AN INVESTIGATION INTO THE USE OF SAFETY RISK MANAGEMENT TO IMPROVE PROJECT PARAMETERS IN THE CONSTRUCTION INDUSTRY IN SOUTH AFRICA

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A research report submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Science in Building.

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Declaration

I declare that this is my own, unaided work. It is submitted in partial fulfilment of the requirements of the Degree of Master of Science in Building at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

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Ntsandeni Joshua Maroge

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Abstract

Construction industry has for many years developed a very bad reputation for coping with project schedule, cost, quality and safety. Not only does construction industry deliver expensive buildings late, it contributes to disproportionate numbers of work-related injuries and fatalities as well. Project safety risk management is acknowledged as one of the techniques that can be implemented on construction projects to enhance performance of the construction contractors in South Africa. This research report investigates the use of project safety risk management by contractors, and evaluates the relationship that exists between project safety risk management and project parameters relative to schedule, cost, quality and safety in the construction industry in South Africa.

The research report adopted empirical study in order to achieve the objectives. An in depth literature review was carried out in order to identify safety project management processes that can be used by construction contractors. To establish how project safety risk management is currently being implemented in the South African construction industry and its importance to projects parameters, a research question was developed based on the information from literature review. The research questionnaire was sent out to 101 construction contractors in the Gauteng province of South Africa. Fifty eight (58) contractors completed the questionnaire.

The study has established that positive relationship exists between projects safety risk management and project parameters in the construction industry in South Africa. This study recommends that construction contractors in South Africa should proactively implement project safety risk management processes in order to improve projects performance. Furthermore, the study recommends that project safety risk management should not be implemented only during the construction phase by contractors, but should be implemented on all phases of the project cycle by all the stakeholders including clients and professional team.

Dedication

I dedicate this report to my only sister,

The late Alvinah Phathutshedzo Munzhelele-Maroge

Acknowledgement

I wish to thank a number of people for their significant contribution to ensure that I complete this research report.

Firstly, to my supervisor, Dr. Harry Quainoo, for his priceless knowledge, feedback and guidance from the inception of the study until submission date.

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Chapter 1 - Introduction

1.1 Introduction

Almost all contract documents around the world in the construction industry incorporate a penalty clause. In a simplified definition, a penalty is an amount which is payable by the contractor to the employer for each day the contractor goes beyond the practical completion date through no fault of the employer.

Penalty clauses are necessary because construction industry has for so many years developed a very poor reputation for coping with construction schedule, targeted cost and desired quality (Smith, Merna and Jobling, 2006, p.1). Raftery (1994, p.10) echoes this perception and says that the construction industry delivers expensive building late. Introducing safety risk management in their book, Lingard and Rowlinson (2005, p.1) postulate that construction industry does not perform poorly on cost only but also in occupational health and safety. They added that more construction workers continue to lose their lives or be injured at construction sites.

South Africa is no exception to the above perception. Choudhry, Fang and Rowlinson (2008, p.87) claim that construction industry in South Africa, like other developing countries, is characterised of poor health and safety performance when compared with that of other industries. According to the Department of Labour's Compensation Commissioner's Report on the 1999 Statistics, which was the most recent statistics by the Compensation Commissioner during the study, construction was among the top three sectors with the highest fatality rate per 100 000 workers. The report continued and claim that permanent disabilities for every 100 000 workers in the construction industry was also high, ranking ninth among other industries. The proceedings of the second conference of the International Council for Research and Innovation in Building and Construction (CIB) Working Commission W99 added that construction industry has fourth highest severity rate after finishing, mining and transport. Severity rate indicates the number of days lost due to accidents for every 1000hours worked, and construction industry's rate is standing at 1.14.

Consequently, these accidents contribute to the cost of construction directly and indirectly. These directly and indirectly cost as a results of an accidents on site are called Cost of Accidents (COA). Indirectly costs are through decreased productivity, quality non-conformances and schedule overruns, and directly costs through increased compensation and insurance (Smallwood, 1999, p.215). CIB also added that in the year 2002, the construction industry completed work to the value of R56billion and the total costs of accidents based on the indirect multipliers was between R2billion and R3billion, which equates to five per cent (5%) of construction costs.

According to Zou and Guomin (2009, p.621), construction contractors' attitude towards safety management is a very serious concern because some of them fail to provide basic safety items such as personal protective equipment. To sum it all, Loosemore et al. (2006, p.1) claim that construction and engineering industries have created negative public perceptions and seemingly irrational and unjustified public reactions to even the most innocuous development proposals due to its bad reputation of poor safety performance and service delivery.

1.2 Research Problem

Notably, construction industry suffers a lot of costs due to these accidents and contributes disproportionate numbers of work-related fatalities and injuries to the economy of South Africa. And usually when there is an accident on a construction site operations are halted until preliminary investigations are conducted. The cost of accidents, as per CIB report, contributes significantly to the cost of construction both directly and indirectly, and this makes proactive management of project safety risks a key component to the achievement of the project goals in relation to project cost, quality, schedule and safety. Similarly, Enshassi et al. (2007, p.43) hypothesise that if construction projects are to be completed on time, without cost overruns and without experiencing accidents, effective and efficient management of project safety on site is critical.

The Construction Industry Development Board (CIDB) Health and Safety Report (2009, p.37) claims that optimum overall project benefits that can be realised by effective and efficient management of the project health and safety are generally compromised due to the preoccupation of construction stakeholders with project schedule, cost and quality. Enshassi, Smallwood and Hassouna (2007, pp. 71-72) posited that project safety performance is just as much a measure of the success of the project as are measures related to project schedule, cost and quality. Then the questions is are construction stakeholders, with special emphasis to construction contractors, aware that risk management processes can be used to proactively manage safety risks on a construction site and increase the overall performance of the project? The study attempts to answer this question by means of structured questionnaire survey.

1.3 Objectives of the Study

- The main objective of the study is to investigate how risk management processes can be utilised to manage project safety risks by construction contractors in South Africa to efficiently achieve project parameters of cost, schedule, quality and safety.
- The research also attempts to develop recommendations on the way safety risk management is currently being practiced by construction contractors.

1.4 Hypothesis Statement

Howarth and Watson (2009, p.89) hypothesize that both the status of the project and integrity of the organisation, which are usually measurable by good safety performance indicators, project profits and quality, are significantly influenced by positive safety culture. Introducing his book, Edwards (1995, p.1) added that construction industry can use risk management to deal with project safety risks. This is to ensure that the construction industry proactively manage project safety risks in order to achieve project goals.

The hypothesis of the research report is that safety risk management can be used by construction contractors to achieve project parameters of cost, schedule, quality and safety in the construction industry in South African. Therefore the null hypothesis and alternative hypothesis statements of the study are as follows:

Null hypothesis statement:

H_0: $\rho = 0$ (There is no relationship between project safety risk management and project parameters of cost, schedule and quality in the South African construction industry).

Alternative hypothesis statement:

H_1: $\rho \neq 0$ (There is a relationship between project safety risk management and project parameters of cost, schedule and quality in the South African construction industry).

Where: ρ is the population correlation coefficient.

1.5 Significance of the Study

Construction industry does not only provide the much needed infrastructure to the country, it also contributes significantly to the expansion of the economy and creation of the jobs. As a result these jobs play important role in the eradication of poverty. However, all the benefits that follow construction projects should not, in fact should never, come at a cost of human life or human body parts which are usually lost during the implementation phase of a project life-cycle.

Accidents affect the construction industry negatively and contribute to the increase of both direct and indirect costs. Anumba (1999, p.157) hypothesises that construction industry can ill-afford huge costs implications as a results of safety incidents and accidents. Therefore it is the responsibility of all construction participants & stakeholders to ensure that construction industry realises its full potential of providing infrastructure, expanding the economy, creating jobs and eradicating poverty. One way of realizing construction benefits is by means of managing project safety risks properly. Though most of the project safety risks are inherent to the construction industry, beneficiaries of the construction industry should manage them.

Loosemore et al. (2006, p.2) postulate that the problem with construction industry has nothing to do with its dynamic environment but more to do with difficulties in identifying project risks, assessing identified project risks and managing project risks and opportunities posed by projects.

1.6 Research Report Scope and Limitation

There are lots of safety risks that need to be managed during the life cycle of the project. Due to time constraint the research report was limited to the risk management of project safety risks during the construction phase by the contractor.

The following assumptions were made during the research:

1. Literature review about international construction industry applies to the South African construction industry.
2. All targeted respondents have interests in the research and would not feel that the information supplied would be used to compete against them.
3. Sample surveyed is a true representation of the South African construction industry.

4. Structured questionnaire survey indicates level and nature of the safety risk management practices implemented by construction contractors in South Africa.

The anticipated constraints during the research are time and confidentiality of the information by respondents.

The research had to be completed and submitted to the Faculty of Engineering and Built Environment of the University of Witwatersrand by December 2011. This means that there are only 10 months, at most, allocated for the research report. To overcome this limitation, a precise research programme was developed with activities to be done and time lines.

Time also affects the research negatively because the proposed methodology relies on other parties for responses. Most of the targeted contractors for responses may not dedicate enough time to go through the questions because of their busy schedules. Construction is known to operate through tight schedules. To overcome this problem, questions on the questionnaire were as short as possible with pre-determined responses.

Most of the companies have confidentiality clause in their employment contracts. Usually this clause binds employees not to give anyone information, about the organisations they work for and the projects they are busy with, without the approval of their superiors. Therefore some of the targeted respondents might feel that responding to the questionnaire might be interpreted as a breach to this important clause and decide not to respond. In many cases the remedy for breaching this clause is dismissal. To avoid this problem, confidentiality of any information submitted was explicitly mentioned on the questionnaire.

Again, because of the confidentiality clause, a lot of research time may be wasted when respondents are waiting for the approval by their superiors. To overcome this limitation, questionnaire were sent on time as stipulated on the programme and there were constant follow ups on all questionnaire sent out.

1.7 Conclusion

1) Chapter 1 introduces the background of the research report which built up to the research problem. The objectives and significance of the research report are also outlined.

2) Chapter 2 covers literature on project safety risk management in the construction industry. Authenticated journals, academic books and various published materials about project safety risk management in construction industry were reviewed.

3) Chapter 3 describes the methodology that was adopted in order to attain objectives of the research report. The empirical research methodology has been used to accomplish the objectives of the research. The main reason for choosing this methodology is that the effect of safety risk management in the construction projects should be assessed accurately and easily.

4) Chapter 4, results of the survey are analysed and presented. Main findings of the study, which seek to address the research question and hypothesis statement, are presented.

5) Chapter 5 discusses conclusions and recommendations of the study.

Chapter 2 - Literature Review

2.1 Introduction

Construction industry is generally acknowledged as inherently risky and dangerous because of the high number of temporary and permanent disablement injuries and fatalities that occur in construction sites. The Compensation for Occupational Injuries and Diseases Act 1993 Report on the 1999 Statistics asserts that out of 1 000 000 workers, the building and construction industry contributed third highest number of occupational fatalities out of 25 classified industries (Compensation commissioner, 2008, p.17). The Compensation Commissioner's 1999 Statistics Report was the most recent available safety and health statistics from the Compensation Commissioner when this study was being conducted.

