Chapter 1 Introduction

1.1 The Need for Risk Management

"Risk is ubiquitous and no human activity can be considered risk free"

Hood *et al.* (1992)

From this sentence, one must attempt to decipher the varying amounts of risk that is carried by each individual human activity. Crossing a road carries an element of risk, but the amount of risk it possesses does not require the person to stop and manage that risk. On the other hand, the activities that are present in the oil and gas and the construction industries do, as each activity could result in physical injury or a fatality, financial disasters, delayed operation, etc. Hence risk management is fast becoming an integral part of major projects in those industries.

Recent decades have been characterised by a vast proliferation of risk management. There are a number of potential explanations for the increased interest in this subject. They are many and varied and include:

- increases in technology;
- tighter financial constraints;
- projects becoming larger and more complex;
- more public interest to decrease risk and improve safety;
- location of the project;
- familiarity with the type of work; and
- more consequential risks.

However, there are potentially two other reasons which outweigh all the above and are described below. One of these is taken from the construction industry and the other from the oil and gas.

Within the construction sector, Thompson and Perry (1992) illustrated that time and cost overruns turn a profitable investment into a loss-maker. The reason for these overruns are simply that the risks are not adequately being dealt with. The extent of the cost and time overruns are displayed in Figure 1.1 and Figure 1.2 respectively. The projects reviewed to achieve the line diagrams were financed by the World Bank (World Bank, 1990) and therefore were projects completed overseas as well as in this country. It is clear to see from Figure 1.1 and Figure 1.2 that the percentage overruns are alarming. In addition, in the UK, a 1975 study on the performance of public sector construction projects found that 1 in 6 contracts overran by more than 40% of the original contract duration, and a significant number by more than 80% (NEDO, 1975). Further, a 1983 report on the speed of industrial building in the UK (NEDO, 1983) revealed that too many projects overrun both cost and time forecasts and, crucially, it found definite evidence that greater attention to project management, which includes risk management, produced significant improvement in meeting targets.

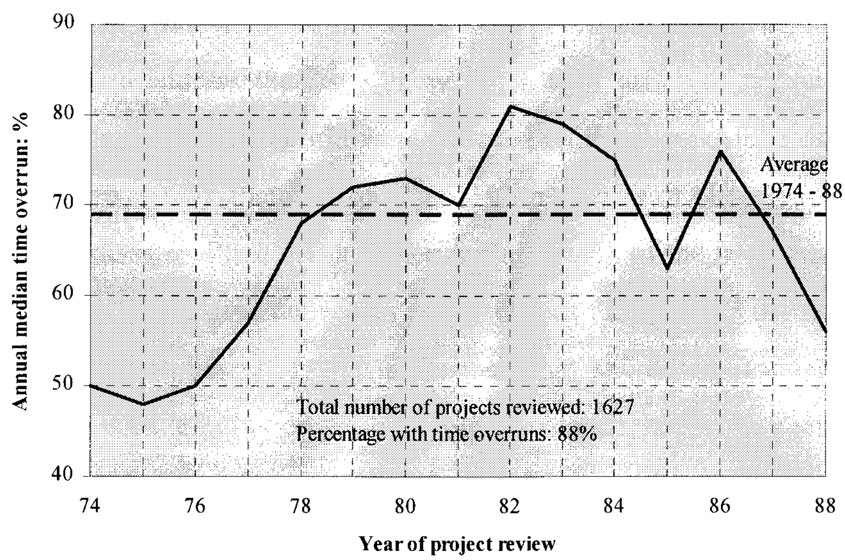

Figure 1.1 *Overrun of actual costs of projects compared with cost estimated at time of appraisal*

Projects sometimes overrun because of unforeseen events, which may not be anticipated by even the most experienced project managers. This is because no two projects are the same, and thus, identifying the sources of risk is critical for every project.

