the projects are projections. This suggests that the opportunity, and the risk, of future projects are both lower than the projects analysed using the project risk model, or that the tendering strategy is optimistic as to the actual projects the business unit will be undertaking. Each possibility would require management investigation.

In addition to assessing the risk and opportunity to the profit in actual monetary terms, similar functions to those shown in Table 6.23 can be applied to the profit represented as a percentage of the actual turnover. Figure 6.16 shows the risk and opportunity functions assessed against the target profit margin for the example business unit of 3%, also limiting the mean at 10% either side of the mean and the extreme at 20% either side.

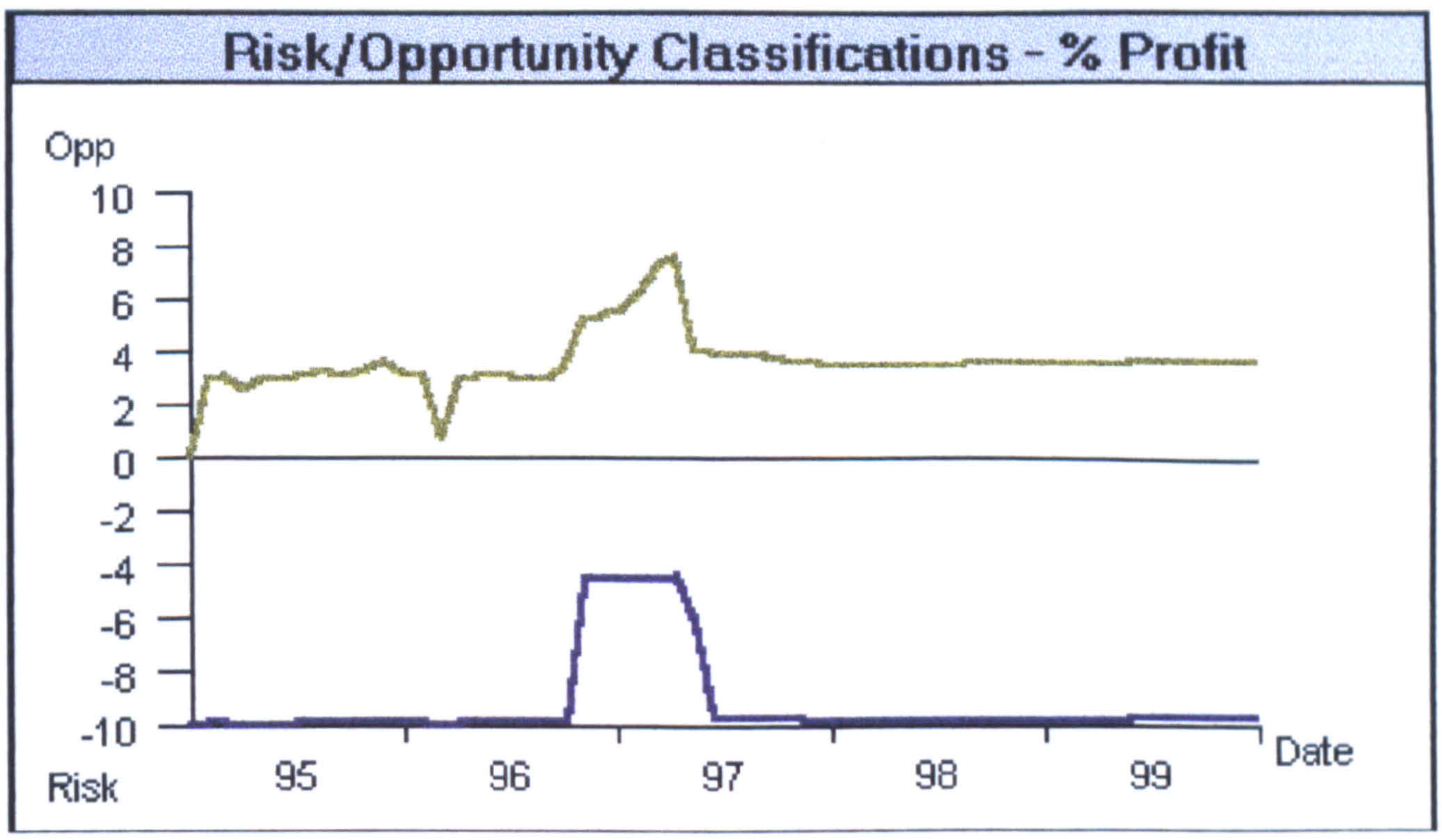

Figure 6.16 - Percent profit risk and opportunity classifications

The function for percentage profit risk returns a maximum of 10, plotted as -10, for most of the study. Only towards the end of 1996 and throughout 1997 does the output of the function reduce. This is showing a considerably higher level of risk than the function for profit in financial terms returned, since this function assesses the level of turnover from which the profit is produced. The opportunity function also produces a higher result than the previous function, peaking at a maximum of 8 in 1997, and for the other years, except the first few months of the study, remaining at a fairly constant level of 4.

6.8.2 Turnover Risk

The risk and opportunity to profit is important, but of equal importance is the uncertainty relating to the turnover which will produce that profit. The difference in the two functions plotted above in Figure 6.15 and Figure 6.16 shows the effect taking the turnover into account can have. A similar function for risk and opportunity can be applied to the distributions of turnover in each time period. The opportunity function becomes the risk that the turnover is exceeded. The output of the functions are shown in Figure 6.17, based on a target turnover of £5m per month. The function for the risk that the target is not reached is plotted on a scale of 0 to -10, while the function for the risk that the target is exceeded is plotted on a scale of 0 to 10.

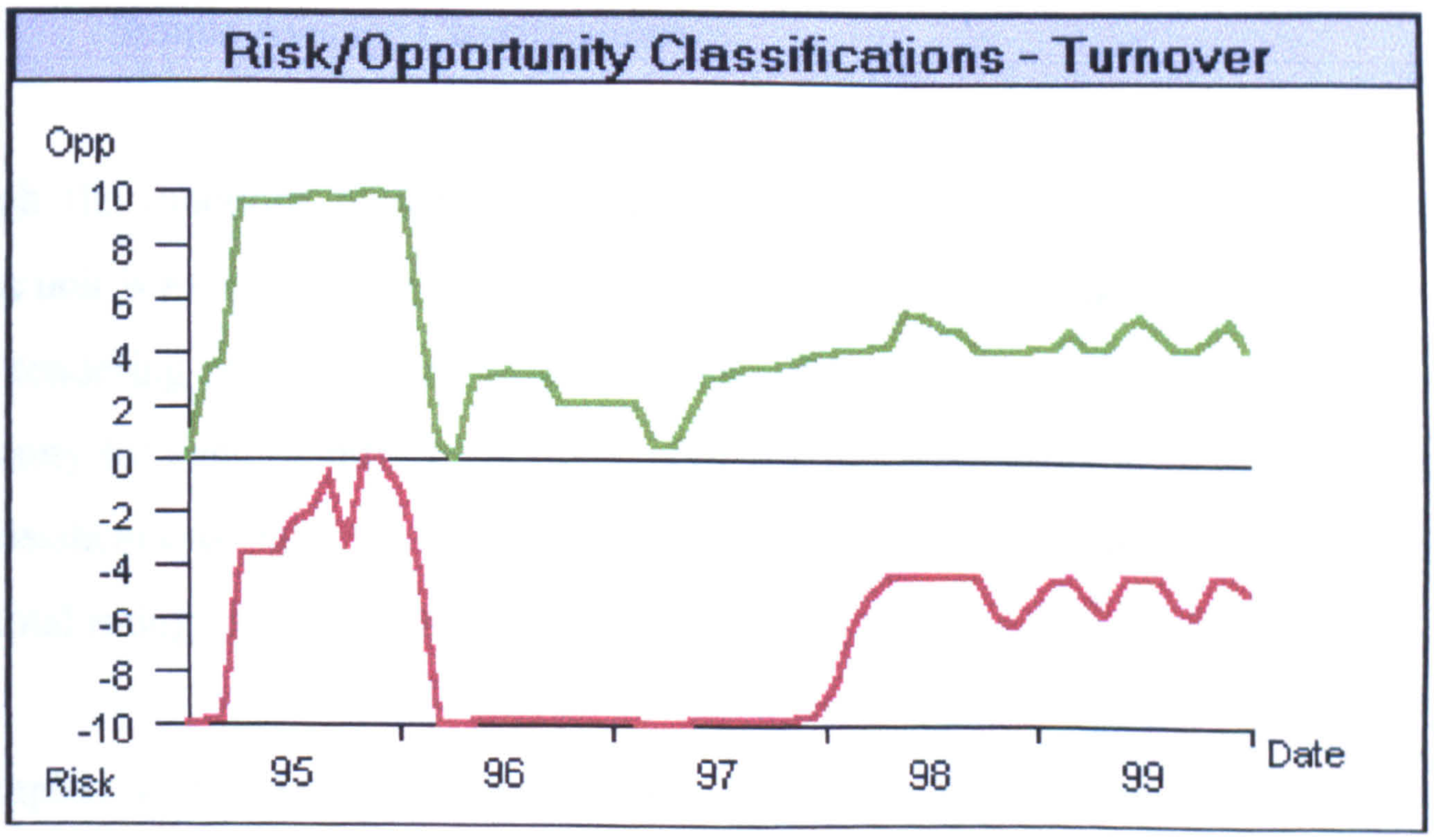

Figure 6.17 - Turnover risk classifications

The below target risk function produces a maximum result and the above target function produces a zero output for most of the first three years of the study. The outputs are reversed for the last eighteen months of the study. The results of the study can be viewed in two ways; either, the functions are too sensitive to changes in the turnover, readily switching from 0 to 10, rarely producing results between the two extremes, or the functions are calibrated correctly and are legitimately reporting a switch from a period of low risk to one of extreme risk. The view which is taken will be influenced by the calibration process undertaken.

For each function, whether profit risk and opportunity in financial or percentage terms or turnover risk, the extreme was set at 20% away from the target for the extreme component and 10% away from the target for the mean component, and the ratio of importance was set at 5 for the mean component, 3 for the extreme component, and 2 for the probability of exceeding the target. If the output of the functions are considered to be too sensitive or not sufficiently sensitive, or not giving enough sufficient importance to some components of the distributions, the parameters in the functions can be modified to calibrate the system.

6.8.3 Single Figure Classifications

6.8.3.1 Simple Average Classifications

Although the functions presented above begin to classify the risk and opportunity the business unit is exposed to as a result of the projects it is undertaking, those it is pursuing, and its tendering strategy, they produce a classification for profit and turnover risk and opportunity for each month of the study. For the five year study used in the example, the sixty classifications show the regions of risk and opportunity through the study but do not give a total rating for the business unit.

The simplest form of such a classification would be to evaluate the average of each function. Although this process could be continued to produce a single number for the business by taking the average of the single number for each classification, the result would be a value which did not offer sufficient information to make an assessment. This approach, of producing a single classification for risk and opportunity to each objective, was also applied to the project risk model.

The average result of each function for the example business unit is presented in Table 6.25 below.

Table 6.25 - Simple Average Classifications

Function	Average
Profit Risk	2.7
Profit Opportunity	0.5
Percent Profit Risk	9.1
Percent Profit Opportunity	3.7
Above Turnover Risk	6.1
Below Turnover Risk	3.7

The average for each function presented above show that the business unit is exposed to considerable risk of not achieving its desired profit margin and turnover.

6.8.3.2 Weighted Average Classifications

Although the simple average provides a mechanism for producing single number classifications for the risk and opportunity to each objective, when viewing the distributions and the functions plotted over time, greater importance may be attached to the results of the first few years than the later years of the study, especially if a longer study period was used. A weighted average classification can be produced, giving higher weight to those time periods considered to be of higher importance. In the simple average classifications, each time period was given a weight of one.

Various functions can be used to describe the relative importance of the time periods. Perhaps the simplest is the straight-line decrease, an example of which is shown below in Figure 6.18, showing the weight decreasing from 1.0 at the start of the study to 0.2 at the end. This describes a situation in which the results of the first few time periods are considered to be five times as important as those towards the end.

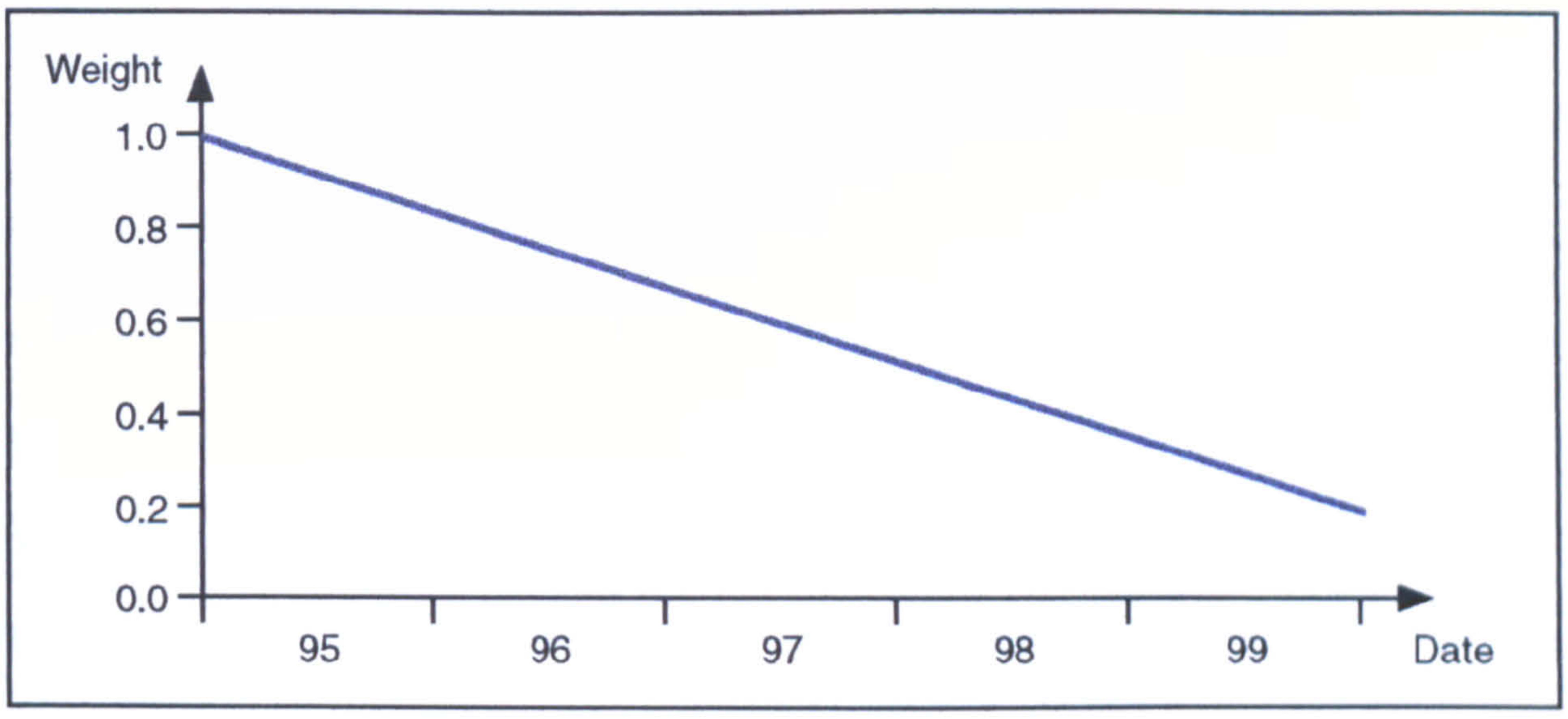

Figure 6.18 - Straight line decrease of risk factor weighting

Applying the weights taken from the straight line decrease shown in Figure 6.18 to the risk factors evaluated for the example business unit produces the results shown in Table 6.26.

Table 6.26 - Weighted average risk and opportunity classifications

Function	Weighted Average
Profit Risk	3.0
Profit Opportunity	0.4
Percent Profit Risk	9.1
Percent Profit Opportunity	3.6
Above Turnover Risk	7.3
Below Turnover Risk	2.5

The results in Table 6.26 show a slight change in the classification between the weighted and simple average functions. The classifications increase for all but the percent profit risk, which stays the same, and the below turnover risk, which reduces. Examination of the distributions and the functions across the time periods showed that the first two years of the study were more uncertain than the last two years; this is reflected in the general increase in the risk classifications using the weighted average which gives more emphasis to the earlier time periods.

6.8.3.3 Other Classifications

The two classifications presented above reflect a universal model in the simple average and one tailored to a particular view of a business unit using the straight-line decrease. The straight line decrease is just one of many possible ways in which the functions evaluated in each time period can be weighted for relative importance. Each function will give a unique assessment of the risk and opportunity of the business unit. The selection of such a function will be part of the calibration process started by selecting the parameters for the functions applied to each time period.

6.9 SUMMARY

This chapter has presented the company risk model, describing the various stages of projects experienced by a business unit and showing how these are incorporated into the model. The resulting uncertainty is then classified, for which suggested functions were presented, including two mechanisms by which the classification for each time period can be combined to produce single classifications for risk and opportunity to each objective. Chapter 7 tests the model presented against its objectives.

CHAPTER 7

TESTING THE COMPANY RISK MODEL

7.1 INTRODUCTION

The previous chapter presented the company risk model, defining the objectives of the model and the mechanisms by which the model seeks to attain those objectives. This chapter assesses the ability of the model to attain the objectives defined. This is achieved by testing the model with various scenarios, comparing the ability of the model to reflect the changes being made. Throughout Chapter 6, as a means of illustrating the principles of the model, an example business unit was used. That business unit will be used as the basis of the scenarios used in this chapter, although the example will be developed as the tests progress, illustrating the mechanisms by which the model can be made more representative.

The chapter begins with a reiteration of the objectives of the model, followed by a discussion of the tests to be performed. Within each test, the model will be tested against one or more business unit scenarios, showing how the model performs in various situation and comparing that with how it would be expected to respond.

7.2 OBJECTIVES OF THE TESTS

The objectives of the company risk model presented in Chapter 6 can be summarised as the ability to combine the sources of uncertainties in the business unit and then to classify that combined uncertainty for risk and opportunity against the objectives of the business unit. The tests performed assess the ability of the model to attain those objectives.

The example business unit was used in Chapter 6 to illustrate the ability of the model to combine the various sources of uncertainty rather than assess the level of that ability, as, for example, only a single market condition was used. Similarly, although the example illustrated that classifications can be produced which to some extent reflect the uncertainty in the cash flows, the ability of the classifications to accurately reflect changes in the business unit to allow comparison, for example, between tendering strategies or individual tenders was not assessed.

The first set of tests will assess the ability of the model to combine the sources of uncertainty, for which the market definition and the effectiveness of tendering strategies are the components to be tested. The second set of tests take the combined uncertainty in the cash flows and assess the extent to which the classification system, both for individual time periods and business unit classifications, can reflect the risk and opportunity arising from that uncertainty.

In order that the performance of the model can be assessed, each test considers an individual component rather than allowing all the possible variables to vary simultaneously. In this way, the anticipated response to a variation can be compared with the actual.

7.3 TESTING THE COMBINING OF UNCERTAINTY

7.3.1 The Tests

The majority of variables within the model are contained in the market definition and the tendering strategy applied to that market to determine the projects tendered for and ultimately undertaken by the business unit. This series of tests assesses the extent to which the mechanisms within the model react to changes in the market definition, and then assess the performance of mechanisms within the tendering strategy. Table 7.1 contains a list of the parameters within the market definition which can be changed and the effect the changes are testing. The model is tested by changing the parameter, and comparing the result with the predicted effect.

Table 7.1 - Market definition parameters to be tested

Parameter	**Effect Tested**
Market Size	Increased and decreased over the duration of the study
Project Value	Range of contract value increased
Project Duration	Range of project duration increased
Project Risk/Opportunity	Increased uncertainty in return

The parameters within the tendering strategy which will be tested, largely to assess the ability of the model to counter the changes in the market definition imposed on it, are presented in Table 7.2 below.

Table 7.2 - Parameters tested within the tendering strategy

Parameter	**Effect to be tested**
Probability of success	Variable percentages reflecting tendering effort
Target turnover	Variable targets reflecting policy
Desired project characteristics	Variable targets reflecting policy

The results of each test, in which a variation is made to the market definition from which projects are selected for tender, will be assessed largely by comparison with those of the model before the change was made. The risk and opportunity classification system was developed to produce a simple measure of the uncertainty to allow just that comparison. Since the robustness of that system will be tested later in this chapter, after the performance of the model it relies on has been tested, the classifications cannot be used to assess the performance of the model. However, since the classification system takes several parameters from the distributions of profit and turnover as input, these same parameters can be used to assess the performance of the model to changes in its input.

7.3.2 Variable market size

The example business unit used in Chapter 6 was based on a market of constant size. Unfortunately, the construction industry in the UK is not so uniform, particularly as a considerable proportion of the clients are public sector and hence susceptible to political influences. In the event that a market starts to decline, the primary effect is that the number of projects available for tendering by any company is decreased. If the business unit attempted to maintain its target turnover throughout the period it would effectively be attempting to increase its market share. This strategy could be expected to increase the risk in the company as it might have to pursue projects it would ordinarily reject in order to pursue the desired quantity of work.

In a more extreme case, the quantity of projects available within a market might be so reduced that it does not offer sufficient for tendering purposes for the business unit. In this case, not only would the profit uncertainty increase for the reasons described above, but the turnover risk would also increase as the business unit could not tender for sufficient projects to maintain its turnover.

The tests performed are designed to assess whether the model produces results similar to the ones envisaged under various scenarios. In order to assess the performance of the model, the mean and extremes of the profit and turnover distributions will be plotted in addition to inspection of the projects available and those selected for tender. The various market sizes applied to the example business unit are presented in Table 7.3 below.

