Appendix P  
Published Material

The following papers have been published in journals or conference proceedings unless otherwise noted, and have been derived from the research described in this thesis. A set of these is bound in this appendix and follow the order that they are numbered below. There are no page numbers for these papers but are clearly separated


3. BAKER S.W., PONNIAH D.A. and SMITH S., Techniques for the Analysis of Risks in Major Projects, *Journal & Operational Society*, (accepted for publication, August 1997)


5. BAKER S.W., PONNIAH D.A. and SMITH S., A Survey of Risk Management in Major Projects, *American Society & Civil Engineers*, (in draft for submission to the ASCE)
A UK Survey of Risk Analysis in Major Projects

S Baker, University of Edinburgh, Scotland
D Ponniah, University of Edinburgh, Scotland
S Smith, Amerada Hess Limited, Scotland

ABSTRACT

Risk analyses consisting of risk identification, risk assessment and the management of risk are fundamental to the success of a major project. The variations in using such risk analyses are considerable and are dependent on numerous factors such as the industry sector, the size of project, and stage of the project life cycle. These dependencies are investigated and presented in this paper. Over one hundred companies within the construction, and oil and gas operators in the UK were surveyed through questionnaires which provided information on the size and range of activities of the company; the company's policy on responding to risk, the techniques of risk analysis currently being used; as well as identifying specific risks encountered during any particular project. One of the major constituents to successful risk analysis is the decision of risk response. This paper concentrates on the most successful risk response methods within the Oil & Gas Industry, ascertained from the replies from that sector. The main conclusion from this paper is that risk reduction is the most popular method of responding to risk.

KEY WORDS: Risk; risk analysis; risk response.
1. INTRODUCTION

The demands and needs of society are increasing with increasing human knowledge, and technological advances. This results in projects we undertake being large and getting bigger. They tend to be complex and multi-disciplinary and a good example of this is with the Oil & Gas Industry. An increasing demand for petroleum based products has resulted in oil and gas being extracted from locations with harsh and challenging environments.

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 imbues all these major projects with considerable uncertainty and risk. It is within this context of major projects that this research into risk analysis was undertaken.

Risks are ever present and depending on the uncertainties and the consequences, we have routinely accepted them and take measures to minimise the consequences. We appreciate the risks in driving a car and ensure that a motor insurance policy provides 'cover' in case of accident. The extension to the management of the risks within the construction industry, and the oil and gas industries are not as straightforward. The consequences can be significantly greater, such as in the Piper Alpha disaster in the North Sea. Therefore, within these industry sectors detailed risk analyses are conducted at all stages of a project life cycle, from feasibility to decommissioning. Despite being a growing element of major projects, there is no standard to which reference may be made for techniques, factors and approaches to risk analysis. It was this lack of information that led to the questionnaire survey described in this paper.

2. METHODOLOGY

The principal objective of the investigation was to ascertain the details of risk analyses carried out by the oil and gas industry, and to compare it with the adopted practices within the construction industry. Thus the investigation had the three stages of:

(a) Questionnaire design,
(b) Selection of the sample, and
(c) Analysis of the responses.

A literature search ascertained that risk analysis consists of risk identification, risk assessment and the management of risk. Thus the questionnaire was divided into seven sections, see Figure 1, and covered the three topics given above. Sections 1, 2 and 7 provided information on risk identification, section 6 on risk assessment, and finally sections 3, 4 and 5 on the management of risk.

![Figure 1 Layout of the Questionnaire.](image)

These stages all fit together into a simple circular procedure which if followed obtains a controlled risk environment. See Figure 2.

The objective of risk identification is, as the name implies, to identify all the risks that could occur on a project, whether the be foreseeable or unforeseeable. There are various methods available for the companies involved in large projects. Once the risks have been fully identified it is usual practice to categorise and place the risks on a priority list. It is then normal to establish a program for developing responses to the major risks. The risks judged to be medium or low should be covered by the project contingency reserves.

When assessing the risks one must establish the causes of the major risks, and estimate a probability of those risks occurring and the possible consequences of them if left untreated.

![Figure 2 Risk analysis life-cycle.](image)

Alternative risk response strategies must then be developed to control/mitigate these identified risks. Following that, the risk response strategies must be analysed in terms of cost/program likelihood of success. Then any secondary risks that could arise from the possible risk response strategies are required to be analysed and considered.
The best risk response strategy is then chosen, developed, and implemented. Finally, this strategy is monitored for success. If it proves to be successful then the risk is acceptable. However, if it is not, the entire process starts again.

The literature search also illustrated that while in the oil and gas industry risk analyses were routinely carried out, only some of the construction companies did so. One of the aims of the present investigation was to examine the differences between the two industries.

Because the research was relevant to major projects only the 100 largest construction companies listed in Jordan’s \(^1\) were included in the survey, with all the oil companies currently operating in the U.K.\(^2\). According to good survey practice, a letter was sent to the Chief Executive/Managing Director of the chosen companies, introducing the research and requesting their input. Also, referred to in the letter was a request for names of the staff directly associated with risk analysis, who would subsequently be canvassed for opinions of risk analyses. These members of staff could be from a variety of areas within the company such as finance, insurance, safety, design, exploration, installation and operations.

3. SUMMARY OF THE REPLIES

The survey was carried out over a period extending from March to December 1995. The introductory letter to the Chief Executives/Managing Directors were dispatched in March, and the follow up call was made a month later. The questionnaires were posted to named individuals in May of 1995, with a suggested date for the returns at the end of June 1995. Questionnaire returns were received over the next 4 months, in some cases after a phone call reminder.

Of the companies selected for the sample 107 expressed an interest in participating and was followed up with the questionnaires. The breakdown of the responses is given below in table 1.

**Table 1 Breakdown of responses**

<table>
<thead>
<tr>
<th>Industry</th>
<th>No. of Companies who showed immediate interest</th>
<th>No. of companies who replied</th>
<th>Percentage of responses (%)</th>
<th>Actual no. of completed questionnaires</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>80</td>
<td>40</td>
<td>50</td>
<td>93</td>
</tr>
<tr>
<td>Engineering</td>
<td>27</td>
<td>12</td>
<td>44.4</td>
<td>45</td>
</tr>
<tr>
<td>Total</td>
<td>107</td>
<td>52</td>
<td>48.6</td>
<td>139</td>
</tr>
</tbody>
</table>

Note: Constr. = Construction

The response rate for completed questionnaires was high, particularly for a questionnaire with 58 questions and requiring about 30 to 40 minutes to complete. The fact that the length of the questionnaire was a factor is further illustrated in figure 3 where the 55 non-completions are shown. 33 companies did not respond at all, but 11 of those who did, said that they were unable to participate because they were too busy or the questionnaire too lengthy.

![Figure 3 The spread of the company's reaction to the Questionnaire](image)

4. ANALYSIS OF PRIMARY RESPONSIBILITY OF THE RESPONDENTS

Question 1 of the questionnaire was designed to ascertain the **primary responsibility** of each respondent. This was imperative, as it determined which questions he/she answered or could answer, and the validity of those answers. From this information, certain trends about risk analysis, as a whole, could be made concerning the different job responsibilities.

Figure 4 is an aggregated pie chart of the 93 respondents from the Construction industry and 46 from the Oil and Gas industry. Figures 5 and 6 illustrate how each of these two sectors are proportioned with respect to primary responsibility.

![Figure 4 Proportions of primary responsibilities for all the replies](image)

Examining the two figures, 5 and 6, it is clear to see that the oil responses are dominated by the ‘Safety/Risk’ category, whereas the construction industry is not, and in fact the area of safety/risk is only fourth most frequent. The reason for this could be because risk and the analysis of risk is a relatively new but appropriate area within the business. The oil industry has become extremely safety conscience, due to events such as the Piper Alpha, and as a result has had a flood of safety/risk interest, and accounting for risk is of prime importance. Therefore, there is an ever increasing abundance of risk analysts (or similar titles associated within safety/risk) within the oil business, but the construction industry is only slowly following suit. However, the finance category is well represented from the Construction Industry when compared with the Oil. This could be accounted for by saying the Construction Industry perceives risk as a financial risk, whereas the Oil Industry recognise it as technical.
5. A SUMMARY OF THE RISK RESPONSE METHODS AVAILABLE.

Risk analysis is a relatively new subject and therefore the terminology not clearly defined and understood. It is appropriate to briefly describe the terms referred to in this paper to avoid misinterpretation.

Risk elimination

Risk elimination is sometimes referred to as risk avoidance and could be as simple as a contractor not placing a bid or even the owner not proceeding with project funding. There are a number of ways through which risks can be avoided, such as: tendering at a very high bid; placing conditions on the bid; pre-contract negotiations as to which party takes certain risks; and do not bid on the high-risk portion of the contract.

Risk transfer

Risk transfer can take two basic forms:

a) The property or activity responsible for the risk may be transferred, i.e. hire a sub-contractor to work on a hazardous process, and
b) The property or activity may be retained, but the financial risk transferred, i.e. methods such as insurance or client takes the costs of risk by contract etc.

They are quite similar in that the financial risk of the property or activity is transferred to another party i.e. the sub-contractor as opposed to the client.

There are other ways of using insurance as a means of transferring the risk, for example through risk sharing or establishing a captive insurance company. The four forms of risk sharing are co-insurance, re-insurance, excess or deductible, and first loss cover. A captive insurance company (Carter & Doherty (1974)) is a privately owned insurance company directly related to risk management. A 'captive' is created and owned by an organisation that insures all the risks encountered by its parent organisation. Table 2 shows a typical breakdown for a company handling risks on a project. It is an illustration and the methods will change from company to company, depending upon the size of the company, the attitude towards risk, the perceptions of risks etc.

A further way of transferring risk is through indemnity clauses in contract agreements, where the financial consequences of injury, loss or damage may be transferred from one party to another.

Table 2 Deciding which method of handling risks depending on likelihood and severity

<table>
<thead>
<tr>
<th>Severity</th>
<th>Improbable</th>
<th>Rare</th>
<th>Possible</th>
<th>Probable</th>
<th>Very likely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large</td>
<td>Insure</td>
<td>Insure</td>
<td>Cease activity</td>
<td>Cease activity</td>
<td>Cease activity</td>
</tr>
<tr>
<td>Medium</td>
<td>Insure</td>
<td>Insure</td>
<td>Cease activity</td>
<td>Cease activity</td>
<td>Cease activity</td>
</tr>
<tr>
<td>Small</td>
<td>Insure</td>
<td>Partial Insure</td>
<td>Insure</td>
<td>Insure</td>
<td>Insure</td>
</tr>
<tr>
<td>Minuscule</td>
<td>Insure</td>
<td>Insure</td>
<td>Partial Insure</td>
<td>Insure</td>
<td>Insure</td>
</tr>
</tbody>
</table>

Risk retention

This is the method of handling risks by the body who controls them. The risks, foreseen or unforeseen, are controlled and financed by the company or contractor that is fulfilling the terms of contract. There are two retention methods, active and passive. Active retention, sometimes referred to as self-insurance, is a deliberate management strategy after a conscious evaluation of the possible losses and costs of alternative ways of handling risks. Passive retention, on the other hand, (sometimes called non-insurance) occurs through neglect, ignorance or absence of decision, e.g. a risk has not been identified and handling the consequences of that risk must be borne by the contractor performing the work.

As one can see from Table 2 the risks suitable for retention are the ones which occur frequently but have small losses, and the very rare events with catastrophic consequences. These risks are usually very expensive to insure because the premiums are high.

Risk reduction

It may argued that reducing risks is a part of risk retention, because the risk has to be retained before pursuing actions to reduce the effects of a foreseen risk. Alternatively risk reduction may be an action within the overall risk assessment and it is because of the possible wider use of risk reduction, it has been categorised separately.
Loss prevention is one of the ways of risk reduction and maybe through:

1) Preconditions for a loss, i.e. faults in the premises, e.g. badly insulated wire,
2) Prevention of loss; devices designed to prevent preconditions for loss, e.g. cut-off switches
3) Early discovery of loss producing events, e.g. sprinkler system, and
4) Limitation of loss, e.g. fire doors, compartmentalisation.