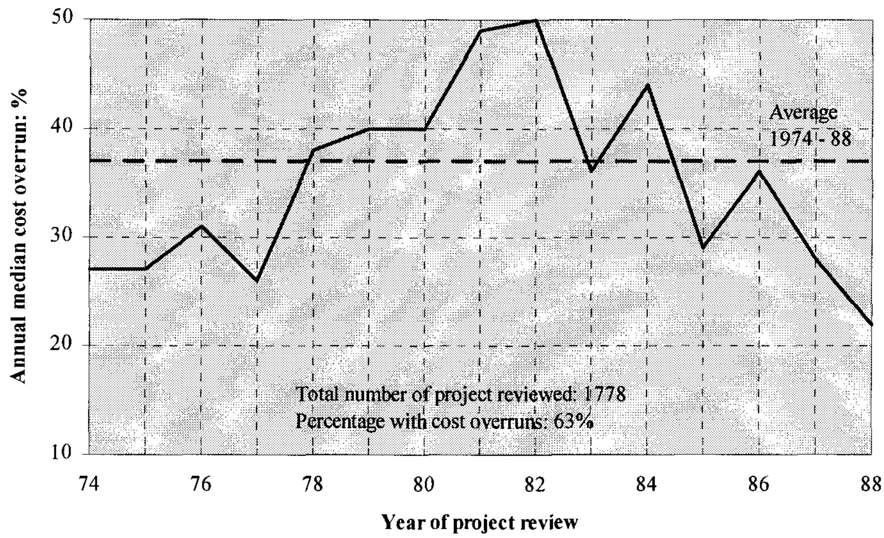

Figure 1.2 *Overrun of project completion times*

Around the time when the construction industry realised that more risk management was necessary, i.e. 1988 when these results were published, the oil and gas industry was also forced to address the issue anew, for a very different reason. On 6 July 1988, the oil industry and the world were shocked by the Piper Alpha disaster in the North Sea (Cullen, 1990). Plate 1.1 to Plate 1.3 are a series of photographs depicting the progression disaster. Plate 1.1 is an aerial photograph of the installation whilst in normal operation. These give the reader an opportunity to imagine the remoteness of such a working environment and to understand that should an accident occur the considerable amount of elapsed time before assistance becomes available. Piper Alpha was situated 110 miles north east from Aberdeen, therefore, relying heavily upon nearby ships and platforms, plus their trained onboard fire fighting team. Sadly, these factors were insufficient in the circumstances.