Table 7.3 - Market size tests inputs

Test	Market Size
Base	£750m throughout the study
1A	£750m, decreasing by 5% per annum
1B	£750m, decreasing by 10% per annum
1C	£750m, decreasing by 20% per annum
1D	£750m, increasing by 5% per annum
1E	£750m, increasing by 10% per annum

For tests 1A, B, and C, the turnover over the later years of the study may be at risk as the number of projects available is reduced. The effect would be extremely pronounced if the size of the market was less than the company was wanting to pursue. In this example, even in Test 1C, this situation is not reached and so it is not expected that the mean turnover, which is plotted in Figure 7.1 below, will be greatly different between tests. None of the projects which the business unit is either pursuing or currently undertaking, are included in the analysis to allow the operation of the market definition and tendering strategies to be tested.

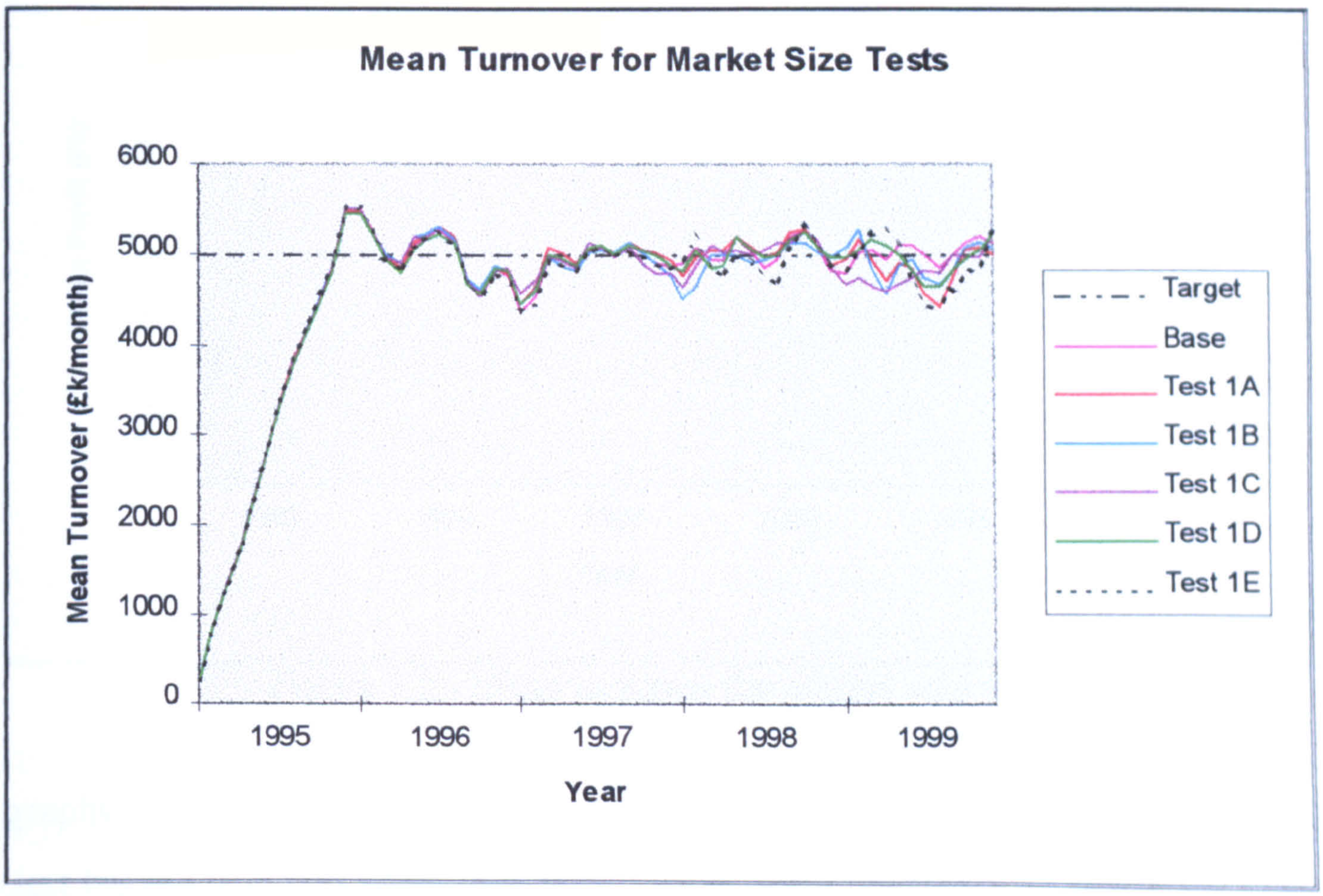

Figure 7.1 - Mean turnover for market size tests

The above graphs show little difference between the mean turnover for each test, as would be expected since the market size does not reach the critical size when it limits the amount of work available to the business unit. The most significant effect which is expected from this test is the change in profit risk as the market size changes. Figure 7.2 below shows the mean monthly profit for each test.

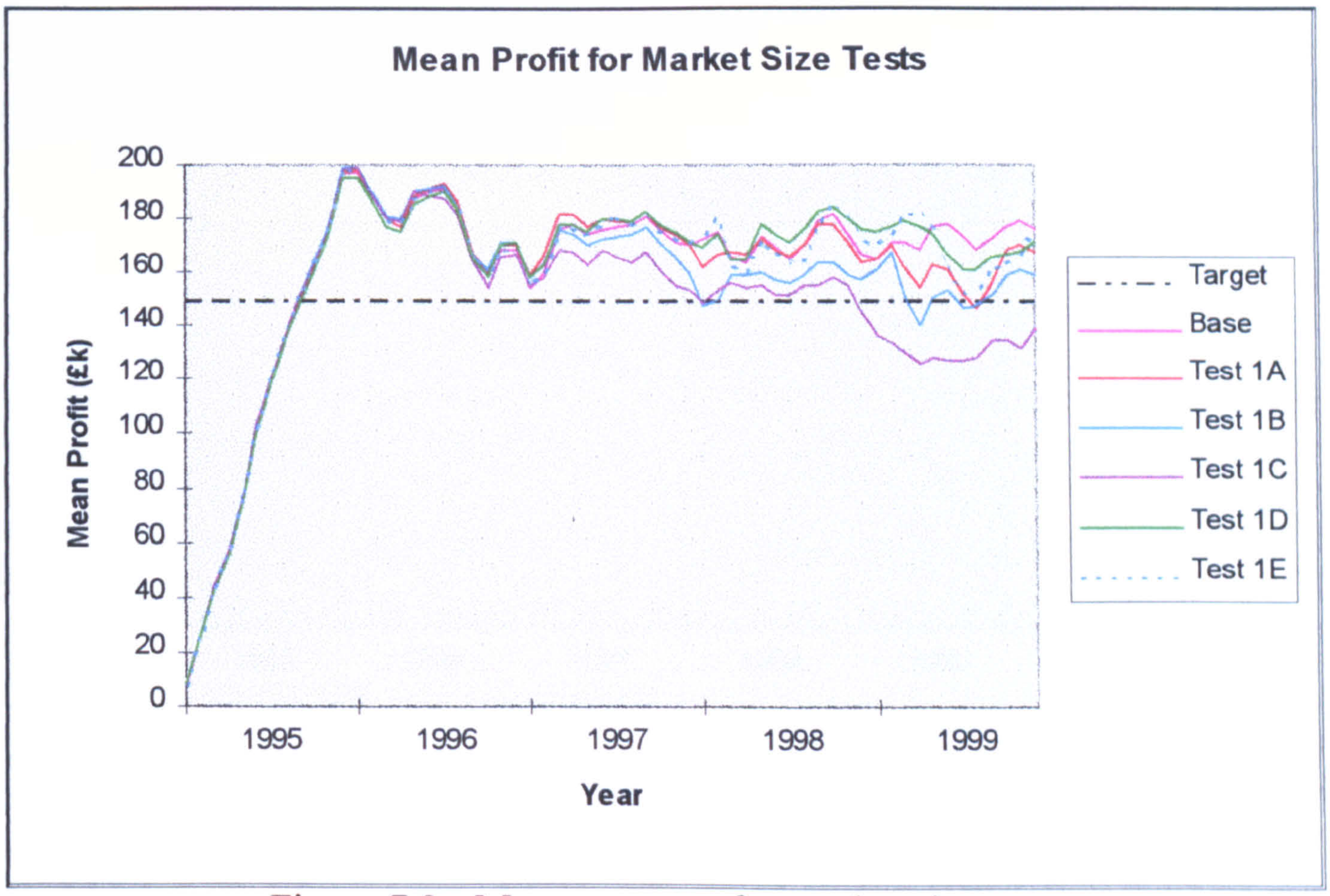

Figure 7.2 - Mean turnover for market size tests

The graphs of mean profit for each test plotted in Figure 7.2 show a similar result for each test for the first two years then tests 1A, B, and C decrease as expected. Tests 1D and E, in which the size of the market increases, in years 1997 and 1998 are similar to the base case, showing the increased number of projects available does not necessarily allow the business unit to select projects which are likely to be more profitable for it. In the final year of the study, the mean profit for these two tests drops below the base case, although never drops below the target for the business unit. The reason for the mean turnover for these tests dropping below the base case cannot be determined from the model since the mean case is not an actual cash flow generated within the model. The result will be a function of the projects generated for that test since the string of random numbers used in the later years will be different due to the increased number used in the first year. Another factor which could affect the mean profit in the final year is the mean turnover; if the turnover is less for the final year for tests 1D and E, the mean profit would also be expected to be lower. To investigate this further, Figure 7.3 plots the mean profit as a percentage of the turnover actually undertaken.

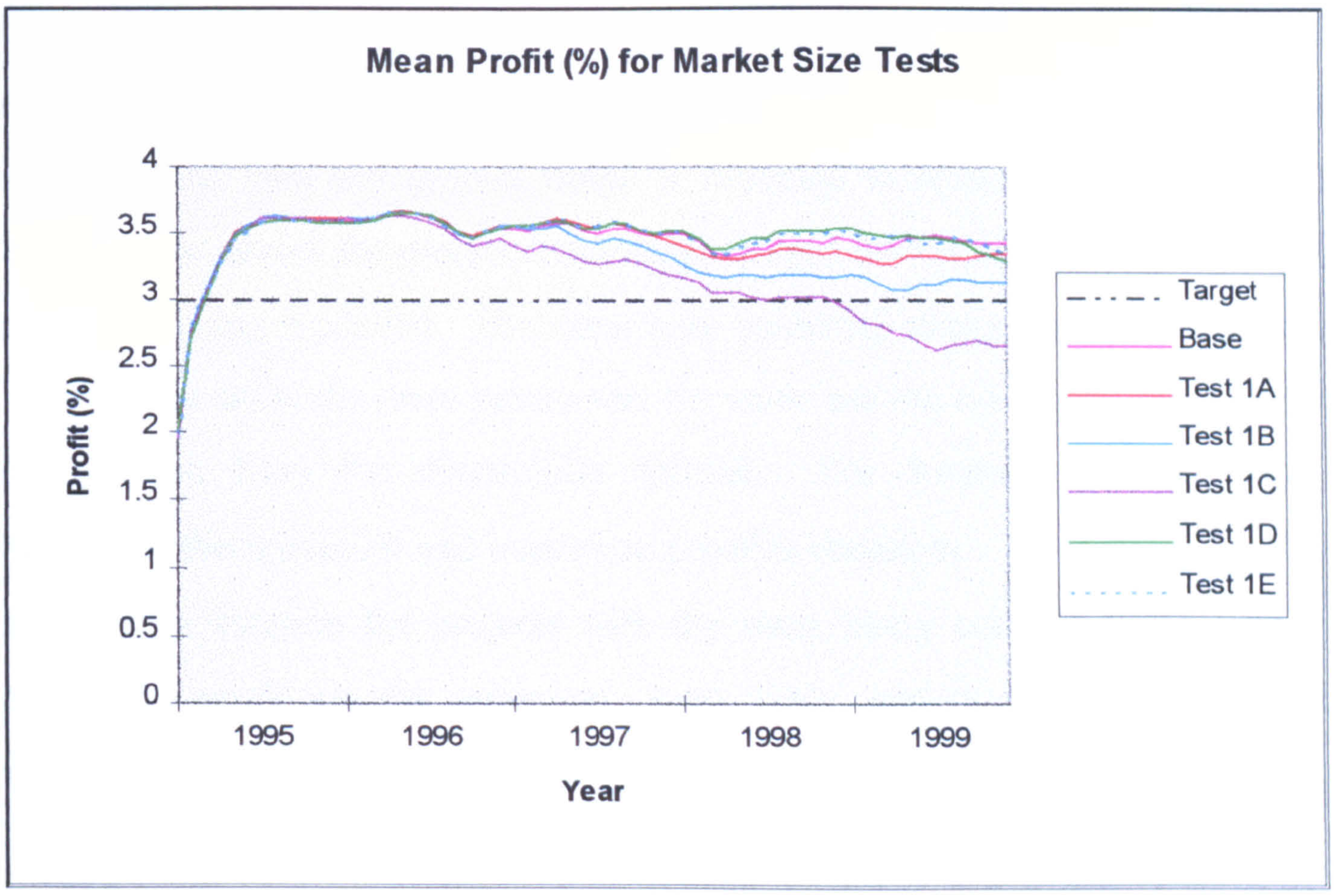

Figure 7.3 - Percentage profit for market size tests

The graphs in Figure 7.3 show the profit as a percentage of the turnover to be similar for the base case and tests 1D and E (the increasing markets), with significant decreases being shown for tests 1A, B, and C. This confirms that the turnover of projects selected, and not the profitability of those projects, causes the profit in Figure 7.2 for tests 1D and E. This is likely to be a result of projects generated for those tests in that or the previous year.

7.3.3 Variable Project Characteristics

The test performed on market size suggests that the model is acting logically to reductions in market size. The reaction of the model to increases in market size was not conclusive as the turnover target was being achieved with the base case market size. However, if Test 1C (the smallest market size) was viewed as the base case, with all other tests showing an increase in the market size, the model can also be seen to be acting logically to increases in the market size.

Test 2 will test the effects of changes in the projects which make up that market, assessing the ability of the model to reflect the appropriateness of the tendering strategy for the market conditions. The base case perhaps represents a balanced tendering strategy, in which only the extremes of the market for project size and duration are unacceptable, and then any project which is expected to return a profit is acceptable. Table 7.4, below, shows the project characteristics used for the tests, with a description of the conditions being modelled. The same base tendering strategy will be used for each test. Within the table, the three parameters for value are the minimum, most likely, and maximum taken from the distribution defined. For duration, the first and third parameters are the minimum and maximum possible durations. The second parameter is the most likely duration for projects with the most likely contract value. The three parameters for profit are the minimum, most likely, and maximum, taken from the distributions for profit, risk, and opportunity.

Table 7.4 - Project characteristics test inputs

Test	Description	Value (£m)	Duration (months)	Profit (%)
Base	Base Case	2,5,17.5	6,9,24	-5,3,10
1	Larger, longer projects	5,15,17.5	6,18,24	-5,3,10
2	Smaller, shorter projects	2.5,5,10	6,9,12	-5,3,10
3	More uncertain projects	2,5,17.5	6,9,24	-7.5,3,12.5
4	Riskier projects	2,5,17.5	6,9,24	-7.5,3,7

With both larger, longer projects and small, shorter projects, the tendering strategy might be expected to become incompatible with the market in which it operates. The effects of Test 2A on the turnover and profit of the business unit are not expected to be as pronounced as those of Test 2B since half the projects generated in Test 2B will be undesirable with respect to their duration. Test 2C, with more uncertain projects, would be expected to increase the uncertainty in the profit of the business, having no effect on the turnover. Test 2D is expected to produce a similar result as Test 2C without the opportunity. The mean monthly turnover of each test is plotted below in Figure 7.4.

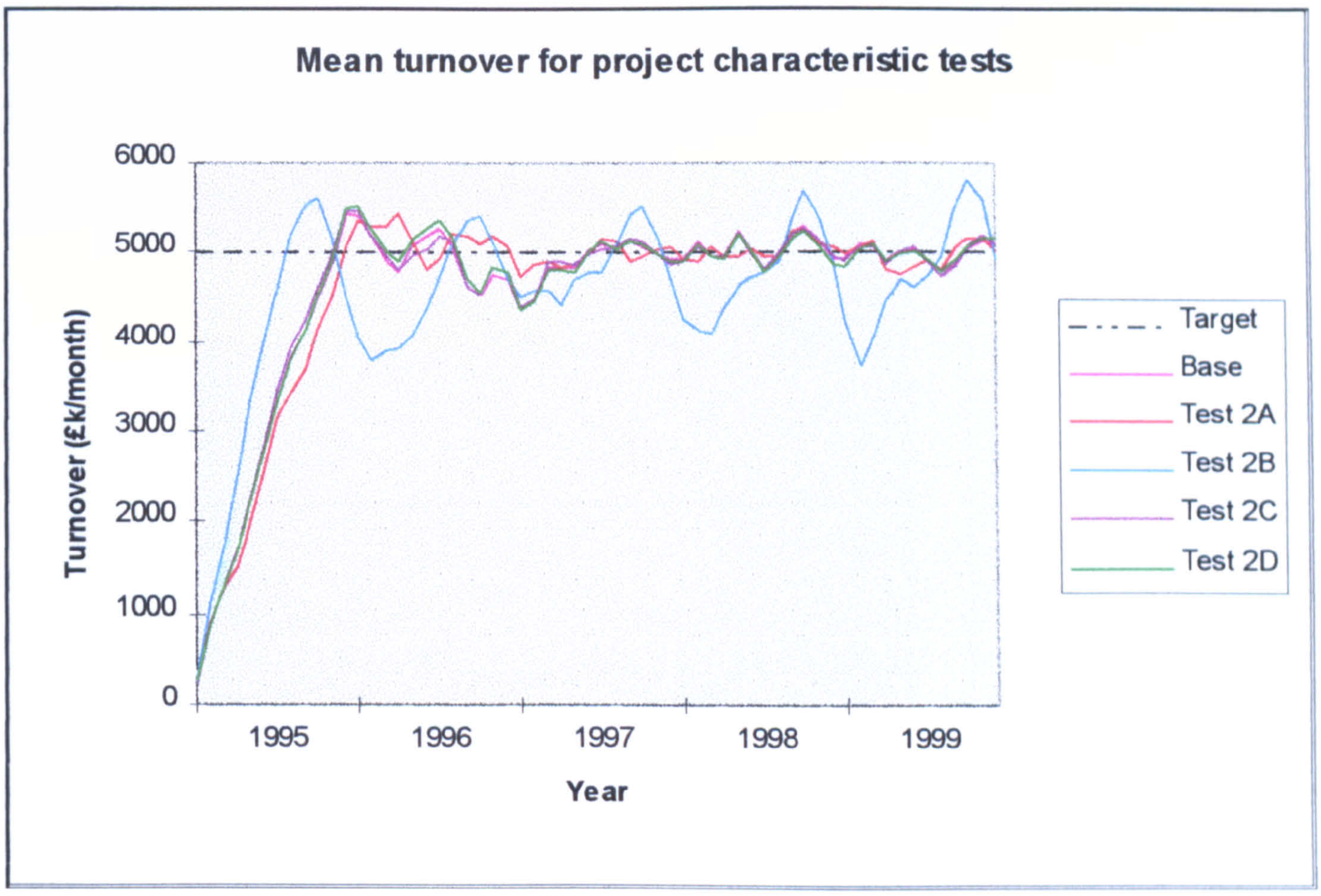

Figure 7.4 - Mean turnover for project characteristic tests

The only test which has had a significant impact on the turnover of the business unit is Test 2B, using smaller, shorter projects. Over the first year of the study, the business unit satisfies its turnover requirement faster than in the base case and then compensates for this by reducing its turnover target. This process produces a cyclic effect, which is clearly visible in the graph. A similar effect can be seen in the mean turnovers for the other tests in which the target turnover is exceeded by the end of the first year and then the business compensates for this. The impact of this on the other tests as the study progresses decreases. In the case of Test 2B, presumably because the projects are of much shorter duration, the business never settles down as the large number of projects are always being undertaken and having to be replaced frequently. This result suggests that the tendering strategy implementation which assesses work load every three months is not adequate for markets in which the projects are usually only 2 or 3 times as long as that period.

The mean of the distributions gives an indication of the expected result. Figure 7.5 below plots the extremes for the monthly turnover for each test, giving an indication of the uncertainty in the turnover prediction.