The actual reduction of risks within these categories are confined to the improvements of the physical, procedural, and educational & training devices. The physical devices can be improved by continually maintaining and updating the devices which help prevent loss. The effect of improving procedural devices can be outstanding. Simple, low cost measures like housekeeping, maintenance, first aid procedures and security can lead to better morale, improved labour relations and increased productivity as well as their more obvious benefits. Education & training within every department of a business is important, none more so than reducing the harmful effects of risks within the working environment. Loss prevention consumes capital resources and with better education & training devices, the effect may be minimised, freeing capital for more productive investments.

Other theoretical methods of handling risks are risk spreading or diversification, and reducing risk liability by use of the employment contract, but these were not supported by the company’s replies.

6. ANALYSIS OF THE METHODS USED TO RESPOND TO RISK

The four principle methods, transfer, retention, reduction and elimination, pertaining to risk response are illustrated in the column diagram on figure 7. The three columns for each of the methods correspond to the aggregate of the two industries, and the individual breakdowns respectively.

It is clear in figure 7 that the most popular method within both industries is risk reduction. Only three respondents from the oil sector and eight from the construction claim that their company does not employ this technique. After risk reduction, there is a dramatic fall to the next favoured method, risk transfer. The method of risk transfer has the support of 73 respondents, with almost an equal number not using the method. Falling almost half again, risk retention receives 41 votes, with risk elimination acquiring 35 positive replies.

Investigating the two industries separately, one finds that the four methods are used by the oil industry, and that three of them are eclipsed by one prominent method, risk reduction, which obtains usage from 93% of respondents. Risk transfer is used by the companies of only 40% of respondents. The figures continue to decrease with 14 positive replies for risk retention and 10 for risk elimination methods. All 10 of the elimination methods were where the owner does not proceed with funding the project.

Risk reduction and risk transfer are the two methods dominating the construction industry with 85 (91%) and 55 (60%) positive replies respectively. However, this industry also has a number of replies for all the methods, so is more widespread than the oil industry. The numbers, nevertheless, do decline in a similar fashion.

Within risk reduction, it was observed that the most effective way in achieving the reduction was through education and training to alert staff to risks, and improved working conditions. Bonus schemes for improved safety standards were not as effective although still successful.

CONCLUSIONS

Risk analysis is a complex means of identifying, evaluating and managing uncertainties within the oil and gas industry, and the construction industry. It was clear that the former industry has a predominance of risk analysts who are involved in both technical and financial risks, while in the construction industry finance is seen as the main area for risk analysis.
The questionnaire covered a wide range of subjects but in this paper only the risk response techniques are described. Risk reduction was the most frequently utilised method. Ninety two percent of replies suggested the constant use of risk reduction techniques. Risk transfer was next with risk retention attained the least employment. The respective percentages for these two techniques were 53% and 30%. Within risk reduction the respondents within the Oil Industry classed their companies as being very competent at education & training to alert staff to potential risks, and used the method of improving working conditions very successfully to reduce these risks. The technique of a bonus system for improved safety standards was also favoured but was not regarded as highly as the previous two.

REFERENCES

1. Jordan's, 'Britains Top Construction Companies', Jordan & Sons Ltd., Bristol
RISK RESPONSE TECHNIQUES CURRENTLY EMPLOYED FOR MAJOR PROJECTS

Scott Baker¹, B.Eng
David Ponniah², B.Sc., M.Eng., Ph.D., MBA, C.Eng., MICE, and
Simon Smith³, B.Eng, Ph.D., C.Eng., MICE

ABSTRACT: Risk management is fundamental to the success of a major project. The variations in using risk management practices are considerable and are dependent on numerous factors such as the industry sector, the size of project, and stage of the project life cycle. One of the major constituents to successful risk control is the use of risk response. This paper concentrates on the choice and use of the most successful risk response techniques within the oil and gas industry and compares them to the use of those chosen by the construction industry. Results were ascertained through a survey of over one hundred companies within these two sectors by use of an extensive questionnaire. The main conclusions to be drawn from this work are that risk reduction as a response to assessed risks is most commonly used by both sectors; and that the construction industry concentrates almost exclusively on reduction of financial risk. It is proposed that the construction industry can benefit greatly from the more experienced oil and gas industry in managing technical risk which, with the advent of the private funding, is likely to become a more predominant part of construction procurement.

KEYWORDS: Risk management; risk response.

¹ Research Student in Risk Management
² Senior Lecturer in Construction Management
³ Shell Lecturer in Project Management
The Department of Civil and Environmental Engineering, The University of Edinburgh, The Kings Buildings, Edinburgh, EH9 3JN. Tel: 0131 650 5814, email: scott@srv0.civ.ed.ac.uk
**INTRODUCTION**

Risks are ever present. Depending on the uncertainties and the consequences, they are routinely accepted and measures are taken to minimise their consequences. Risks are appreciated when driving a car and, as a response to this, a motor insurance policy provides ‘cover’ in case of an accident. The extension to the management of the risks within the construction industry, and the oil and gas industries are not as straightforward. Further, the consequences of an accident can be significantly greater, such as in the Piper Alpha disaster in the North Sea (Cullen, 1990). Therefore, within these industry sectors, detailed management of risks are routinely carried out. They are conducted at all stages of a project life cycle, from feasibility to decommissioning (Buchan, 1994). Despite being a growing element of major projects, there is no standard to which reference may be made for techniques, factors and approaches to risk management. It was this lack of information that led to the research described in this paper.

It can be acknowledged that the oil and gas industry has far greater experience in risk management than the construction industry. An extensive literature review had illustrated that within the oil and gas industry risk management is routinely carried out, but within the construction industry only some companies did so (Lock, 1992). With this in mind, the main objectives of the work presented, which are twofold, can be stated. Firstly, it is appropriate to determine and then compare the risk management techniques that have been adopted by the construction, and the oil and gas industries. In particular, the ways in which these two industries respond to identified risks is investigated and reasons for any differences are discussed. Secondly, the question is raised as to whether the construction industry can benefit from the experience of the oil and gas industry. An attempt is made to answer this. The paper concludes by summarising the information elicited from a questionnaire survey and placing this in the context of a changing construction industry.

**RISK MANAGEMENT IN CURRENT PRACTICE**

Buchan (1994), in his recent article, took three processes, namely risk identification, analysis and response, and implemented a fifteen step sequence, to account for risk management. He concluded that the process is a simple step by step procedure, but if followed beneficial results and a stable risk environment should be attained.

Three steps for risk management are identified by Buchan (1994). However, this increases to four in Bostwick’s (1987) paper, and five by Mehr and Hedges (1963), Nummedal et al. (1996), Eloff et al. (1993) and the British Standards BS 8444 (1996). It is these five steps that are most commonly used in contemporary risk management. By using the terminology from BS 8444 (1996), the systematic five steps involved for a comprehensive risk management process are:

- Risk identification
- Risk estimation
- Risk evaluation
These five stages fit together into a simple circular procedure, which if maintained obtains a controlled risk environment, see Figure 1. The stages of risk identification and estimation can also come under the broader title of risk analysis. Risk analysis, with risk evaluation, can be grouped under risk assessment, with response and monitoring collectively entitled risk control. Of these five, the stage of risk response is the focus in this paper.

**METHODOLOGY**

Information on risk response techniques was gathered through the use of a questionnaire survey, targeted at relevant companies within the construction and oil and gas industries. The investigation of risk response techniques was part of a larger determination on risk management in general, which elicited information on how such companies, in the terminology of BS 8444: 1996 analysed, then evaluated and finally controlled risks. The investigation had the three stages of:

(a) Questionnaire design,
(b) Selection of the sample, and
(c) Analysis of the responses.

The questionnaire was initiated and based on extensive discussions with many risk analysts within a major construction company and a principal oil company. Many versions of the questionnaire were piloted out to a number of industrial personnel from the construction industry and experts in the field of oil exploration, before the final version was dispatched.

The questionnaire contained 56 questions split into seven separate sections: background information to elicit information about the respondent and the company itself; general risk questions, determining general practices, policies and attitudes of the company; risk transfer, determining if, how and why this risk response is used; risk retention; risk reduction; risk analysis, with specific questions on the identification and estimation of risk; and specific risks, finding more information regarding the types and variation of risks experienced by the company.

The research presented is intended to be relevant to ‘major’ projects; therefore, only the 100 largest construction companies listed in Jordan’s (1992/93) were included in the survey. The oil and gas industry is a relatively much smaller industry in terms of number of players, but with the majority dealing with projects that can be considered major. Therefore, all the oil companies (M-G Information Services Ltd., 1994/95) currently operating in the UK were targeted.

According to good survey practice (Tull and Hawkins, 1990), a letter was sent to the Chief Executive/Managing Director of the chosen companies, introducing the
research and requesting their input. Referred to in the letter was a request for names of the staff directly associated with risk management, who would subsequently be canvassed for opinions. These members of staff could be from a variety of areas within the company such as finance, insurance, safety, design, exploration, installation and operations.

**SUMMARY OF THE REPLIES**

The survey was carried out over a total period extending from March to December 1995. The questionnaires were posted to named individuals in May of 1995, with a suggested date for the returns at the end of June 1995. Questionnaire returns were received over the next 4 months, in some cases after a phone call reminder.

Multiple copies of the questionnaire were distributed to the 107 companies who expressed an initial interest. Completed questionnaires were eventually received from 52 of these companies with a total of 139 responses from individuals. The breakdown between the industries is given in Table 1.

The response rate for completed questionnaires was high. Of the 55 non-completions, 33 of those companies did not respond at all. Eleven of those who did, said that they were unable to participate because they were too busy or the questionnaire too lengthy, whilst the remaining 11 declared that it was company policy not to partake in surveys.

**PRIMARY RESPONSIBILITY OF THE RESPONDENTS**

The primary responsibility of the respondents to the questionnaire should indicate important information as to the policies and attitudes of the company to the type of risk that is managed. For example, a company which places little emphasis on financial risk may not employ financial people to assess and control risk of a different nature. It is for this reason that the first question asks the respondent which area is his/her primary field of responsibility.

Table 2 contains the aggregated replies of the 93 respondents from the construction industry and 46 from the oil and gas industry. Table 2 also illustrates how each of these two industries are proportioned with respect to primary responsibility of the respondents.

From Table 2, it can be seen that the differences between the two industries are small with respect to primary responsibility, with the notable exception of two categories: safety/risk and finance. As could be perhaps anticipated, the oil and gas industry is extremely safety conscious because of their working environment. This has been enhanced by events such as Piper Alpha, and therefore accountability for safety/risk is of prime importance. Thus, as also commented by Powell (1991) there is an ever increasing abundance of risk analysts or similar within the oil business.
Conversely, the construction industry relies on well established technologies and operate in physical environments considerably less hostile. In terms of severity of hazard, safety/risk is of relatively lesser importance than it’s oil and gas counterpart. However, the construction industry operates in a much harsher financial environment (Edwards, 1995), and this is reflected in the significantly higher percentage of financial analysts responding to the questionnaire. The construction industry seems to place more emphasis on financial risk.

RISK RESPONSE METHODS

It is appropriate to briefly describe the methods available for responding to risk. Raftery (1994) has identified four possible techniques: risk elimination, risk transfer, risk retention and risk reduction. An analysis of the results obtained from the questionnaire will reflect these techniques.

Risk elimination

Risk elimination is sometimes referred to as risk avoidance. A contractor not placing a bid or the owner not proceeding with project funding are two examples of eliminating totally the risk. There are a number of ways through which risks can be avoided, such as tendering at a very high bid; placing conditions on the bid; pre-contract negotiations as to which party takes certain risks; and not bidding on the high-risk portion of the contract (Carter and Doherty, 1974).

Risk transfer

Risk transfer can take two basic forms (Thompson and Perry, 1992):

a) The property or activity responsible for the risk may be transferred, i.e. hire a sub-contractor to work on a hazardous process;

b) The property or activity may be retained, but the financial risk transferred, i.e. methods such as insurance.