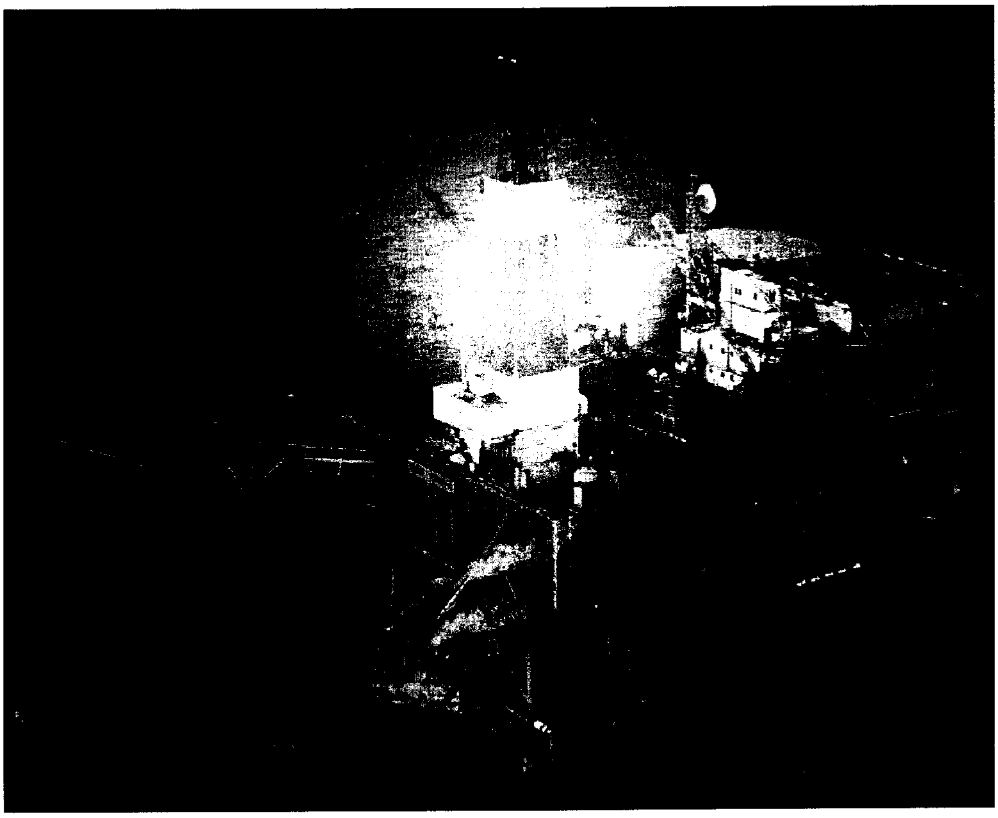

Plate 1.1 *Piper Alpha installation*

Plate 1.2 illustrates the sheer magnitude and colossal nature of such an event and demonstrates the exact dangers of extracting flammable fossil fuels. Every precaution must be taken to avoid this, the ultimate catastrophic eventuality.

Plate 1.2 *The Piper Alpha disaster happening on the 6 July 1988*

Finally, Plate 1.3 displays the outcome of this disaster. All that remains is a small segment of the main deck, which sits precariously on part of the jacket, whilst the remainder of the installation still burns some 12 hours after the initial explosion. A total of 165 people died.