To put things into perspective, construction has been among the industries with the highest number of work related accidents. The 1999 Statistics show that building and construction industry experienced 3,203 accidents and its frequency rate was 4.89 per 1000 000 workers (Compensation Commissioner, 2008, p.17). Its severity rate per 1000 hours worked was sitting at 1.14 (Compensation Commissioner, 2008, p.18).

Despite its bad reputation in terms of safety and health performances, the building and construction industry do not fully utilize risk management techniques to prevent and or reduce accidents on construction sites, thereby maximizing opportunity of realising full benefits of efficient safety management processes. Helledi (1999, p.7) claims that formal risk assessment and management techniques are not widely used to improve safety performance in the construction projects.

Therefore, this research report aims to study how risk management processes can be used to manage project safety risks by construction contractors in South Africa to efficiently achieve project parameters of cost, schedule, quality and safety. The research also attempt to develop recommendations on the way safety risk management is currently being practiced by construction contractors.

2.2 Construction Industry Safety Performance in South Africa

2.2.1 Outline of the South African Construction Industry

The building and construction industry plays a significant role in the South African economy. The construction industry does not only provide the necessary infrastructure, but also provide employment to South African and global citizens. This means that construction industry is a global contributor so its challenges and contributions cannot be ignored.

The Quarterly Employment Statistics (QES) March 2010 report (QES March 2010) showed that the construction industry employs some 408 000 people at a gross earnings of R10 billion (Statistics South Africa, 2010, p.11). This equates to 5% contribution to employment and 3% to the gross earnings of the South Africa economy.

The February 2011 South African Budget Speech by the Minister of Finance, Minister Pravin Gordhan, forecasted that government and state owned enterprises would spend more than R800 billion over the next 3years on public infrastructure (SOUTH AFRICA: Department of Treasury, 2011, p.36). These infrastructures include schools, hospitals, port facilities, water supply pipelines, road and rail networks, power stations and government building.

From the data above it is clear to acknowledge that construction industry is a significant contributor to employment and gross domestic product of South Africa. However, the construction industry is notoriously known for the high proportion of the work-related accidents and poor safety records. The CIDB report (2009, p.1) states that disproportionate numbers of work-related fatalities, permanent and temporary injuries are being contributed by the construction industry in South Africa.

The South African construction industry is also notoriously known for its reluctant to comply with safety rules and regulations. This proposition was also highlighted on the proceedings of the South Africa's Construction Occupational Health and Safety seminar organised by the Department of Labour (DoL) on the 17th May 2011. On Page 6 of the report, DoL states that in the 2009/2010 period construction industry had only 58% compliance to occupational health and safety act and regulations among inspected projects during that period.

Lai, Liu and Ling (2011, p. 1018) claim that construction industry should take safety management serious and implement it adequately if it is to achieve project objectives. They further state that construction accidents affect project schedule, which will consequently lead to accident costs. This implies that safety management is an important factor that cannot be ignored by construction contractors. Hughes and Ferrett (2008, p.60) advocate that a positive safety culture results in improved health and safety standards and reduction in work-related accidents.

2.2.2 Construction industry health and safety legislation

Despite the fact that the contractor often get involved in a project at a rendering stage, construction contractors have the responsibility of ensuring that the direct field workers and everyone involved in the project during construction phase is safe and that the project does not pose any risk to their health. Construction contractors are also expected to be competent or to have a competent person on health and safety matters either as a consultant or employee. Seo and Choi (2008, p.72) claim that safety accidents are more likely to occur in the construction projects, hence the need to have safety management technique.

The Occupational Health and Safety Act No. 85 of 1993 as amended by the Occupational Health and Safety Amendment Act No 181 of 1993 (OHS Act) (SOUTH AFRICA, 2008, p.9) states that it is the responsibility of every employer to ensure that the working place is free from risk and that the safety of employees is not compromised in any way at all times. Therefore construction contractors should ensure that construction sites are safe place to all employees and visitors at all time.

The main purpose of the OHS Act is to provide a framework for the provision of health and safety of persons at work and for the health and safety of persons in connection with the use of plant and machinery; the protection of persons other than persons at work against hazards to health and safety arising out of or in connection with the activities of persons at work; to establish an advisory council for occupational health and safety; and to provide for matters connected therewith (SOUTH AFRICA, 2008, p.1). The OHS Act was introduced to replace all the Machinery and Occupational Safety Amendment Act No. 6 of 1983 & its amended acts that were introduced later on.

The OHS Act applies throughout all industries and therefore employers and employees in a construction project should adhere to its rules and regulations. That's if the contractor is failing to provide a safe working environment, free of hazards, the Act gives the Chief Inspector powers to direct the contractor in writing to have a written plan with respect to the health and safety of his or her employees while at work (SOUTH AFRICA, 2008, p.9). Clause 1(1) defines The Chief Inspector as an individual who have been appointed under section 27 as such and this include any individual who may be appointed as acting chief inspector (SOUTH AFRICA, 2008, p.4).

It is important to note that clause 31 on page 18 of the OHS Act highlights that an inspector can investigate any incident in which according to his opinion might have cause harm to any person. Such a report would be handed over to the Attorney-General for further investigation depending on the case and the Attorney-General would be guided by the Criminal Procedure Act No. 51 of 1977 or the Inquest Act No. 58 of 1959.

Therefore it is imperative to note that it is criminally chargeable to breach laws that regulate health and safety, and it comes with adverse consequent to the construction contractor. Summerhayes (2010, p.39) hypothesises that it is criminal law to break safety rules. Furthermore he states that the responsibility to prove innocent rests with the duty holder. This means that the employer is deemed guilty until he or she can proof otherwise. To add to the criminal charges, according to clause 29 of the Compensation for Occupational Injuries and Diseases Act No. 130 of 1993 as amended by the Compensation for Occupational Injuries and Diseases Amendment Act No. 61 of 1997 (Compensation Act), the contractor may be responsible for the compensation payment to the employee whose injury, disease or death happen during the course of employment.

The Compensation Act aims to provide for compensation for the disablement caused by occupational injuries or diseases sustained or contracted by employees in the course of their employment, or for death resulting from such injuries or diseases, and for matters connected therewith (SOUTH AFRICA, 2005, p.1).

2.2.3 Construction industry's occupational safety performance

In South Africa, according to OHS Act (SOUTH AFRICA, 2008, p.7), the Department of Manpower is responsible of collecting and disseminating of occupational health and safety statistics and information. However, when this study was conducted the latest available detailed statistics of construction health and safety performance was for the year 1999, entitled the Compensation for Occupational Injuries and Diseases Act 1993 Report on the 1999 Statistics. It is for this reason that this research has used the 1999 Compensation Statistics Report for looking at how construction industry performs against other local industries in terms of occupational health and safety.

It is not uncomplicated to do a direct comparison of construction-related occupational health and safety accidents between countries due to different laws and policies used to guide the reporting of such accidents. However, due to time and resources constraints this research report did not compare safety performance of the construction industry in South Africa with that of other countries.

2.2.3.1 Against other industries in South Africa

This research report uses the accident frequency rate and accident severity rate provided by the 1999 Compensation Statistics Report, which was the most recent report at the time of writing this research report, to compare occupational health and safety performance of the construction industry with other industries in the South African economy. As per 1999 Compensation Statistics Report there are 24 classes of different industries in the economy of South Africa.

The Construction Industry Development Board Health and Safety Report (2009, p.5) defines the accident frequency rate as the rate that shows the number of disabling injuries over a given time, usually measured in man-hours, that happen at a working place, and accident severity rate as the rate that shows on average the time lost due to the seriousness of the injury. The accident severity rate basically indicates the time lost by the worker in days due to occupational accident per 1 000 hours worked and the seriousness of the accident. Accident frequency rate is sometimes referred to as a disabling injury incidence rate (DIIR).

The accident frequency rate and accident severity rate can be calculated by the following formulae as advocated in the 1999 Compensation Statistics Report:

$$\text{Disabling Injury Incident Rate (DIIR)} = \frac{\text{Number of injuries x 1 000 000}}{\text{Number of man-hours of exposure}}$$

$$\text{Accident Severity Rate (SR)} = \frac{\text{Total time charges in days x 1 000}}{\text{Number of man-hours of exposure}}$$

Table 2.1: South Africa's Accident Frequency Rate

Class	Industry	Number of Workmen	Hours of Exposure to Risk	Number of Accidents	Frequency Rate
1 & 2	Agriculture and Forestry	582 606	1 322 515 620	4 929	3.73
3	Fishing	4 648	10 550 960	222	21.04
4	Mining	89 363	202 854 010	1 821	8.98
5	Building and Construction	290 444	654 951 220	3 203	4.89
6	Food, Drink and Tobacco	242 758	544 587 113	3 092	5.68
7	Textiles	183 482	410 999 680	1 181	2.87
8	Wood	131 451	313 839 263	2 710	8.63
9	Printing and Paper	63 492	141 745 890	630	4.44
10	Chemical	174 094	383 587 113	1 726	4.50
11	Leather	34 276	75 492 890	215	2.85
12	Glass, Brick and Tiles	60 497	122 506 425	887	7.24
13	Iron and Steel	515 567	1 202 817 811	7 052	5.86
14	Diamonds, Asbestos and Bitumen	18 563	44 644 015	88	1.97
15	Trade and Commerce	781 431	1 773 848 370	4 171	2.35
16	Banking, Finance and Insurance	230 806	523 929 620	280	0.53
17	Transport	333 955	758 077 850	5 547	7.32
18	Local Authorities	166 826	378 695 020	1 921	5.07
19	Personal Services and Hotels	457 081	1 037 573 870	2 276	2.19
20	Entertainment and Sport	35 712	81 066 240	148	1.83
21	Medical Services	124 835	283 375 450	353	1.25
22	Professional Services	157 389	357 273 030	277	0.78
23	Education Services	161 195	365 912 650	753	2.06
24	Charitable, Religious, Political and Trade Organisations	78876	179 048 520	354	1.98
TOTAL		4 919 347	11 169 892 630	43 836	3.92

Source: Compensation Commissioner, 2008, p.17.