There are other ways of using insurance as a means of transferring the risk, for example, through risk sharing or establishing a captive insurance company. The four forms of risk sharing (Hertz, 1964) are co-insurance, re-insurance, excess or deductible, and first loss cover. A captive insurance company (Edwards, 1995) is a privately owned insurance company directly related to risk management. A ‘captive’ is created and owned by an organisation; it insures all the risks encountered by its parent organisation.

Table 3 (Flanagan and Norman, 1993) shows a typical breakdown for a company handling risks on a project. It is an illustration and the methods will change from company to company, depending upon the size of the company, the attitude towards risk, the perceptions of risks, etc.
Risk retention

This is the method of handling risks by the company who controls them. The risks, foreseen or unforeseen, are controlled and financed by the company or contractor that is fulfilling the terms of contract. There are two retention methods (Carter and Doherty, 1974), active and passive.

Active retention, sometimes referred to as self-insurance, is a deliberate management strategy after a conscious evaluation of the possible losses and costs of alternative ways of handling risks. Passive retention, on the other hand, (sometimes called non-insurance) occurs through neglect, ignorance or absence of decision, e.g. a risk has not been identified and handling the consequences of that risk must be borne by the contractor performing the work.

As one can see from Table 3 the risks suitable for retention are the ones which occur frequently but have small losses.

Risk reduction

It may be argued that reducing risks is a part of risk retention, because the risk has to be retained before pursuing actions to reduce the effects of a foreseen risk. Alternatively risk reduction may be an action within the overall risk management and it is because of the possible wider use of risk reduction, it has been categorised separately.

The actual reduction of risks within these categories are confined to the improvements of a company’s physical, procedural, and educational and training devices (Flanagan and Norman, 1993). The physical devices can be improved by continually maintaining and updating the devices which help prevent loss. The effect of improving procedural devices can be significant. Simple, low cost measures like housekeeping, maintenance, first aid procedures and security can lead to better morale, improved labour relations and increased productivity as well as their more obvious benefits. Education and training within every department of a business is important, none more so than reducing the harmful effects of risks within the working environment. Loss prevention consumes capital resources and with better education and training devices, the effect may be minimised, freeing capital for more productive investments.

Analysis of the Methods used to Respond to Risk

The questionnaire ascertained which risk response method, or methods, the respondents’ company employed. The responses to the four principle methods, i.e. transfer, retention, reduction and elimination, are summarised in Figure 2.

The most popular method overall is risk reduction with only eleven respondents claiming that their company does not employ this technique. Overall, the methods available are favoured in the order of risk reduction, risk transfer, risk retention, and risk elimination.
Similar trends are observed within each industry. All four methods are used by the oil industry, but three of them are eclipsed by one prominent method, i.e. risk reduction which obtains usage from 93% of respondents. Risk transfer is used by 40% of respondents in oil, with only 14 positive replies for risk retention and 10 for risk elimination methods. In all 10 responses for risk elimination it was stated that the client/owner did not proceed with the project.

Risk reduction and risk transfer are the methods dominating the construction industry responses, with 85 (91%) and 55 (60%) positive replies respectively. However, this industry also has a number of replies for the other methods. Interestingly, when construction companies eliminate risks, they do so either by not placing a bid, or tendering at a very high price.

Within the response methods themselves, there are many alternative ways of reacting to a risk. There follows a discussion of the three main techniques, starting with the most popular, risk reduction.

**Risk Reduction**

A company that actively seeks to reduce risk can do so in many ways. The fifth section of the questionnaire attempted to elicit from the respondent information of this nature and was devised carefully, drawing on a combination of the authors experience and texts on the matter. Carter and Doherty (1974) in particular was referred to in the derivation of many parts of the questionnaire.

The first question investigated the competency of the company, in the eyes of the respondent, in activities for reducing risk. The four activities identified were a) education and training; b) physical protection to reduce the likelihood of risk; c) brainstorming to identify new risks; d) physical protection for people and property. As would have been expected the responses were all better than ‘adequate’, see Figure 3. The oil industry did consider itself to be nearer ‘excellent’ than ‘adequate’. The construction industry had an identical pattern to that of the oil’s, but ranked all four activities notably lower. Respondents from both industries felt that activities a), b) and d) were competently handled by their companies. Similarly all respondents clearly felt that there is room for improvement with activity c), which involves exposing new risks. It would seem sensible that risk analyses should be regularly reviewed and updated as a project progresses, thus enabling the identification of new risks.

The respondents were then asked to rank the relative success of particular approaches to reduce the risk to/from employees. In Figure 4 the approaches or methods a) to d) employed are shown with the average value of rank, from 1 to 5 and corresponding to ‘very successful’ to ‘not successful’ respectively. The distribution of ranking is similar in both the oil and construction industries. Two methods of risk reduction, namely ‘Prevention by educating employees’ and ‘Improved working conditions’, are clearly more successful than the remaining three. Education, by experts in the
field, is the key to introducing new ideas, methods, procedures etc. to personnel who lack the insights, or knowledge. Therefore, it is important to train and educate the employees for the future of the companies existence, as better outcomes leads to a more enjoyable working environment, stronger employee relations, profit etc. This in turn results in secure employment, loyalty and full understanding of the company’s procedures and policies.

Method c), ‘bonus system for improved safety standards’, is ranked at around 3.0, which would indicate that it is not always successful. Method d), ‘penalty system for decreased safety standards’, is the converse of method c). While the bonus system, c), has had some limited success, the punitive methods of d), and b), are clearly identified as unsuccessful. The punitive methods are negatively biased and tend to generate attitudes of distrust and nervousness. This can itself lead to accidents. The methods with a positive outlook are preferred, and are proving to be more successful.

**Risk Transfer**

Risk transfer may be considered a form of risk reduction, but is being examined separately because of the numerous ways in which the risk can and is transferred. Risk transfer is used by over 52% of the respondents, and the purpose of this section of the questionnaire was to identify the techniques most commonly used.

The first part investigated the frequency of risk transfer either to a specialist subcontractor or through financial means such as insurance. Both techniques are frequently used as seen on Figure 5. The construction industry uses both methods frequently, but favour transferring the risk to a specialist. On the other hand, the oil industry, while still using both techniques, prefer to financially transfer their risks.

There are a number of different ways in which a company can transfer their risks financially. This was further investigated and the results are given in Figure 6. Transferring the risk to an employee through higher remuneration, d), is clearly not a method favoured in either industries. There are a few instances where the risk is transferred back to the client, c), who either retains it or further transfers it through insurance. The most popular methods were with insurance, and exclusion or indemnity clauses in contracts. The frequency of usage of the techniques is similar between the two industries.

Rather than transfer all of the risk it is possible to transfer risk partially through sharing. This was investigated next through a question which identified the frequency with which the risk was shared, through: a) co-insurance; b) excess; c) first loss cover. Seventy three percent of the entire sample replied that their company has shared, or is sharing, a risk. The most frequently used method was to share the risks with an ‘Excess or deductible’, see Figure 7. The two other methods are used but not as often and with a much wider range of responses. Further methods used by the respondents are ‘Consortium agreements’ and ‘Joint ventures’.
Captive insurance companies for the transfer of risk have been identified in the literature and were examined in the next part. It is not unusual to find a ‘captive’ located in a tax-free country, like Jersey or Andorra for example, so as to reap tax benefits. Approximately 20% of the entire sample have used or are using a captive. A subsidiary question established that all of those are still actively using one. A follow up question indicated the success of ‘captives’, where of the 27 respondents, 82% found that using a captive is the most manageable way of insuring risks, with all of them still continuing to do so. Although 11% answered negatively to this question, they still continued to use a captive. This suggested that captives are beneficial to the company once they are set up, and advantages identified were cost efficiency, tax savings, and facilitated central control.

Risk Retention
The corollary to risk transfer is risk retention, and was investigated in the next section of the questionnaire. Almost thirty percent of respondents did at some stage of risk management retain some of the risks. Eighty five percent of them did so through active risk retention. This suggests that these companies have identified the possible risks, measured their likelihoods and consequences, and have concluded that risk retention was the best response to the risk.

The subsequent question investigated as to why this decision to retain the risk was made in preference to other response methods. The principal reason was that the required insurance premium was judged to be too high: sometimes insuring risks can result in very large premiums but have associated very low probabilities with the result that retaining the risk is considered to be more cost effective.

If the decision is made to retain a risk, it is necessary to be able to finance that risk. The final question of this section aimed to find out how often certain methods were used. The results, see Table 4, clearly identified two. Those two were ‘internal funding’, or self insurance, and ‘absorbing losses as part of current operating costs’.

The method of actively retaining risks requires identifying the risks, evaluating all outcomes, and then comparing it to other forms of risk response. As the management of risk becomes routine and an integral part of a project, with alternative responses becoming more expensive, risk retention is likely to become a much more widely used form of risk response.

DISCUSSION AND CONCLUSIONS
Risk management is a complex means of analysing, evaluating and controlling uncertainties. One of the principal conclusions that can be drawn from the survey presented here is the relative difference between the perceptions of the oil / gas and construction industries to what constitutes risk. If the main functions of staff engaged in risk management is an indicator as to what that company and industry considers to be risk then it is clear that the construction industry places relatively little importance to technical risk.
Possible reasons for this are discussed in the text but it is an indicator as to how the construction industry can learn from the techniques of others. The construction industry is changing rapidly and it is no longer solely concentrated on the provision of a service to a client. In the UK, contractors are becoming multi-disciplinary and the nature of construction procurement is changing. Private Finance, in its many forms, has not only increased the financial risk of projects but has increased the predominance of technical risk - those projects that are effectively owned by the construction company for a concession period cannot be ignored in terms of potential failure.

As an example, the design, build, finance and operate scheme that is now used for road procurement places responsibility for long term maintenance and, to a lesser extent, safety of users, with the construction company. These companies must assess the risk of long term failure and manage it accordingly. There is also, perhaps, little flexibility in the response to such risks: they cannot be eliminated or transferred to a specialist and must be actively retained, reduced or insured. It is likely, therefore that such companies will, in the future, employ increasing numbers of risk analysts at the design stage to assess the technical risks of the design.

The survey provided other conclusions which can be summarised:

Risk reduction was the most frequently utilised method. Ninety two percent of replies suggested the constant use of risk reduction techniques. Risk transfer was next with risk retention least used. In a comparison between the industries, the relative frequency of the methods was similar indicating that the two perceptions of risk already identified, financial and technical, may be managed in an equally effective way by the same method. That risk reduction is the most favoured technique is perhaps no surprise: it is the author’s opinion that reducing a risk requires the greatest understanding of that risk. The end result would be a better management of the risk produced by improved procedural (such as quality management) and training devices - areas of a company’s expertise that will produce benefits in other areas in addition to risk management.

Within risk reduction the respondents within the oil industry classed their companies as being very competent at education and training to alert staff to potential risks, and used the method of improving working conditions very successfully to reduce these risks. The technique of a bonus system for improved safety standards was also favoured but was not regarded as highly as the previous two.

When transferring risk, the construction industry prefers to use both specialists and through financial transferral. Unlike, the oil industry who prefer to transfer the risks financially. Insurance and exclusion or indemnity clauses in contracts are the most popular way of financially transferring risks. Risk sharing is frequently used, with excess or deductibles being the preferred options. Companies who have ever used captives, are still using one with 82% of them believing that it is the best way of
insuring one's risks. This is a situation that may prove useful to the construction industry in the future. The oil industry has to effectively manage all projects until their decommissioning date. If a risk is transferred to a third party, control over that risk is to some extent lost. Construction companies that are involved in privately financed and owned projects cannot afford to lose control of such aspects and must either retain or reduce the risk, or transfer them financially. As a reflection of the ‘risks’ of risk transfer, it is interesting to see the increasing use of ‘partnering’ whereby risks are shared by all parties but the specialist knowledge and skills of the subcontractor are retained.

Eighty five percent of respondents, i.e. those replying to this method, actively retain their risks. The main reason for retaining these risks is because the required insurance premium is judged to be too high. Internal funding and absorbing losses as part of current operating are currently favoured for financing retained risks.