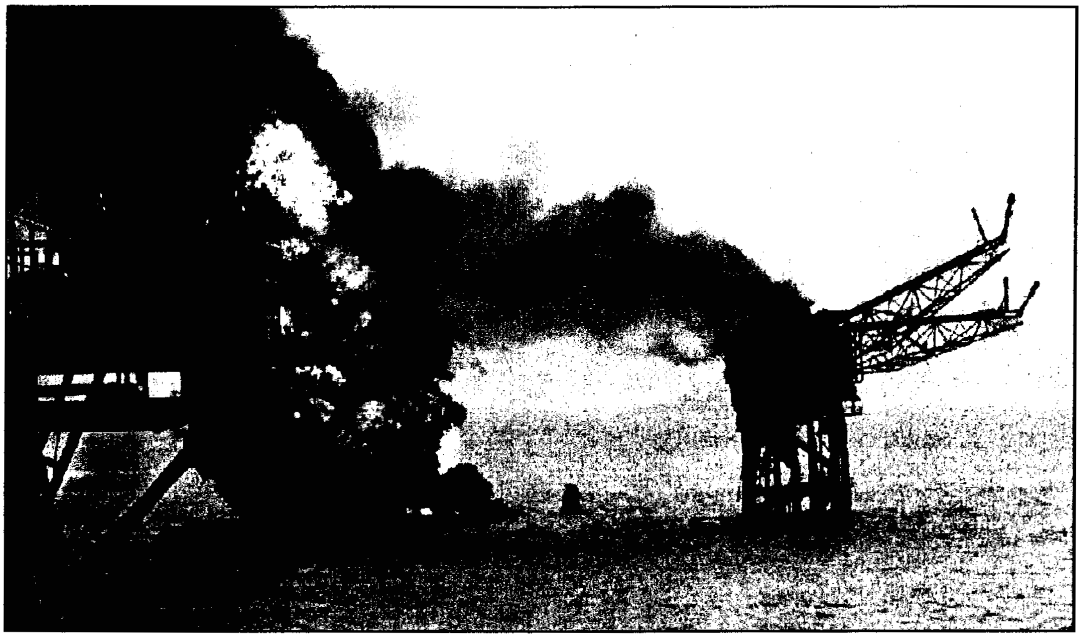

Plate 1.3 *All that remains of the Piper Alpha the following morning*

1.2 The Need for Continued Research

It is a subjective view as to whether the Piper Alpha disaster would have been avoided if sufficient risk management measures were already in place, but it caught the attention of the public to such an extent that a surge of safety/risk interest was inevitable. This surge compelled the Department of Energy to employ the Hon. Lord Cullen (1990) to present to Parliament a Public Inquiry into the disaster. As a result, many companies set up or reinforced their existing safety/risk departments. Safety Cases (SC) are now required for all current and future offshore installations. Companies are then obligated to submit these SC's to the Health and Safety Executive (HSE) for certification to extract oil and gas. Safety cases must be re-submitted every three years of the installation's life and an additional SC is also required when the platform is to be de-commissioned. These SC's should demonstrate that the installation is fit-for-purpose. This is achieved by the identification of all the potential risks and the evaluation of their respective qualitative and quantitative risk levels. A number of regulations were constructed to complement the creation of these SC's, within which specific levels of safety needed to be met before construction and operation could continue. What was not specific, was the process to which these levels were to be achieved. Therefore, the separate companies performed risk management techniques and procedures differently.

It was this lack of standardisation, within the two industries, towards risk management that led to the present investigation. This combined with projects being undertaken becoming larger, more complex and multi-disciplinary, the demands and needs of society multiplying with further human knowledge, together with more competitive financial environments and technological advances, place a greater dependence upon risk management determining the outcome of a project (Chapman and Cooper, 1987).

These massive projects may be extrapolations of past projects, and also may have similarities, but still only provide a base from which to start. The differences, and the economic and technological innovation required imbue all these major projects with considerable uncertainty and risk. It is within this context of major projects that this research into risk management was undertaken.

It is the objective of this thesis to firstly identify the more common practices of risk management that are currently employed by the construction and the oil and gas industries, by means of a questionnaire. Then from the results, improve the techniques used to analyse these risks. This is achieved by the use of a real-life case study and by viewing its methods retrospectively. This case study was attained from Amerada Hess Limited (AHL), who sponsored this Doctoral Thesis. The work presented in this thesis goes some way in identifying and quantifying a new approach towards risk analysis with the long term view of incorporating it in future major projects. However, before any of the objectives can be satisfied, it is important to define the terms of risk and risk management relevant to this thesis.

1.3 Definition of 'Risk' and 'Risk Management'

1.3.1 Risk

Risk and risk management have been given a multitude of definitions. Each definition is slightly different and it is important that the meaning of the term 'risk' throughout this thesis is clear from the outset.

A few definitions are given to supply the reader a feel for the term before the definition which is to be used is given. The dictionary defines risk as:

> " *n* hazard, danger, chance of loss, failure or injury; the degree of probability of loss; a person, thing or factor likely to cause loss or danger.- *vt* to expose to risk; to incur the chance of unfortunate consequences, loss or danger by (doing something)"
>
> Chambers dictionary (1992)

Willet (1951) identified the basic elements necessary for understanding and measuring risk. Although some authors would disagree with this definition, he said:

> "**Risk** is the objective uncertainty as to the occurrence of an undesirable event. It varies with uncertainty and not with the degree of probability."..."the greater the probable variation of the actual loss from the average, the greater the degree of uncertainty."
>
> Willet (1951)

Greene (1979) simply defines risk as:

> "the uncertainty that exists as to the occurrence of some event"
>
> Greene (1979)

The following definition, by Denenburg (1974), indicates that risk measurement and interpretation are somewhat subjective in nature, much like some economic decision.

Two individuals or companies exposed to similar risks may perceive the risks differently, depending upon their net worth, financial expenditure and attitudes towards risk:

> "Risk is uncertainty of loss.....it can be viewed as a psychological phenomenon that is meaningful in terms of human reactions and experiences"
>
> Denenburg (1974)

Some authors such as Pfeffer (1956) have suggested that risk is measured by probability. This is the case in some of the risk analyses, discussed in Chapter 2, but not in all of them.