Table 2.2: South Africa's Accident Severity Rate

Class	Industry	Number of Workmen	Hours of exposure to Risk	Time Loss (Days)	Severity Rates
1 & 2	Agriculture and Forestry	582 606	1 322 515 620	772 859	0.58
3	Fishing	4 648	10 550 960	151 258	14.34
4	Mining	89 363	202 854 010	336 103	1.66
5	Building and Construction	290 444	654 951 220	746 157	1.14
6	Food, Drink and Tobacco	242 758	544 587 113	379 837	0.70
7	Textiles	183 482	410 999 680	61 819	0.15
8	Wood	131 451	313 839 263	249 028	0.79
9	Printing and Paper	63 492	141 745 890	49 202	0.35
10	Chemical	174 094	383 587 113	258 356	0.67
11	Leather	34 276	75 492 890	18 627	0.25
12	Glass, Brick and Tiles	60 497	122 506 425	142 376	1.16
13	Iron and Steel	515 567	1 202 817 811	924 265	0.77
14	Diamonds, Asbestos and Bitumen	18 563	44 644 015	38 994	0.87
15	Trade and Commerce	781 431	1 773 848 370	568 249	0.32
16	Banking, Finance and Insurance	230 806	523 929 620	37 670	0.07
17	Transport	333 955	758 077 850	1 008 610	1.33
18	Local Authorities	166 826	378 695 020	179 664	0.47
19	Personal Services and Hotels	457 081	1 037 573 870	497 944	0.48
20	Entertainment and Sport	35 712	81 066 240	13 578	0.17
21	Medical Services	124 835	283 375 450	23 463	0.08
22	Professional Services	157 389	357 273 030	43 437	0.12
23	Education Services	161 195	365 912 650	83 424	0.23
24	Charitable, Religious, Political and Trade Organisations	78876	179 048 520	19 911	0.11
TOTAL		4 919 347	11 169 892 630	6 604 831	0.59

Source: Compensation Commissioner, 2008, p.18.

Tables 2.1 and 2.2 show that construction industry had 290 444 number of workmen and 654 951 220 hours exposed to risk. This means that construction industry contributes 6% to the overall total number of workers on the South African economy.

According to table 2.1, construction industry has the fifth highest number of occupational health and safety accidents sitting at 3 203, and is the ninth highest contributor of disabling injury incident rate of 4.89. The average number of accidents for all industries is 1 906 and the overall disabling injury incident rate for all industries is 3.92. This shows that construction industry's occupation accidents are higher than the norm of the industries of the South African economy.

According to table 2.2, construction industry has the fourth highest number of time lost according to the extent of disablement at 746 157 days. Construction industry has the fifth highest number of accident severity rate among the classified industries sitting at 1.14. Thus the construction industry looses 1.14 days per 1 000 hours worked due to accidents. The average severity rate for all industries is 0.59 and overall average lost time according to the extent of disablement is 287 167 days. This means that lost time due to accidents in the construction industry doubles the average lost time of the industries in the South African economy.

2.3 Project Risk Management

Introducing risk management in his book, Dallas (2006, p.5) quotes Latham's constructing the team report, and postulates that construction projects are not free of risks, therefore these inherent risks need to be managed and ignoring them is not a technique to be used. Since risks are inherent to construction projects, management of project risks is inevitable if construction contractor are to complete projects within their objectives. Van Wyk, Bowen and Akontoye (2008, p.149) claim that risk management forms an integral part of the project management of construction projects in order to minimise uncertainties and achieve project objectives. Kwak and

Smith (2009, p.814) argue that lack of a systematic approach to manage project risks lead to schedule and cost overruns.

2.3.1 Project risk

There is a consensus among construction stakeholders that due to the nature of its activities construction industry is a complex business and prone to risks (Garrido, Ruotolo, Ribeiro and Naked, 2011, p.243). Taroum (2010, p.52) suggests that project risk is connected to processes and decisions that are made during the life-cycle of the project. Chapman (2006, p.303) hypothesises that it not contentious that construction projects call for effective and efficient management of project risks and uncertainties. A number of authors have written widely about project risk, but it still lacks an agreed clear definition. However most of the definitions are similar.

According to the Project Management Institute (2008, p.446) project risk is a doubtful event that can create the possibility of a negative or positive outcome on the objectives of the project if it occurs. Dallas (2006, p.34) added on the definition given by Project Management Institute and defined project risk as an uncertain event that its occurrence will have a consequence on the realisation of the project objectives. Anton, Rodriguez and Lopez (2011, p. 12325) hypothesise that though most of construction risks are associated with negative outcome, opportunities are also presented by these risks.

From the above definitions, it can be concluded that risk is associated with "uncertain" circumstances, conditions or events. Oxford Student's Dictionary defines uncertainty as a situation where one is not completely confident or sure about something. In this context, risk is being associated with events where no-one is sure of their occurrence. Then the question is how contractors deal with these uncertain events if they are to complete the projects within schedule, budget, expected quality and satisfactory safety performance. However, it is worth mentioning that cost overrun, schedule overrun, inferior quality and poor safety performance are not events but potential impacts or consequences of the occurrence of project risks.

Further research by Smith, Merna and Jobling (2006, p.4) differentiate risk from uncertainty. They claim that uncertainty happen when the possibility of an event to occur and its consequence are not known, whereas project risk can be defined as an event where statistical probability can be used to predict the occurrence of that event and its outcome. This means that the occurrence of uncertainty events is not known and even their effects on the project objectives will also not be known. Figure 2.1 shows the major difference between risk and uncertainty.

Table 2.3: Distinction between project risk and uncertainty events

Description	**Risk**	**Uncertainty**
Event identification	Yes	No
Probability of occurrence	Yes	No
Quantifiable outcome	Yes	No

Source: Author's own assessment, 2011.

Smith, Merna and Jobling (2006, p.4) redefined risk and uncertainty as follows:

- Risk is when an event can be identified, the probability of its occurrence can be estimated and its effect on the project can be measured.
- Uncertainty is the event cannot be identified, probability of occurrence is not known and the consequence of the event cannot be quantified.

Loosemore et al. (2006, p.9) noted that risk uses statistical data to produce an evaluation of an event or circumstances while evaluation of an uncertainty event relies on informed opinion. According Olsson (2007, p. 747) when an uncertain event is measurable it is considered to be a risk. Burtonshaw-Gunn (2009, p.10) aptly echoed Smith, Merna and Jobling's theory and argue that the occurrence of a project risk can be viewed either as a threat to attain the objectives of the project or opportunity that can benefit the project by increasing the contractor's ability of achieving project goals. Since risks have either negative or positive effects on the project objectives, construction contractors together with project team should manage project risks carefully. The contractor's aim is to complete the project on time, within targeted costs and with the desired quality, and with no harm to employees and anyone visiting the project. Therefore it is the contractor's discretion to view risk as either a threat or an opportunity and manage it. This means that the contractor can manage risk to his advantage or detriment. Unfortunately when the word risk is mentioned, a lot of contractors think of negative effect only. This research is attempting to change that perception and show contractors that risk can be an opportunity to achieve project objectives. The threat or opportunity can only be realised if the contractor performs risk management process thoroughly.

In contrast to the above theories, OHS Act (SOUTH AFRICA, 2008, p.6) defines risk as the likelihood of damage or injury to occur. This definition looks at a risk as a potential for a loss only. The biggest downfall of such a mentality is that opportunities are usually neglected when too much emphasis is put on potential losses. Thus the occurrences of a risk will have adverse consequences to the project parameters. This can then be expressed as the product of a probability of an event multiplied by impact of a loss. In a formula this is shown as:

Risk = Likelihood of event x Magnitude of loss;

Where:

> Likelihood of an event is a number between zero (0) and one (1) inclusive, with 0 representing the lowest probability and 1 representing the highest probability; and

> Magnitude of loss represents the effect of a loss to project parameters quantified as low, medium, high or extreme.

Nonetheless, the author has decided to lean more on a definition given by Loosemore et al. (2006, p.10). They noted that projects risk is concerned with unpredictable events that might occur in the future whose exact likelihood & outcome is uncertain but could potentially affect their interests or objectives in a positive or negative way. This definition adds on OHS Act's definition and highlights that opportunities can also be realised should risk occur. This can then be expressed as a product of the likelihood of an event multiplied by impact such occurrence will have on the project, measured as a loss or gain. Therefore the project risk formula given above can be redefined as follows:

Project Risk = Likelihood of event x Magnitude of loss/gain

Where:

> Probability of an event is a number between zero (0) and one (1) inclusive, with 0 representing the lowest probability and 1 representing the highest probability; and

> Magnitude of loss represents the effect of a loss or gain to project parameters quantified as low, medium, high or extreme.

According to Kutsch and Hall (2005, p.595), project managers deny or / and conceal project risks rather than discussing them with their clients. They further claim that they cover up in order to reduce client consternation and anxiety.

2.3.2 Risk management

Abd-Karim et al. (2011, p. 2471) indicated that risk management concept originates from gambling where profits are made based on prediction. Many contractors know and believe that risk exists in construction projects but only a few practice risk management. Flanagan and Norman (1993, p.23) pronounce that most of the contractors rely on intuition or experience than to risk management process. They further suggest that project risk management is a systematic way of identifying and quantifying all project risks in order to make an informed decision to manage them effectively. El-Sayegh (2008, p. 438) argues that failure to deal with project risks satisfactorily has resulted in schedule and cost overruns in the construction industry.

Project Management Institute (2008, p.273) builds on Flanagan and Norman's definition and adds that risk management involves the process of increasing the benefits that results from positive events and reducing consequences of undesirable events. Therefore risk management is about minimizing the threats of failure as much as it is about maximising opportunities of gains (Loosemore et al., 2006, p.12).

Demir and Bostanci (2010, p.1587) suggest that risk management guarantees that project resources are efficiently and effectively used to advance intended project objectives. According to Smith, Merna and Jobling (2006, p.2), the following benefits are realised if a formal project risk management process is followed:

1) Clarification and understanding of project issues are known from the start;
2) Methodical analysis assist to make informed decisions;
3) Project monitoring function becomes a continuous responsibility until the completion of the project.
4) Historical data can be accumulated easily in order to assist with future procedures of risk management

Despite all the advantages listed above many organisations are still reluctant to deploy and invest meaningful resources to formal risk management. Smith, Merna and Jobling (2006, p.2) suggest that organisations think that risk management waste time but these organisations spend lot of time and money correcting projects that have deviated from original plans. Loosemore et al. (2006, p.7) further argue that though it is usually difficult to point a finger at a single party at fault, many organisations that are involved in occupational accidents do not have an effective risk management system in place or do not implement it effectively. This means that most of the projects that experience high frequency rate can be traced back to lack of risk management.

According to Project Management Institute (2008, p.273), project risk management process can be summarised by the following four sequential steps:

a) Identification of project risks – at this step project risks that may affect the project are identified and their characteristics are documented.

b) Assessment of project risks – the impact of identified project risks on the objectives of the project are analysed or assessed either through qualitatively or quantitatively process.

c) Planning of project risks responses – this is the stage where plan of action is developed on how to deal with identified and assessed project risks.

d) Monitoring and controlling of project risks – at this stage, the plan of responding to project risks is implemented, identified project risks are tracked, residual project risks are monitored, and the whole process start again from project risk identification until monitoring throughout the life-cycle of the project.

Loosemore et al. (2006, p.29) suggest that the aim of any project is not to avoid project risks but to take calculated risks, make more informed decision, identify opportunities and avoid surprises. Therefore the ultimate objective of project risk management is to ensure that project objectives are achieved and ideally exceeded with very little hustle if not nothing at all.