ACKNOWLEDGEMENTS

The assistance of the Engineering and Physical Research Council (EPSRC) and Amerada Hess Limited is gratefully acknowledged. The authors are also indebted to the candidates who took the time to complete the questionnaire. The authors would also like to thank the two anonymous reviewers who made constructive comments on the first draft of this paper.

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### Tables

<table>
<thead>
<tr>
<th>Industry</th>
<th>No. of Companies who showed immediate interest</th>
<th>No. of companies who replied</th>
<th>Percentage of responses (%)</th>
<th>Actual no. of completed questionnaires</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constr.</td>
<td>80</td>
<td>40</td>
<td>50</td>
<td>93</td>
</tr>
<tr>
<td>Oil</td>
<td>27</td>
<td>12</td>
<td>44.4</td>
<td>46</td>
</tr>
<tr>
<td>Total</td>
<td>107</td>
<td>52</td>
<td>48.6</td>
<td>139</td>
</tr>
</tbody>
</table>

Note: * Constr. = Construction

**Table 1** Breakdown of responses
<table>
<thead>
<tr>
<th>Primary Responsibility</th>
<th>Aggregated (%)</th>
<th>Construction (%)</th>
<th>Oil and Gas (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety/Risk</td>
<td>23</td>
<td>14</td>
<td>41</td>
</tr>
<tr>
<td>Finance</td>
<td>15</td>
<td>22</td>
<td>2</td>
</tr>
<tr>
<td>Gen. Management</td>
<td>27</td>
<td>26</td>
<td>28</td>
</tr>
<tr>
<td>Design</td>
<td>7</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>Construction</td>
<td>9</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>Insurance</td>
<td>7</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Other</td>
<td>12</td>
<td>15</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 2 Proportions of primary responsibility for total replies, then subdivided into the two industries

<table>
<thead>
<tr>
<th>Severity (£'s)</th>
<th>Improbable</th>
<th>Rare</th>
<th>Possible</th>
<th>Probable</th>
<th>Very likely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negligible (Up to 500)</td>
<td>Retain</td>
<td>Retain</td>
<td>Retain</td>
<td>Retain</td>
<td>Retain</td>
</tr>
<tr>
<td>Small (500-2k)</td>
<td>Retain</td>
<td>Retain</td>
<td>Partial</td>
<td>Partial</td>
<td>Partial</td>
</tr>
<tr>
<td>Moderate (2k-5k)</td>
<td>Retain</td>
<td>Partial</td>
<td>Insure</td>
<td>Insure</td>
<td>Insure</td>
</tr>
<tr>
<td>Large (5k-50k)</td>
<td>Insure</td>
<td>Insure</td>
<td>Insure</td>
<td>Insure</td>
<td>Insure</td>
</tr>
<tr>
<td>Disastrous (over 50k)</td>
<td>Insure</td>
<td>Insure</td>
<td>Cease activity</td>
<td>Cease activity</td>
<td>Cease activity</td>
</tr>
</tbody>
</table>

(after Flanagan and Norman, 1993)

Table 3 A typical framework for deciding which method of handling risks to use depending on likelihood and severity

<table>
<thead>
<tr>
<th>Method of financing retained risks</th>
<th>Mean value</th>
<th>Verbal description of frequency of use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diminution of assets</td>
<td>4.00</td>
<td>Infrequently</td>
</tr>
<tr>
<td>Absorbing losses as part of current operating costs</td>
<td>2.58</td>
<td>Frequently</td>
</tr>
<tr>
<td>Diversion of internal funds</td>
<td>3.73</td>
<td>Sometimes</td>
</tr>
<tr>
<td>Ad-hoc loans</td>
<td>4.56</td>
<td>Almost never</td>
</tr>
<tr>
<td>Contingency loans</td>
<td>4.53</td>
<td>Almost never</td>
</tr>
<tr>
<td>Internal funding</td>
<td>2.70</td>
<td>Frequently</td>
</tr>
</tbody>
</table>

Table 4 A table showing which methods are most frequently used to finance retained risks
Figures

Figure 1  Risk Management life-cycle

Figure 2  Methods used when responding to risk.
Factors:  

a) Education and training to alert staff to risks  
b) Physical protection to reduce the likelihood of risk  
c) Brainstorming sessions to expose new risks  
d) Physical protection to protect people and property

Figure 3  
Line diagram to display the competency of four factors used to reduce risks

Methods:  
a) Prevention by educating employees,  
b) Deterrence,  
c) Bonus system,  
d) Penalty system  
e) Improved working conditions.

Figure 4  
A summary of the mean ranks allotted to the five risk reducing methods
Figure 5  A graph illustrating how often the
two methods of risk transfer are used

Figure 6  A graph showing how often the methods for
financially transferring risks are utilised
Figure 7  Amount of usage of the three risk sharing methods postulated
TECHNIQUES FOR THE ANALYSIS OF RISKS IN MAJOR PROJECTS

Scott Baker, B.Eng, Research Student, University of Edinburgh;
David Ponniah, B.Sc., M.Eng., Ph.D., MBA, C.Eng., MICE, Senior Lecturer, University of Edinburgh; and
Simon Smith, B.Eng, Ph.D., C.Eng., MICE, Shell Lecturer, University of Edinburgh

ABSTRACT: Risk management currently has an important bearing on the outcomes of major projects. It usually consists of three core areas: risk analysis, risk evaluation and ultimately the control of those risks. One of the vital decisions to be made within risk analysis is the choice of technique to be used which are broadly classified under qualitative and quantitative methods. Through a questionnaire, this paper attempts to identify the most successful risk analysis techniques within both categories. Over one hundred large companies within the construction industry, and every oil and gas operator in the UK were approached. The areas surveyed on were: risk techniques employed by the companies; the relative success of the techniques; the size and range of activities of the company and the company’s policy on indentifying and responding to specific risks encountered during any particular project. The main conclusions are that personal and corporate experience, and engineering judgement are the most successful qualitative techniques; scenario analysis, EMV, ENPV, and break-even analysis being the principal quantitative techniques.

KEY WORDS: Risk; risk analysis techniques; qualitative; quantitative.
INTRODUCTION

Construction work is often a hazardous undertaking, particularly with many current projects being large and complex. This, coupled with increased technological advances and a more competitive financial environment, leads to a greater dependence on risk management in determining the outcome of a project. While this risk management has been routinely carried out, the importance of it has never been greater. Further, the consequences of an accident are now perceived to be significantly greater, such as in the Piper Alpha disaster in the North Sea. It is within the context of large projects in two industry sectors, construction and oil, that the use of the various techniques of risk analysis within risk management, have been investigated.

Within these industry sectors detailed risk management is routinely carried out at all stages of a project life cycle, from feasibility to decommissioning. However, despite being a growing and important element of these major projects, there is no standardisation within the sectors, and numerous techniques, factors and approaches to risk analysis are currently deployed. This led to the present investigation: to identify the extent to which qualitative and quantitative methods were being used within the construction and oil industries; to identify, if any, differences in the approaches between the two sectors; and to assess the relative success of the various techniques.

METHODOLOGY

Risk management consists of risk analysis, evaluation and risk control and the overall goal of this investigation was to obtain and understand details of risk management carried out by the construction and oil industries. The framework for the investigation is illustrated in Figure 1, with the questionnaire designed to elicit information on how risks were analysed, evaluated and finally controlled. This paper will discuss the first of these three issues, that is which techniques were used to analyse risks.

The starting point for the investigation was an examination of published, and some unpublished, information on the use of risk management in the two industries. This search ascertained that the oil industry has been meticulous in its management, and this is not particularly surprising for an industry operating in quite harsh and hazardous physical environments. What was surprising was the absence of an industry norm, although some companies had internal manuals for managing risk. Despite its relatively poor health and safety record, the management of risk within the construction industry is not widespread and seemed to be limited to companies involved in ‘major projects’. These considerations subsequently influenced the choice of the sample and the design of the questionnaire.

Because of the relatively small number of oil and gas related companies operating in the UK, the questionnaire was sent to all twenty seven. While there are over 8000 companies involved in construction, only large companies were identified as being
involved in 'major projects'. Therefore, only the 100 largest construction companies listed in Jordan's 7 were included in the survey. This was based on the turnover per year and number of employees within the construction company.

The questionnaire was devised carefully, drawing on a combination of the authors experience and texts on the matter. Carter and Doherty 8 in particular was referred to in the derivation of many parts of the questionnaire. Also many discussions and pilot runs to industry personnel enabled the author to finalise details. The questionnaire combined additional sections to provide background information on the respondent, general questions on risk, and risk response methods being practised. The questionnaire contained 58 questions and was estimated to require approximately 30 to 40 minutes to complete. According to good surveying practise 9, an initial letter was sent to the Chief Executive/ Managing Director of the chosen companies, introducing the research and requesting their input. In addition, the letter requested names of the staff directly associated with risk management, who would subsequently be canvassed for their opinions. These members of staff could be from a variety of areas within the company such as finance, insurance, safety, design, exploration, installation and operations. The questionnaire itself and the consequent original data are available to any interested readers with the explicit permission from the authors 10.

The survey was carried out over a total period extending from March to December 1995. Of the 127 companies selected for the sample, 107 expressed an interest in participating and questionnaires were sent to named individuals. The response rate for completed questionnaires was 49% overall, with 50% for construction and 44% for oil. This was encouraging, particularly for such an extensive questionnaire.

**GENERAL RISK QUESTIONS**

The primary responsibilities of the respondents covered the principal activity areas of safety/risk, finance, general management, design, construction and insurance. Over 65% of the respondents were from the first three activity areas. In relation to primary responsibility the only difference between the two industries was in safety/risk and finance. The oil and gas industry is extremely safety conscious because of the working environment; a consequence of this being an increasing abundance of risk analysts (or similar titles associated within safety/risk) within it 11. On the other hand, the construction industry relies on well established technologies and operate in physical environments considerably less hostile. Thus, safety/risk is of relatively lower importance and would have less technical risk analysts. The construction industry does however operate in a competitive and harsh financial environment 12; this was reflected in the significantly higher percentage of financial analysts responding to the questionnaire.

While risk management is becoming more important, it was considered prudent to ask whether current practice was acceptable, and the question was posed in relation to estimated losses from unforeseen risks. A significant proportion of all respondents,
(31%), expressed the view that the estimated losses were an acceptable proportion of the project costs and maybe catered for through contingencies. This left sixty nine percent of responses who considered the amount unacceptable. Approximately a tenth of them suggesting that further improvements were not practically possible, however, the remainder felt that improvements were possible with better risk analysis. The percentage splits between the oil and construction industries who believed the amount to be unacceptable were 57% and 74%, respectively. A high proportion from both industries are keen to better their risk analyses: all replies from the oil industry suggested improvements were possible, and 88% of the construction respondents supported this view. The logical progression for this discussion was to find out more about the analysis techniques currently used in industry and to try to ascertain a combination of methods which have been successful in achieving the aims of risk analysis.

**RISK ANALYSIS METHODS: QUALITATIVE and QUANTITATIVE**

A literature search, with preliminary discussions with two oil companies, served to identify the commonly used techniques within risk management. While it is appreciated that this list of techniques, summarised in Tables 1 and 2, is not exhaustive it was a starting point for the survey. The questionnaire was designed to permit a respondent to suggest other techniques not included on the list.

The techniques are broadly categorised into two groups, namely qualitative and quantitative methods. Qualitative techniques are used to distinguish the possibility of a risk occurring in a linguistic manner; for example, a risk will be described as low if that risk is unlikely to occur. It is an analysis in relative terms of the outcome and probability of a risk, e.g. a high risk compared to a medium or low risk. It is dependent on the experience of the analyst allied to engineering judgement, and thus is inclined to be subjective. Therefore, these techniques are prone to inconsistencies but are extremely valuable as an analytical process in the planning and control of a project.