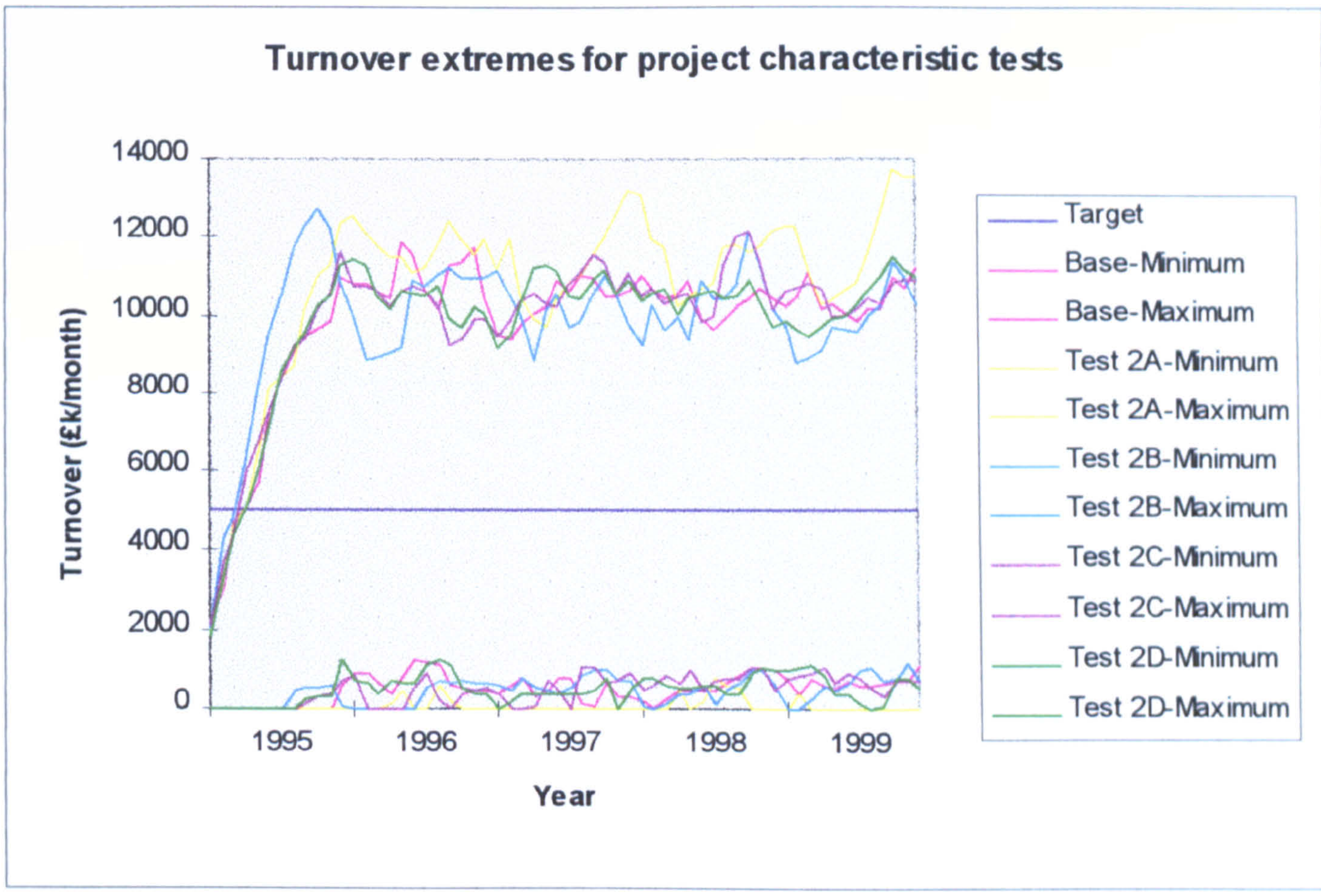

Figure 7.5 - Turnover extremes for project characteristic tests

The graphs in Figure 7.5 show some variation in the extremes for turnover for each test, although the result for all tests appear to fall within the same band. Since the extreme of the distribution is dependent on the random numbers used (when compared to the mean), this variation is expected and should not be interpreted as a function of the markets tests. The only result which is significant is that for Test 2A, for longer, larger projects. This test gives a minimum turnover of zero for a considerable proportion of the study. The reason for this is that the company, in order to satisfy its turnover target, will be tendering for fewer projects, so increasing the probability that it fails to win any of the contracts it is bidding for. The greatest impact of the various project characteristics tested is expected to be in the profit distributions, the monthly means of which are plotted in Figure 7.6 below.

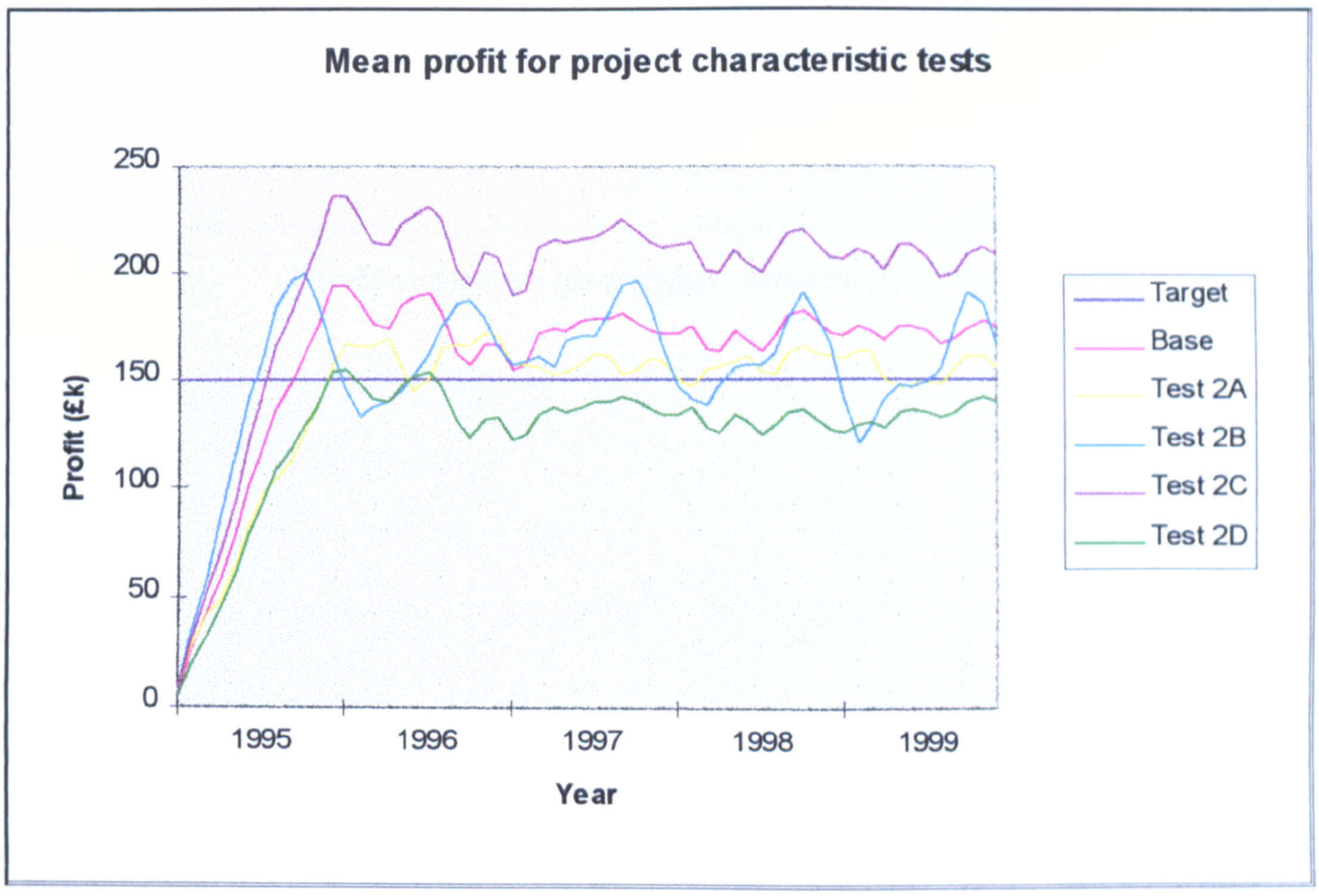

Figure 7.6 - Mean profit for project characteristic tests

Considering each test in turn, Test 2A, using larger, longer projects, produces a mean profit lower than the base case for the majority of the study. However, the mean profit is at or above the target profit and hence is not a cause for concern. Since the profitability of the projects in the base and Test 2A are the same, the lower mean profits are either caused by a lower mean turnover or greater uncertainty in the turnover in Test 2A. Since no difference in the mean turnover could be seen in Figure 7.4 and it was evident that the turnover in Test 2A had the potential to be zero, it is likely that it is the uncertainty in the turnover which is reducing the mean profit.

In Test 2B, using smaller, shorter projects, the mean profit exhibits cyclic behaviour, which

is the expected result since the turnover also followed a cyclic pattern. Test 2C, using more uncertain projects, produced a result significantly higher than the base (or any test). This is as expected because the model is selecting projects which are expected to produce a return of 3% or higher and the maximum profit has been increased. Test 2D, using riskier projects, returned a mean profit usually lower than the target. This is as expected because for this test the projects selected had a larger probability of returning a loss than they did of producing a return higher than 3%. Figure 7.7 plots the extremes of monthly profit for each test to assess the extent to which the uncertainty has been affected.

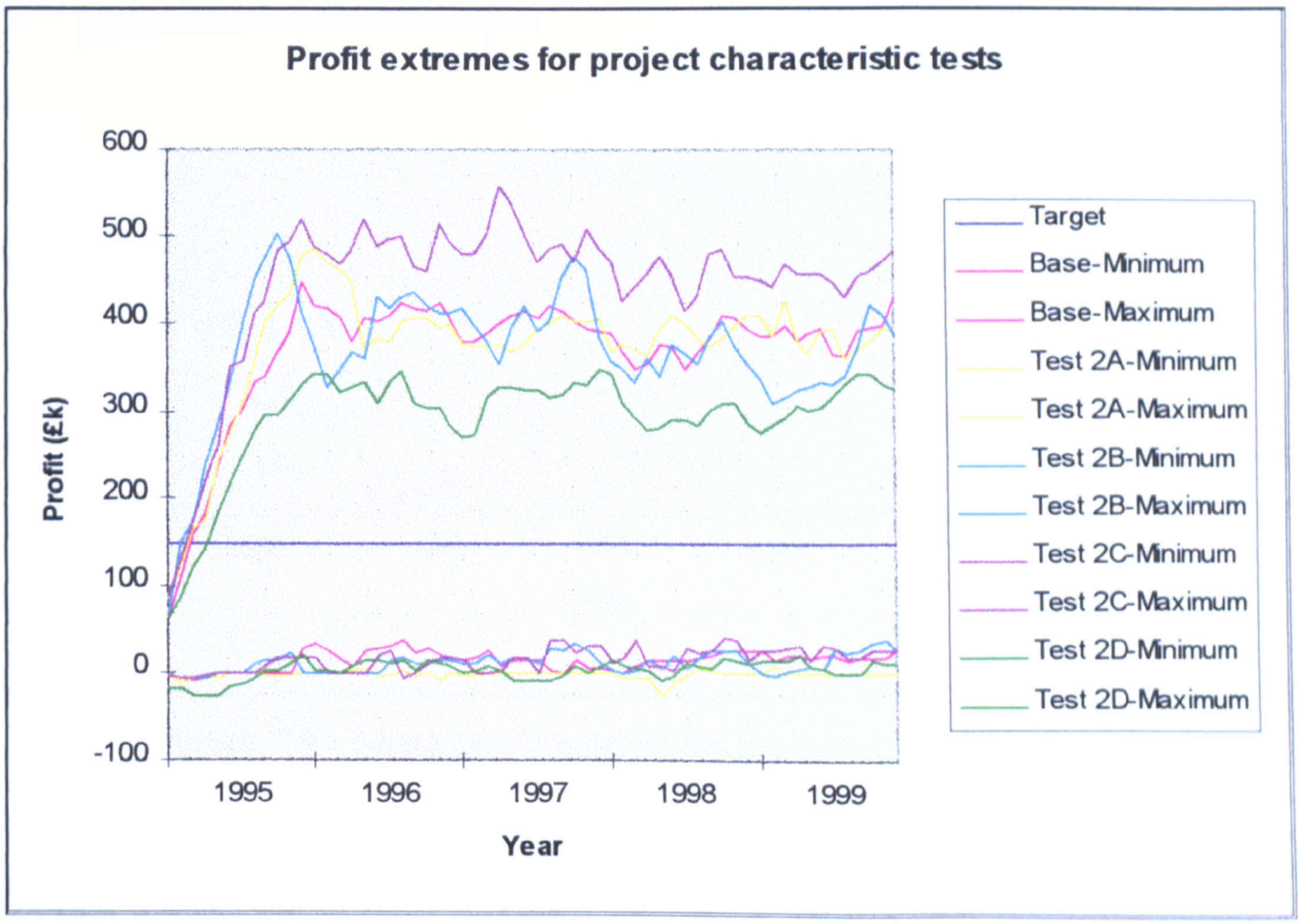

Figure 7.7 - Profit extremes for project characteristic tests

The extremes of the profit distributions, shown in Figure 7.7 above, follow a similar pattern to those of the mean profit reflecting an as expected result. To confirm the expected effect on profit, and to remove the effects of variable turnover Figure 7.8 plots the mean monthly profit margin for each test.

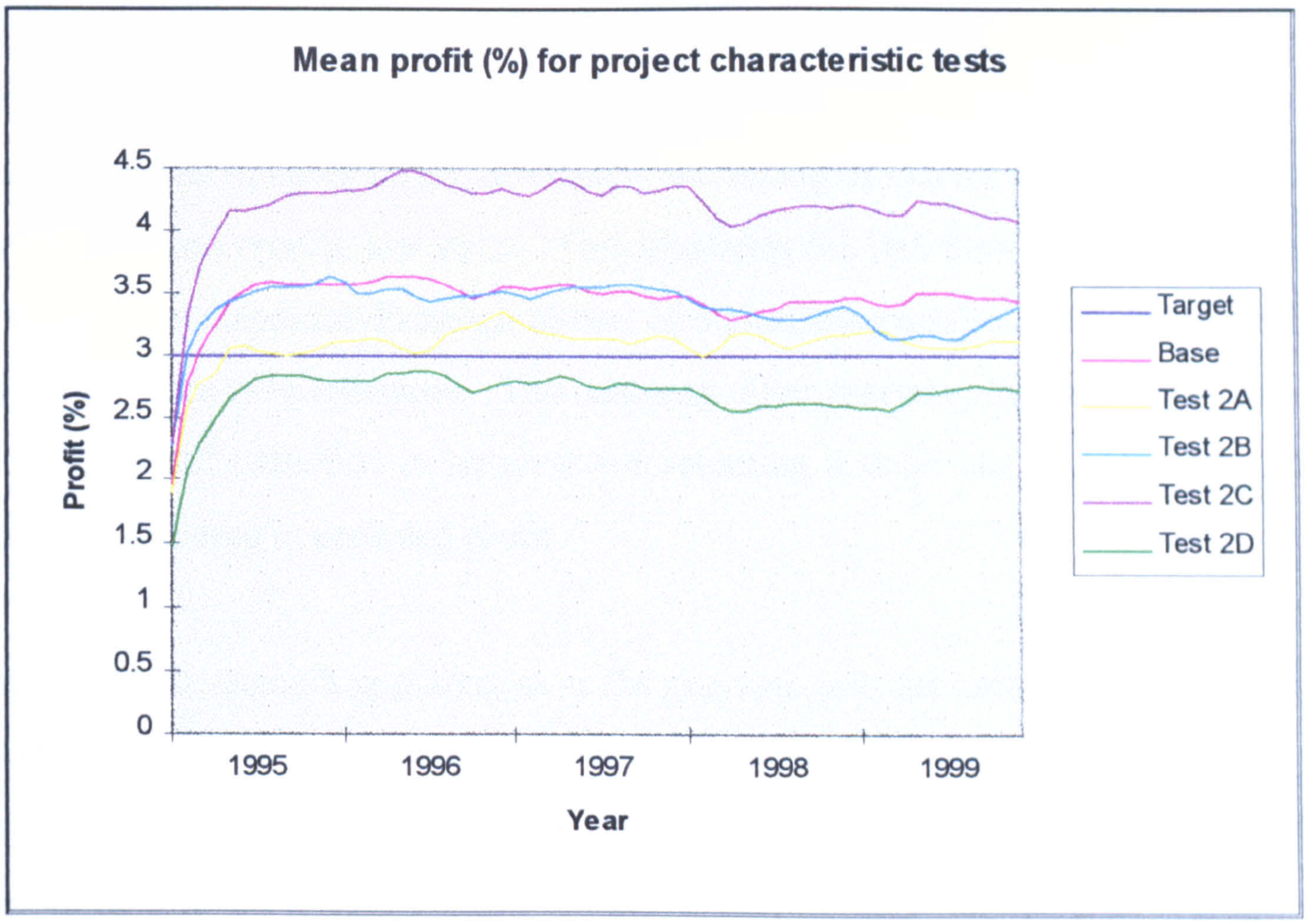

Figure 7.8 - Mean profit margin for project characteristic tests

The graphs of mean profit margin confirm the expected result with regards to the effect on profit of the various tests.

7.3.4 Target Turnover

The previous tests examined the ability of the model to react to changes in the market. In practise, any changes in the market would not usually be allowed to take place without a reaction from the company. These reactions are modelled using the tendering strategy. The parameters within the tendering strategy which can be changed are the target turnover, the success rate for tenders, and the targets for project value, duration, and expected profit.

The first test of the company risk model examined the effect of changes in the market size on the business unit. Without changing the tendering strategy, this resulted in changing the target market share of the company since the target turnover did not change. The result, in the case of declining markets, was that the company had to accept projects which fell outside its target range, either in terms of contract value, duration, or expected profit. If the company decided it did not want to accept such projects, it would have to accept a reduction in its turnover. Within the model, this reduction in the target would have to be made manually, in anticipation of the changes. If however, it decided it would try to maintain its turnover target, effectively increasing its market share, it would have to make its selection criteria less strict. This illustrates the link between market share and profit. The two outcomes discussed above, of maintaining market share and maintaining profit, are not the only outcomes. The company, after assessing the risks, may decide to take only a small reduction in turnover (representing a small increase in market share) and a small decrease in expected profit.

In the case of an expanding market as in the previous test, the company was reducing its market share and as a result saw its returns increase as it was always selecting from projects within its target range. If the business unit did decide to maintain its turnover, it might be able to make its selection criteria stricter in order to increase returns. If it decided to take advantage of the expanding market and maintain its market share, it would have to increase its target turnover. In a similar way to the declining market, a combination of increased turnover and improved profits could be chosen.

In order to investigate the effects of this, a low target turnover and increasing target profit margins will be tested. The expected result, in light of the discussion above, is that the target profit margin can be increased, producing the desired level of turnover and an increased profit margin only up to a point. If the profit margin is set too high, although the profit margin will be met, the turnover target will not. A market size of £750m and a target turnover of £40m are tested with target profit margins starting at 2% and increasing in increments of 0.5%.

For each test, the rules are strictly applied so if the turnover target is not achieved applying the rules to the each of the projects, the rejected projects are not reassessed and selected until the target has been achieved. This will show whether the target profit margin is too high for the projects available and the desired turnover. The mean monthly turnover for each test is plotted in Figure 7.9 below.

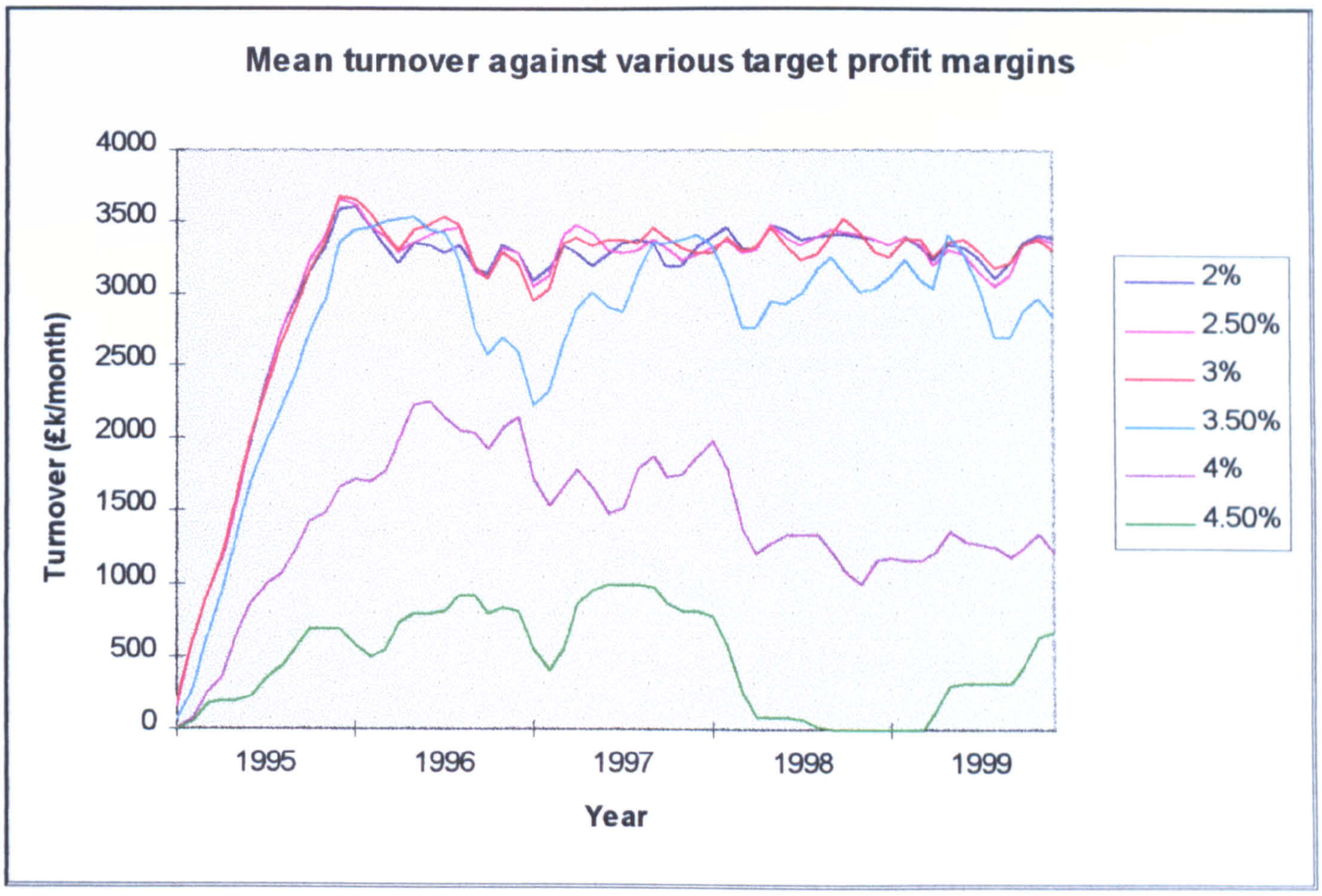

Figure 7.9 - Mean turnover for various target profit margins

The graphs of Figure 7.9 show the mean monthly turnover increasing over the first year of the study and settling down at the target for target profit margins of 3% or less. For a target of 3.5% the target is sometimes achieved but more often is not attained. For targets of 4% and 4.5% the business unit never reaches its target turnover; at 4.5%, less than a third of the target is attained. In light of the effect on turnover, mean profit is expected to increase for the first three tests and reduce for the last two. For the test at 3.5%, the return is expected to be the highest for those periods in which the turnover is achieved and reduced when it is not. These results are confirmed by inspection of the graphs plotted in Figure 7.10 below.