2.4 Safety Risk Management

The International Labour Organisation (ILO) occupational safety and health convention, 1981 (No. 155) push for employers to ensure that the working place is as safe as reasonably practical, equipments and machines used are safe and fit for use, and that the working place is free from risks that can adversely affect the health of employees and visiting persons. South Africa is a participant to the ILO convention. Therefore South Africa is expected to ensure that all workplaces and equipments used at workplaces are injury free. To drive the necessity of having a safe working place, the Occupational Health and Safety Act, 1993 state exactly what the ILO has stated to ensure that South African working places are a safe place for all.

As already stated many business enterprises are increasingly using risk management as a tool to enhance their performance and products. Construction enterprises can also use risk management to attain the objectives of the project, which are completing the project on time, within budget, to the desired quality and without safety casualties. Trethewy, Cross and Marosszeky (1999, p.909) cite that despite its poor record in health and safety, formal risk assessment and management techniques are not widely used in the building and construction industry.

According to Lingard and Rowlinson (2005, p.18) safety relates to the freedom from risks that are harmful to a person or group of persons, either local to hazards. Because of the need to have a safe working place a systematic management of workplace risks is a necessity and risk management provides such a systematic process. Edwards (1995, p.1) emphasised the use of risk management to manage project safety risks and postulates that other industries have already assimilated risk management technique in dealing with their risks, therefore construction industry should follow suit and apply risk management process to control project safety risks.

However project safety risk management is not a linear process that is performed once and everything thereafter fall into place, but an interaction process that involves a continuous cycle of safety hazards identification, assessment, treatment, reviewing and monitoring. Loosemore et al. (2006, p.29) say that risk management is concerned with continuous management of opportunities that arises should the risky event occur and potential threats that may occur. The ways in which project safety risks are treated, reviewed and monitored is dependent on how these risks were identified and assessed.

Figure 2.1 shows the project safety risk management stages and the linkages between these stages are discussed in more detail below.

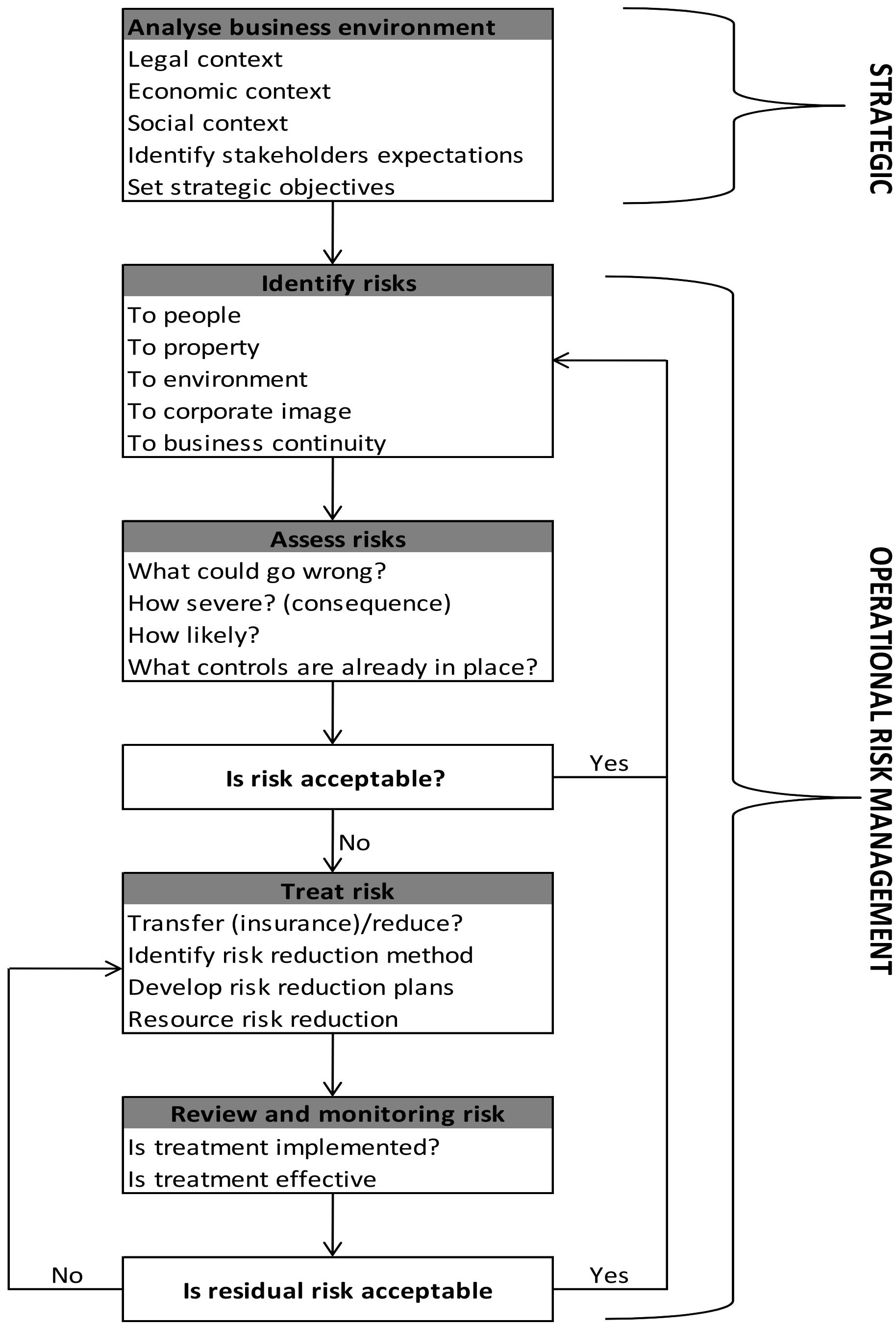

Figure 2.1: Project Safety Risk Management (Standards Australia, 1999, p.11)

2.4.1 Analyse business environment

This stage happens at the company's strategic level and it enables contractors understand the environment within which their enterprises operate. That is, project safety risks are dealt with at an executive level to ensure that thorough project safety risk management policies are in line with the organisation's strategies. However, this research report will not discuss this sub-topic into details because the research report is focused on safety risk management at implementation or operational level, which is at construction site level.

2.4.2 Risks identification

Having analysed the business environment and goals the next stage is to identify safety risks. Risk identification involves the process of identifying project safety risks that may affect the objectives of the project and recording of such risks (PMI, 2008, p.282). Thus the identification of project safety risks according to occupational health and safety. Dikmen, Birgonul and Han (2007, p. 494) posit that successful identification of project safety risks lead to successful management of those risks, which involves assessment of the magnitude of their occurrence and implementation of response strategy to deal with them.

According to Burke (2009, p.276) project safety risks identification process is in many ways the most important stage of the project safety risk management processes because if you cannot identify a project safety risk, it would be excluded from further analysis and consequently such risk cannot be managed or would impose difficulties to manage. Such unidentified risks may cause accidents which will affect cost, productivity, quality and safety negatively. Only identified, described and understandable project safety risks can be managed effectively (Pritchard, 2005, p.35).

Key questions that are asked at this stage are “why is this event a safety risk?”, “where and how could problems arise?”, “what happens if the safety risk eventuates?” and “how can it impact on achieving the project’s objectives?”.

Burtonshaw-Gunn (2009, p.38) claims that the identification of project safety risks is usually done by risk management team or chosen individuals with project experience followed by a second iteration by the entire team with the primary stakeholders. There are techniques used to identify project safety risks. According to Pritchard (2005, p.36) the tools and techniques that are used to identify project safety risks depend on the project they would be applied to since each project has its own challenges and dynamics. The following are the tools and techniques used to identify project safety risks:

a) Structured questionnaires and interviews

This technique uses structured questionnaires and interviews with industry experts, colleagues and all stakeholders to identify risks that the project may experience (Hulett, 2009, p.87). The objective is to get clear descriptions of the project risks.

b) Brainstorming

This is probably the most used technique in identifying project risks. The aims of brainstorming are to obtain a detailed list of project risks and capture all risks mentioned during the process (PMI, 2008, p.286). Brainstorming can be done with anyone who has interest on a project and is directed by a facilitator. The main advantages of brainstorming are that it involves all stakeholders and does not limit participants’ thinking to a specific project only, while its disadvantage is that if the technique is dominated by strong characters other participated may be prevented from contributing (Summerhayes, 2010, p.92).

c) Checklist (Historical data)

According to Edwards and Bowen (2005, p.103), the goal of historical data is to learn from similar past projects. This is achieved by accessing historical information and knowledge gained from completed projects both internally and externally. Edwards and Bowen (2005, p.103) further claim that the checklist's strong point is that it is quick and simple to do and use, whereas its main drawback is that it is not possible to have an exhaustive list of the project safety risks. It is important to mention that the checklist can be significantly improved by updating it every time a project is closed out for use on subsequent projects.

d) Flow charts (build-method, walk-through)

According to PMI (2008, p.286), flow charts are also referred to as Ishikawa or fishbone diagrams. This technique uses the interaction of various elements and their causation mechanism to identify project safety risks **(**Pritchard, 2005, p.215).

e) Delphi technique

In this technique project risk experts are made to participate in identifying project risks anonymously (PMI, 2008, p.286). Therefore this facilitates consensus on project risks among the experts. According to Summerhayes (2010, p.92), the main benefit of using The Delphi technique is that it removes undue influence of the outcome by one expert and its main disadvantage is that sometimes it may be very slow in getting all a complete desired list of project safety risks.

f) Scenario analysis

This is also referred to as the “what-if” analysis (Burke, 2009, p.277). The scenario analysis technique is developed based on the assumption that every project is conceived and developed under certain hypotheses, scenarios or assumptions Edwards and Bowen (2005, p.110). This technique uses the “what-if” connotation to identify project safety risks, which looks at the inaccuracy, instability, inconsistency or incompleteness of the project assumptions.

These techniques depend on how the project risk management team have been selected and brought together. In many cases, the project safety risks identification process or strategy will be guided by the level in which the project team would like to control project activities and is established during the briefing stage (Dallas, 2006, p.314).

2.4.3 Risk assessment

Kar (2009, p. 89) postulates that many construction projects fail because of their failure to assess project risks. The next stage after identifying project safety risk is to quantify the probability of project safety risks occurring and the impact or consequence to the project. This is the evaluation of the likelihood that the project safety risk will result in harm, the severity of the consequences of such a project safety risk and the degree of their effect on project objectives in relation to time, cost, quality and safety (Schatteman et al., 2008, p.886).

Risk quantification has been summarised as the process where identified and recorded project safety risks are evaluated or assessed and the data that would be used to make decisions on what to do about such risks is also developed (Murray, 2004, p.187) Thus the main concern of risk assessment process is to determine project safety risks that warrant a response. According to Campbell (2008, p.55), risk estimation can be expressed as predicted mortality rates, frequency versus consequence plot and / or expected loss rates.