Quantitative techniques are normally mathematically and/or computationally based and provide numerical probabilities, or frequencies, of the consequences and likelihood of identified risks. The values used in these techniques are obtained from historical databases or are estimates; they still contain some extent of uncertainty, due to the possible use of subjectively attained values. Qualitative techniques are usually employed at the beginning to identify and rank risks. Those risks with a high or intermediate rank may be further analysed through quantitative techniques. The results of a quantitative technique are compared against company criteria, and decisions made as to whether the risks are acceptable or not. These techniques are then used to validate the qualitative techniques.

This approach was borne out by the response to being asked whether the respondents use one or other of qualitative and quantitative methods, or in combination, shown in Figure 2. From this it can be seen that qualitative techniques, and their use in
combination with quantitative techniques, is common while the use of quantitative methods alone is rare. Eighteen percent of the responses indicated an exclusive use of qualitative techniques, all being from construction companies. Forty one out of 42 (97.6%) of the oil industry companies that responded, use a combination of both qualitative and quantitative techniques.

An oil company stated that the quantitative techniques are introduced if sufficient resources are available, and if it can be demonstrated that the costs and benefits of the method outweigh the costs of the risks occurring. Almost a third of construction would complete the first qualitative stage and consider it unnecessary to proceed further. This proportion would decrease with risk analysis becoming an integral component of major projects utilising increased technology and complex designs, particularly if it can be demonstrated that cost benefits accrue through the analyses. Conversely, the oil industry makes full use of both available methods.

**RISK ANALYSIS TECHNIQUES CURRENTLY PRACTISED**

Within the two risk analysis methods, namely qualitative and quantitative, are a plethora of risk analysis techniques used within the construction and oil industries. From the literature and initial discussions with industry representatives, six techniques were identified within qualitative analysis, and fourteen for quantitative analysis, see Tables 1 and 2. These techniques were then listed in the questionnaire and the respondents were asked to rank each technique on two scales, as follows;

<table>
<thead>
<tr>
<th>Ranking Scale</th>
<th>Requested Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>Very often 1 2 3 4 5 Never</td>
</tr>
<tr>
<td>Success</td>
<td>Very successful 1 2 3 4 5 Not successful</td>
</tr>
</tbody>
</table>

The responses to the qualitative and quantitative methods are summarised in Tables 1 and 2, respectively, for their frequency and success of use, and expressed as a percentage of the total responses for the overall, construction and for oil.

In Table 1, technique A, at a usage of below 6%, is not popular probably due to its ‘complexity’. Interestingly, when the technique has been used, around 20% had a measure of success. Maybe the popularity of Fuzzy Set Analysis will increase with a greater understanding of the method. All the other qualitative techniques are widely used, with Personal and Corporate Experience and Engineering Judgement clearly the most popular at around 75% frequency of use. Approximately 60% indicating success in their use of these two methods.

No discernible difference exists between the two industries for the qualitative techniques, but differences can be identified for the quantitative methods. In Table 2, the percentages of responses for above average frequency and success, that is ranks of 1 and 2, are presented for the quantitative techniques. Overall nine of the quantitative techniques rate over 10%, and of these only four rate above 30%. This,
as a general conclusion, would be misleading because of the distinct differences that exist between the two industries. For construction, only three of the techniques, A (31%), H (36%), and I (33%), are widely used, with technique B used by 19%. (Techniques H and I are more commonly used together and are collectively called a sensitivity analysis \(^{15,16,17}\).) These are four techniques used principally to evaluate financial risks, and illustrates the construction industries pre-occupation with finance. This is probably due to the relatively lower profitability of the sector. The oil sector, on the other hand, use a range of quantitative techniques, with F,G,J,L and N around and below 10% usage. The differences in the risk analysis that exists between the oil and construction sectors is likely to lead to conflict when required to work together. This may be avoided through standardising methods and expected outcomes of a risk analysis.

The percentages for the relative success reflect the frequency of use of the techniques. The oil sector have found the use of a range of techniques successful. Construction, on the other hand, having success in a more restricted range of techniques with H and I being the most popular. Within construction, technique D is anomalous with only a 13% frequency but a 38% success rating; a low frequency of use but when used proving successful. If this level of success is being achieved then it may result in an increasing use of risk analysis within construction.

With the percentages in Tables 1 and 2 the qualitative and quantitative methods were graded and league tables for the frequency of use and success of use are shown in Tables 3 and 4, respectively. Qualitative has 6 techniques and quantitative has 14, and the position in the table reflecting the relative frequency of use (from the values in Table 1), and the relative success in the use of the technique (from the values in Table 2). The grading increases from 1 to 6 or 1 to 14, with 1 being the most frequently, or most successfully, used method, and 6, or 14, the least. The first column gives the overall grade of all the replies which are then split into the two industries in the next two columns. When a technique has been graded equally it has been denoted by a equals sign, ‘=’, after the grade number.

Within Tables 3 and 4 there is a remarkable consistency between industries in the frequency and success in the use of techniques for both the quantitative and qualitative methods. Within the qualitative method there is consistency in the grading of the techniques. The grading splits the six techniques into two groups of three: the top three being Personal and Corporate Experience, Engineering Judgement; and Brainstorming, with Interviewing, Percentage Contingency from historical data and Fuzzy Set Analysis belonging to the bottom group. Experience and Engineering Judgement have been identified as qualities important to the two industries and not just in risk analysis \(^{18}\). The frequency of these top two techniques are 76% and 81% respectively, and are indicative that they are used as an integral part of risk analysis by almost every respondent. The next two methods, Brainstorming \(^{12}\) and Interviewing \(^{1}\) are similar to one another, as they involve individual subjective assessments \(^{19,20}\) of situations and possible risks. The results would indicate that Brainstorming is more popular, possibly because it takes less time to achieve results.
Percentage Contingency from historical data is still used by many companies but with varied success. A problem of this technique is maintaining and updating the data information and producing useful databases. In addition, this method relies heavily on all risks being reported, which does not always happen. Fuzzy Set Analysis retained the bottom spot of the qualitative methods throughout all the divisions, and received little support.

There is similar consistency within the quantitative methods. The first five quantitative techniques, bar a few exceptions, remain in the top five across the columns. Equally clear is that the bottom five quantitative techniques, namely Stochastic Decision Trees, Bayesian Theory, Portfolio Theory, EMV using Delphi and Stochastic Dominance are rarely used.

There are numerous computer simulation packages currently available, e.g. @RISK, BRISK, Opera, Sonata, Crystal Ball, Ohrat, and Geostatistics, and thus it was a little surprising that Simulation is graded overall only 7th in frequency of use. However, both the oil and construction industries have graded it fourth for its success and the use of these techniques would seem specialised and not widely used.

There is a clear correlation between the frequency of use of a technique and success and as a result the two league tables look similar. The top two qualitative techniques being clearly quite successful and are very rarely outside of these two positions. These observations are the same for the quantitative techniques. The five quantitative techniques appear in the same sequence at the top of both tables. If anything, there is a slightly reduced consistency in success across the industry divisions. This is equally true for the bottom five quantitative techniques.

**CONCLUSIONS**

Risk analysis is a complex means of identifying, evaluating and managing uncertainties within the oil and gas industry, and the construction industry. It was clear that the former industry has a predominance of risk analysts who are involved in both technical and financial risks; in the construction industry, finance is seen as the main area for risk analysis.

Eighty percent of respondents use a combination of qualitative and quantitative techniques. The remaining 20% use qualitative methods only, with a very small percentage solely using quantitative techniques.

There is a close correlation between the frequency of use of the techniques and the relative success. It is not clear whether this is through the increased use of a technique data is gathered which is used to further enhance the relevance of a technique, or that simply the success of a technique leads to an increased use.

Based on the response to the questionnaire and often detailed discussions it is possible to infer a scenario for the analysis of risk in major projects. An initial
qualitative analysis is carried out using a combination of Experience and Engineering Judgement. In some of the cases this stage has been extended to include Brainstorming and Interviewing. After prioritising the risks with respect to likelihood and consequence, quantitative techniques are deployed to numerate and estimate the probabilities of each of the risks. These techniques generally include Break-even analysis, EMV, Scenario analysis, ENPV and Decision Trees. There is evidence that Decision Matrices and Simulations are also used.

ACKNOWLEDGEMENTS

The assistance of the Engineering and Physical Research Council (EPSRC) and Amerada Hess Limited is gratefully acknowledged. The authors are also indebted to the candidates who took the time to complete the questionnaire. The authors would also like to thank the two anonymous reviewers who made constructive comments on the first draft of this paper.

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**Figure 1** Risk Management life cycle

**Figure 2** A summary of the replies for the type of techniques used for risk analysis

**Table 1** Percentages of respondents who allocated ranks 1 and 2 for the frequency and success of qualitative techniques

**Table 2** Percentages of respondents who allocated ranks 1 and 2 for the frequency and success of quantitative techniques

**Table 3** A table to display the ‘graded league’ of the FREQUENCY of techniques, (by their percentages of ranks 1 and 2)

**Table 4** A table to display the ‘graded league’ of the SUCCESS of techniques, (by their percentages of ranks 1 and 2)
### Percentages of respondents who allocated rank 1 or 2

<table>
<thead>
<tr>
<th>Ref. Letter</th>
<th>Qualitative techniques</th>
<th>Frequency</th>
<th>Success</th>
</tr>
</thead>
<tbody>
<tr>
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† % contingency = Percentage contingency from historical data
P & C Experience = Personal & corporate experience
Engin. Judgement = Engineering Judgement
Over = Overall replies
Cons = Replies from the Construction Industry

### Percentages of respondents who allocated rank 1 or 2

<table>
<thead>
<tr>
<th>Ref. Letter</th>
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<tr>
<td>G</td>
<td>Stoch. dec. tree †</td>
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<td>4</td>
</tr>
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<tr>
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<td>EMV with Delphi †</td>
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<td>3</td>
</tr>
<tr>
<td>K</td>
<td>RADR †</td>
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<td>L</td>
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<td>N</td>
<td>Portfolio theory</td>
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† EMV = Expected monetary value
ENPV = Expected net present value
EMV with Delphi = EMV using Delphi peer group
Stoch. dec. tree = Stochastic decision tree
RADR = Risk adjusted discount rate
Stoch. dominance = Stochastic dominance
Over = Overall replies
Cons = Replies from the Construction Industry
# FREQUENCY TABLE

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## Quantitative (graded)

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‡ EMV = Expected monetary value  
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Engin. judgement = Engineering judgement  
P & C Exper = Personal & corporate experience  
% contingency = Percentage contingency from historical data  
* Const = The Construction Industry  
Oil = The Oil Industry
### SUCCESS TABLE

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#### Qualitative (graded)

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<td>D Brainstorming</td>
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* Const = The Construction Industry
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The most popular way of managing the multiplicity of risks involved in major oil and gas projects is to take practical, and non-financial, steps to reduce them.

That’s the main conclusion drawn from a survey of over 100 companies which sought to compare the risk management techniques of locally-based and international oil and gas companies in the UK with those of companies in the UK construction industry.

The survey was prompted by the lack of information about the techniques, factors and approaches used by companies to analyse the financial, physical and safety risks involved in large offshore and onshore oil and gas projects. Despite the growing importance of risk analysis in project management, there is no agreed standard on how the risks are best managed.

One fact emerging from the survey was that oil and gas industry has a predominance of risk analysts who are involved in both technical and financial risks, while in the construction industry finance is the main area for risk analysis.

The survey categorised four possible risk management techniques, namely risk elimination, risk transfer, risk retention and risk reduction.

Risk reduction through education and training, physical measures to reduce the level of risk, early identification of new risks and physical protection for people and property was the most frequently used technique for 92% of respondents in both industries.

Risk transfer by, for example, handing over hazardous work to a specialist sub-contractor or transferring a risk financially through some form of insurance, was the next most popular method and was used by some 60% of oil and gas industry respondents.

Risk retention, namely the conscious and non-conscious bearing of a total risk by the company-at-risk, was the next most used with some 30% of respondents employing this method.

Risk elimination by, for instance, simply not proceeding with a high-risk project, was used by just over 20% of respondents in the oil and gas industry.
The stress laid on risk reduction in the oil and gas industry reflects the large physical risks to life and property involved in an industry which often operates in dangerous conditions.