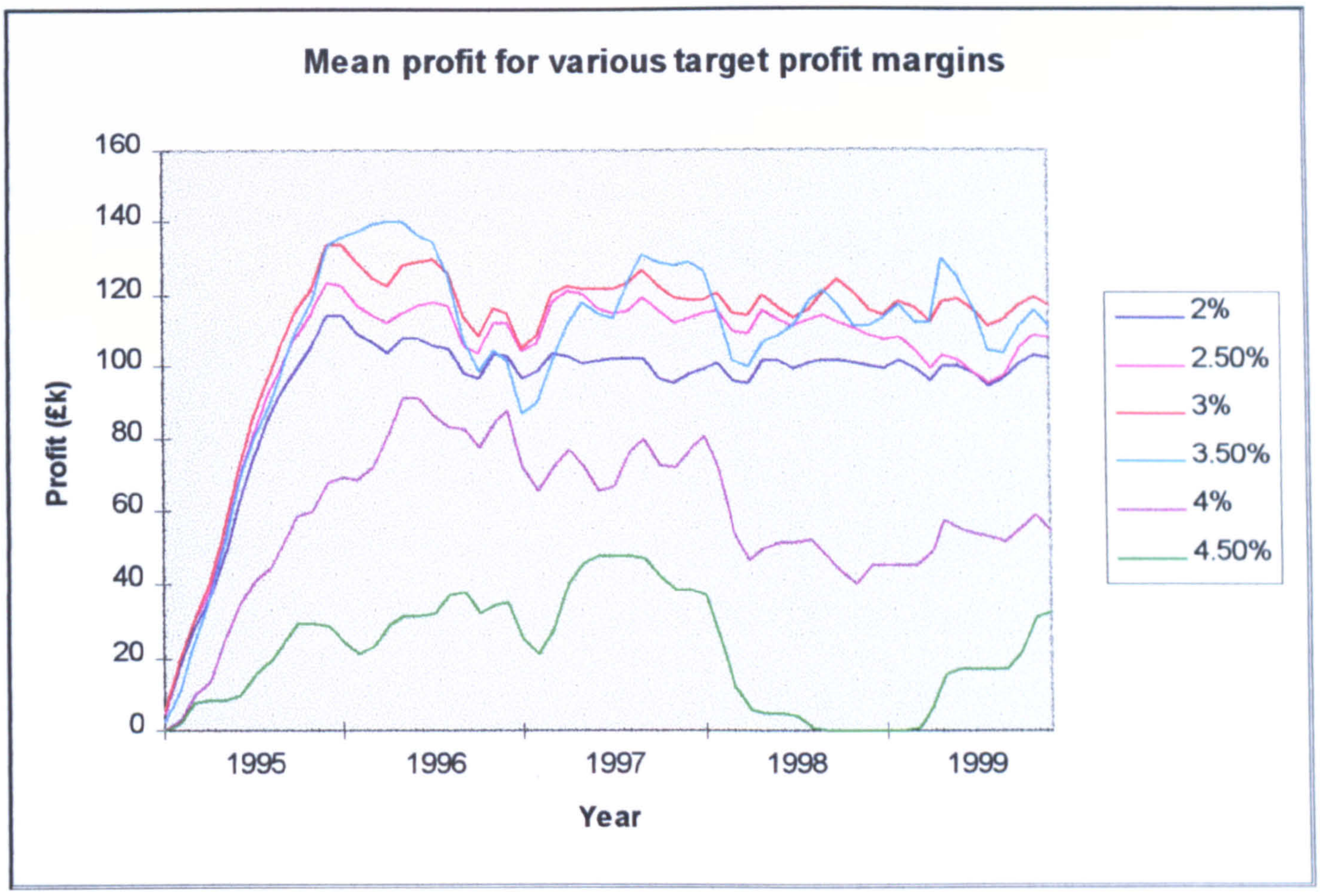

Figure 7.10 - Mean profit for various target profit margins

Viewing the mean monthly profit in financial terms does not give a true reflection of the performance of the business. For profit margins above 3% it can be seen from Figure 7.9 that turnover is affected. Viewing the mean return as a percentage of the turnover will give a more accurate representation of the performance and allow management to assess the trade between turnover and profitability. The mean monthly profit margin for each test is plotted in Figure 7.11 below.

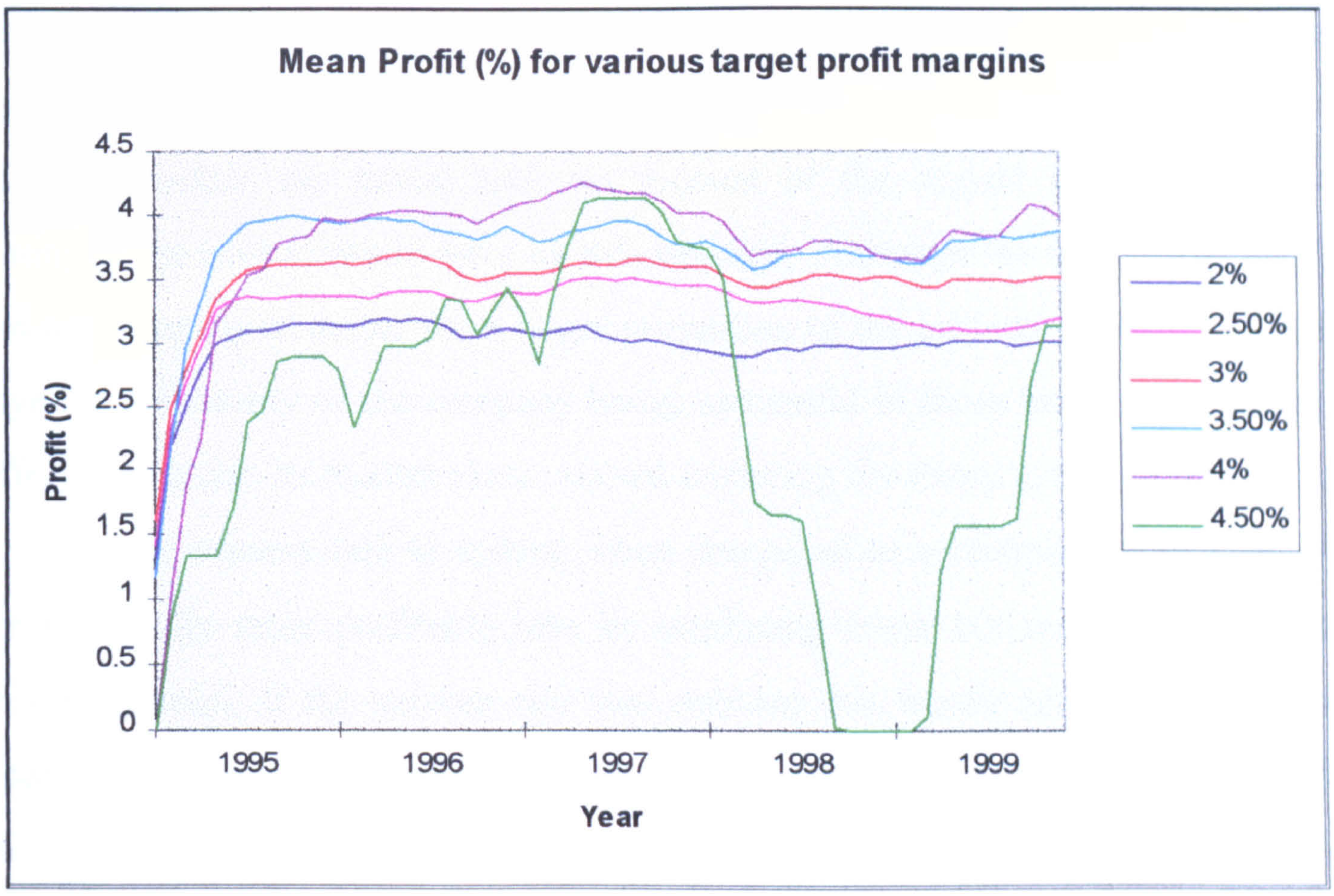

Figure 7.11 - Mean profit margin for various target profit margins

The graphs of mean profit margin illustrate the trade between turnover and profit margin. The profit margin increases with the target except for 4.5%, due to the extreme impact the high target had on turnover.

This test has examined the effects of various target profit margins on the performance of the company keeping a constant turnover target. The model has responded to changes in the target profit as expected. If the tests were repeated for various target turnovers, a similar result would be seen but, in the case of a larger target turnover, more pronounced as more projects are required of the desired return or higher. For a smaller target turnover, the impact would not be as pronounced, and the target could be set higher than the 3% seen in these tests before the turnover target was not achieved.

7.3.5 Tender success rate

A parameter within the tendering strategy which has an impact on the performance of the business unit is the success rate for tenders. This figure is used firstly to determine the volume of work to tender for (by dividing the turnover target by it) and secondly to determine whether the company is successful in those contracts it bids for. In the tests regarding market size, in several of the tests the company was effectively attempting to increase its market share as it was maintaining its turnover in a declining market. The mechanisms within the model took no account of the impact the other companies operating in the market would have on this strategy. Although the mechanism employed forces the company to tender for a larger proportion of the projects available, it does not change the probability of the company being successful in those bids. If a company, in an effort to increase its market share, started tendering for every available project it may well expect its success rate to reduce when compared to a company which decides to target potentially more profitable jobs by producing fewer but more accurate tenders. Within the model, if the success rate was reduced this would automatically force the company to tender for yet more projects, knowing that it would be less successful in them. If this was taken to its extreme, the company would be wanting to tender for more projects than were available.

If the company decides to increase its market share it pursues, and sometimes is awarded, projects which it would otherwise have rejected. This means that the projects awarded to the competitors has reduced, reflected in a lower success rate. It follows then that if the competitors decide to increase their market share, the success rate of the company will reduce. However, until the company was aware of the situation, only the success rate which determined the outcome of the bid and not how much work to tender for would be affected. Within the model the same value is used for each. If the model was to incorporate the effects of competitors, the two uses would have to be split, allowing the factor by which the tender target is scaled to be set independently of the tender success rate.

7.3.6 Summary of tests

The tests performed have examined the ability of the model to represent common changes in the market and produce reactions to those. With the exception of small project value and duration and the influence of competitors, the model produces the expected results in both turnover and profit. This allows the risk and opportunity classifications, which use the output of the model, to be investigated to assess whether they can reflect the uncertainty in the attainment of the business objectives in order that those risks and opportunities can be managed effectively.

7.4 RISK AND OPPORTUNITY CLASSIFICATION SYSTEM

Having examined the model and shown that it can combine the various sources of uncertainty in a business unit, the risk and opportunity classification system can be tested. The objective of the classification system is to produce a simple means of interpreting the effects of changes in the model. The various graphs which had to be produced to assess the effect of each of the earlier tests illustrates the need for such a system. Indeed, in some of the tests, the desirability of one situation over another could not be readily determined by viewing the graphs of turnover, profit, and margin.

The risk and opportunity classification system has two components; the turnover, profit, and margin are assessed in each time period with reference to the objectives for both risk and opportunity, and then the classifications for each time period are combined to produce single classifications for risk and opportunity for each parameter. The need to view profit and margin separately was illustrated in the target profit margin test, in which the profit margin was increasing while the financial profit was decreasing due to variable turnover results.

The functions applied to each time period will be assessed to determine if they reflect the perceived risk and opportunity to each objective and then the functions used to combine them into single classifications will be reviewed similarly.

7.4.1 Functions Applied to Each Time Period

A single classification is produced for risk and for opportunity for each objective for each time period. With objectives of turnover, profit, and margin this gives six classifications for each time period. A classification is produced by

- producing a classification for the mean outcome with reference to the target,
- producing a classification for the extreme outcome with reference to the target,

- producing a classification for the probability of being above/below the target,
- combining the three classifications to produce the single classification.

The three functions which are applied to the distribution to produce the classifications for mean, extreme, and probability are the same as those used in the project risk model. The only variable within those functions which may require change is the cut-off point, above which all results return the maximum value. This will change the sensitivity of the functions.

The proportions by which the three functions are combined is another parameter which may need changing. Varying the proportion changes the relative importance of the three functions. At present the mean is the most important, followed by the extreme, with the probability of being above/below the target having lowest importance.

As a means of testing the performance of the various functions, they will be applied to several of the scenarios tested earlier in this chapter. By using scenarios with which the mechanics of the model has been tested, the distributions produced, against which the functions will be applied, have already been shown to be a fair representation of the risk and opportunity change.

7.4.1.1 Base case assumptions

The assumptions within the base case presented in Chapter 6 are presented in Table 7.5 below. The assumptions listed relate to the cut-off value for each function and the proportions used to combine them.

Table 7.5 - Assumptions used within the base case risk and opportunity classifications

Parameter	Assumption
Mean Cut-off	10% above/below the target
Extreme Cut-off	20% above/below the target
Probability Cut-off	100%
Mean Weight	5
Extreme Weight	3
Probability Weight	2

The objective of the various tests which will be undertaken is to assess whether these assumptions give a fair representation of the risk and opportunity in the business and allow changes in that exposure to be quantified. It should be noted that the resulting calibration will only be valid for the example business unit, however the methodology applied to the example business unit will be applicable to others.

7.4.1.2 Sensitivity of individual functions

The sensitivity of the individual function is controlled by the cut-off value. As the cut-off value is increased, the function becomes less sensitive to smaller changes in the uncertainty. If the cut-off value is set too high, the function will not react to changes in the uncertainty; if it is set too low, the function will switch from returning zero to returning its maximum value with minor variations in the uncertainty.

The function for the probability that the mean is above or below the target is automatically limited at 100% and the application of the square root function returns a value between 0 and 10, as required for combination with the other functions. This could be changed so that the maximum result was returned for lower probabilities, however the current function is based on a common function for both risk and opportunity which apportions the probability of making a loss to risk and a profit to opportunity and hence will not be changed. The functions which act on the mean and the extreme outcomes are not limited automatically and so it is these two parameters which can be varied in terms of their sensitivity.

In order to assess the extent to which the boundaries are suitable for the example business unit, the mean and extreme outcomes for various scenarios will be examined with reference to the boundaries set using the assumptions in Table 7.5 above. The scenarios which will be tested are described in Table 7.6 below.

Table 7.6 - Scenarios tests for sensitivity of individual risk and opportunity functions

Test Name	Description
Base Case	Example business unit, excluding defined projects.
Defined Projects	Example business unit, including defined projects.
Decreasing Market	Test 1C - £750m market decreasing at 20% per annum.
Uncertain Projects	Test 2C - increased profit uncertainty.
High Expected Return	Test 3 - 4% target profit margin

In order to assess the sensitivity of the functions, each objective will be viewed in turn. For profit, like all the functions, both the mean and extreme components of the function will be tested. Figure 7.12 below plots the mean monthly profit for each scenario, marked on which is the upper and lower boundaries for the mean component of the function.

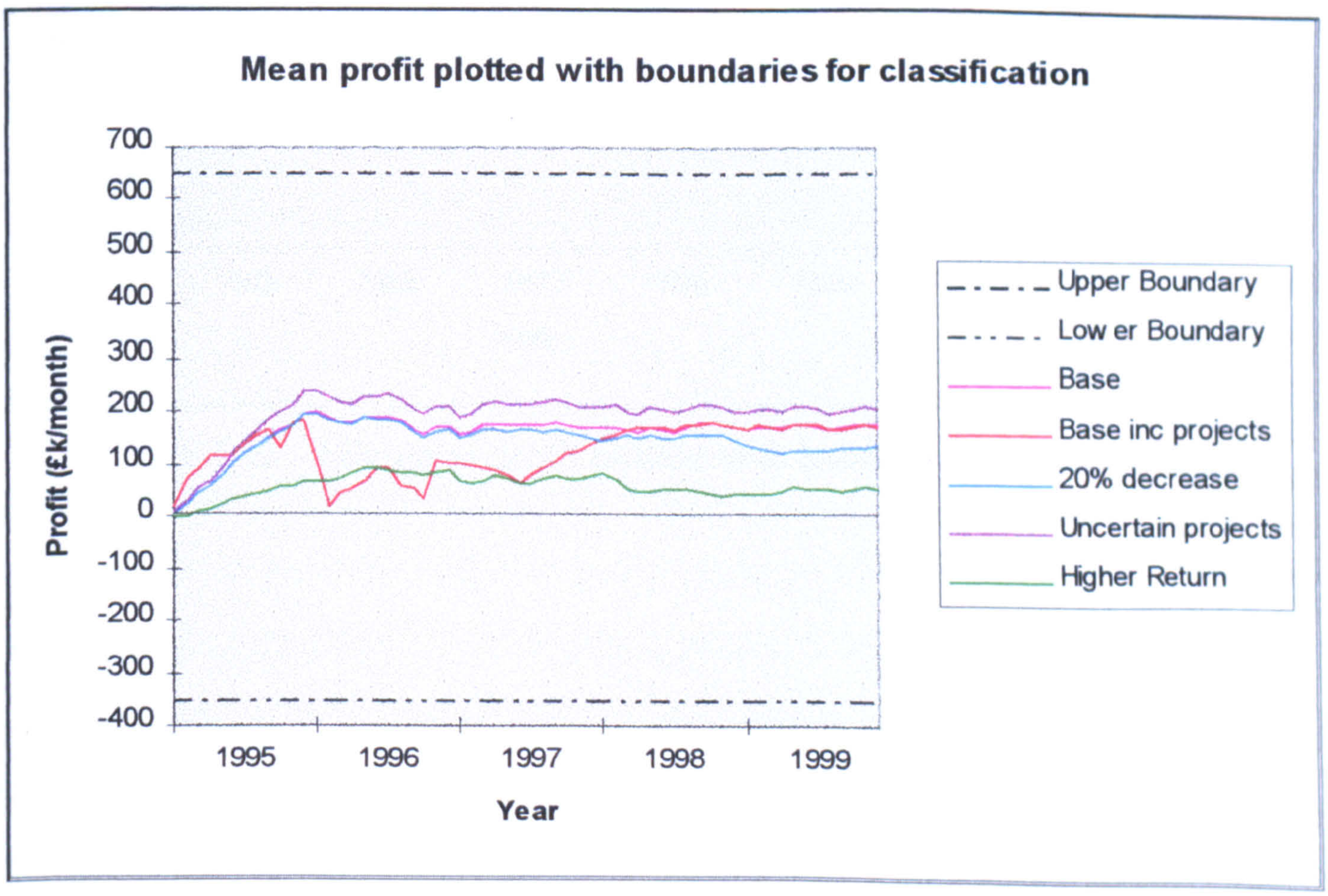

Figure 7.12 - Mean profit plotted with boundaries for classification

The graphs of mean monthly profit show that although there is significant difference between the scenarios none of the results approach the boundaries of the functions, making the functions insensitive to changes in the business unit. The sensitivity of the function can be increased by raising the lower boundary to zero (so if the mean profit is zero the risk function returns a maximum value) and the upper boundary to double the target (£300k per month).

Figure 7.13 and Figure 7.14 plot the extremes of monthly profit for the scenarios and the upper and lower boundaries of the extreme components of the risk and opportunity functions.