The type of risk assessment method used depends on the type of safety risks that are being considered and the availability of data. There are two methods of estimating frequency and severity values of the project safety risk. However, these methods are both underpinned by same principle that every event that represents safety risk to a construction project has a probability of happening and consequence if it happens.

2.4.3.1 Qualitative risk assessment

Qualitative risk analysis is based on subjective judgement of both the probability of a project safety risk occurring and the consequence of such project safety risk to project objectives when it occurs (Yung, 2008, p.33). Qualitative risk analysis uses descriptors or words to analyse the project safety risk like low, medium, high and extreme.

Qualitative risk assessment method uses project safety risk matrices to rate the likelihood or probability that such risk will occur and the effect of its consequence. The likelihood and consequence of the project safety risk are ranked using verbal descriptors and cross-referenced to determine the risk position in the matrix. These positions on the risk matrix are used to determine the risk response plan and to determine the main concerns for the implementation of the responses.

Below are the techniques and tools used in qualitative risk analysis:

a) Probability / impact matrix

This method can be applied to the overall project safety risks and also to specific project safety risk events. In other words it helps the project team to highlight project safety risks that requires more attention. In looking at a probability / impact matrix it should be noted that due to the uniqueness of the actual project it may be imperative to produce a series of different severity matrices against the project's criteria for time, cost, quality and safety in addition to an understanding of the relative priority of these factors for the specific project (Burtonshaw-Gunn (2009, p.61).

It is imperative to mention that the probability of an event is a number between zero (0) and one (1) inclusive, with 0 representing the lowest probability and 1 representing the highest probability; and magnitude of loss/gain represent the effect of a loss/gain on the project quantified as low, medium, high or extreme. The magnitude of a loss or gain may be measured by project cost, schedule, quality and safety performance or other quantifiable parameters or multiple parameters scale (Pritchard, 2005, p.40). Table 2.4 shows an example of the severity of the project safety risk to project parameters.

Table 2.4: Impact definitions per Project Parameter

		IMPACT DEFINITIONS				
		Very low	**Low**	**Medium**	**High**	**Very High**
		0.05	**0.1**	**0.2**	**0.4**	**0.8**
PROJECT PARAMETERS	**Cost**	Insignificant cost increase.	< 5% cost increase.	5-10% cost increase.	10-20% cost increase.	> 20% cost increase.
	Programme	Insignificant schedule slippage.	Schedule slippage < 5%.	Overall project slippage 5-10%.	Overall project slippage 10-20%.	Overall project slippage > 20%.
	Scope	Scope decreases, barely noticeable.	Minor areas of scope are affected.	Major areas of scope are affected.	Scope reduction unacceptable to client.	Project end. Item is effectively useless.
	Quality	Quality degradation barely noticeable.	Only very demanding applications are affected.	Quality reduction requires client approval.	Quality reduction is unacceptable to client.	Project end. Item is effectively unacceptable.

Source: Burtonshaw-Gunn, 2009, p.53.

The probability / impact risk matrix rating where the degree of project safety risk is analysed based on the level of the probability of occurrence and the severity of the impact on the project. The probability / impact matrix plots the likelihood of the project safety risk occurring against its effect on the project parameters (Burke, 2009, p.280) and below is a graphical example of the probability / impact matrix (Table 2.5).

Table 2.5: Probability / Impact Matrix

Probability	**Almost Certain**					Extreme risk
	Likely			High risk		
	Moderate		Moderate risk			
	Unlikely					
	Rare	Low risk				
		Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**

Consequence or Severity

Source: Yung, 2008, p.34.

Where:

1. Probability level measures the likelihood of a project safety risk to occur:

   Almost certain means project safety risk is expected to occur in most circumstances.

   Likely means project safety risk will probably occur in most circumstances.

   Moderate means projects safety risk might occur at some time.

   Unlikely means project safety risk could occur at some time.

   Rare means project safety risk may occur only in exceptional circumstances.

2. Consequence or severity level of:

   Insignificant means no injuries, low financial loss.

   Minor means first aid treatment, on-site release immediately contained, medium financial loos.

   Moderate means medical treatment required, on-site release contained with outside assistance, high financial loss.

   Major means extensive injuries, loss of production capability, off-site release with no detrimental effects, major financial loss.

   Catastrophic means death, toxic release off-site with detrimental effect, huge financial loss.

b) Ishikawa (Fishbone diagrams)

The cause and effect diagram explores all the possible or actual causes or inputs resulting in a single effect or output and can be used for problem solving and to examine causes of risk (Burtonshaw-Gunn, 2009, p.64). Therefore Ishikawa diagrams can be used as a tool to discover how a threat or opportunity might arise. According to Pritchard (2005, p.216), the key component of the Ishikawa diagram is to identify the root cause for significant concerns. Figure 2.2 shows a typical example of an Ishikawa diagram.

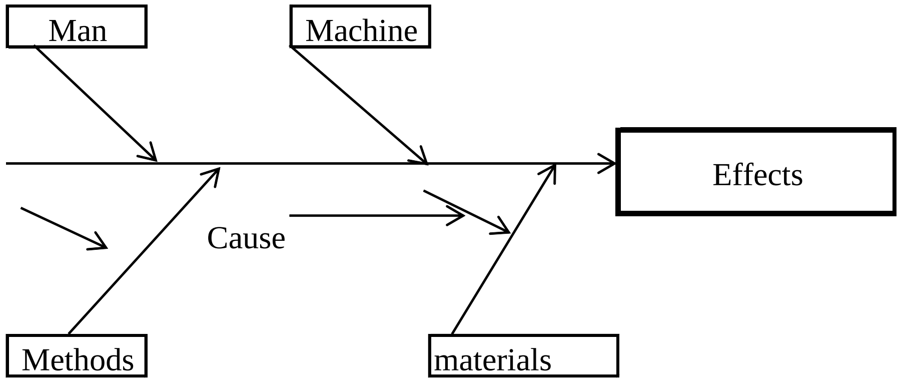

Figure 2.2: Ishikawa Diagram (Pritchard, 2005, p.215)

c) Fault trees

According to Loosemore et al. (2006, p.60), fault tree analysis is a sophisticated analytical technique that uses tree diagrams to predict risk. They further claim that fault tree analysis is concerned with looking for potential faults or weaknesses in a system that might cause failure and mapping the connections between them. Fig 2.3 illustrates a fault tree diagram indicating the logic through which different faults are inter-connected.

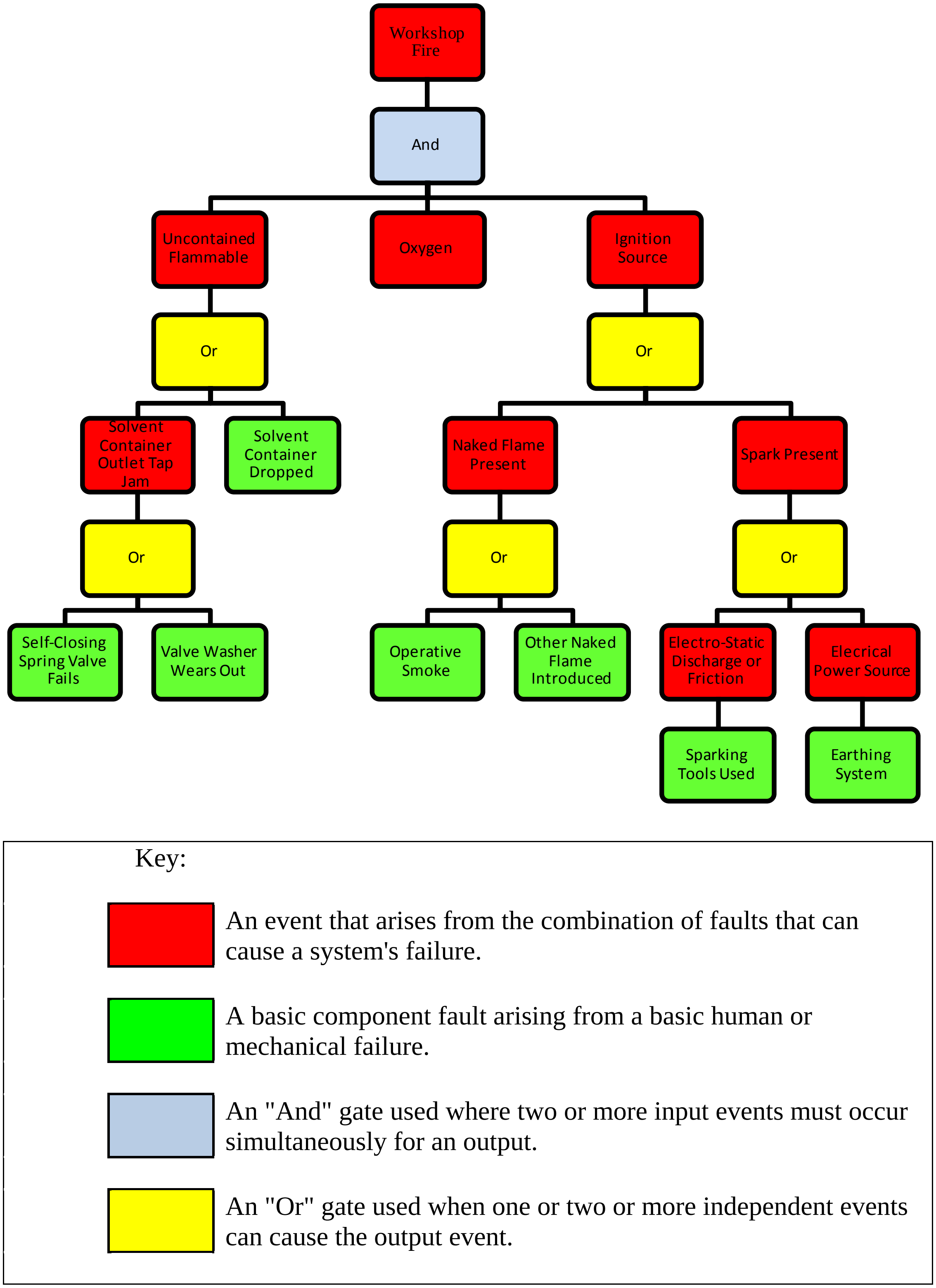

Figure 2.3: A Typical Fault Tree (Loosemore et al. (2006, p.62)

d) Failure Mode and Effect Analysis (FMEA)

According to Burtonshaw-Gunn (2009, p.64), Failure Mode and Effect Analysis starts by considering the risk events and then proceeds to predict all their possible effects in a chart form. Table 2.6 indicates the typical chart form used in FMEA.

Table 2.6: Failure Mode and Effect Analysis

Item	Description	Failure Mode	Cause of Failure	Effect	Remedy: Recommend action
1					
2					
3					

Source: Burtonshaw-Gunn, 2009, p.65.