Where risk transfer is used, oil companies executives prefer to transfer risks financially for the most part, unlike construction companies which tend to transfer risks both to expert sub-contractors.

There are a number of ways in which a company can transfer risks financially, but the most popular methods are through insurance and the use of indemnity or exclusion clauses in contracts.

Risk sharing is also used. Some 73% of the sample said their company had shared, or is sharing, a risk. The most frequently used method was to use an ‘excess or deductible’ provision which caps the liability of the company. Respondents also used consortium agreements and joint ventures.

Some 20% of respondents had used, or are using, a captive insurance company, namely an insurance offshoot created and owned by the parent company for the purpose of insuring the parent. Eighty two percent of those respondents said using a captive is the most manageable way of insuring risks.

Eighty five percent of respondents, i.e. those replying to this method, actively retain risks and the main reason is because insurance premiums are judged too high. Internal funding and the absorption of losses as part of operational costs are the favoured ways of financing retained risks.
A SURVEY OF RISK MANAGEMENT IN MAJOR PROJECTS

Scott Baker †, B.Eng, Research Student, University of Edinburgh;
David Ponniah †, B.Sc., M.Eng., Ph.D., MBA, C.Eng., MICE, Senior Lecturer, University of Edinburgh;
and Simon Smith ††, B.Eng, Ph.D., C.Eng., MICE, Senior Lecturer, University of Edinburgh.

ABSTRACT: Risk management consisting of risk analysis, risk evaluation and the control of risk are essential to the success of a major project. The variations in using such risk management practices are considerable and are dependent on numerous factors such as the industry sector, the size of project, and stage of the project life cycle. These dependencies are investigated and presented in this paper. Over one hundred companies within the construction, and oil and gas operators in the UK were surveyed through questionnaires which provided information on the size and range of activities of the company; the techniques of risk analysis currently being used; the company’s policy on responding to risk, as well as identifying specific risks encountered during any particular project. This paper highlights the vital conclusions accumulated from the various sections of the questionnaire. The main conclusions from this paper are; personal and corporate experience and engineering judgement are the most successful qualitative techniques; and EMV, ENPV, sensitivity analysis and decision analysis are the principal quantitative techniques; risk reduction is the most popular method of responding to risk.

KEY WORDS: Risk; risk analysis; risk response.

† † Department of Civil & Environmental Engineering, Kings Buildings, Crew Building, Edinburgh, EH9 3JN
INTRODUCTION

The demands and needs of society are increasing with increasing human knowledge, and technological advances. This results in projects we undertake being large and getting bigger (Chapman and Cooper, 1987). They tend to be complex and multi-disciplinary and a good example of this is with the Oil and Gas Industry. An increasing demand for petroleum based products has resulted in oil and gas being extracted from locations with harsh and challenging environments.

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.

STATE OF THE ART

The subject 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 B.C. 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, whether the idea 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 method was of qualitative or quantitative 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 confidence and authority. As the Asipu were priest-like in their 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 B.C., there is a religious link to modern quantitative risk analysis. Numerous treatises discuss the probability of an afterlife based upon the behaviour and beliefs one conducts oneself with, in the here and now. Arnobius the Elder, in 4th century A.D., proposed a sophisticated analysis, on this issue of afterlife, pertaining to probabilistic risk analysis. He presented a $2 \times 2$ 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 afterlife, 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 start 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.

In Covello and Mumpower’s paper, there is evidence from archaeologists that gambling games occurred in ancient times, and since the first inventions of primitive man. 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. Sheynin (1974) offered several tentative explanations, none of which are considered 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 17th and 18th centuries.
- related to the growth of firms dealing in life annuities. This argument falters when by the third century A.D. selling of annuities were already commonplace.
- that 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 preconditions 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 built upon previous work to calculate theoretically the annual number of Prussian soldiers dying from kicks by horses. His study lasted 10 years and was to ascertain whether an observed rash 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.

The actual name “risk analysis” first really originated with 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 utilising computers. This would be a new method for making risk explicit. In his example, nine factors were considered about
which there was uncertainty (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. Shift in the nature 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. Increase in new risks, e.g. nuclear war, supertanker 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. Increase in number of formal quantitative risk analyses that are produced and used.
8. Increase in the participation of special interest groups in societal risk management, therefore the government decision makers have to consult representatives from these groups (e.g. industry, environmentalists groups, etc.) and to make risk analysis 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 construction within the past few decades. The reason for this sudden increased need to manage risk is the rapid advancement of technology. Risk, therefore, and 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 this is possible, then not only will project costs be more explicitly known, but also profits will be maximised. The most current risk analysis procedure consists of risk analysis, risk evaluation and the control of risk (Grier, 1981), and can be further divided to fit together into a simple circular procedure, which if followed obtains a controlled risk environment, see Figure 1. This sequence provided the framework for the questionnaire survey, entitled ‘Risk Analysis Questionnaire’ (R,A,Q), described in this paper. It is the objective of this paper to extract all the most pertinent practices and prevalent approaches, from the replies, which are currently most successfully used for each of these stages, so as to suggest modifications or improvements to manage risk. The
main reason for this is that there is no standard to which reference may be made for techniques, factors and approaches to risk management.

![Figure 1 Risk Management life-cycle.](image)

**QUESTIONNAIRE SURVEY**

The principal objective of the investigation was to obtain details of risk management practices carried out by the oil and gas industry, and to compare it with the adopted practices within the construction industry. To achieve this, three steps required intricate attention. These three steps were the questionnaire design, the selection of the sample, and the analysis of the responses.

**Design and Layout of Questionnaire**

The questionnaire was long with 58 questions, but was designed in such a way that completing it should have taken no longer than 30 minutes. The questions were posed with the possible answers already detailed. All the respondent had to do was either circle a five scale ranking system, with the extremes at either end of the scale, or tick the most appropriate box. If any answers were left out there were ample opportunities for the respondent to relay the alternative information in the spaces provided. A handful of questions were open, and hence the respondent was required to expand on their reply.

The layout of the questionnaire followed the framework adopted in Figure 1. Thus the topics and subjects covered in the questionnaire are depicted in Figure 2.

**Selection of the sample**

The research was relevant to major projects, therefore only the 100 largest construction companies listed in Jordan’s (1992/3) were included in the survey, with all 27 oil companies currently operating in the UK (M-G Information Services Ltd., 1994/5). The selection criteria used were twofold from a possible nine. These two were turnover per year and the number of employes.
According to good survey practice (Tull and Hawkins, 1990), a letter was sent to the Chief Executive/Managing Director of the chosen companies, introducing the research and requesting their input. Also, referred to in the letter was a request for names of the staff directly associated with risk management, who would subsequently be canvassed for their opinions. These members of staff could be from a variety of areas within the company such as finance, insurance, safety, design, exploration, installation and operations.

Response to the Questionnaire

Of the companies selected for the sample 107 expressed an interest in participating and was followed up with the questionnaires. The breakdown of the responses is given below in table 1.

<table>
<thead>
<tr>
<th>Industry</th>
<th>No. of Companies who showed immediate interest</th>
<th>No. of companies who replied</th>
<th>Percentage of responses (%)</th>
<th>Actual no. of completed questionnaires</th>
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</thead>
<tbody>
<tr>
<td>Construction</td>
<td>80</td>
<td>40</td>
<td>50</td>
<td>93</td>
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<td>Oil</td>
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<td>Total</td>
<td>107</td>
<td>52</td>
<td>48.6</td>
<td>139</td>
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</tbody>
</table>

Table 1 Breakdown of responses
The response rate for completed questionnaires was high, particularly as the questionnaire was extensive. The fact that the length of the questionnaire was a factor is further illustrated in Figure 3 where the 55 non-completions are shown. Thirty-three companies did not respond at all, but 11 of those who did, said that they were unable to participate because they were too busy or the questionnaire too lengthy.

Having ascertained the amount of replies this survey attained, it is now necessary to find out the most prevalent and successful approaches to satisfy Figure 1. Firstly, however, a little background information on the respondents is required.

**Figure 3** *The spread of the company’s reaction to the Questionnaire*

**Background Information**

The primary responsibilities of the respondents covered the principal activity areas of safety/risk, finance, general management, design, construction and insurance (Baker *et al.*, 1996). Over 65% of the respondents were from the first three activity areas. In relation to primary responsibility the only difference between the two industries was in safety/risk and finance. The oil and gas industry is extremely safety conscious because of the working environment and thus there is an ever increasing abundance of risk analysts (or similar titles associated within safety/risk) within the oil business (Lock, 1992). On the other hand, the construction industry relies on well established technologies and operate in physical environments considerably less hostile. Thus, safety/risk is not of prime importance and would have less technical risk analysts. The construction industry does however operate in a competitive and harsh financial environment (Edwards, 1995), and was reflected in the significantly higher percentage of financial analysts responding to the questionnaire.
The mean age of respondents is 44.8 years, and this was taken from the entire sample, i.e. 139 respondents. The mean years spent in the industry, whether it be oil or construction, is 19.7 years, and the years spent with their present company averages out at 13.6 years.

**General Risk Questions**

The conditions in which risk management is performed is crucial and it was the subject of this section in the questionnaire. Five questions were posed with the respondents required to rank, on a scale of 1 to 5, as to whether they were satisfied with the companies current policies on managing risk. A rank of 1 was a ‘considerably yes’ and a 5 ‘not at all’. These five questions are listed below, and are referred to as 1 to 5 in Table 1 and in the ensuing discussion. Table 1 summarises the mean and standard deviation values for each of these questions from an aggregated perspective and divided between the two industries.

1. Is there sufficient interaction between non-experts on the subject of risk and risk management?
2. Is the time span long enough for carrying out a comprehensive management of risk?
3. Is the reward a risk analyst gets for attaining a close risk estimate amount satisfactory?
4. Are you satisfied with the way your company manages risk?
5. Is it possible to improve on the way your company manages risk?

Values for the first question concentrate around 2.6 which suggests there is adequate interaction between non-experts and experts in the field of risk analysis. The communication lines, which are crucial in this field (Hadden, 1989), are adequate between the hierarchical positions within the organisations, but really need improving. Identifying risks and proposing upgrades is not exhaustive, and enabling the non-experts entering discussions and meetings with the experts could be very fruitful, given the right circumstances.

The overall mean time for sufficiently completing a comprehensive management of risk is mediocre. However, it can be seen from Table 1 that this question is quite clearly divided between the two industries. The construction industry is below a mean value of 3.0 which suggests their management of risk are more of a latest edition to the strategy of a project and as a result, is a rushed affair. The oil industry, by contrast, are more contented with the time span. The oil industry are tending to spend more time due to the vast amounts of financial outlay involved in any oil project. Thus sums of money that could be saved by incorporating a risk management programme outweigh the time spent producing it. Having said that, the rank could still be increased.
Question 3 in Table 1 attained the least satisfaction from all the divisions, without exception. The general attitude towards the reward for attaining a close risk estimate (using hindsight) is one of dis-satisfaction.

The overall mean response to question 4 is 2.6, with a mean of 2.8 for construction and 2.3 for oil. While there is some satisfaction in current risk management, there is a clear need for improvement.

This particular point was addressed in the next question which asked the respondents to similarly rank the possibility of improving the methods of risk management. The overall mean is 2.36, reinforcing the response above. The respondents were then invited to identify how these improvements could be made and the responses illustrated the growing importance of risk management. There was a general need for more and better risk management practises. Risk management should be extended to all aspects of the project with wider participation and with regular re-evaluations. The methods could be improved through better data collection, focussed research and objective evaluation of completed projects. There was a further identified need for guidelines for structured and systematic risk management.