The definition that is chosen which is applicable to this thesis is:

> "The combination of the probability of an abnormal event or failure and the consequence(s) of that event or failure to a system's operators, users, or its environment."
>
> Bell (1989)

For the purposes of this thesis an abnormal event is one which is considered to present a hazard. **A** hazard is

> **"A** source of potential harm or a situation with potential for harm in terms of human injury, damage to property, damage to the environment, or combination thereof."
>
> IEC Publication 50(191)(1990)

1.3.2 Risk Management

Although this does not define risk management explicitly, the general risk management question, proposed by Coates (1994), gives the analyst a good starting platform by enabling him/her to think ahead sequentially. The question is:

> "Who is at what kind of risk, when, where, with what effects, from what causes, with whom, responsible (for), by what instruments, in what value context, at what costs and benefits for its management?'
>
> Coates (1994)

It is possible to break this question down into individual clauses, (e.g. individual questions like 'Who or what is at risk', 'What kind of risk', and 'With what effects' etc.) in order to gain further insight into the risks. Obviously Coates' question, and thus the broken down set of exploratory responses, could be extended further to evolve into an even more general search tool.

The definition for 'risk management', taken from both IEC 50(191) (1990) and British Standards 8444 (1996) is:

> "The systematic application of management policies, procedures and practices to the tasks of analysing, evaluating and controlling risk."
>
> IEC 50(191)(1990) and BS 8444 (1996)

This definition is still pertinent, but by reading the BS 8444 (1996), the three steps of management can be expanded to five and is for this thesis, and thus the definition is amended to read:

> "The systematic application of management policies, procedures and practises to the tasks of identifying, analysing, evaluating, responding and monitoring risk"

As Jennings (1994) pointed out in her thesis, effective and efficient application of risk management involves a number of contributing elements. These include; models, methods and computer software, as well as tangible skill-related elements such as methodology design, specialist expertise and study team management.

Any other pertinent terminology relevant to this thesis are defined in the glossary. It is important, having just defined risk management, to ascertain its origin and past application by examining its history.

1.4 Programmatic History of Risk Management

The concept of risk management has been influential since colonies of people have evolved. It can be traced back to Roman and Greek times (Covello and Mumpower, 1985). In Covello and Mumpower's article, and according to Grier (1981), the first signs of risk management go back even further to 3200 BC in the Tigris-Euphrates valley with a group of people called the Asipu. One of their functions was to act as risk consultants. Their procedure would be to identify the important dimensions of the problem, propose alternative actions and collect data on the likely outcomes. Their data sources, though, were signs from the Gods. Each alternative option would be interpreted from the Gods and either a plus or a minus sign would result, determining whether the option was a favourable one, or not. Then the most favourable action would be selected from the pool of positive responses, and reported to the client.

It is difficult to assess whether the Asipu method was of qualitative or quantitative (see section 2.3.1 and 2.3.2) origin. When referring to quantitative risk analysis, the modern day analysts express their results in terms of mathematical probabilities and confidence intervals; whereas the Asipu of ancient Babylonia expressed their results with assurance and authority. The Asipu used non-numerical analyses, probability played no part, therefore the search for the origins of modern day quantitative analysis must be found elsewhere.

In Plato's *Phaedo* in the 4th century BC, there is an embryonic quantitative risk analysis, albeit in a religious context. Numerous treatises discuss the probability of an after-life based upon the behaviour and beliefs one conducts oneself by, in the here and now. Arnobius the Elder, in 4th century AD, proposed a sophisticated analysis, on this issue of after-life, using probabilistic risk assessment. He presented a 2x2 matrix. Arnobius argued for two alternatives: "accept Christianity" or "remain a pagan." There are also two possible, but uncertain state of affairs: "God exists" and "God does not exist". If God does not exist, then there is no difference between the two alternatives. If God does exist, however, then there is a higher probability of after-life, if one is a Christian rather than a pagan.