2.4.3.1.1 Summary of qualitative risk assessment

The worth in each of these qualitative risk assessment techniques depends on the systematic way of approach, which forces discipline and consistent evaluation of project safety risks. Probability impact matrix technique analyses the project safety risk based on the matrix of the likelihood of occurrence and the severity of impact on the project objectives. Ishikawa, fault trees and FMEA methods generally look at the root cause of the project safety risk. Therefore these techniques can be used to discover how an opportunity or gain might arise throughout the life-cycle of the project.

2.4.3.2 Quantitative risk assessment

Quantitative risk analysis follows on from qualitative risk analysis and it uses statistical concept (numerically) to analyse the likelihood of each risk to occur and its consequences on the objectives of the project (Burtonshaw-Gunn, 2009, p.65). Lingard and Rowlinson (2005, p.200) echo Burtonshaw-Gunn theory and postulate that quantitative risk analysis assign numerical values to the represent the maximum possible loss that could arise as a result of the risk, the frequency with which the risk is identified during inspections and the probability with which the risk will result in the harm.

The assessment of risk should be undertaken with an understanding of the organisational goals in terms of occupational health and safety. Sometimes risks are borne by external parties to the organisation, such as general public or subcontractors employees. These people may be exposed to project safety risk posed by the construction operations and therefore they should be considered when performing risk assessment.

Quantitative risk analysis uses numerical values to assess probability and impact in order to make a decision on project safety risks. The following are the techniques and tools used in quantitative risk analysis:

a) Expected monetary value (EMV) analysis

Construction companies use monetary values to show their successes or failures in projects. Losses and profits are shown to shareholders & all stakeholders year after year in rand terms. Therefore it is easier to show the impact of project safety risks in rand terms or monetary values. Rand terms in this instance refer to South African Rand.

Pritchard (2005, p.43) defines expected monetary value (EMV) as a numerical impression that takes into account the probability to occur and impact of risks by multiplying those values together to generate a numeric value to be applied in risk decision making. This means that by multiplying two values together (one being probability in percentage & the other being the impact in rand values), the product is what is known as expected monetary value of the project safety risk. The EMV method can be applied at phase during the project to identify the probabilities and relative costs associated with particular courses of action.

EMV aims to give the construction team a value that could be spent on treating a project safety risk. For example, should the expected monetary value be higher than the cost of transferring a project safety risk, the contractor can expend the money and transfer the project safety risk.

b) Programme Evaluation and Review Technique (PERT) analysis

This is a widely used scheduling system that employs use of three durations for each activity, namely, most likely duration, optimistic duration and pessimistic duration (Burtonshaw-Gunn, 2009, p.70). From this three durations Task PERT mean and standard deviation and project PERT duration and standard deviations are established, which allow the contractor to evaluate the likelihood of achieving specific targets based on the network and PERT durations (Pritchard, 2005, p.205). This method is usually used when historical data is insufficient or when team members are reluctant of sharing information.

Nowadays computer systems are used to compute PERT mean and standard deviations. However PERT mean and PERT standard deviations can be calculated by using the following formulae as advocated by (Pritchard, 2005, p.206).

$$\text{PERT Mean} = \frac{\text{Optimistic duration + Pessimistic duarion + (4 x most probable duration)}}{6}$$

$$\text{PERT Standard Deviation} = \frac{\text{Pessimistic duration - Optimistic duration}}{6}$$

c) Monte Carlo simulation

The Monte Carlo method refers to a name that is generally given to any approach that uses simulation method, parametric model for risk-factor changes, to measure project safety risks (McNeil, Frey and Embrechts, 2005, p.52). They further postulate that this method can be either unconditional or conditional model, but the choice of the model depends on whether the project uses a static distribution model or dynamic time series model for risk-factor changes.

The Monte Carlo technique is not only concerned about the project safety risk for individual activities but takes into account the impact of project safety risk on a holistic project level. The technique is applicable when the contractor needs to know the probability that a project would be completed successfully within project parameters. However its main set back is that it relies a lot on the use of computer software that needs structured training and skill to decompose the project safety risk into relative independent sub system; whereas the main advantage of Monte Carlo simulation is that it is able to cope with large data of input distributions which is used to produce probability density and cumulative distribution functions for measuring exposure of the project to safety risks (Loosemore et al., 2006, p.108). These functions are simple yet powerful tools used to decide on the level of exposure that is applicable to the project.

d) Decision tree analysis

Decision tree can be defined as a diagram that graphically represents the decision analysis process, including separate branches for each decision to be made and for each respective event that may result from that decision (Pritchard, 2005, p.362). Therefore the decision tree analysis helps the contractor breakdown project safety risk into various work breakdown structures to simplify potential decision making.

Yung (2008, p.42) cites that the event tree method looks at the event before constructs an event succeeding the formation of a project safety risk for more information which is used to make decision on probability, consequence and rating of such a risk. Figure 2.4 is an illustration of a typical decision tree analysis.

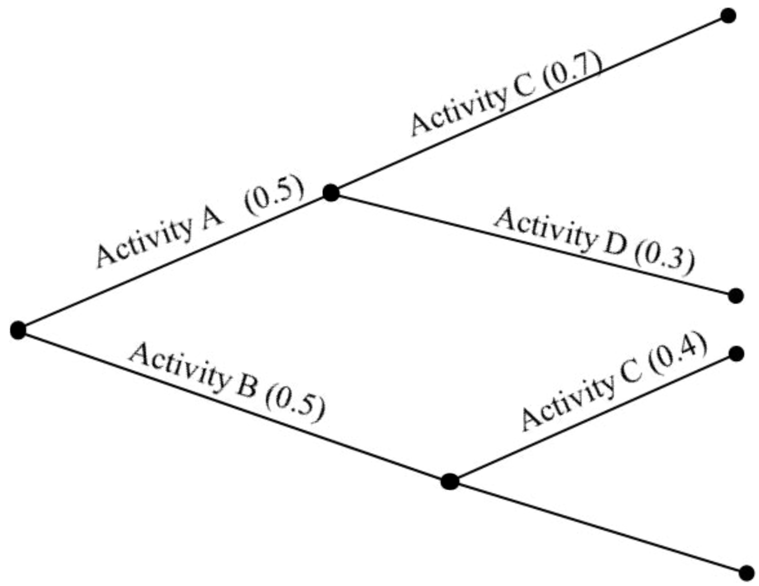

Figure 2.4: A Typical Decision Tree Analysis (Source: Pritchard, 2005, p.334)

e) Expert judgement analysis

This analysis is an insight that is shared by individuals with significant project expertise relating to specific request for information (Pritchard, 2005, p.364). This means that experienced individuals with expertise about a project safety risks on a particular project are requested to offer their advices. These expert individuals can be either from within the company or outside of the company that is busy with a construction project.

However, Pritchard (2005, p.335) advices that when acquiring expert judgement analysis, the following axioms of probability must not be violated:

- ✓ The probability of all possible events must sum to 1.
- ✓ The probability of any event, P(A), must be a number greater than or equal to 0 and less than or equal to 1 ($0 \leq P(A) \leq 1$).
- ✓ The probability of joint events is the product of the probability that one event occurs and the probability that another event occurs, given that the first event

has occurred, P(A) x P(B1|2A)). Under these circumstances, the events are termed dependent.

- ✓ When the probability of joint events' occurring is simply the product of the probabilities of each P(A) x P(B), the events are said to be independent. That is the two events have nothing in common or can occur simultaneously.

2.4.3.2.1 Summary of quantitative risk assessment

Quantitative risk analysis uses numerical values to assess probability and impact in order to make a decision on project safety risks. All the techniques utilise mathematical approaches, which in real life can be challenging and might be time consuming. However, expected monetary value is the most common technique because many construction companies use monetary values to show their successes or failures in projects and it is easier to show the impact of project safety risks in rand terms or monetary values.

2.4.4 Risk response

Having undertaken the project safety risk assessment the contractor, in consultation with project consultants & in some cases with client, should respond to the project safety risks that have the potential of causing threat or opportunity to the project objectives. Wang, Dulaimi and Aguria (2004, p.238) suggest that it is critical that construction contractors decide and formulate a suitable strategy to treat project safety risks. This means that the contractor should have a plan of action on how he / she will deal with project safety risks should they occur. El-Sayegh (2008, p. 437) claims that most of the risks in a construction project is shared by the contractor and client. According to Lam, Wang, Lee and Tsang (2007, p. 485), the allocation of the project risks remains a concern in the construction industry, even though the allocation is usually defined in contract documentation. Therefore it is important to allocate a project safety risk to a party that will best deal and control it.

There are four techniques that contractors can use to respond to project safety risk. The identified techniques are listed below:

a) Risk acceptance

Project safety risk acceptance is the decision to acknowledge and endure the consequences if a risk event occurs (Pritchard, 2005, p.49). It is also referred to as risk assumption (Kerzner, 2003, p.683). According to PMI (2008, p.304), this approach is acknowledged because it is rare, if not impossible, to purge all project safety risks from the project.

Below are two strategies that are used in risk acceptance response:

i. Active acceptance – is when the project team has accepted the project safety risk but with contingency plan to fall back on should the risk occur.

ii. Passive acceptance – is when the project team has accepted the project safety risk with no strategy to take any action to manage or resolve it, except just the documentation of such project safety risks.

b) Risk avoidance

According to PMI (2008, p.303), project safety risk avoidance involves changing the project management plan to eliminate the threat entirely, and the contractor may isolate the project objectives from the risk's impact or change the objective that is in jeopardy. This might seem ideal as it is easy to do, but this response usually introduces other project safety risks.

Loosemore et al. (2006, p.157) summarise risk avoidance and argue that risk taking is the main source of wealth creation in business and prosper. They further claim that it is inevitable that contractors must take risks at some point. However the trick is to avoid project safety risk that cannot be controlled and managed effectively.

c) Risk transfer

This is also known as risk deflection. Burtonshaw-Gunn (2009, p.75) postulate that risk transfer is concerned with moving the consequences of a project safety risk and ownership of the response plan to a third party, for example taking material insurance. It is important to note that risk transfer does not eliminate a risk, but just simply shift the responsibility of managing such a risk to another person or organisation. A good example would be a contractor who subcontracts scaffolding work to a sub-contractor; should the scaffolding collapse on site and cause accident, the main contractor would still be liable since the contractor is him / her who has contractual obligation with the client.

Project safety risks can be deflected to another organisation in many ways such through insurance covers, subcontracting works, warranties, partnerships or vending. Pritchard (2005, p.362) says that project safety deflection is transferring project safety risk from one party to another through insurance, warranties, guarantees or contractual arrangements. According to Editorial (2005, p.3), it is better for the contractor to insure all project safety risks with significant impact on the project objectives if they occur, and manage all project safety risks with high probability of occurring but with small impact on the project targets if they occur.

d) Risk mitigation

Risk mitigation is the process of reducing the likelihood and/or effect of an unfavourable project safety risk to tolerable limits in a construction project (PMI, 2008, p.304). A more comprehensive definition is the one given by Pritchard (2005, p.367) where he claims that risk mitigation is a projects safety risk response strategy designed to proactively minimize either or both the occurrence probability of a project safety risk and the magnitude of its impact to the objectives of the project.