<table>
<thead>
<tr>
<th>Questn. no.</th>
<th>1. Mean</th>
<th>S.d.</th>
<th>2. Mean</th>
<th>S.d.</th>
<th>3. Mean</th>
<th>S.d.</th>
<th>4. Mean</th>
<th>S.d.</th>
<th>5. Mean</th>
<th>S.d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>2.65</td>
<td>0.86</td>
<td>2.83</td>
<td>0.98</td>
<td>3.16</td>
<td>0.89</td>
<td>2.64</td>
<td>1.00</td>
<td>2.36</td>
<td>0.96</td>
</tr>
<tr>
<td>Constr.</td>
<td>2.69</td>
<td>0.86</td>
<td>3.08</td>
<td>0.91</td>
<td>3.31</td>
<td>0.89</td>
<td>2.80</td>
<td>0.95</td>
<td>2.33</td>
<td>0.93</td>
</tr>
<tr>
<td>Oil</td>
<td>2.59</td>
<td>0.86</td>
<td>2.32</td>
<td>0.93</td>
<td>2.85</td>
<td>0.83</td>
<td>2.30</td>
<td>1.03</td>
<td>2.43</td>
<td>1.04</td>
</tr>
</tbody>
</table>

Constr. = Construction Industry.

**Table 2 Table containing means and s.d. for the section on the conditions under which risk analyses are performed**

While a thorough and comprehensive management of risk would be a part of an ideal world, in reality the cost of such analyses are compared to the likely benefits. This aspect of costs was investigated by requesting information as to the proportion of a project currently spent on general management and further, on risk management, shown on Figure 4 and 5, respectively. Over a fifth of the respondents said that over 10% was spent on general management of the project. The number is far greater, about half, were spending over 6%. A clear indication of the increasing importance of proper management of major projects.
Figure 4 The spread of replies for the percentage of the total project cost spent on the Management of the Project

The percentage spending is much lower for risk management. Around 90% spend less than 2% on risk management. None of the respondents spent over 5%. The overall patterns and those for construction and oil are quite similar, but construction has a mean of 1.88% in comparison to oil’s marginally higher figure of 2.24. It is difficult at this stage to suggest what an optimum spending profile should be but the feeling is that current expenditure is insufficient and improvements are being suggested.

Figure 5 The spread of replies for the percentage of the total project cost spent on Risk Management

This aspect of costs was investigated further through a question requesting estimates on the amount each company loses due to unforeseen risks. The estimates are shown on Figure 6 and expressed as a proportion of the total project costs. A significant proportion, 80%, estimated that the losses were less than 5%, a reasonable value for contingencies within the budget of a project. A significant proportion suggested that
the figures may be higher, with over 8% estimating that it could be greater than 20%. There is once again a clear cause for better risk management in major projects, a point further probed by asking whether this level of loss was acceptable to the respondent. Sixty nine percent of responses stated this range was not acceptable, with the remaining 31% finding it was. Of these 69%, nine percent accepted that it was not possible to lower the financial loss through unforeseen risks. Eighty five percent, however, believed that this loss could be reduced by using a more thorough risk management, leaving the remaining 6% to feel that another method could be utilised to abate such a loss. Such methods suggested were; complete health, safety and environment management system; risk management and; closer analysis of costs at tender stage. All of these could be argued to come under a more thorough risk management. Therefore, by far the plurality of replies to these questions perceive their company’s risk management is not thorough enough. This could come will time and learning from previous experience, but will probably best come with research and encouraging more work done on the subject, by allowing more time and by allocating more money to it; another reason why the percentage of total project cost will increase for risk analysis. Therefore, it is clear to conclude from this section that very few of the respondents are completely satisfied in the way their company performs risk management. It is the objective, therefore, of the remainder of this paper to find out more about the successful techniques currently used in industry and to try to ascertain a combination of methods which entirely satisfy the aims of risk analysis and the five steps from Figure 1, to ultimately achieve a controlled risk environment.

Figure 6  Financial loss through unforeseen risks expressed as a percentage of the total project cost
RISK ANALYSIS TECHNIQUES

The first three steps of the risk management life cycle, Figure 1, are risk identification, risk analysis and risk evaluation. This section on risk analysis techniques covers all three issues. However, the detailed results from this section of the questionnaire are the sole subject of another journal paper written by the authors (Baker et al., 1997a) and should be referred to if more information is required. Nevertheless, the conclusions from that paper will be displayed and discussed here.

Briefly, the risk analysis techniques are broadly grouped into two categories, namely qualitative and quantitative (Miller and Rubin, 1979). Qualitative techniques are used first to identify the risks and to distinguish the possibility of the risk occurring in a linguistic manner. It is an assessment in relative terms of the outcome and probability of a risk, e.g. a high risk compared to a medium or low risk. It is subjective and is dependent on the experience of the analyst allied to engineering judgement, and is thus prone to inconsistencies. Those risks with a high or intermediate rank, say, are then forwarded to a quantitative assessment. Quantitative techniques (Thompson and Perry, 1992) are then applied to obtain numerical probabilities, or frequencies, of the consequences and likelihoods of those risks occurring. The methods used for this stage are normally mathematically and/or computationally based, and back up the assumptions or decisions made in the qualitative assessment. The values used in these techniques are obtained from historical databases, or are estimates and still contain an element of uncertainty. The results are then evaluated against company criteria, and decisions made as to whether the risks are acceptable or not.

Qualitative and quantitative techniques are generally accepted to be best used as a combination, one after the other. This view was backed up by 80% of the respondents, with the remaining 20% concentrating on just qualitative methods. This is probably because there is not enough data to proceed to the quantitative techniques. There are a number of techniques available from both categories, qualitative and quantitative. Both types were then listed under two separate questions, in no specific order, and the respondents were required to circle two ranking systems for each technique as to how often they are used and how successful they are. A summary league table was selected and created, see Table 2, as the best means of analysing this part of the questionnaire. The methods were graded purely according to their mean values. Table 2 possesses the graded lists from the industrial perspectives which collectively yields the overall position. Quantitative has 14 techniques and qualitative has 6, so grade 1 denotes the most frequently used or the most successful technique and 14 or 6 the least. There will sometimes be methods with identical means; these are denoted by an equals sign, ‘=’, after the grade number. Correlation Coefficients (Chapra and Canale, 1989) were found to ascertain whether there is a relationship between the frequency of a technique and its success. The possible values of this coefficient range between -1 and 1. The values are incorporated into the frequency table on Table 2, and from those values it is clear to see that the coefficients are all extremely high to conclude that the two ranking systems are dependent upon each other, and thus could have been answered in either order.
Studying the qualitative methods there are two distinct bands, both through positional standings in each division and from their mean values, even though there are only six techniques on offer. They split evenly into two groups of three, with the top three including ‘Personal and corporate experience’ (Raftery, 1994), ‘Engineering judgement’ and ‘Brainstorming’ (Edwards, 1995; Jackson and Carter, 1984), with ‘Interviewing’ (Fiorino, 1989), Percentage contingency from historical data’ and ‘Fuzzy set analysis’ (Kangari, 1989) belonging to the bottom band.

The five most frequently used quantitative techniques are break-even analysis (Eschenbach, 1992), scenario analysis (Flanagan and Norman, 1993) (often more collectively called a sensitivity analysis (Hayes et al., 1986; Singhvi, 1980; Ho and Pike1992)), ENPV, EMV and decision tree. These are the same five, albeit in a different order, within the two individual industries. Their places in the success league differentiate from that in the frequency. This is because their mean values for how often they are used are in a tight clustered band by themselves at the top of the frequency table. Beyond these five, there are two more methods whose mean values suggest that they are also frequently used by a proportion of the respondents, and those two techniques are decision matrix (decision matrix and decision trees can be used together to produce decision analysis) and simulation. Apart from these seven techniques, the remainder have means which suggest occasional usage. Therefore, such methods are very specialised in their use and for a common risk analysis approach these techniques should be used with care, if at all, and if possible favour the top seven.

Therefore, qualitative techniques should be performed first, i.e. one or a combination of the top three recognised above, to identify the risks initially, and to try to prioritise them by their likelihood of occurring and/or by their consequence if they do occur. Then once the risks are evaluated under say, catastrophic, major, and minor risks, then the quantitative methods, of which the more successful ones are the top 7 in Table 2, should be brought in to numerate and estimate scientifically the probabilities of each of the more important risks (probably catastrophic and major) and for contingency plans and risk reducing methods to be drawn up.

**RISK RESPONSE**

The fourth stage of the life-cycle is risk response and is part of the two step process of managing risk. Again like for risk analysis, another detailed journal paper has been written by the authors (Baker et al., 1997b) which concentrates solely on the topic of risk response, so only the conclusions will be conveyed, and if further information is required then refer to the referred paper.
Table 2 A table to display the 'graded league' of the FREQUENCY and SUCCESS of techniques, (with the max. no. of replies per technique and division)

<table>
<thead>
<tr>
<th>FREQUENCY TABLE</th>
<th>Overall</th>
<th>Industry division</th>
<th>Correl. Coeff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. no. of replies per division</td>
<td>125</td>
<td>83</td>
<td>42</td>
</tr>
<tr>
<td>Techniques</td>
<td>Quantitative (graded)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Break-even analysis</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>EMV †</td>
<td>2</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Scenario analysis</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>ENPV ‡</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Decision tree</td>
<td>5</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Decision matrix</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Simulation</td>
<td>7</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Algorithms</td>
<td>8</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>RADR †</td>
<td>9</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Stoch. dec. tree †</td>
<td>10</td>
<td>11=</td>
<td>10</td>
</tr>
<tr>
<td>Bayesian theory</td>
<td>11</td>
<td>11=</td>
<td>11</td>
</tr>
<tr>
<td>Portfolio theory</td>
<td>12</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>EMV using Delphi †</td>
<td>13</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>Stoch. dominance †</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SUCCESS TABLE</th>
<th>Overall</th>
<th>Industry division</th>
<th>Qualitative (graded)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. no. of replies per division</td>
<td>125</td>
<td>83</td>
<td>42</td>
</tr>
<tr>
<td>Techniques</td>
<td>Quantitative (graded)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario analysis</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>EMV †</td>
<td>2</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Break-even analysis</td>
<td>3</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>ENPV ‡</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Decision tree</td>
<td>5</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Decision matrix</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Simulation</td>
<td>7</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Algorithms</td>
<td>8</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>RADR †</td>
<td>9</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Stoch. dec. tree †</td>
<td>10</td>
<td>11=</td>
<td>10</td>
</tr>
<tr>
<td>Bayesian theory</td>
<td>11</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>Portfolio theory</td>
<td>12</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>EMV using Delphi †</td>
<td>13</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>Stoch. dominance †</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
</tbody>
</table>

| P & C Experience † | 1 | 1 | 1 | 0.71 |
| Engin. judgement † | 2 | 2 | 2 | 0.80 |
| Brainstorming | 3 | 3 | 3 | 0.84 |
| % contingency † | 4 | 4 | 4 | 0.91 |
| Interviewing | 5 | 5 | 5 | 0.89 |
| Fuzzy set analysis | 6 | 6 | 6 | 0.93 |

† EMV = Expected monetary value  
‡ ENPV = Expected present value  
= Stoch. dec. tree = Stochastic decision tree  
Stoch. dominance = Stochastic dominance  
Engin. judgement = Engineering judgement  
P & C Exper = Personal & corporate experience  
Const = The Construction Industry  
Oil = The Oil Industry  
Correl. Coeff = Correlation Coefficient  
% contingency = Percentage contingency from historical data
A question asked the respondents whether their company used one or a combination of the four risk response techniques (Carter and Doherty, 1974). The four being risk reduction, risk transfer, risk retention and risk elimination. Depending on which of the four the candidates used, then determined their next moves within the questionnaire. There were further sections on each of the risk response techniques which asked more specific questions about those methods.

The results of the four principle methods pertaining to risk response are illustrated in Figure 7. The three columns represent the overall replies and the two industries separately. The columns are presented as a percentage of the total replies for each of the respective three divisions.

The most popular method within both industries is risk reduction (Thompson and Perry, 1992). Only three respondents from the oil sector and eight from the construction claim that their company does not employ this technique. After risk reduction, there is a dramatic fall to the next favoured method, risk transfer (Baker et al., 1997b). The method of risk transfer has the support of 73 respondents. Falling almost half again, risk retention (Baker et al., 1997b) receives 41 votes, with risk elimination acquiring 35 positive replies.