Arnobius' matrix analysis was extended by Pascal when he introduced his probability theory in 1657 (Ore, 1960). Given the probability distribution that God exists, Pascal concluded that the expected value of being a Christian outweighed the expected value of atheism. Pascal was the first of a number of intellectuals involved in this field during the 17th and 18th centuries. In 1692, John Arbuthnot argued that the probability of different potential causes of an event could be calculated. In 1693, Halley proposed improved life expectancy tables. In 1728, Hutchinson examined the trade-off between probability and utility in risky choice situations. Cramer and Bernoulli proposed solutions to the St. Petersburg paradox in the early 18th century. Then, in 1792, Laplace developed an analysis of the probability of death with and without smallpox vaccination. This was a true prototype of modern quantitative risk analysis.

From Covello and Mumpower's (1985) paper, there is evidence from archaeologists that gambling games occurred in ancient times. Well polished tali (predecessor to the modern dice; a four sided talus was made from the knucklebone or heel of deer, oxen etc.) are regularly found in Egyptian, Sumerian, Roman and Assyrian sites with scoring boards suggesting that they were used for games. It would seem to follow that mathematical calculations of averages, probabilities etc. should be as old when these games started. Yet, the mathematical theories relating to such games appear 1500 years later in the work of Pascal, Laplace and others. Hacking (1975) and Sheynin (1974) offered several tentative explanations, none of which are considered to be completely satisfactory. The arguments proposed for the rapid development of the mathematical probability theory were:

- in response to specific economic needs, i.e. traced to the rise of capitalism in the 17^{th} and 18^{th} centuries.
- related to the growth of firms dealing in life annuities. This argument falters as, by the third century AD, the selling of annuities was already commonplace.

- prior to the 17th century, mathematical concepts were not rich enough to generate a theory of probability. This argument fails when one considers that the concept of probability requires little besides simple arithmetic.
- that the conditions leading to the emergence of a mathematical theory of probability are the same as those leading to the emergence of modern science in the 16th and 17th centuries.
- Suggested by Grier (1981) that the pre-conditions for the emergence of probability theory were established approximately a century and a half before Pascal, largely because of a change in attitude of the Catholic Church.

One of the earliest attempts to apply probability analysis to a risk problem was in the 19th century by Von Bortkiewicz (Campbell, 1980). He aimed to calculate the annual number of Prussian soldiers dying from kicks by horses. His study lasted 10 years and was to ascertain whether an observed spate of kicking was random or due to a change of circumstances. The results indicated that the occurrences were in fact random and therefore, no disciplinary action was taken.

A paper in the International Insurance Monitor (Anon, 1981) describes a brief history of risk management. The term "risk management" originated in the U.S., attributed to two American authors, Mehr and Hedges (1963). They used it in the title of their insurance manual. After the 2nd World War, the U.S. insurance industry developed from a seller's into a buyer's market and the security officers examined ways of decreasing the amounts spent on premiums, without causing any reduced lack of cover. This could only be done by a full evaluation of the risk situation. Apart from judging the probabilities of loss for single and multiple risks, the unavoidable risks and those that could be limited also had to be determined. Cost/benefit calculations were made of the various risk response possibilities as well as adjusting the degree of insurance protection to the financial strength of the company involved.

The phrase "risk analysis" then became more widespread through Hertz (1964). In order to derive the probability distribution of the rate of return (or the net present value) of an investment project, he proposed simulation using computers. This technique would be a new one for making risk self-evident. In his example, nine factors were considered regarding the various uncertainties (Chapman and Cooper, 1987): market size, selling price, market growth rate, market share, investment required, useful life of facilities, residual value of facilities, operating costs and fixed costs. Hoping this method would lead to better investment decisions, an output called a 'risk profile' (Cozzolino, 1979) would need to be constructed in the form of a graphical display.