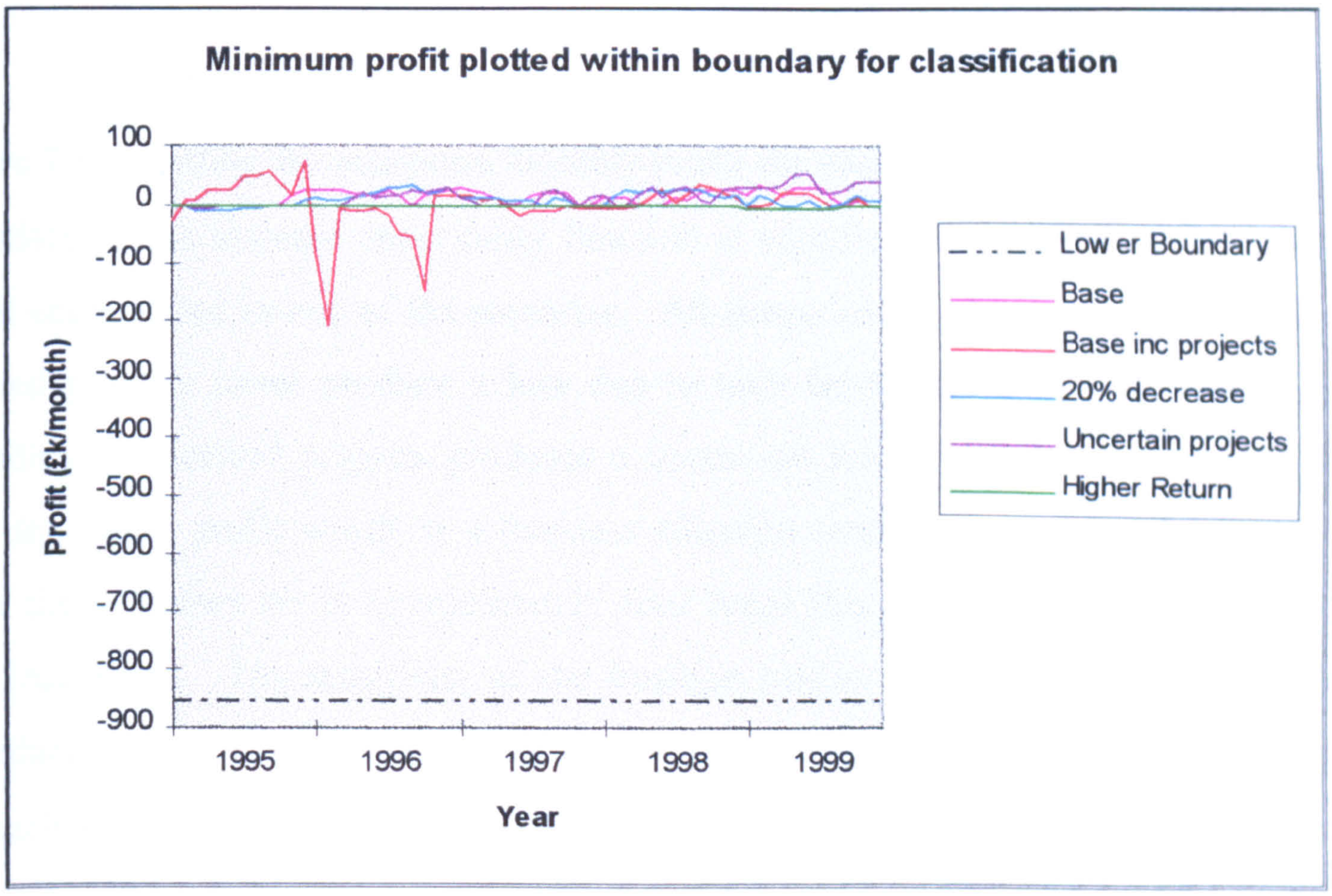

Figure 7.13 - Minimum profit plotted with boundary for classification

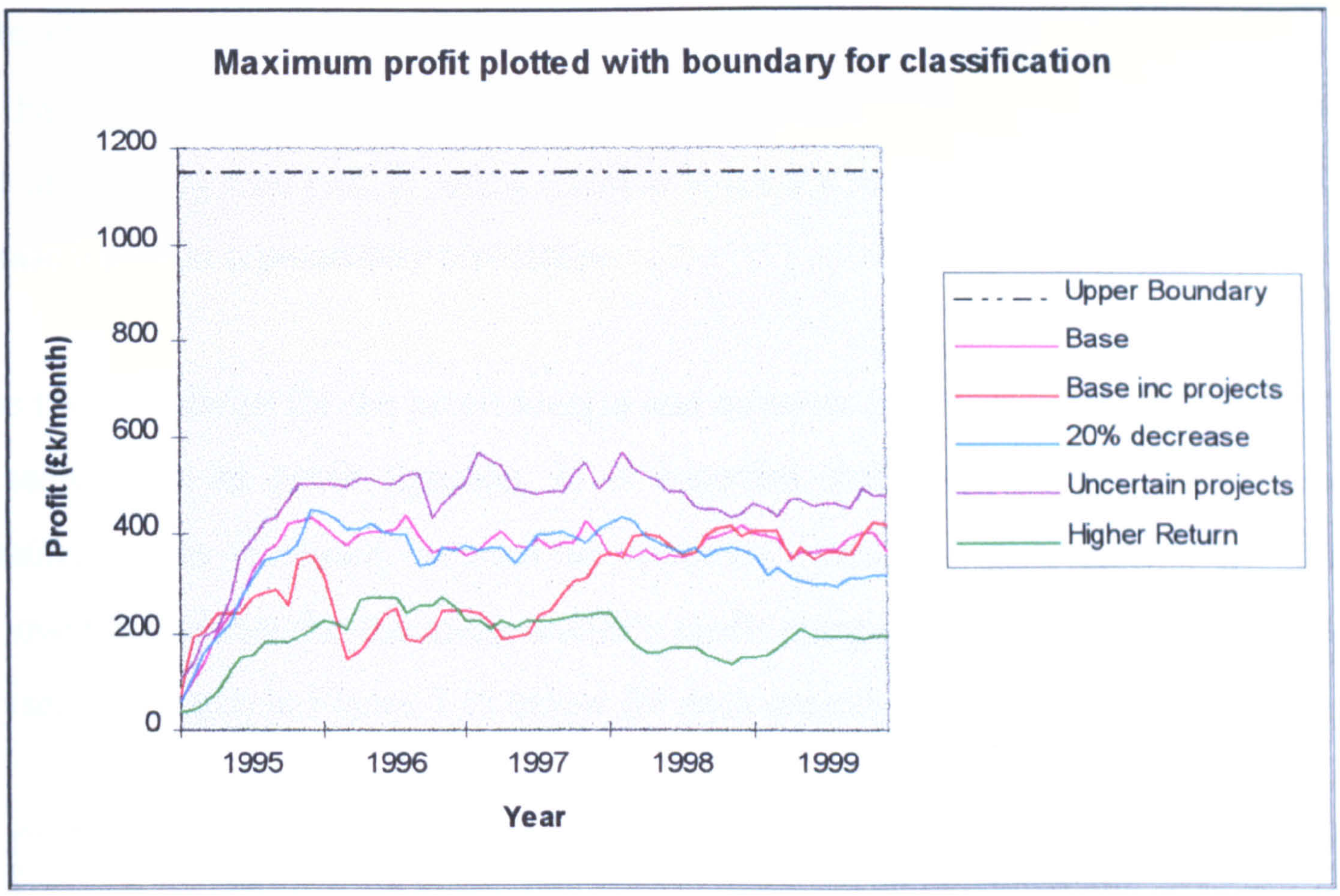

Figure 7.14 - Maximum profit plotted with boundary for classification

Figure 7.13, plotting the minimum monthly profit for each scenario, shows that the lower boundary of the extreme opportunity function is significantly lower than the minimum profit encountered in any of the scenarios. All scenarios but the one which includes the defined projects never produce a loss due to their tendering strategies. The scenario including the defined projects produces a maximum loss in some time periods greater than the target profit which in a business situation would be considered a major risk. With the boundary set at approximately four times this maximum loss, the function is also insensitive. The sensitivity of the function can be increased by setting the lower boundary at, say, a loss of £150k per month, which means that if the business unit loses as much as it was aiming to earn, the function returns the maximum score.

The graph of maximum monthly profit, Figure 7.14, shows that the maximum profits produced do not exceed the boundary and yet some scenarios produce a maximum of approximately half the range. Although this boundary was set with the same logic as the other boundaries, the greater uncertainty in the maximum profit results in the maximum profit approaching the boundary to a greater extent than the other parameters. If it was felt that the scenarios which produce the maximum profits should return a maximum value from the risk function, then the boundary can be reduced. Reducing the boundary, say to £600k per month would result in the function being more sensitive to changes in risk than opportunity. Since, from the results, it appears the business unit is exposed to more opportunity than risk, it seems sensible to set the sensitivity of the functions so any increase in risk is immediately noticeable.

Since the boundaries for the profit margin and turnover functions were initially set using the same logic as profit function, it is expected that those functions will also be insensitive to the variations between the scenarios tested. To investigate this, the upper and lower boundaries for the mean monthly profit margin function and the results of the analyses are plotted in Figure 7.15 below for each scenario.

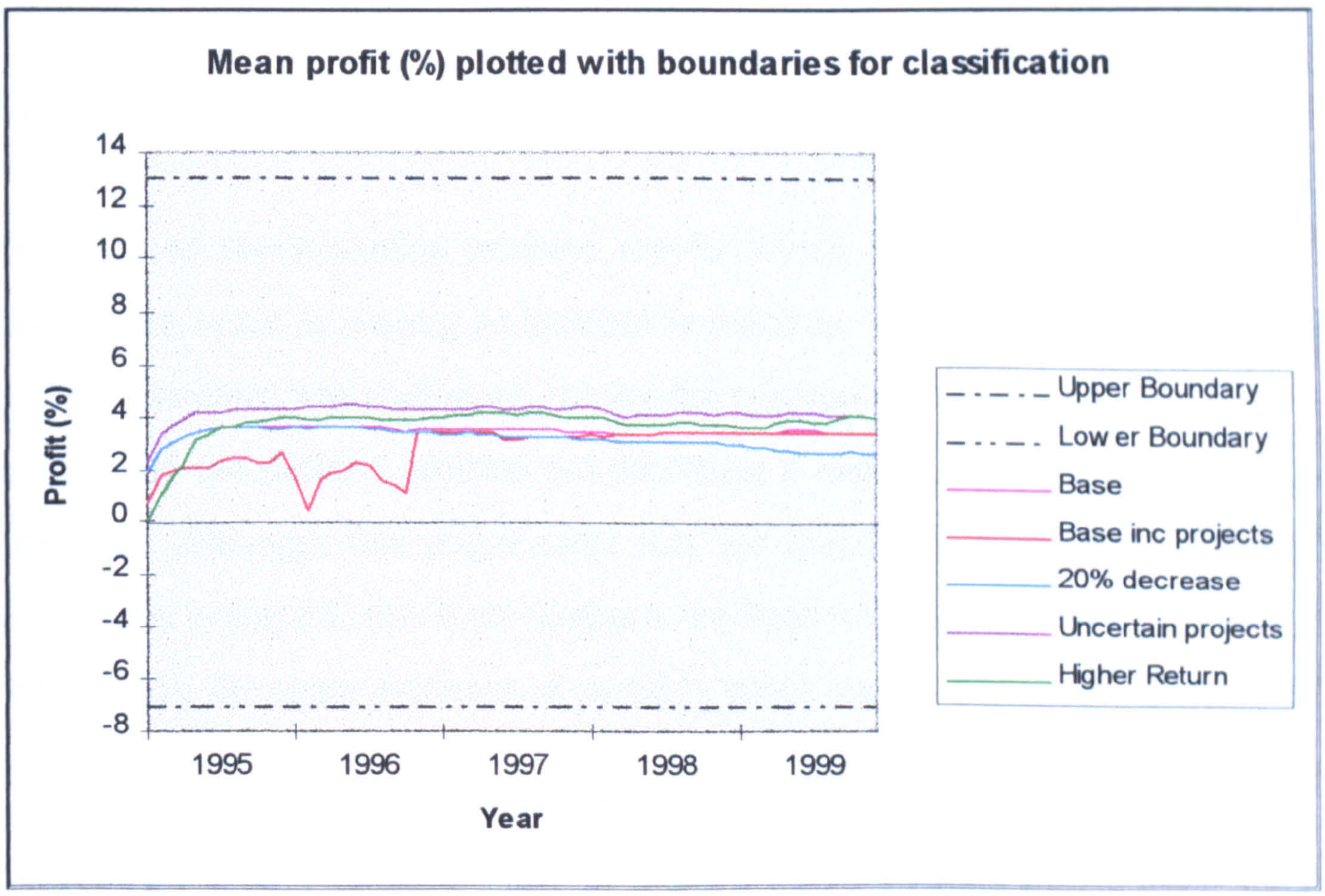

Figure 7.15 - Mean profit margin plotted with boundaries for classification

As expected, although there is significant variation in the mean margins of the scenarios, none of the tests approaches the boundaries, making the function insensitive. Following a similar pattern to profit, the sensitivity of the function could be increased by setting the lower boundary at zero and the upper at 6% (twice the target). The lower extreme for monthly profit margin and the boundary for the associated function are plotted below in Figure 7.16.

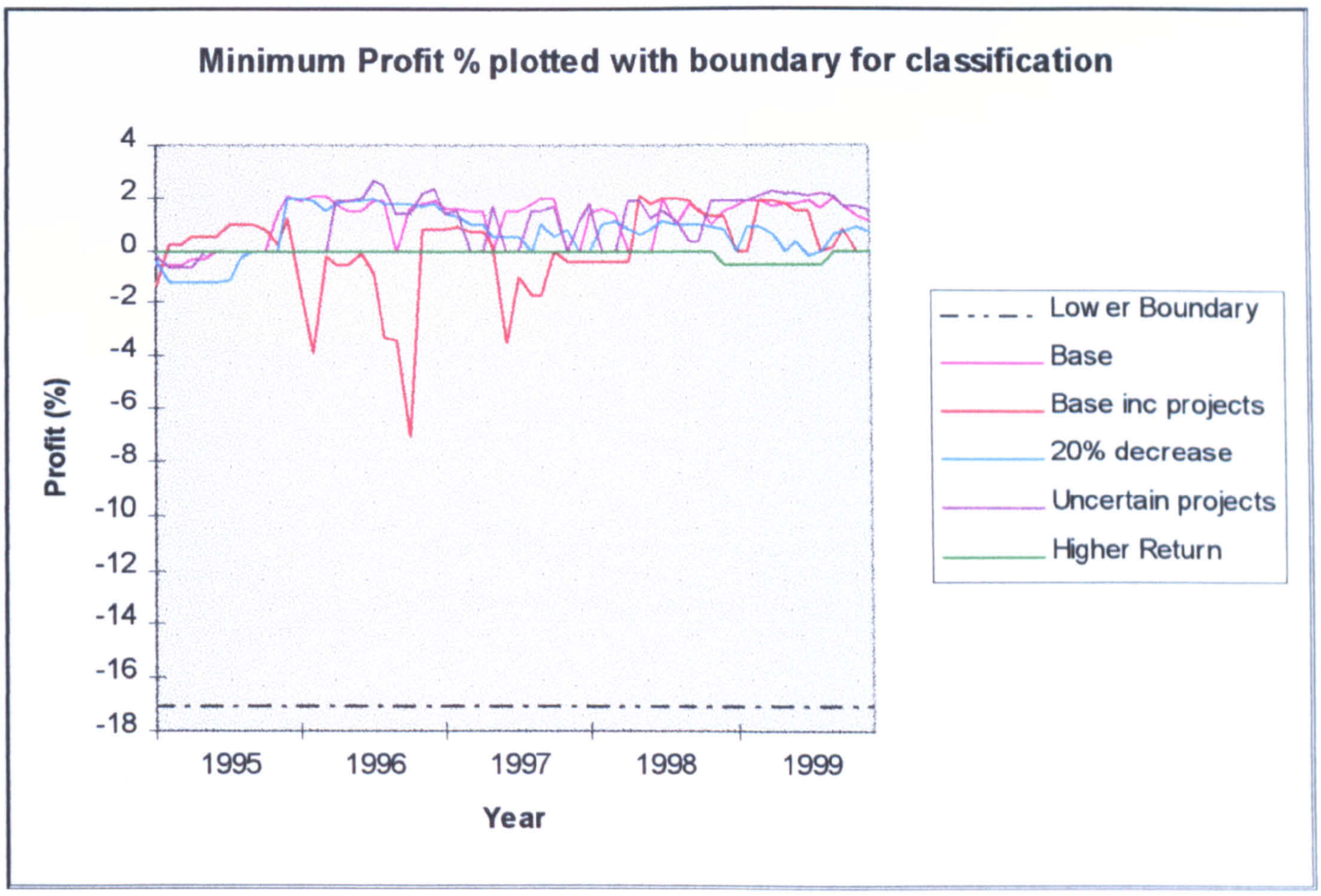

Figure 7.16 - Minimum profit margin plotted with boundary for classification

The majority of the scenarios produce results which lie in the lowest tenth of the functions range, again producing an insensitive function. If the same logic as was applied to the profit extremes was continued, raising the minimum boundary to -3%, the scenario which included the defined projects would return a maximum value for several of the time periods. Although this might seem that the function is now too sensitive, if the business unit is losing this much on contracts, perhaps warnings should be issued. Figure 7.17 below plots the upper extremes of monthly profit margin and function boundary.

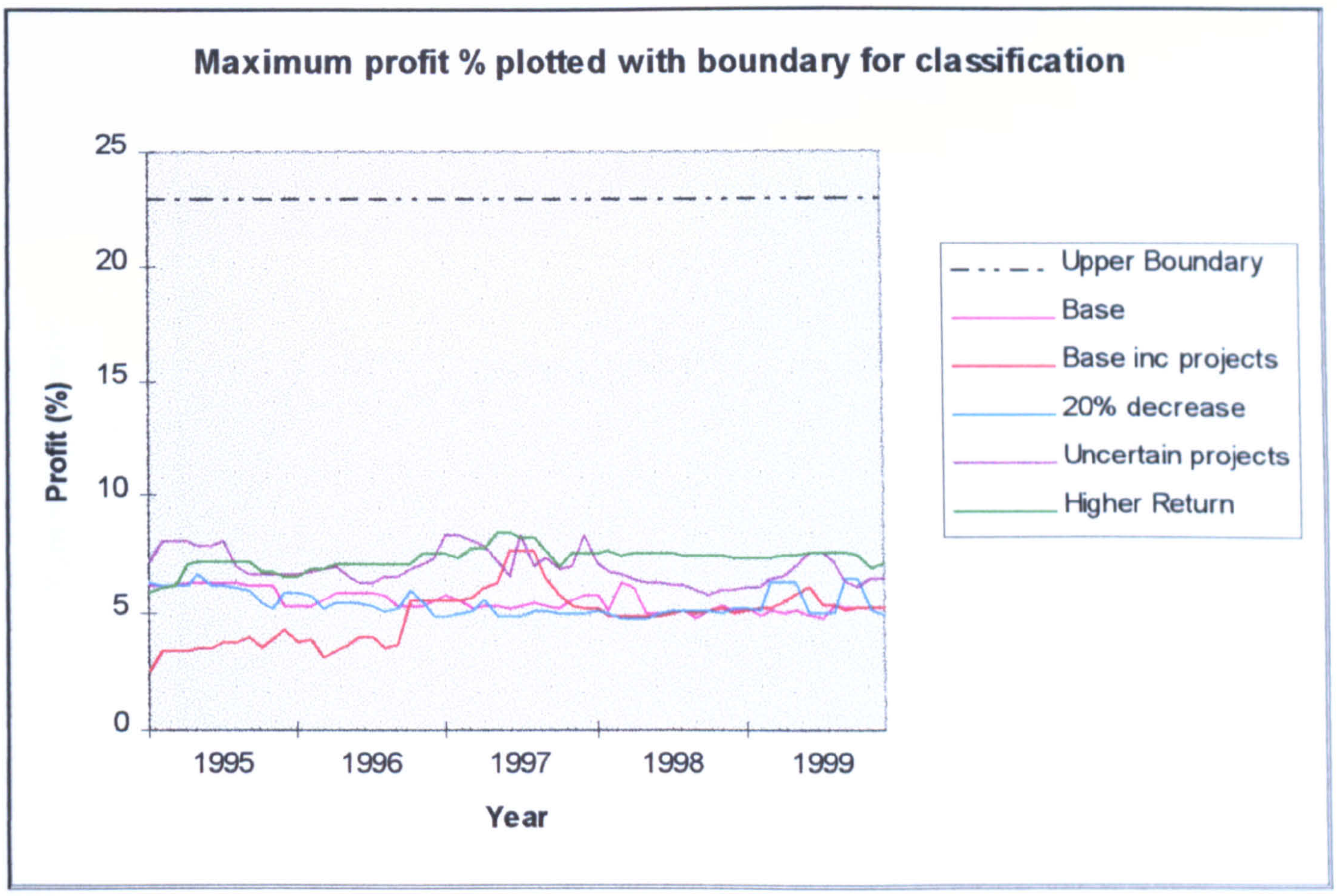

Figure 7.17 - Maximum profit margin plotted with boundary for classification

Since all the scenarios produce results within the lower third of the range of the function, as expected the boundary may also be set too high. Reducing the boundary in line with that for the other profit function, results in a value of 9%.

In order to assess the sensitivity of the functions based on turnover, Figure 7.18 plots the mean monthly turnover for each scenario and the upper and lower boundaries for that function.

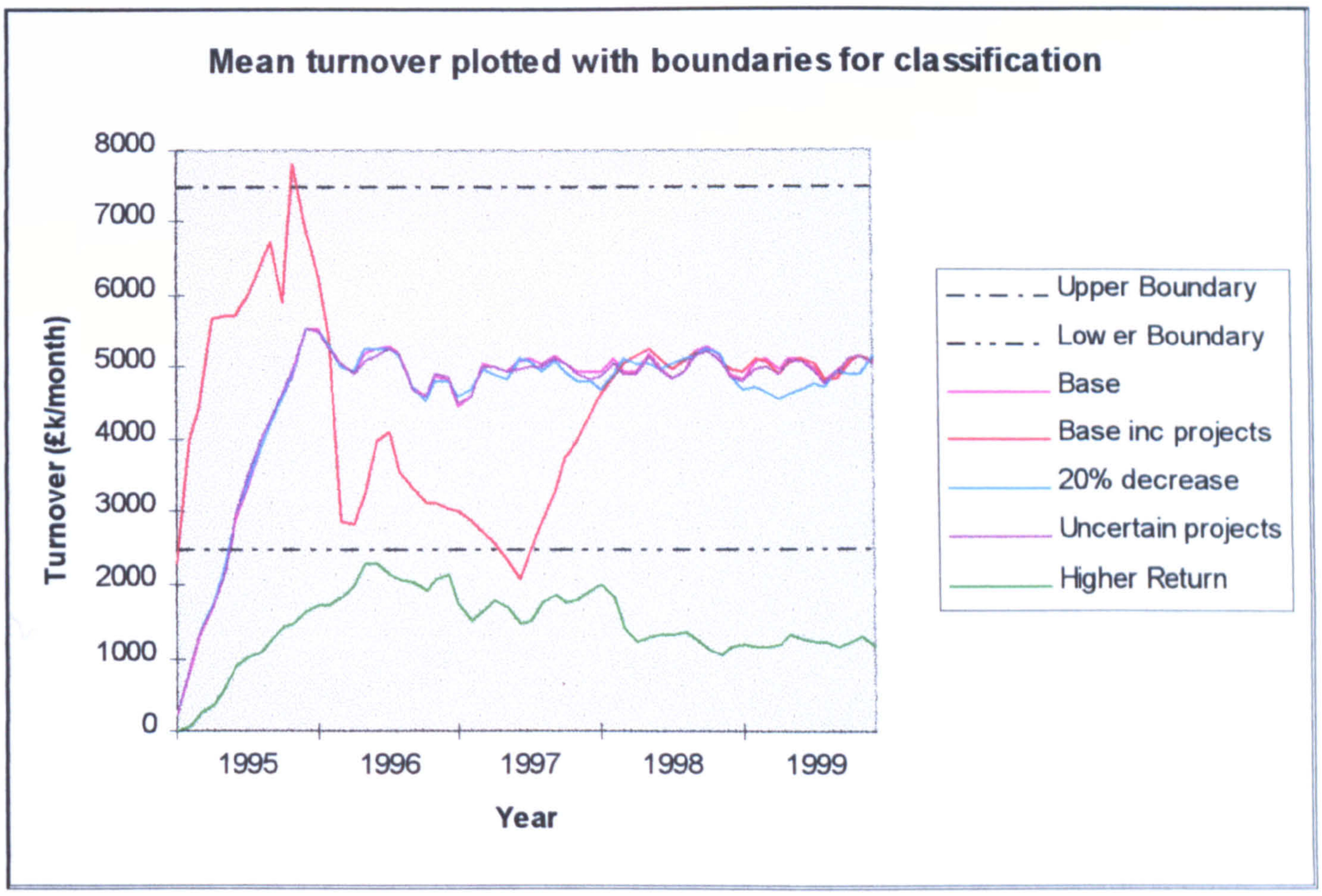

Figure 7.18 - Mean turnover plotted with boundaries for classifications

With the upper and lower turnover boundaries set at £2.5m and £7.5m per month (half and one and a half times the target), two scenarios stand out. The scenario requiring a higher return from projects produces a mean turnover less than the lower boundary throughout the study. This would produce a zero for above target risk and a maximum ten for above target risk for that scenario. The scenario which includes defined projects reaches both the upper and lower limits over the course of the study, the business swinging from over-performing to under-performing. In light of these two results, and the knowledge that the turnover of the other scenarios are similar, it seems that the sensitivity of the mean turnover functions is set correctly.