In this strategy, the contractor develops plan of actions to minimise the chances or impact or both of the project safety risk on a construction project. The contractor may use any legal action to execute the plan of action to diminish the impact or probability of the project safety risk. For example, a person using a metal cutting grinder can wear goggles to protect his or her eyes.

2.4.4.1.1 Summary of risk response strategy

Kerzner (2003, p.685) argue that the risk response strategy preferred in many projects is inclined towards the project manager’s tolerance of project safety risks and the magnitude of the impact should such a risk occur. It is significant to note that risk avoidance, risk transfer and risk mitigation approaches require the contractor to take actions, while risk acceptance strategy requires no action. However, all these project risk response methods consume resources.

2.4.5 Risk review and monitoring

Once the risk mitigation steps have been selected, their implementation should be carefully managed. That is those responsible for risk control need to be aware of the events happening during the implementation of the project. Lingard & Rowlinson (2005, p.203) suggest that control measures that are aimed at the source of the project safety risk work better than control measures that are aimed at changing the behaviour of the exposed worker. This means that technological control measures that are intended at eliminating and substituting project safety risks are more favourable than individual or human control.

According to PMI (2008, p.308), monitoring and controlling project safety risks is the process of implementing project safety risk response plans, tracking identified project safety risks, monitoring residual project safety risks, identifying new projects safety risks, and evaluating project safety risk process effectiveness throughout the project life cycle. Thus during this stage, project safety risk audits would be conducted to see how effective the risk management process has been.

2.5 Conclusion

The literature review findings comparative to the questions raised and objectives of the study as outlined in chapter 1 can be summarised as follows:

a) Construction industry contributes disproportionate numbers of work-related injuries and fatalities when compared with other sectors of the South African economy. Though construction industry is inherently risky and complex in nature, most of the accidents have nothing to do with its dynamic environment but more to do with difficulties in identifying, assessing and managing project safety risks.

b) Consequently, these accidents contribute to the cost of construction, directly through increased compensation and insurances, and indirectly through decreased productivity, quality non-compliance, schedule overruns and poor safety performance statistics. This means that project parameters relative to cost, schedule, quality and safety are adversely affected, hence the claim that construction industry delivers expensive building late.

c) Given the late delivery, non-compliance to quality, cost expenditure and loss of lives in construction projects, construction industry has developed a very bad perception and reputation.

d) Risk management technique is acknowledged as one of the tools that can be used by construction contractors to successfully manage project safety risks and enhance performance of construction projects. However, in order for construction contractors to realise full benefits of the risk management process, they should be proactive in the implementation of risk management in their projects.

Chapter 3 - Research Methodology

3.1 Introduction

This chapter explains the type of research methodology that was adopted to carry out this study and reasons for choosing that methodology. It also describes how the research investigation was designed and conducted.

3.2 Research Methodology

The empirical research methodology has been used to accomplish the objectives of the research. The main reason for choosing this methodology is that the effect of safety risk management in the construction projects should be assessed accurately and easily.

To answer the research question, qualitative research approach was predominately followed because the study seeks to understand how project safety risk management can be used by construction contractors to increase overall performance in the South African construction industry. An in depth literature review on project safety risk management in the construction projects was carried out. Research questionnaires were sent out to construction contractors with the purpose of establishing how they are implementing project safety risk management in their projects in South Africa.

3.3 Data Compilation

This section describes how the researched data was compiled. According to Welman, Kruger and Mitchell (2005, p.52), when the researcher conducts a research to investigate a research question or a research hypothesis, that researcher compiles a data from the objects of inquiry in order to solve the problem concerned. The population which the data has been compiled from is fully defined and the sampling method and sample, and size thereof, has been described below.

3.3.1 Research population

According to Welman, Kruger and Mitchell (2005, p.52) a research problem is connected to a definite population and the population includes the entire group of all the units to be analysed. Population can be group of individuals, items or objects. Therefore a population as per Lapin (1993, p.10) can be defined as the collection of all the possible observation of one or more variables.

The population for this study is defined as all the building contractors who are actively registered with Construction Industry Development Board (CIDB) in South Africa. CIDB has been found by the Act of Parliament as a schedule 3A public entity. Its main purpose is to advance framework for regulating and developing delivery capabilities of the South African construction industry (SOUTH AFRICA, 2000, p.2).

As at 04th August 2011, there were 115,204 actively registered construction contractors with the CIDB database. This figure has been adopted as a population for this research report. Table 3.1 shows different CIDB grades and threshold of the registered contractors. The threshold represents the maximum amount the contractor is allowed to tender for on all government contracts.

Table 3.1: CIDB's Active Registered Contractor Database

CIDB Grade	Threshold	No. of
1	R 200,000.00	102,676
2	R 650,000.00	4,274
3	R 2,000,000.00	1,509
4	R 4,000,000.00	2,257
5	R 6,500,000.00	2,069
6	R 13,000,000.00	1,519
7	R 40,000,000.00	565
8	R 130,000,000.00	208
9	No limit	127

Source: CIDB, 04 August 2011.

3.3.2 Research sample

Parasuraman, Grewal and Krishnan (2004, p.356) defines sampling as the process of selecting a small number of the population for analysis purpose with the ultimate aim of drawing general conclusion about the entire population. However, for results to be generalised the sample should be a true representative of the population it comes from (Welman, Kruger and Mitchell, 2005, p.55). Sorinolu (2008, p.48) echoed this concept by claiming that when a research is being undertaken, it is important that the researcher have a sample that will represent the population that is being investigated because investigating the whole population is not always feasible due to time and financial constraints.

According to Holt (1998, p.91), sampling has the following advantages:

- It takes less time and therefore costs less to survey a sample than it would for an entire population
- It is usually extremely difficult to identify and survey every member of a population.
- Some of the test would be unhelpful; hence it is not be practical to test every unit in a population.
- Surveying a sample make it easy to draw a general conclusion with a degree of accuracy about a population.

Probability sampling and non-probability sampling are the two main methods used for sampling. The major distinction between the two methods is that probability sampling involves randomisation and non-probability does not use randomisation. Randomisation means that each unit within a sampling frame has equal probability of being chosen for analysis. It is for this reason that this study has used random sampling.

The study has collected the data using stratified random sampling because the population to be surveyed is divided into groups as per CIDB grading. Given that no sampling method can guarantee a precise elimination of sampling error and biasness, sampling data to be analysed would be drawn from each strata and the minimum sample size would be calculated using simplified formula for proportion as advocated by Israel (1992, p.3). Sidumedi (2009, p.48) summarizes the importance of enough response and claim that higher response rate helps to reduce the problem associated with non response biasness.

The CIDB Health and Safety report (2009, p.22) claims that though there is no scientific evidence in the South African construction industry that suggest that lower grade CIDB registered contractors have worst health and safety performance and culture than contractors with higher CIDB grade. Similarly, accidents frequency rate decreases as the business size grows in the construction industry (Kheni, Gibb and Dainty, 2010, p.1105). Thus it is almost conceivable that small contractors would demonstrate poorer health and safety and performance and culture due to their strict resources and capacity. This means including these lower grading contractors into a study would skew findings and conclusions. Therefore, sampling frame for this research report is consisted of actively registered general building contractors with a 7GB, 8GB and 9GB CIDB grading. That is contractors with Grades of 1GB to 6GB were found to be of little scientific importance, hence they were not included in the sample frame list. And again due to time and financial constraints, the research will only look at the contractors who are registered in the province of Gauteng in South Africa.

As at 15th August 2011, there were 113 actively registered general building contractors with 7GB, 8GB and 9GB with the CIDB database (refer table 3.2) in the Gauteng Province. The minimum sample required for the study has been calculated by using a simplified formula of proportion as advocated by Israel (1992, p.3).

$$n = \frac{N}{1+e^2}$$

Where:

n = the minimum required number of the sample

N = the population size

e = the level of precision; When confidence level is at 95%, precision level is 5%.

The formula relies on the level of precision and the confidence level of the population. Assuming a 95% confidence level, the minimum sample size required for the study would be 101 contractors as per the breakdown below (refer table 3.2). The sample size is further divided into strata for better analysis and to ensure that data is collected from all three stratums.

Table 3.2: Minimum Sample Size Required

Contractor Grading (GB)	Number of Contractors	Sample frame	Sample required	Sample per Stratum
7	62	113	101	53
8	34			31
9	17			16

Source: Author's own assessment.

3.4 Data Collection

There are two main methods of collecting a data, namely qualitative and quantitative method (Lapin, 1993, p.7-8). Quantitative data is all about quantifying the relationship between variable and involves numerical values (Hopkins, 2000, p.1), whereas qualitative research uses non-numerical results to understand a situation (The PREST core team, 2004, p.17). This study has mainly used quantitative technique to collect data.

3.4.1 Research questionnaire

After a thorough literature review and taking account of time constraints it was decided that structured questionnaire would be used to collect the data from the sample. The questionnaire was designed to be as short as possible but straight to the point to achieve its objective.

The main advantages of the structured questionnaire are:

- It is relatively straightforward and quick to complete.
- Respondents have time to think about their responses.
- It is easy to administer and analyse.
- Confidentiality and anonymity is usually preserved.

The main disadvantages of the structured questionnaire are:

- The researcher cannot go back to the respondents for clarity in case of receiving ambiguous answers especially if respondents are anonymous.
- It is occasionally not easy to achieve a satisfactory number of responses, particularly with postal questionnaire.

- Certain questions may be ignored or some of the questions may be incorrectly completed.

On this study the research questionnaire focuses on the way safety risk management approach is practised by the contractors on site. The questionnaire gives a specific focus on the implementation of the risk management processes to manage safety. Because the questionnaire had to be of reasonable length most of the questions were close-ended questions, which require a tick from various possible answers. These close-ended questions make it easy to compare and analyse the responses you get from different contractors.

The questionnaire was also designed to ensure that all data supplied and responses would be treated in the most strict confidence, hence the covering letter explicitly states that all information collected would be used purely for research purposes and that no traceability either to the respondents or their companies was possible.

The questionnaire consists of three main sections, namely general information, risk management procedure and general comments.

The first section, general information, was designed to acquire relevant details about the respondents and the organisation the respondents work for. This is the individual's and company profile.

The second part, risk management procedure, sought to indicate whether the respondents know about risk management processes which can be used to improve the chances of completing the project with its objectives. This section also sought to indicate the way in which risk management techniques with more emphasis on safety are being used or implemented by the contractors to achieve the project's goals.

The third section was designed to obtain what the respondents thought about safety risk management, either as a way of improving project parameters and safety of their projects or as a way of wasting money and time.

The copy of the structured questionnaire that has been used on this research report is attached in Appendix A.

3.4.2 Pilot study

Once the questionnaire was designed, it was sent to three experienced contract managers to critically analyse it with respect to its content and presentation. Piloting was done in order to provide guidelines for rephrasing inappropriate questions to encourage more affluent response and cancel questions that are not relevant.