Covello and Mumpower (1985) identify nine important changes between the risks from the past and those of the present:

1. Reduction of the risks, e.g. rate of fatal accidents in the British coal mines, fell from 4 per 1000 workers in mid 19th century to 1 per 1000 in recent decades.
2. Increase in the average life expectancy.
3. New risks, e.g. nuclear war, super-tanker oil spills etc.
4. Increase in ability of scientists to identify and measure risks, due to advances in laboratory tests, computer simulations, environmental modelling, etc.
5. Increase in the number of scientists and analysts whose work is focused on health, safety, and environmental risks, i.e. literature on such subjects has increased from a few papers to formidable collections of material in the last decade alone.
6. Increased number of formal quantitative risk analyses that are produced and used.
7. Increase in the role of the Government in assessing and managing risks.
8. Increase in the participation of special interest groups in societal risk management, the obligation of the Government decision makers to consult representatives from these groups (e.g. industry, environmentalist groups, etc.) and to make risk management information publicly available, and
9. Increase in public interest, concern, and demands for protection.

However, formal risk management has only become an integral part of the construction industry within the past few decades. The reasons for this sudden increased need to analyse risk are many and are discussed in section 1.1. Risk, therefore, and ultimately the management of risk has become a specialised subject in itself. Risk is apparent in every project (whether it be construction, business, financial, medical etc.) but particularly so in large projects such as those within the oil business. Risk, therefore, must be managed in order to keep it to an acceptable minimum. If that is possible, then not only will project costs be more accurately known, but also profits will be maximised, or more importantly, losses, of every kind, minimised.

1.5 Outline of Following Chapters

This introductory chapter concludes with a brief summary of the work presented in the remainder of this thesis. This is sub-divided into a number of chapters each dealing with a particular area of research, which has been undertaken by the author.

Chapter 2 Literature Review

An objective summary of published literature relevant to the current investigation is presented. This is divided into appropriate sections based upon the steps required to fulfil risk management.

Chapter 3 Questionnaire on Risk Management

The need, design, format and work program of the questionnaire, entitled 'Questionnaire on Risk Analysis' (RMQ, i.e. Risk Management Questionnaire due to altered current terminology), is explained. In addition, some fundamental requirements when analysing the questionnaire responses are described, as well as presenting a summary of the replies.

Chapter 4 Analysis of the Questionnaire

An extensive analysis of the responses to the RMQ is presented. Many different graphs and statistical tools are utilised to simplify the enormous amount of data. The information is expressed from the entire sample's perspective, with comparisons made between the construction and the oil and gas industries. In addition, any contrasts between the replied job responsibilities are also highlighted.

Chapter 5 Techniques used by AHL when compared with other oil companies

Channelling the attention more to the oil and gas industry, the risk analyses techniques, both qualitative and quantitative, are collated from the RMQ, and contrasted against another leading oil company and the industry itself. Certain quantitative techniques are then emphasised for further development to encourage and improve the risk analysis methods practised by AHL.

Chapter 6 Case Study: AH001 Quantitative Risk Analysis (QRA)

A previously designed and constructed, but presently operating installation, named AH001 is described. The management process of the risks present on AH001 are discussed in detail. The current technique analyses the major hazards, by use of event trees with single point values (SPV) on the nodes of their branches. These values can sometimes be subjective in nature, and/or from non-installation specific data sources, hence are potentially unreliable. Recent reports are detailed, which identify the best estimates and uncertainty with each input. Therefore, discussion concentrates on the attainment of the present event tree values currently within the re-submitted SC (AHL, 1996a).

Chapter 7 Improvements to AHL Risk Analysis Process

Obviously, the introduction of the best estimates is an improvement in itself. However, further improvements to the quantitative risk analysis phase is proven in this chapter. There is currently little use of the uncertainty quotient. Therefore, the technique proposed improves the reliability of the input data, for these event trees, by using probability distributions instead of single points (SP). Normal distributions are used, which require two parameters; the mean and standard deviation. The best estimates pertain to the former and the uncertainty quotient the latter. This technique utilises the @RISK[1] package and Monte Carlo simulation. The resulting output graphs provide more information, whereby better decisions concerning the risks are possible.

Chapter 8 Conclusions

The results and conclusions are presented together to give an overview of the main findings of the research.

Chapter 9 Recommendations for Future Work

Areas of further examination, which have been highlighted by the current investigation and are considered pertinent by the author, are discussed and advocated.

[1] @RISK is a package name used for risk analysis produced by the Palisade Corporation