![Figure 7 Methods used when responding to risk.](image)

Other theoretical methods of handling risks are risk spreading or diversification, and reducing risk liability by use of the employment contract, but these were not supported by the company’s replies.
**RISK MONITORING**

Once the stages of risk identification, risk analysis, risk evaluation and ultimately, risk response have been accomplished, it is necessary then to monitor that risk to make sure that it agrees with the company’s acceptance criteria throughout its existence. This, in turn, depends on a number of factors but mostly on the employees’, and their company’s, attitudes towards accidents and their definition of acceptable risk.

It was the purpose of three questions after the risk response sections to ascertain information on the above attitudes. These same three questions were also the subject of a survey done by Tore J. Larsson (1985) in 1985, who tried to find out similar attitudes and definition. The questions are answered using a five scale ranking system. The extremes are rank 1 denoting ‘totally agree’ and rank 5, ‘totally disagree’. For each of the questions there are a number of factors which were offered which each require the respondents to circle a rank from 1 to 5.

The three questions are: 1) How far would you agree the following nine factors account for accidents at the workplace?, 2) How far do these statements agree with your company’s description of ‘acceptable risk’? and 3) How do these statements agree with your company’s attitudes towards accidents?. Larsson posed these questions to a sample of Swedes, which included high risk groups (such as air-force pilots and workers in the explosives industry) and to 130 Swedish candidates at a seminar on risk analysis in November 1983. These respondents were mostly safety executives in industries and authorities. The results are given in Tables 3 and 4. The results give the percentages in the first two ‘agree-yes’ categories, i.e. ranks 1 and 2.

Table 3 reveals some very distinctive differences from the first of these 3 questions. The order of attributable factors for the R.A.Q respondents does not resemble that of either the Swedish sample or of the safety executives. Although, one thing is clear and that is the three most attributable items that account for accidents at the workplace are the same for all three bodies, although the safety executives also regard ‘technology makes accidents unavoidable’ as an equally attributable factor. These first three are, risk taking employees, human factors and a lack of planning and cooperation. After the global agreement of these three items, the remaining factors do not correspond within the subsets. The differences in attitudes between the Swedish population, and to a certain extent the safety executives, and the R.A.Q. could be for two reasons. The original survey was performed in 1982, whereas the R.A.Q. was completed very recently in August 1995. Time could have affected attitudes towards risk and safety, which is why risk monitoring is so important as time is a critical factor as attitudes do change, especially allowing for the advanced developments of safety laws, procedures, perceptions etc. and the continual introductions and improvements of risk analysis techniques. The second reason could be because the respondents originate from different nations. Respondents from Sweden could have contrasting opinions and understandings of accidents than the British due to the divergent medias and backgrounds, as well as different hypotheses on Civil or Structural Engineering (e.g. building practices, safety regulations, levels of
technology, etc.), as an industry.

It is good to see that fatalism and technology makes accidents unavoidable having very low percentages from the R.A.Q respondents. Fatalism seems to be believed more by the person walking down the street (so to speak) than an expert or professional. Obviously times have changed, as the safety executives in 1983 believed the latter factor here was a significant problem, but now in Britain new technology does not pose serious accident potential. This is illustrated in the replies from all three groups.

<table>
<thead>
<tr>
<th>Statement on accident attribution</th>
<th>Sample of Swedes Agree %</th>
<th>Safety executives Agree %</th>
<th>R.A.Q respondents Agree %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk-taking</td>
<td>90</td>
<td>89</td>
<td>69</td>
</tr>
<tr>
<td>Human factors</td>
<td>89</td>
<td>60</td>
<td>83</td>
</tr>
<tr>
<td>Lack of planning and cooperation</td>
<td>88</td>
<td>96</td>
<td>70</td>
</tr>
<tr>
<td>Technology makes accidents</td>
<td>60</td>
<td>60</td>
<td>4</td>
</tr>
<tr>
<td>Fatalism</td>
<td>52</td>
<td>27</td>
<td>5</td>
</tr>
<tr>
<td>Accident, small problem</td>
<td>46</td>
<td>25</td>
<td>29</td>
</tr>
<tr>
<td>Accident, big problem</td>
<td>37</td>
<td>37</td>
<td>30</td>
</tr>
<tr>
<td>Accident proneness</td>
<td>28</td>
<td>13</td>
<td>9</td>
</tr>
</tbody>
</table>

Sample size (n) (982) (130) (133)

* The items are developed by Tore J. Larsson.
The percentage values are rounded to the nearest whole percent.

Table 3 *Distribution of the eight items on accident (at the workplace) attribution for a representative sample of the Swedish population, a group of safety executives and the respondents from the Risk Analysis Questionnaire 'R.A.Q'*

The percentage values for questions 2) and 3) are in Table 4, but the sample of Swedes, were, however, not included in these questions. The results on the meaning of ‘acceptable risk’ are very interesting and contrary. Nevertheless, the one definition that seems to be approved, whether one is Swedish or British is ‘A quantified safety level’. A total of 64% of the R.A.Q. respondents and 74% from the safety executives agreed with this definition. This definition specifies a level, by quoting frequencies or probabilities, of risk which if exceeded, on a project or over a year say, then it is deemed unacceptable. However, the Swedish safety executives seem to support more than one definition of ‘acceptable risk’. In fact, they have three over 50%. It would seem that the Swedish safety executives had very varied opinions and meanings of ‘acceptable risk’, which could possibly have lead to confusion and misunderstanding. Conversely, the second definition from the R.A.Q. respondents, ‘benefits outweigh the risk’, received agreement from 40% of the sample. After that, there is only one other description of acceptable risk that has any support at all and that is ‘the risk is eliminated/zero risk’ with 34%. It is clear from these 3 definitions that the R.A.Q. respondents are quite targeted and focused on their understanding of ‘acceptable
risk’, resulting in goal-setting strategies and teamwork, all trying to achieve the one objective, of achieving as little risk as possible.

<table>
<thead>
<tr>
<th>Statement on the meaning of ‘acceptable risk’</th>
<th>Swedish safety executives Agree %</th>
<th>R.A.Q. respondents Agree %</th>
</tr>
</thead>
<tbody>
<tr>
<td>A quantified safety level</td>
<td>74</td>
<td>64</td>
</tr>
<tr>
<td>No alternative way of solving the risk problem</td>
<td>61</td>
<td>11</td>
</tr>
<tr>
<td>Benefits outweigh the risk</td>
<td>50</td>
<td>40</td>
</tr>
<tr>
<td>No obvious benefits on risk reduction made</td>
<td>37</td>
<td>20</td>
</tr>
<tr>
<td>The risk is voluntary</td>
<td>35</td>
<td>18</td>
</tr>
<tr>
<td>The risk is eliminated, zero risk</td>
<td>19</td>
<td>34</td>
</tr>
<tr>
<td>The risk is equal for everyone</td>
<td>7</td>
<td>9</td>
</tr>
</tbody>
</table>

Sample size (n) (130) (128)

<table>
<thead>
<tr>
<th>Attitude statement towards accidents</th>
<th>Swedish safety executives Agree %</th>
<th>R.A.Q. respondents Agree %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prosecute those effecting accidents and harm</td>
<td>90</td>
<td>25</td>
</tr>
<tr>
<td>The society should protect the citizens against risks, even voluntary risk exposure</td>
<td>63</td>
<td>46</td>
</tr>
<tr>
<td>Money and costs don’t matter when saving lives</td>
<td>58</td>
<td>71</td>
</tr>
<tr>
<td>Priority to the safety of myself</td>
<td>50</td>
<td>29</td>
</tr>
<tr>
<td>Risk-taking — the individuals right to choose</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>Balloon-effects — Fatalistic attitude</td>
<td>11</td>
<td>1</td>
</tr>
</tbody>
</table>

Sample size (n) (130) (130)

The percentage values are rounded to the nearest whole percent.

Table 4 The responses of the group of Swedish safety executives and Risk Analysis Questionnaire (R.A.Q.) respondents on items about the definition of acceptable risk and items on attitudes towards risks.

Examining the second half of Table 4, the contrasting company attitudes towards accidents of the two sectors are distinctive. Again, as in question 2), over half of the Swedish contingent have agreed on more than one statement, four in fact, whereas the majority of respondents from the R.A.Q have only agreed on one, maybe two. It would seem in Sweden, unless time has altered this system, the attitudes towards accidents, from a company’s perspective, are very different that those held in Britain. Heading the Swedish attitudes towards accidents is ‘prosecute those effecting accidents and harm’, with a staggering 90%. Conversely, very few replies from the R.A.Q. respondents agreed with this method, but this was already thought and proven on the subject of risk reduction. The two most important statement held by the British companies’ attitudes towards accidents are ‘money and costs do not matter when saving lives’, and ‘the society should protect the citizens against risk, even voluntary risk exposure’ with 71% and 46% respectively. By understanding these two statements, it is very clear that in the Civil or Structural Engineering companies in Britain the principal concern are their employees, and regard them as their most valuable asset. The Swedish companies do not share the same concern. The notion of
prosecution overshadows the remaining five statements. This cannot be good for team morale, trust or loyalty towards the employing company. This leads to selfishness, hence the popularity of the statement 'priority to the safety of myself, and a care less working environment, which is less likely to produce results and more likely to result in additional risk. This view may, however, have changed as companies globally are now more safety conscious and aware.

**QUESTIONS ABOUT SPECIFIC RISKS**

This section ascertains the importance of certain types of risks, by posing six types of risks and asking the respondents to rank them in order of importance. The six types of risk are Financial, Technical, Operational (logistical), Time, Political, and Environmental.

In Table 5, the means are displayed for the ‘overall’ replies and also the industry division, to show the contrasting perceptions between the construction and the oil industries. Position 1 denotes the most important type of risk and 6 the least. Both industries, construction and oil, reveal that ‘financial’ risk is the most important type of risk, from the six choices available. However, the construction industry are definite about that decision, from their mean value, whereas the most important risk from the oil industry is keenly contested by the ‘technical’ risk. This confirms that the oil industry view the risks from a technical perspective as well as financial, but the construction perceive the risks as just financial. Concentrating solely on the mean values one can distinguish two significant differences between the two industries, namely between the ‘time’ and ‘environmental’ risks. The oil sector regards the ‘environmental’ risk as being important, quite understandably as they are constantly handling fossil fuels in harsh environmental conditions and heavy wildlife areas, and ‘time’ as being less significant, unlike the construction industry who feel the exact opposite. Time constraints within both industries are always imposed, but the construction industry rank it higher, relatively speaking, as they deal in a harsh financial environment, and a less harsh working environment. The others which have not been mentioned, i.e. ‘operational’ and ‘political’ which were third and last respectively, are comparable amongst all three categories.

**CONCLUSIONS**

Risk management is a complex means of identifying, analysing, evaluating, responding and monitoring uncertainties within the oil and gas industry, and the construction industry. It was clear that the former industry has a predominance of risk analysts who are involved in both technical and financial risks, while in the construction industry finance is seen as the main area for risk management.

The questionnaire covered a wide range of subjects and this paper investigates some of the more pertinent findings from each section. The general feeling of risk management practises at present is one of further improvement possible and necessary, by allowing more resources and time to perform such analyses.
The preponderance of respondents believed that their company uses a combination of both qualitative and quantitative techniques for analysing risk. The most successfully used techniques are personal and corporate experience, engineering judgement and brainstorming for qualitative use, and break-even analysis, scenario analysis, decision tree, decision matrix and simulation for quantitative.

Risk reduction was the most frequently utilised method for responding to risk, with 92% of replies suggested its constant use. Risk transfer was next with risk retention least used.

The British companies regard risk taking employees, human factors and a lack of planning and co-operation as the main attributions to accidents. However, the attitudes towards accidents is predominately one of money and costs do not matter when saving lives. The R.A.Q respondents feel that their companies most valuable asset are the employees.

Certainly at the present moment, as risk management is still relatively a new area, the entire analysis is required to be performed in the existing schedule for a project, which means tight time boundaries. This subject needs continual assessment throughout the life-time of all projects and in the future, the project durations and schedules will need to be extended to allow thorough and comprehensive management of risk to be undertaken.

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