Figure 7.19 plots the minimum monthly turnover for each scenario and the lower limit used in the function.

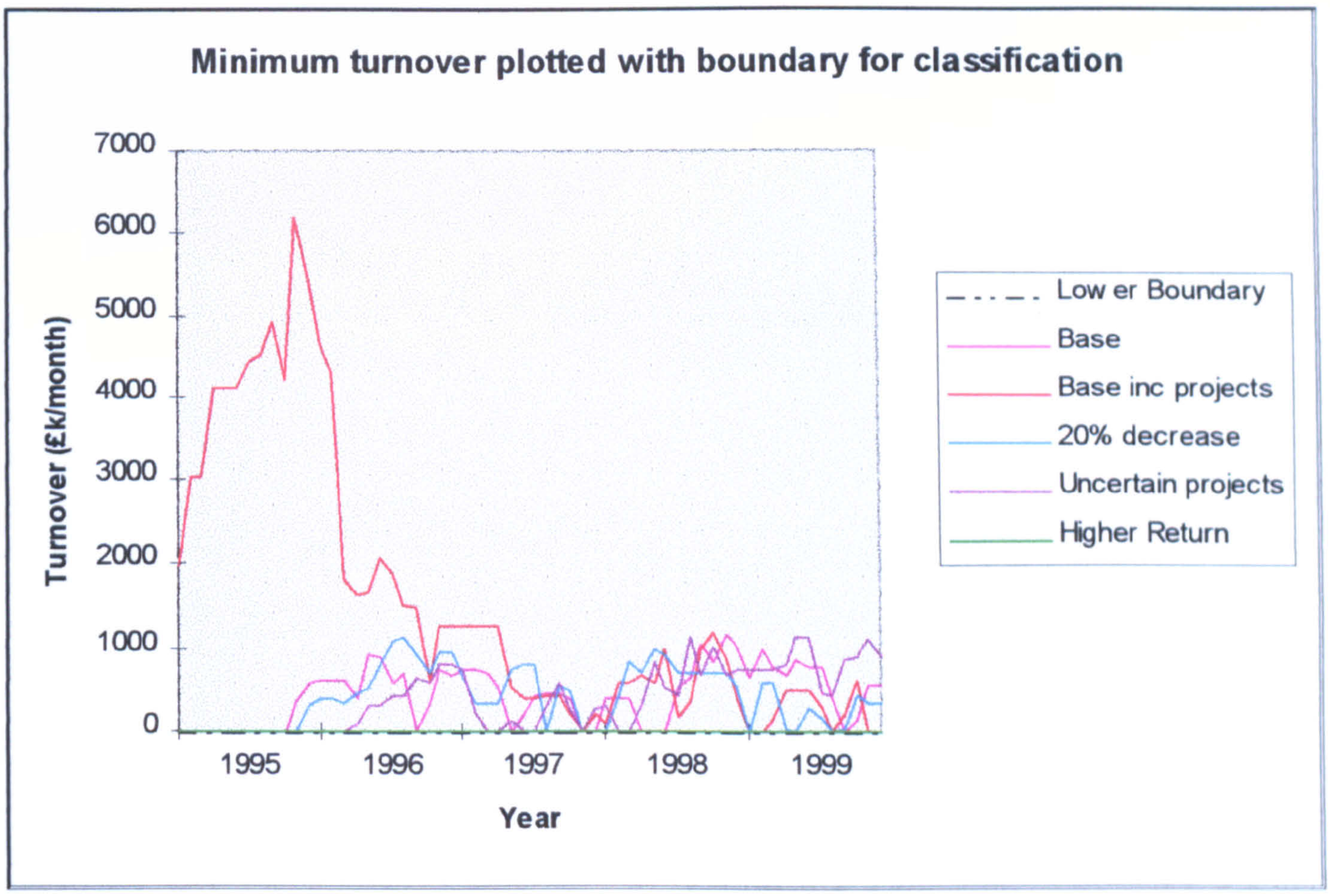

Figure 7.19 - Minimum turnover plotted with boundary for classification

The minimum turnover boundary was initially set at zero as the turnover has a physical limit of zero. It can be seen from the graph in Figure 7.19 that most scenarios touch the limit at some point during the study. The scenario which stands out from the others is, again, that which includes defined projects. The higher minimum turnover for this scenario over the first two years of the study confirms the greater certainty in the turnover over that period. It appears from this that the minimum extreme boundary has been set correctly for the current operations of the business unit.

The maximum monthly turnover for each scenario and the boundary used for that function are plotted in Figure 7.20 below.

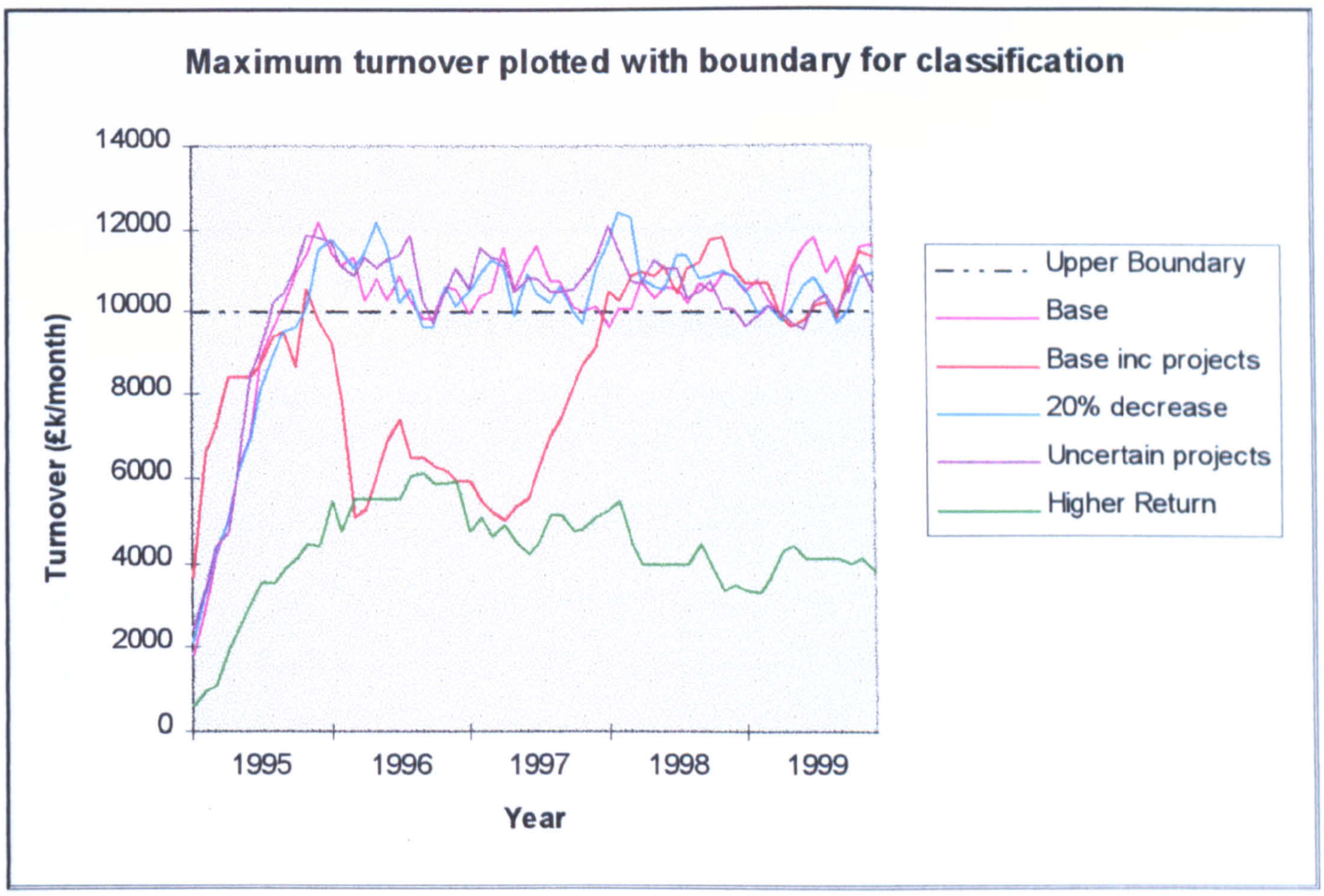

Figure 7.20 - Maximum turnover plotted with boundary for classification

The graph of maximum turnover shows that the boundary is exceeded by several of the less risky scenarios throughout the duration of the study. The scenario which is known to produce the largest risk to turnover, seeking higher returns, is consistently below the £5m target and hence the function would return a zero for most of the study. In light of the usual result of the maximum turnover being above the boundary, the sensitivity of the function should be reduced by increasing the boundary, say to £15m per month. This boundary, at three times the target rather than twice, would allow business units which could produce turnover greater than was usual to be identified through inspection of the output of the function.

The changes made to the functions have increased the sensitivity of the profit and margin functions, although the sensitivity to risk has been increased to a greater extent than that for opportunity. For turnover, the sensitivity of the above target return has been reduced with the other functions remaining at their initial values.

To illustrate the difference in the classification produced by changing the sensitivity of the individual functions, Figure 7.21 below plots the original and revised profit risk and opportunity classifications for the base case. The weights given to each function are as set out in Table 7.5 above.

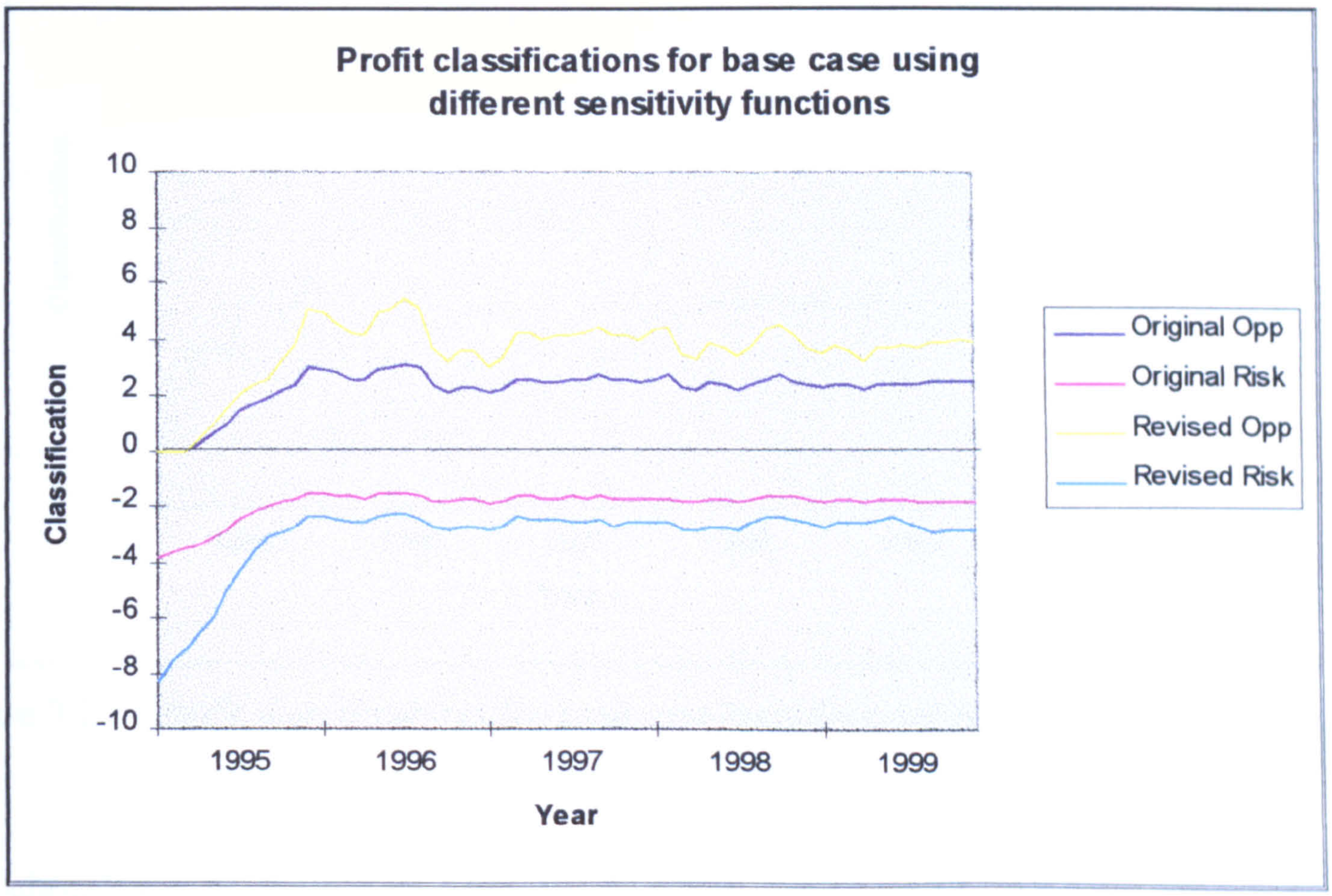

Figure 7.21 - Profit classifications for base case using different sensitivity functions

The two sets of classifications show a slight increase in the output of the risk classification and a larger increase in the output of the opportunity classification. If the base case is set as the normal or desired operating situation for the business unit, the risk and opportunity classifications of other approaches will be compared with it. To illustrate the effectiveness of increasing the sensitivity of the profit classifications, Figure 7.22 plots the original and revised classifications for the base case including the defined projects. The scenario which includes the defined projects has been selected to illustrate the effect of changing the sensitivity of the functions as the results it produces vary significantly from the base case for the first three years of the study.

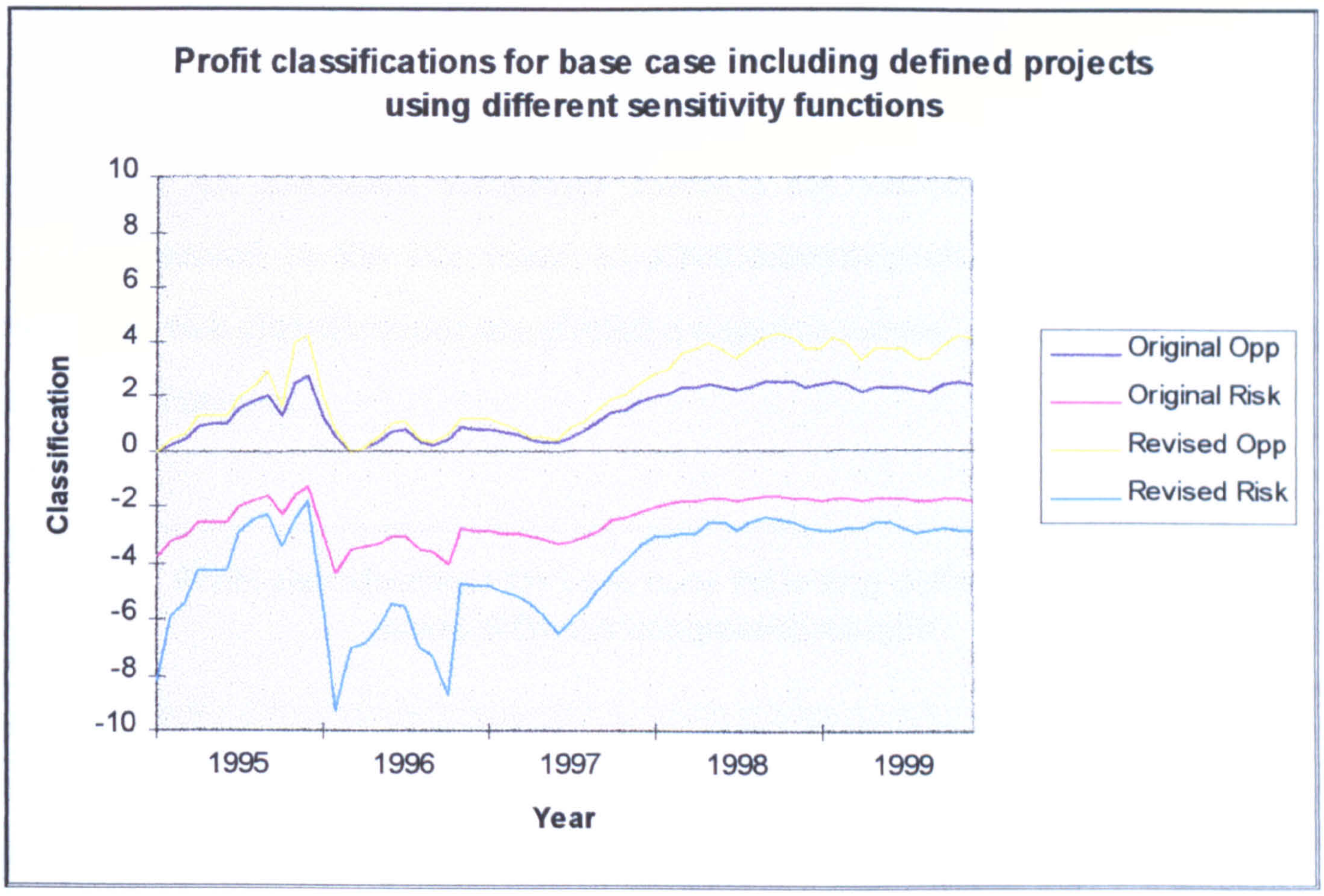

Figure 7.22 - Profit classifications for base case including defined projects using different sensitivity functions

The classifications plotted in Figure 7.22 show the areas of risk and opportunity are accentuated when the sensitivity of the functions are increased. Comparing the base case with the business unit undertaking the defined projects, using the increased sensitivity classifications the impact the defined projects could have on the business is significantly more pronounced.

7.4.1.3 Relative importance of each function

Having set the sensitivity of each function, these need combining to produce the single classification for risk or opportunity for the time period. The initial weighting, summing to 10, gave 5 to the mean function, 3 to the extreme function, and 2 to the probability function. The above weights will produce a function which is more sensitive to the output of the mean function, giving decreasing importance to the extreme and the probability functions. In a business which considered the uncertainty it was experiencing to be of equal importance to the mean, the weights of the extreme and mean functions would be set at the same level, since the greater the output of the extreme function, the more uncertain the result is.

Figure 7.23 below shows the profit classifications for the base case including defined projects using the increased sensitivity function for various relative weights. The proportions denoted in the key relate to mean:extreme:probability. As was used in Chapter 5, the risk classifications are plotted a negative values, symbolising their negative impact on the business.

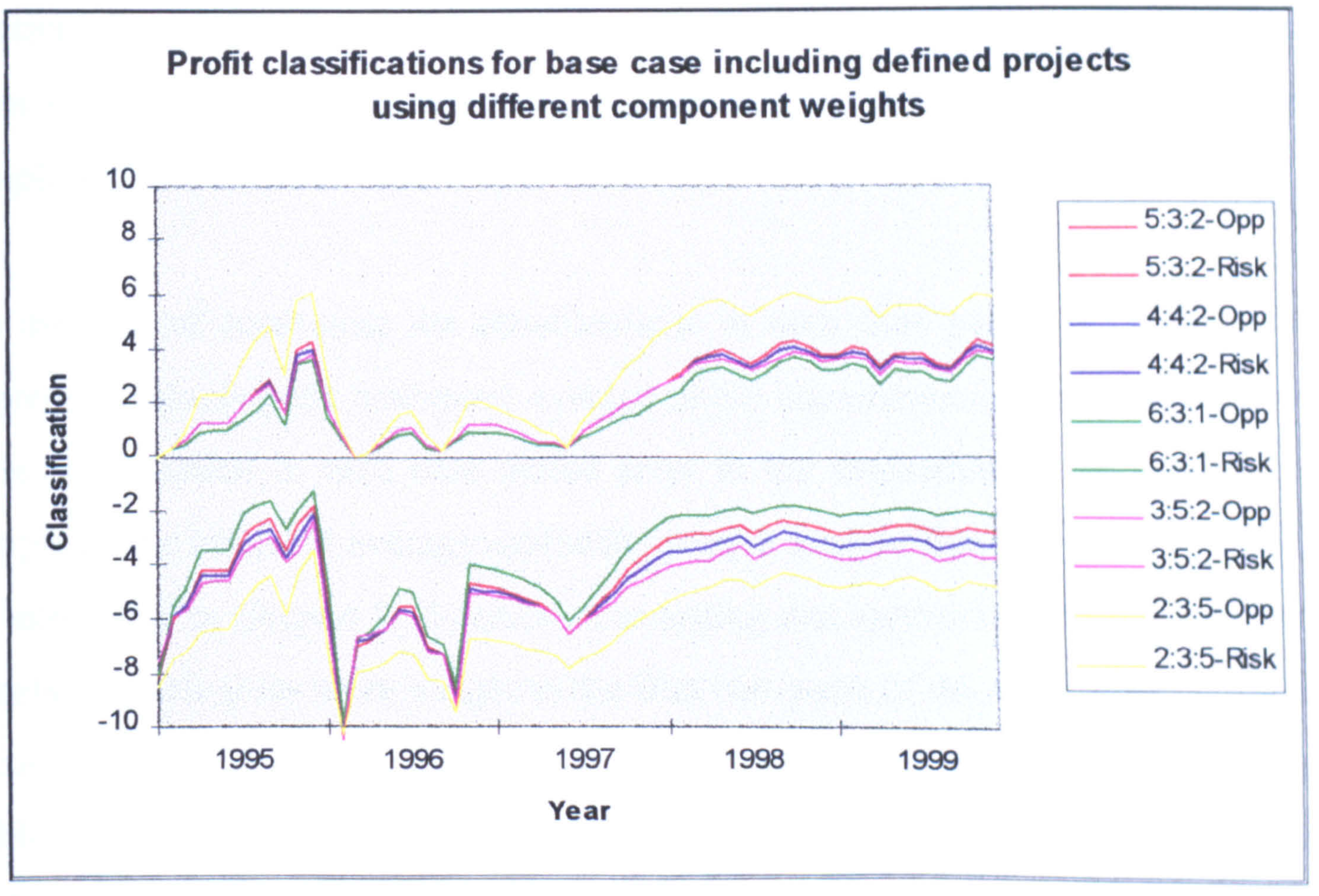

Figure 7.23 - Profit classifications for base case including defined projects using different component weights

The graphs of Figure 7.23 show some variation between the resulting classifications when different component weights are used. The least sensitive combination is where greatest importance is given to the probability component, judged by the extent to which the peaks and troughs identifiable in all classifications are pronounced. Using the similar criteria, the most sensitive combination is that in which greatest weight is given to the extreme component. Since all the combinations shown give a similar impression as to the risk and opportunity to profit over time, the exact weight of each component is more a matter for the user. For the remainder of the example, use of the original weighting of 5:3:2 will be continued.

7.4.2 Functions Applied to Produce a Single Classification

The previous sections have considered the sensitivity of the individual components and then the relative importance of each. In order to allow the various classifications to be assessed with ease and to compare the merits of various strategies, the classifications produced for each time period are combined to produce a single classification for each objective. Since the components of those monthly classifications have been tested, the objective of assessing the single value classifications is to assess the extent to which the output of the classifications reflect the known changes in the business unit when the example scenarios are analysed.

Two methods of combining the classifications in each time period were introduced in Chapter 6: evaluating the arithmetic average of the classifications and applying a weight to the classification in each time period prior to the evaluation of the average. One example of the weighted average approach, using a straight line decrease of importance, was introduced in Chapter 7. In addition to testing that approach, a percentage decrease, a function which gives more weight to the first two years of the study than the last and a function which gives low priority to the first six months of the study (as this is not an established model) and the last two years will be tested. The four functions, including the equal weight, simple average, are plotted in Figure 7.24 below.

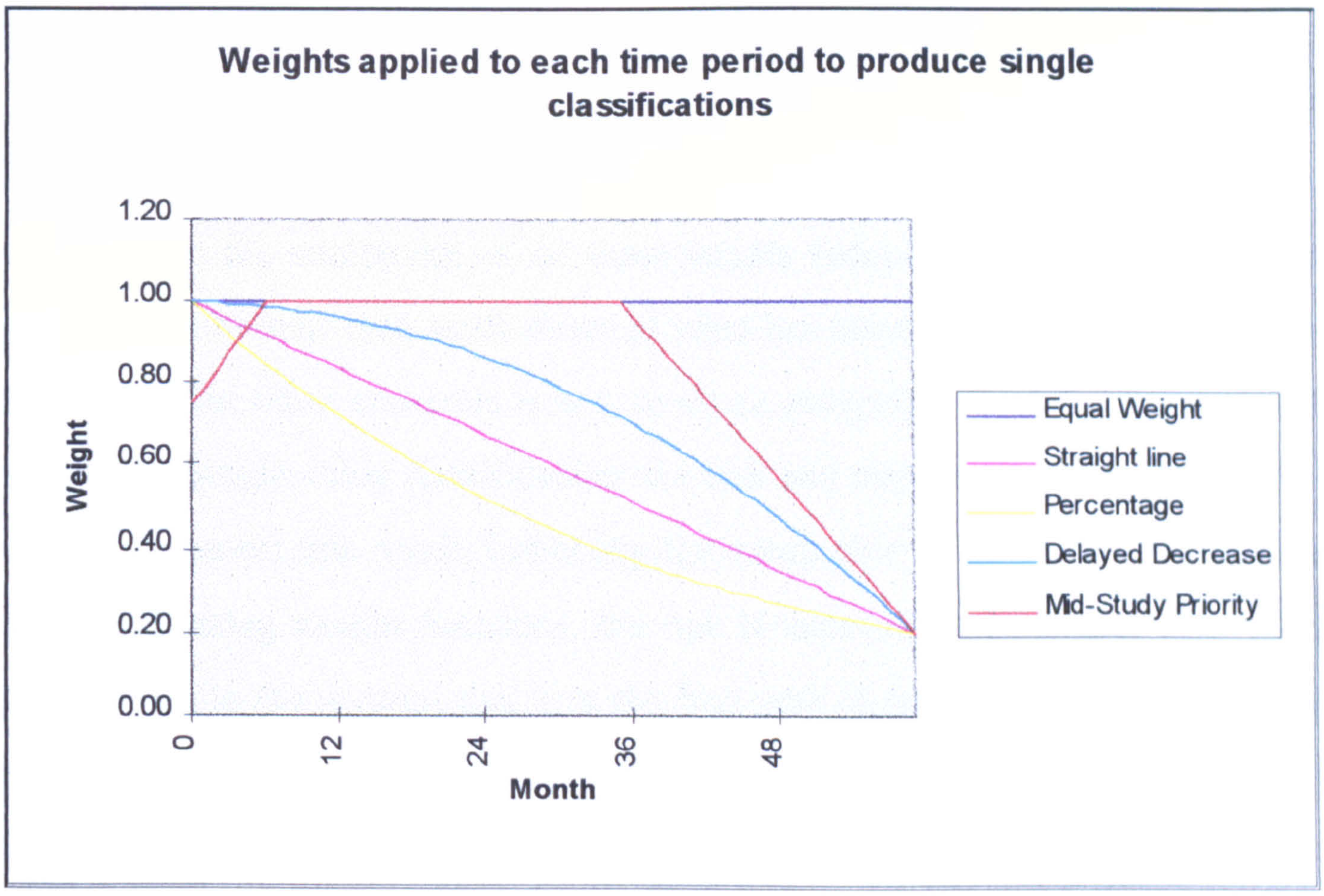

Figure 7.24 - Weights applied to each time period to produce single classifications

Each of the continuously decreasing functions return 1.0 at the start of the study, reducing to 0.2 at the end. The function based on a percentage decrease, reduces by 2.7% per month. The delayed decrease function takes the form set out below.

Delayed Function = fn(1.0 - A.COSH(B.t))

where A and B are constants and t is the time period. The function and the value of the constants in it were chosen with reference to the resulting graph. Any function could be used, such as exponential smoothing, if the resulting graph reflected the importance which was to be given to each time period.

Rather than assessing the performance of each approach in turn, they will be assessed against a selection of the scenarios used earlier in the chapter in turn to allow comparison between the various approaches.

7.4.2.1 Base Case

The distributions of profit, margin and turnover for the base case in each time period show the risk to the attainment of all three targets reducing over the first year of the study. The distributions then settle down at what has been shown, with reference to the distributions of the other scenarios tested, to be an acceptable level for the remainder of the study. The single value classifications for risk and opportunity to each objective are expected to represent this result, indicating the acceptable levels for each classification. Using the decreasing weight functions, the risk is expected to be higher than the equal weight function, as the greatest risk is in the first year of the study. The function giving greatest weight to the middle of the study is expected to reduce the risk classification, although the reduction only applies to the first six months of the study. The classifications using each function for weight are shown in Table 7.7 below.

Table 7.7 - Base case risk and opportunity classifications using different weights

	Equal Weight	Straight line	Percentage	Delayed Decrease	Mid-Study Priority
Profit Opportunity	3.560	3.358	3.252	3.453	3.573
Profit Risk	3.073	3.348	3.473	3.232	3.083
Margin Opportunity	3.276	3.317	3.309	3.320	3.329
Margin Risk	2.061	2.146	2.205	2.092	2.025
Above Turnover Risk	2.848	2.668	2.580	2.749	2.851
Below Turnover Risk	4.984	5.419	5.600	5.250	5.040

The results in Table 7.7 show little variation between each function for weight. If the classification was presented accurate to no decimal places, a difference would only be evident in Profit Opportunity and Below Turnover Risk. The classifications follow the expected result, except for the mid-study priority function, which returns a slightly higher value for Profit Risk and Below Turnover Risk. The expected decrease has not been achieved because the function did not reduce the effect of the start of the study to a large enough extent and the impact of the final two years of the study were reduced significantly.

Since the base case reflects an acceptable position for the business unit, the classifications produced represent the acceptable value against which other scenarios can be compared.

7.4.2.2 Base Case Including Defined Projects

Including the projects which the company is undertaking or pursuing in the model reduces the uncertainty in the first two years of the study, as would be expected. The increased knowledge of these projects does, in some cases, indicate an expected profit less than that within the tendering strategy. The classifications are expected to reflect this knowledge by increasing the profit risk and reducing the profit opportunity and decreasing the below turnover risk and increasing the above turnover risk. The classifications are presented in Table 7.8 below.

Table 7.8 - Base case including defined projects classifications using different weights

	Equal Weight	Straight line	Percentage	Delayed Decrease	Mid-Study Priority
Profit Opportunity	2.559	2.152	2.098	2.220	2.322
Profit Risk	3.766	4.117	4.167	4.056	3.951
Margin Opportunity	2.597	2.880	2.897	2.849	2.811
Margin Risk	3.285	3.813	3.919	3.692	3.526
Above Turnover Risk	2.901	2.949	2.993	2.906	2.890
Below Turnover Risk	4.331	4.173	4.086	4.265	4.344

The classifications in Table 7.8 show the expected result has been returned for the profit objective, with the Profit Opportunity classifications reducing by between 1.0 and 1.2 and the Profit Risk classification increasing by between 0.7 and 0.9 when compared to the base case. A similar result is produced for the margin objective.

The turnover classifications show an increase in Above Turnover Risk of between 0.05 and 0.2 when compared to the base case. A more significant result is produced for Below Turnover Risk, with decreases of between 0.6 and 1.6.

7.4.2.3 Decreasing Market Size

The scenario in which the business is operating in a decreasing market whilst attempting to maintain its turnover shows an increase in the profit risk the company as the study progresses. The reduction in the volume of the market is not such that the business has particular difficulty maintaining its turnover if it is prepared to relax its targets for project profitability. This increased profit and margin risk is expected to be reflected in the classifications, which are presented in Table 7.9 below.

Table 7.9 - Decreasing market size classifications using different weights

	Equal Weight	Straight line	Percentage	Delayed Decrease	Mid-Study Priority
Profit Opportunity	2.913	2.998	2.918	3.038	3.099
Profit Risk	3.448	3.586	3.700	3.487	3.356
Margin Opportunity	2.597	2.880	2.897	2.849	2.811
Margin Risk	2.777	2.657	2.689	2.637	2.611
Above Turnover Risk	2.757	2.606	2.529	2.674	2.762
Below Turnover Risk	2.227	5.612	5.775	5.460	5.272

The classifications in Table 7.9 show increases in Profit Risk and reductions in Profit Opportunity, and similar changes in the margin classifications, as expected. Similar, but not as significant, changes in the turnover classifications are produced, reflecting the increased uncertainty in the turnover. The margin classifications show a slight, but important, trend between the various weight functions. The highest risk and lowest opportunity are returned by the equal weight function, with the lowest risk being returned by the percentage decrease function and the highest opportunity being returned by the mid-study priority function. Both these functions give little importance to the final year of the study, which in this case is when the market is at its smallest.

7.4.2.4 Uncertain Project Profitability

This scenario increases the expected profitability of projects, not the risk and opportunity inherent in them. Consequently there are more projects which the business can pursue which are expected to return a significantly higher profit than the company's target. The downside is there are projects which are expected to result in a loss for the business. However, the tendering strategy applied does not allow the business to pursue these unless the turnover can not be achieved by those expected to return the desired profit.

Translating this into the expected classifications, the Profit Opportunity and Margin Opportunity are expected to be significantly higher than those of the base case. The risk classifications for those targets may be higher than the base case, as the business may have to undertake some of the loss making projects to maintain its turnover. The classifications produced using the various weight functions are presented in Table 7.10 below.

Table 7.10 - Uncertain project profitability classifications using different weights

	Equal Weight	Straight line	Percentage	Delayed Decrease	Mid-Study Priority
Profit Opportunity	4.731	4.391	4.253	4.520	4.687
Profit Risk	2.942	3.200	3.314	3.097	2.958
Margin Opportunity	4.708	4.742	4.748	4.732	4.729
Margin Risk	1.982	2.058	2.094	2.029	1.990
Above Turnover Risk	2.689	2.488	2.404	2.566	2.667
Below Turnover Risk	5.046	5.455	5.625	5.296	5.097

As expected, the profit and margin classifications give lower risk and higher opportunity values than those for the base case. The risk classifications are not reduced by a significant amount (typically by 0.1); the opportunity classifications are increased significantly (typically by at least 1.0).

7.4.2.5 Expected Higher Return

If a higher return is expected, so raising the profit margin criteria, it is expected that, if the turnover can be maintained at that margin, the profit and margin classifications will increase and there will be no effect on the turnover classifications. Previous tests on this scenario have shown that the turnover can not be maintained as there are insufficient projects delivering the desired profit margin. In this case, although the profit margin following the expected result, both the profit and turnover classifications are affected detrimentally. The classifications produced by this scenario for the various weight functions are presented in Table 7.11 below.

Table 7.11 - Higher expected return classifications using different weights

	Equal Weight	Straight line	Percentage	Delayed Decrease	Mid-Study Priority
Profit Opportunity	0.482	0.510	0.491	0.522	0.536
Profit Risk	6.509	6.522	6.578	6.479	6.423
Margin Opportunity	4.591	4.446	4.362	4.521	4.622
Margin Risk	2.614	2.749	2.829	2.679	2.579
Above Turnover Risk	0.046	0.057	0.056	0.058	0.056
Below Turnover Risk	10.000	9.999	9.999	9.999	9.999

The classifications confirm the expected result. The Margin Opportunity classification is between 1.1 and 1.3 higher than the base case, reflecting the greater margin on the work undertaken. The Margin Risk classification has, however, increased, reflecting those occasions when no projects were undertaken. Since the turnover target is sacrificed to return a higher margin, it is not surprising that Below Turnover Risk is very close to ten and Above Turnover Risk is close to zero.

7.4.2.6 Summary

Having tested a selection of scenarios against the various weight functions described, each approach gives a similar answer in terms of defining the trend and allowing comparison. The slight differences between each function, typically up to 0.25, only refine the result, rather than offering a significantly different interpretation. The choice of function is therefore a matter for the user, as a function can be defined which gives the greatest emphasis to the periods of greatest importance. The mid-study priority function also suggests that not only does the period of importance have to be identified but the impact of the other regions must be reduced to a level which has the desired impact on the result.

7.5 SUMMARY

The tests presented in this chapter had two objectives. The first set of tests aimed to assess the performance of the model, and the second considered the performance of the risk and opportunity classifications system. The model performed well under the scenarios tested, illustrating that it reacted to changes in input as expected and that mechanisms designed to manage those changes could be modelled. Through the use of scenarios the limit of the model, in terms of the duration of projects, was identified.

The assessment of the risk and opportunity classification system investigated each component in turn. The most significant changes, to calibrate the system, were related to the sensitivities of the mean, extreme and probability functions applied to each time period. Finally, the single risk and opportunity classifications were tested against various weight functions. These tests showed that the classifications did indicate the changes in the business the scenarios were designed to reflect.

Having described and tested the project and company risk model, the next chapter discusses the wider issues raised by each model and their combined use.

CHAPTER 8

ISSUES RELATING TO THE HIERARCHICAL APPROACH

8.1 INTRODUCTION

Chapter 3 described a hierarchical approach to the management of risk from projects. In order that the ability of that approach to allow the effective management of those risks could be assessed, two risk models were produced: the project and company risk models. Each model has its own objectives which together lead to an hierarchical approach. Chapters 3 through 7 presented and tested the risk models against their own objectives.

The main objective of the company risk model is to assess the extent to which a project currently being tendered for is desirable to the company based on the current exposure to risk and opportunity to both profit and turnover targets and the impact that the project has on that exposure. This allows projects to be viewed in the wider picture of the company which will be undertaking the project. A deficiency in the current approaches to project risk management is that they tend to view projects in isolation (see Section 2.7.1). The main objective of the project risk model is to combine the various sources of uncertainty in the project to act as input to the company risk model. The project risk model was also designed to allow the project team to assess the uncertainty in a project, but the main objective is to provide input to the company risk model. This allows the hierarchical approach to function in that the company level should not have to consider the detailed information regarding each project or operation but should be concerned with the overall impact on the business.

This chapter discusses issues relating to the combined use of the models, relating to the hierarchical approach, concluding with a discussion of the extended uses of the system.

8.2 COMBINED USE OF THE RISK MODELS

8.2.1 Initialising the Company Risk Model

The company risk model is intended to be used for a period of study, updated whenever information within it changes. For instance, if a tender is successful the status of that project within should be changes to reflect the change in the risk profile. Additionally, once a project is being undertaken, the periodic reviews are likely to record changes in the uncertainty with time; this will also require the company risk model to be updated. The project risk model is intended to be started fresh for each project and to be continued until the project is complete. The company risk model therefore requires initialising before it can be used, whereas the first use of the project risk model initialises it.

The initialisation of the company risk models requires the following tasks:

1. The modelling of all projects which the company is currently undertaking which may impact the study period, either by using the project risk model or by using the simplified method within the company risk model.
2. The modelling of all projects which the company is pursuing, including an assessment of the probability of success of each tender.
3. The definition of the market in which the company operates, requiring the characteristics of the projects which make up that market.
4. The setting of the tendering strategy, defining the range of projects the company will pursue.
5. Defining the turnover and profit targets for the company.

This process will initialise the model, enabling it to be used to assess an individual tender. The initialisation of the company risk model was not considered in any depth in Chapter 6. However, it can be seen (Section 6.5) that the build up of projects under construction starts at the start of the study and this therefore models a new business unit rather than an established company. As the initialisation steps detailed above show, in the case of an established company, all projects which could have an impact on the study period should be modelled.

8.2.2 Updating the Company Risk Model

The company risk model is a dynamic model and once initialised requires updating when any of the information contained within it changes. The updating of the company risk model will comprise several aspects, as listed below:

1. Updating the status of projects which are being tendered for, either to remove them from the model or to include them as contracts.
2. Updating projects if they have been re-analysed using the project risk model.
3. Changing targets for turnover and profit.
4. Updating market information.
5. Modifying the tendering strategy.

In order to update a project within the company risk model, the previous impact on the cash flow must be removed and then the new impact added. This requires that for each project which is added to the company, the source from which the project cashflows are taken is retained. If the source are not retained, the company cashflows have to be generated each time a modification is made. This increases the analysis time considerably, so reducing the effectiveness of the model to allow management to make decisions.

8.2.3 Updating the Project Risk Model

As discussed above, the company risk model must be updated when the status of the projects it contains changes. Since the uncertainty whose impact the models are concerned with changes constantly throughout the duration of a project, the project risk model will usually only be valid at the time it is produced; further information or decisions will change the assessment of uncertainties even if the underlying uncertainty does not change. Since it is impractical to constantly update the project risk model, and consequently the company risk model to which the results are input, a regular review should be held to ensure that the project risk model is representative of the status of the project.

In order to keep the project risk model up to date, the following activities must be undertaken:

1. The previously identified uncertainties must be reassessed to determine if they still exist and if so whether their probabilities and effects remain unchanged. Part of this process will be the assessment of the effectiveness of actions developed to manage the risks and opportunities at a previous meeting.
2. Through a brainstorming exercise, any further sources of uncertainty which had not been identified previously should be identified. It is expected that the uncertainties will change as the project proceeds, as risks and opportunities are managed and the project develops and changes its focus.
3. Actions should be allocated to seek to actively manage the uncertainties, aiming for the opportunities and avoiding the risks.

Carrying out the first two tasks enables the project risk model to be updated. The need for the third task highlights a key difference between the risk management process at tender stage and through construction. At tender stage, the focus of the process is on the analysis of the risks and opportunities, whereas during construction, the focus is on the management of them. Indeed, many of the management responses formulated during the tender stage will be actions which the project team are expected to carry out.

As the project progresses, regular assessments of the current risk and opportunity will, in addition to bringing the company risk model up to date and actively managing the risks, provide the management with an indication of the possible outcome of the project. If the results of the risk analysis for each assessment are plotted against time, say by plotting the lower and upper extremes and the average outcomes for cost, profit, and duration, the movement in the uncertainty with time will be visible. For the purpose of reporting the expected final outcomes of the project, such information allows the confidence in that forecast to be stated. As the project proceeds, and the major sources of uncertainty are managed, the confidence in the final outcome would be expected to increase.

8.3 PROBLEMS ASSOCIATED WITH THE HIERARCHICAL APPROACH

8.3.1 Basis of the Hierarchical Approach

The hierarchical structure of the company management, on which the system is based, aids the company by allowing each level to consider information to differing levels of detail. This approach has been continued into the risk models, in which the company risk model views each project as a single source of uncertainty to its cashflow and yet the project risk model considers the various sources of uncertainty which make up the total.

8.3.2 Inconsistencies and Conflicts Between the Objectives of Different Levels of the Company

As discussed in Section 3.3, the hierarchy relies on communication between the levels, both with instruction to lower levels and reporting to higher levels. That discussion also identified the source of a possible breakdown in that communication. People have personal and professional objectives. If those objectives are not consistent, the objectives at one level may be distorted from those the higher levels think are in place. This possible inconsistency between the objectives of levels is the major deficiency with the hierarchical approach.

8.3.3 Inaccuracies in the Information Used and Reported

Another possible source of problems in the approach is that the business unit must be satisfied that the uncertainty reported is a good representation of the true uncertainty in the project. Although it is impossible to say that all sources of uncertainty have been identified and quantified, by the very nature of uncertainty, the project team must be able to convince the business unit that the uncertainty reported is representative.

Possible reasons for the uncertainty reported not being a fair reflection of the true uncertainty include:

- A systematic approach to risk identification and quantification may not have taken place, either because of time restrictions or the project team's reluctance to undertake formal risk management.
- The project team have not been given adequate guidance on the definition of probability and effect.
- The team wish to make the project appear more or less attractive because of their opinion of the project.

Although the above problems are real, they can be managed. In the case of unintentional failure, adequate training and guidance can be provided. In the case of intentional failure, the nature of the formal approach, requiring that all possible sources are considered and hence actively discarded, and implementing strict documentation procedures limits the potential for abuses. Referring back to the traditional approach, in which very little documentation was produced, the controls on such abuses were minimal both in the literature and in the company investigated.

8.4 USE OF THE SYSTEM AT OTHER LEVELS

The system which incorporates the risk models was designed to allow projects to be assessed at tender stage allowing the effective management of the risks and opporutnities. However, the system is applicable at higher levels because it is based on the hierarchy of the organisation. For example, consider the hierarchy in Figure 8.1, showing various organisational levels.

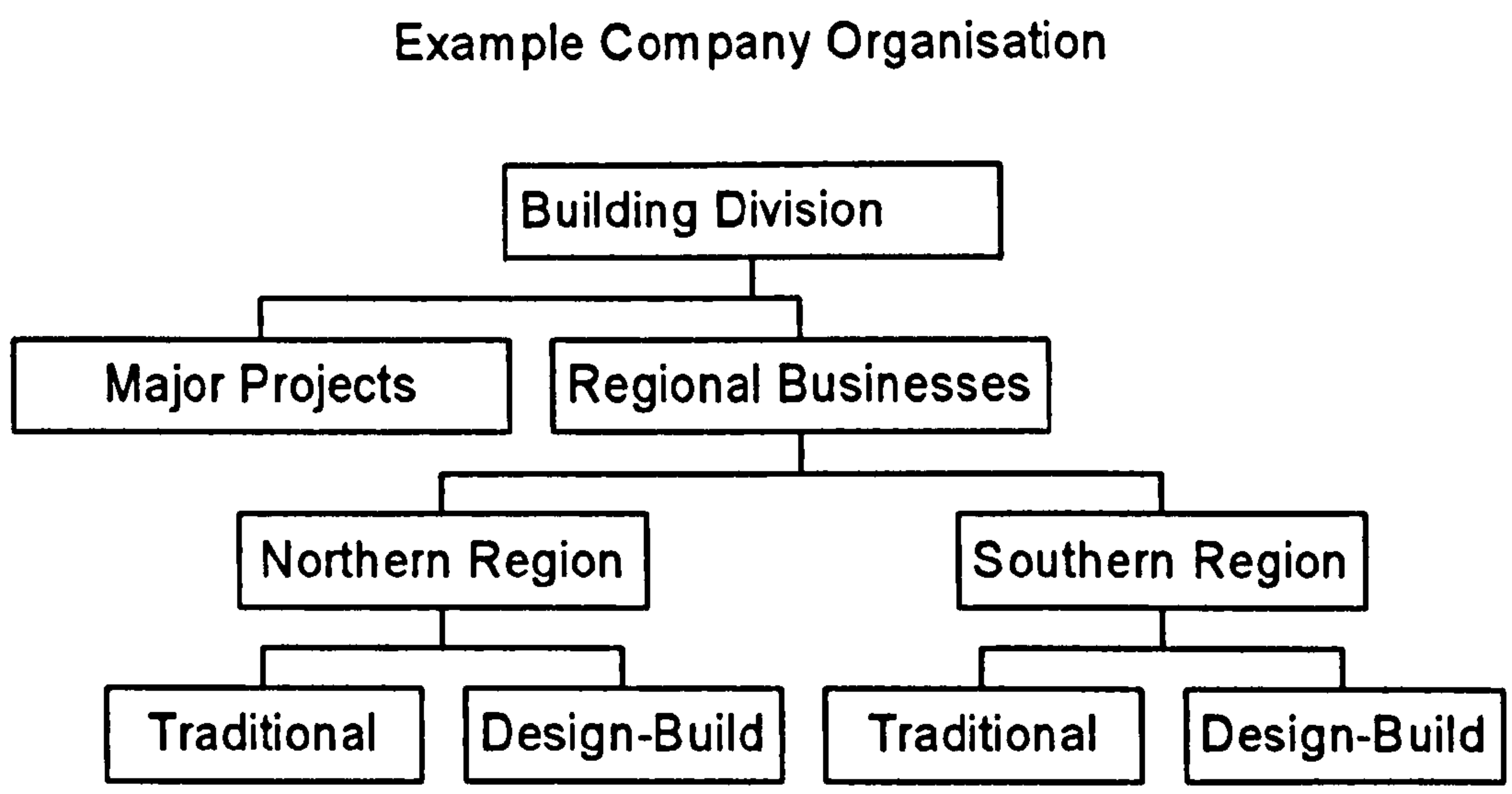

Figure 8.1 - Example Company Hierarchy

The use of the model considered throughout this thesis is that of the business units which undertake projects, for example Regional Traditional Building. Since one of the fundamental principles of both models is the taking of several sources of uncertainty to determine their combined impact on a set of objectives, the approach is applicable at the higher levels, such as, in the example, Building Division. The sources of uncertainty to its objectives are the business units which report to it, since it will set their targets for turnover and profit as a means of fulfilling its own targets. The company risk model should, therefore, be applicable at the higher levels.

The following sections discuss the differences between the purely organisational level and the project orientated level previously considered. The possible sources of uncertainty treated as input to the model, and the need to model non-financial measures in addition to those considered previously are discussed.

8.4.1 Differences Between A Project Orientated and Organisational Level

The project oriented level considered previously has readily identifiable sources of uncertainty when compared to the project level. However, since the projects and their status are constantly changing, the sources of uncertainty were not fixed because some tenders would not be successful and projects would be completed. At the higher, organisational level, the sources of uncertainty are fixed so long as the company does not create other departments.

In addition to knowing the sources of uncertainty for the whole of the study duration, the sources will be likely to exist for the whole of that study, except in the case of new or closed departments. This observation is consistent with the hierarchical approach when considered with respect to the company risk model. The output of the company risk model, in addition to the classifications, is the uncertain cashflow of the business which would act as input to the model at the higher level.

8.4.2 Possible Inputs to the Model at an Organisational Level

The main source of uncertainty at the organisational level will be the levels which report to it and undertake the projects. As the discussion above illustrates, if these lower levels are assessed using the company risk model, the uncertain cashflow is produced automatically. If the company risk model were to be modified to be applicable at the higher level, the ability to add the results of an analysis of a lower level would be required. In terms of the mechanics of the model, this would be viewed as a series of possible cashflows which would start at the start of the study and continue throughout the duration.

The business unit considered for the company risk model and the preliminary discussion on the higher level only contained projects and the collection of them for organisational purposes, neglecting other activities of the company. Even a company whose business is solely project related will have operations in addition to those projects. For instance, a tendering team will be employed, containing planners and estimators, which may seek legal and commercial advice from a separate department, communicate using IT supported from another department to pursue projects identified by a marketing department.

In order to model these other operations, the company risk model requires, in the absence of a model for specific use at those levels, the ability to model a business using a similar technique to that used to model projects without using the project risk model. In the case of operations, this could consist of an expected expenditure and a possible deviation. If this is not considered to provide the confidence required, a risk model could be produced for such a level utilising the company risk model

8.4.3 Modelling Non-Financial Measures

As discussed in Section 3.2.3, towards the top of the organisational hierarchy the objectives include non-financially based targets in addition to the more traditional finance based ones. The project and company risk models presented concentrate on the use of financial measures, such as profit and turnover. In order to model non-financial measures, such as quality and image, two approaches can be taken. Either, the impact can be translated into a financial impact or a unit for measuring the impact can be developed. Although the latter is more difficult it is preferable as some risks to quality or image cannot be readily translated into an equivalent financial impact (Drucker, 1974).

If a unique unit was used for the objective, the impact of uncertainties could be defined in terms of that unit allowing both the project and company risk models to be used without requiring significant modification. The only modification required would be to change the units in which the results are presented and the effects entered. As an example, if quality was to be modelled with the target that the project should improve the perceived quality of the company, the unit for quality could be set at ranging from -10 to +10 with 0 representing a neutral result. In this way, the project, as a base, would have a zero quality rating throughout its duration. Then, any risk factor which could have an impact on quality could be defined. For each risk factor, the distribution of effect would use the dimensions defined for quality: a negative value would result in a lowering of quality and a positive value a raising of quality. Although the project and company risk models have been presented with respect to financial objectives, they can easily be adapted to allow non-financial measures to be modelled.

8.5 SUMMARY

This chapter has discussed the combined use of the project and company risk models, the problems associated with the hierarchical approach and how the models can be extended, by virtue of the hierarchical approach, for use at higher levels in the organisation.

CHAPTER 9

CONCLUSIONS

9.1 INTRODUCTION

This thesis has presented research into the effective management of risks from projects within a construction company. The thesis began with a statement of the objectives of the research and, through investigations into the traditional and more formal methods of managing such risks, the requirements of a system were formulated. A system for managing the risks within the hierarchical framework of the company, requiring a project and a company risk model, was presented and tested. This chapter concludes the thesis by, firstly, listing the objectives of the thesis and by examining the work presented, assessing the extent to which those objectives are attained.

9.2 OBJECTIVES OF THE RESEARCH

The objectives of the research, as set out in Chapter 1, were as follows:

- To investigate the nature of risk and uncertainty in a construction company arising from the projects it undertakes.
- To investigate the link between project and company risk.
- To assess the effectiveness of current methods and techniques employed to manage those risks.
- To determine whether a system can be produced which allows the effective management of risk arising from projects, whether to their own objectives or those of the company. This will include the following:

    a mechanism for assessing the uncertainty in a single project,

    a mechanism for assessing the uncertainty in a company undertaking several projects,

    a method for relating those uncertainties to the objectives of each level in order that the risks and opportunities can be managed effectively.

This chapter assesses the extent to which the research presented has attained those objectives.

9.3 CONCLUSION OF INVESTIGATION INTO TRADITIONAL AND FORMAL RISK MANAGEMENT APPROACHES

The investigations into the traditional and formal approaches to the management of risk from construction projects were undertaken to investigate the link between project and company risk, investigate the nature of those risks, and to assess the effectiveness of the approaches.

The investigation into the traditional form of project risk management concluded the following:

- Risks and opportunities arise out of the action of uncertainty on objectives.
- Opportunities should be given equal importance to risks as it is because of the opportunities that the risks are accepted.
- Projects are undertaken by a company in an attempt to fulfill its objectives.
- For a contractor, it is at tender stage that uncertainties are apportioned, through the contract, and those uncertainties translated into risks and opportunities through the price submitted.
- When assessing a project, in addition to the exposure the project would bring, the extent to which the company wants the project, its current risk exposure, and the price which the market is expecting are considered.

The investigation into the formal subject of risk management concluded the following:

- Projects are treated as independent entities whereas they should be treated as temporary parts of a company's ongoing operations.
- The other considerations of the company, external to the project, are not considered.
- The name "risk management" is sometimes taken literally and the opportunities are not considered.

- Many techniques are not applicable at tender stage due to the detailed information they require as input.

9.4 THE HIERARCHICAL SYSTEM PROPOSED

The investigation into the traditional approach to the management of project risk concluded that the company, when assessing a project at tender stage, considers many aspects external to the project. Therefore, the effective management of the risk from projects requires an approach which, although it allows the project being tendered for to be considered in detail, also considers the other operations of the company. The system produced is based on the hierarchical structure of the organisation, utilising two risk models. Through the project risk model, the project team are allowed to define the risks and opportunities in the project to a high level of detail. The techniques used to achieve this were mostly taken from the review of the formal risk management approach set out in Chapter 2. The project risk model then combines these to act as a single source of uncertainty for input to the company risk model. The project risk model overcomes the issue of the limited amount of available information by taking an approach which can be enhanced as and when more information becomes available. This is in contrast to some techniques, particularly network based solutions, which require a high degree of detail before any analysis can be undertaken.

The company risk model, in order to determine the current exposure to risk (and opportunity) considers more than the projects the company is currently undertaking. Since the study extends into the future, the projects currently being pursued and a market prediction of the mix of projects the company could be undertaking is necessary. The hierarchical approach allows the other projects to be entered into the model as single sources of uncertainty even though, in the case of those under construction and those being pursued, they are likely to have been considered in the same detail as the one under consideration.

9.5 EFFECTIVENESS OF THE PROPOSED SYSTEM

The effectiveness of the system has three components; the ability of the project and company risk models to combine the sources of uncertainty and extent to which they enable the effective management of those uncertainties once they have been translated into risks and opportunities.

9.5.1 Effectiveness of the Project Risk Model

The objectives of the project risk model are to combine the various sources of uncertainty, for input to the company risk model, and to allow the effective communication of the uncertainty with respect to the objectives for the project. The identification of the sources of uncertainty is the most difficult part of that process, which uses proven techniques of checklists and structured brainstorming. A simple method of modelling those uncertainties, here termed risk factors, is used. Monte Carlo simulation is used to combine those various sources, producing the uncertainty in the project. In order to enable the communication of the resulting risk and opportunity, a classification system was developed which related the uncertainty to the objectives. This classification was shown to adequately reflect the views of managers when changes to test project were made or projects were compared.

A limitation on the project risk model is that it has to be able to be used to within the tender period of the project. For a contractor, the tender period is often too short and information is rarely available when required. The project risk model was tested on projects as their tenders were being produced. This approach to testing in a live situation confirmed the applicability of the model in practice as well as in theory.

9.5.2 Effectiveness of the Company Risk Model

The company risk model is initialised by adding together the uncertain cashflows of all the project it is undertaking or pursuing and producing a projection of project it may be undertaking in the future. Although the risk and opportunity could be determined in each time period, a classification system was also developed to relate the uncertainty to the objectives in all time periods of the study. To enable a project to be assessed at tender stage, the risk and opportunity classifications illustrate the extent to which the project would assist in the attainment of the company's objectives.

9.5.3 Effectiveness of the System to Enable Effective Management

The hierarchical solution, using the project and company risk models, addresses the main issue missing from the formal approach to risk management, that a company considers more than the project being tendered for when finalising a bid. Further to this, the classifications systems produced relate the uncertainty to the various objectives of either the project or the company. Tests on the threshold between risk and opportunity demonstrated the concept that only through the impact does uncertainty create risks and opportunities; if our objectives changes, even if the uncertainty remains constant, the risks and opportunities will also change. The classifications systems, in addition to relating the uncertainty to the objectives, allows the management of the resulting risks and opportunities by highlighting the effect of possible management actions.

9.6 SUMMARY

This thesis has presented research undertake in the field of project risk management, aimed at allowing the effective management of such risks. The research has considered work undertaken by others in this field, and produced a system, using a project and a company risk model, to allow the management of the risk from projects by considering them in the context of the company undertaking them rather than treating them as independent entities.

CHAPTER 10
FURTHER WORK

10.1 INTRODUCTION

This thesis has presented research aimed at the effective management of the risk from construction projects from the point of view of the company undertaking them. This chapter suggests work which could be undertaken to advance the subject still further. The work is divided between that relating to the project risk model, the company risk model, and the overall system.

10.2 WORK RELATING TO THE PROJECT RISK MODEL

10.2.1 Dependent Risk Factors

The risk factor, as it is defined for use within the project risk model, treats all risk factors as independent; a risk factor cannot influence the probability or the impact of another risk factor. Although the experience gained during testing showed that in most cases, the project team viewed the risk factors as independent events, there will be some situations in which the perceived links which exist should be modelled to maintain the integrity of the model.

In order to link the probability or effect of one risk factor to that of another requires a significant modification to the risk factor definition. In order to retain clarity, two sets of risk factors could be defined. The first set, the primary risk factors, would be independent and defined as detailed in the previous chapters. The second set would be dependent on the primary risk factors. Although there are several ways in which the dependency can be modelled, the mechanism used in the company risk model to link contract value and duration in the market projections could be repeated (Section 4.7.10).

This would require distributions for the dependent risk factor to be defined for several outcomes of the primary risk factor.

In addition to risk factors being dependent on the outcome of other risk factors, they can also be dependent on the status of the project as a whole at a given time. For instance, a risk factor modelling acceleration costs would be linked to the perceived duration of the project rather than the outcome of another risk factor. If the duration was greater than a specified limit, this could trigger the risk factor whose effect would be to reduce the duration at a cost. Conversely, a risk factor could be defined to act as a bonus for completing the project early, representing an opportunity. Similarly, a risk factor could be dependent on the perceived final cost of the project, where the cost of the project triggers the risk factor occurrence. In both these cases, each risk factor could still have its own probability of occurrence if the trigger had been activated and the effect could be dependent on the extent to which the trigger had been exceeded.

However, in developing solution to these problems, the limited time and information available must be considered; some solutions may increase the complexity of the model to an extent that the usefulness is reduced.

10.2.2 Sensitivity Analysis

One analysis technique which was identified as useful in Chapter 2 was sensitivity analysis. This aims at determining the sensitivity of the project to the individual risk factors, so allowing management action to be efficiently targetted. Although this was identified as an important aspect of the risk analysis stage, neither the project nor the company risk models undertake such analysis explicitly; such analysis has to be performed manually. The company risk model is aimed at determining the sensitivity of the company to individual projects.

For the project risk model, sensitivity analysis can undertaken in several ways. The technique described in Chapter 2, the production of spider diagrams, could be applied. Since the expected outcome of each risk factor is used in sensitivity analysis, and is not evaluated currently, this would require an extension to the analysis. As identified in Chapter 2, the limitation of sensitivity analysis is that it assumes all other risk factors take their expected outcome for the analysis, and since the model is produced through the acknowledgment that all risk factors can vary simultaneously, this deviates from one of the fundamental principles of the model.

There are two other approaches which can be taken. The first is to apply the usual sensitivity analysis approach and classify each risk factor in much the same way that the final outcome is classified. By assessing, with respect to the value of the project, the most likely outcome and the extremes for each risk factor, a classification between -10 and +10 could be produced (-10 for a potentially extreme risk and +10 for an extremely significant opportunity). By producing such a classification, the relative importance of each risk factor can readily be determined. The drawback of such an approach, and an area which requires further consideration, is that some risk factors have impact on duration only or a combination of cost and duration. The approach suggested above does not allow such complexity.

The third approach to sensitivity analysis combines the fundamental principles of both traditional sensitivity analysis and Monte Carlo simulation in that it considers each risk factor in turn but, rather than varying it whilst keeping all others fixed, it would do the opposite. By assuming all other risk factors could vary simultaneously and performing a Monte Carlo simulation for various values of the risk factor under consideration, the sensitivity of the project under various degrees of uncertainty in the other risk factors could be tested. The importance of such an approach is that a project may not be sensitive to a risk factor under normal conditions, i.e. that used for traditional sensitivity analysis and yet that risk factor could become increasingly important as other risks occur. This is an area of work which would not only enhance the project risk model, but advance the techniques of Monte Carlo simulation and sensitivity analysis.

10.3 WORK RELATING TO THE COMPANY RISK MODEL

10.3.1 Non-Financial Objectives

The need for a mechanism by which non-financial based objectives could be modelled was identified in Section 8.4.3. In that chapter, a possible way of including such measures was presented although it was not tested. That approach requires testing and the possibility of using other approaches need to be investigated.

10.3.2 Non-Project Based Operations

The need to extend the company risk model to allow non-project based operations was identified in Chapter 8. Although a possible mechanism was suggested in that chapter, no testing has been undertaken. As discussed, the inclusion of non-project based operations is important if the company risk model is to contain all the operations of a company.

10.4 WORK RELATING TO THE HIERARCHICAL SYSTEM

10.4.1 Use of the System at Higher Levels

As discussed in Section 8.4, the approach used in this thesis could be extended to enable the risks and opportunities at higher levels of the organisation to be modelled and hence managed effectively. Similarly to the extension to non-project based operations, which would become more important at higher levels, this approach has not been tested.

10.4.2 Modelling PFI Projects

The UK Government's recent re-appraisal of its procurement strategy has led to large construction companies facing new risks in the form of PFI projects. The main risk companies face, in addition to any apportioned through the contracts, is that several divisions of a company can be involved in the same project and in many cases an equity investment is also required. The relevance to the project and company risk models is that each division will be assessing the contract relevant to themselves whereas the company will be wanting to know the overall benefit to it of pursuing the concession contract (which is an expensive task in itself). The situation in which one division, for example the facilities management operator, sees a great benefit in the project and another division, for example building, does not want to pursue the project could easily exist. It is in these situations that a company-wide view of a project is important. The hierarchical nature of the project and company risk model should allow them to be adapted to address this issue and allow companies to pursue projects knowing the overall impact on the company and the relative importance to each division.

Another aspect of PFI projects which also requires attention is the equity investment. As the PFI process develops, companies are viewing each project as a single investment and yet, if the process establishes itself, each project will be adding to the existing investments of the company. Indeed, one decision may be to liquidate existing investments in order to allow the company to pursue the current contract. Even in this situation, it may be that the company is seeking the project because of the relatively short term contracts it would provide rather than any long term investment opportunity.

10.5 SUMMARY

This chapter has suggested work which could be undertaken. The work relates to the project and company risk models and then to the extended use of the hierarchical approach, intended to develop the system presented in this thesis and the subject of risk management still further.

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