The main function of the pilot group was to ensure that questions asked in the questionnaire achieve the following:

- The respondents understand instructions and would be able to complete it without difficulties.
- The questionnaire was not ambiguous and it is easy to understand.
- The respondents will not get bored or offended by the questions asked.
- The logic behind the questions and pre-determined responses were correct.
- The presentation of the questions was not congested or confusing, that is the questionnaire design should be appealing and professional.

The pilot study group found that the questionnaire was taking too long to complete. It was taking 15-20 uninterrupted minutes. The group recommended that some of the questions that were not relevant to the hypothesis and objectives of the research be omitted. The group also suggested that questions that needed a written response should be replaced with questions that offer ticking option.

3.5 Data Analysis

Inference statistical method has been used to make conclusion and recommendation of the research report. In order to analyse the data to test hypothesis the research has utilized effect statistics of mean, standard deviation and Spearman rank-order correlation coefficient. The effect statistics method was chosen because it enables the researcher to measure the effect of safety risk management on the parameters of the construction project in relation to schedule, cost, quality and safety. Therefore the measuring instrument of the study is the project goals of schedule, cost, quality and safety. The hypothesis statement of the research is as follows:

- There is a positive relationship between project safety risk management and project parameters.

3.5.1 Mean

According to Welman, Kruger and Mitchell (2005, p.233), mean is the arithmetic average of a set of scores and it is usually denoted by $\bar{x}$. Thus the sum of all values observed values divided by the total number of observations. The mean is used to measure the central tendency of the data. The statistical formula of the mean is shown as follows:

$$\bar{x} = \sum_{i=1}^{n} xi$$

Where:

$\bar{x}$ = the mean of the sample

n = the number of observation in a sample

x = the observation of elementary units in a sample

3.5.2 Standard deviation

Eysenck (2004, p.11) claims that standard deviation is a dispersal of special significance to the normal distribution, and is the square root of the variance. Standard deviation has been used in this research report to check if whether the score of all the observations are spread out or similar to each other and also shows how the data is spread around the mean. The statistical formula for standard deviation is:

$$s = \sqrt{\frac{\sum x^2 - n\bar{x}^2}{n-1}}$$

Where:

S = the standard deviation of the sample

n = the number of observation in a sample

x = the observation of elementary units in a sample

$\bar{x}$ = the sample mean

3.5.3 Spearman's rank-order correlation coefficient

The study utilised Spearman rank-order correlation coefficient to establish a relationship between project safety risk management and project goals of schedule, cost, quality and safety. According to Lapin (1993, p.846) sample correlation is used to measure the level in which two variables are associated. Welman, Kruger and Mitchell (2005, p.229-230) suggest that the Spearman rank-order correlation coefficient should be used when both variables are ordinal or if variables are going to be converted into ranks, however the study utilised the Spearman rank-order correlation coefficient only when the two variables were ordinal. According to

The Spearman's rank-order correlation coefficient was used to analyse the collected data due to the following three reasons as advocated by Gauthier (2001, p.359).

- It is a nonparametric technique and therefore it is not affected by the distribution of the population.
- It is relatively insensitive to outliers because the technique operates on the ranks of the data.
- It can be used with a very small sample size.

The Spearman rank-order correlation coefficient is shown in calculation as follows:

$$r_s = 1 - \frac{6\sum(x-y)^2}{n(n^2-1)}$$

Where:

r_s = Spearman rank-order correlation coefficient of the data

x = the ordinal independent variables of the research (safety risk management data)

y = the ordinal dependant variables of the research (schedule, cost and quality)

n = the number of observation in a sample

3.6 Ethical Issues

According to Saunders, Lewis and Thornhill (2009, p.160), the rights of the research participants should be protected from harm, embarrassment or any significant disadvantage. In order to fully protect the rights of the participants, the following key issues were adopted during research design:

- The purpose of the research and what the researcher hopes to do with the results were explicitly explained to all participants.

- Voluntary participation was encouraged, therefore no person was pressurised into participating in research. Thus no penalty was enforced against anyone who decided not to participate in the research.
- Research procedures and risks were elucidated to all participants and their unequivocal consent was obtained.
- Strict confidentiality of information and anonymity of participants were guaranteed.

Without infringing on participants' rights, all participants were made aware that the research would be used purely for academic purposes.

3.7 Conclusion

One hundred and one (101) research questionnaires were disseminated to construction contractors in the Gauteng Province of South Africa. The questionnaire was made to be as short as possible. Pilot study was also undertaken to ensure that the questions asked are not inappropriate and ambiguous, and are simple to complete.

The study utilised Spearman rank-order correlation coefficient to establish a relationship between project safety risk management and project goals of schedule, cost, quality and safety.

Chapter 4 - Survey Results and Discussion

4.1 Introduction

In this chapter the main findings of the study, which seek to address the research question and hypothesis statement, are presented. The objectives of the research are also discussed. These findings are based on information provided by survey results and literature review.

4.2 Response to Questionnaires

A total of 101 research questionnaires were disseminated to Grade 7, 8 and 9 contractors. Fifty four (54) were sent to Grade 7 contractors, thirty one (31) to Grade 8 contractors and Sixteen (16) were distributed to Grade 9 contractors. 81 questionnaires were sent by electronically mail whereas the other 20 were hand delivered; this represents that 80% of questionnaires were electronically mailed and 20% were hand delivered.

Out of the 101 questionnaires distributed, a total of 58 responses were received from contractors of different CIDB Grades. Thirty (30) questionnaires were received from Grade 7 contractors while Eighteen (18) and ten (10) were received from contractors with Grade 8 and 9 respectively. It is important to highlight that four (4) contractors have registered interest on a copy of the final document of the research report. The overall response rate was 59%, which was found satisfactory for the study.

Table 4.1 illustrates the number of questionnaires that were distributed to contractors with different CIDB grades and the response received.

Table 4.1: Questionnaire Response Rate

Contractor Grading (GB)	Questionnaire Distributed	Questionnaire Received	Response Rate (%)
7	54	30	56%
8	31	18	58%
9	16	10	63%
Total	**101**	**58**	**59%**

For results to be generalised the sample should be a true representative of the population it comes from (Welman, Kruger and Mitchell, 2005, p.55). This means that the sample to be used to arrive at a conclusion should not be too big or too small but large enough for the researcher to make a decisive conclusion about the population. Sorinolu (2008, p.48) echoed this concept by claiming that when a research is being undertaken, it is important that the researcher have a sample that will represent the population that is being investigated because investigating the whole population is not always feasible due to time and financial constraints.

Therefore it is crucial to have sufficient response in order to make an inference decision when conducting a research survey. Sidumedi (2009, p.48) summarizes the importance of enough response and claim that higher response rate helps to reduce the problem associated with non response biasness. As already mentioned, the response rate of fifty nine percent (59%) for the study was found satisfactory.

4.3 Profile of the Respondents

This section of the questionnaire, general information, was designed to acquire relevant details about the respondents and the organisation the respondents work for. That is the individual's profile, project details and company profile. The demographic characteristics of the respondents are covered in the graphs and discussions below.

a) Experience in the construction industry

In order to determine the length of experience and knowledge in the construction industry, survey participants were asked to indicate the number of years that they have been working in the construction industry.

Figure 4.1 shows that five percent (5%) of the respondents have less than five years of work experience in the construction industry. Majority of the respondents, sitting at forty one percent (41%), have between 11-15 years construction industry work experience. The remaining twenty six percent (26%), twenty one percent (21%) and seven percent (7%) represent respondents with construction experience of 5-10 years, 16-20 years and greater than twenty years respectively.

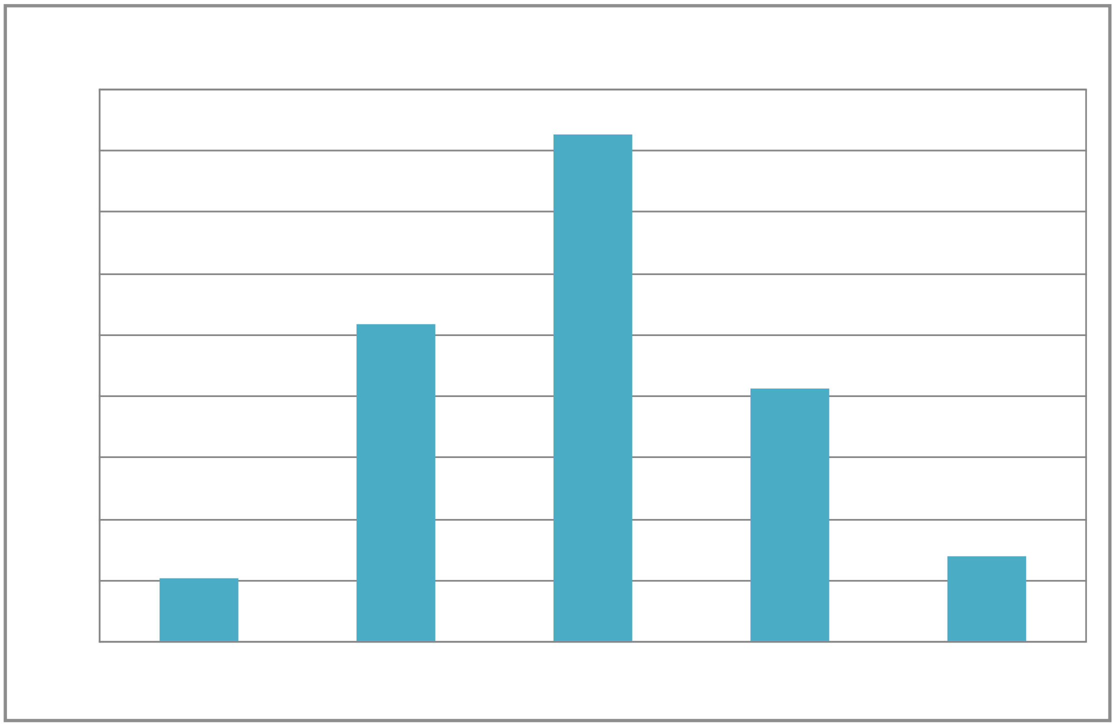

Figure 4.1: Respondents' number of years in the construction industry

b) Position in the organisation

The question sought to understand the influence individual respondents may have in the organisations they represent and projects they work on. This was found to be invaluable information that would benefit the study in that the information obtained is from individuals with enough influence and power on how project safety risk should be applied in the project.

Figure 4.2 reveals that nine percent (9%) of the participants were directors whilst forty one percent (41%) were project managers and nineteen percent (19%) were construction managers. This means that sixty nine percent (69%) of the respondents were senior managers who would normally have power to influence the implementation of project safety risk management on construction projects. That also helps in strengthening the credibility and authenticity of the information obtained from the survey.

The remaining twenty nine percent (29%) of the respondents were split between safety managers, risk managers and other, with sixteen percent (16%), seventeen (17%) and six percent (6%) respectively.

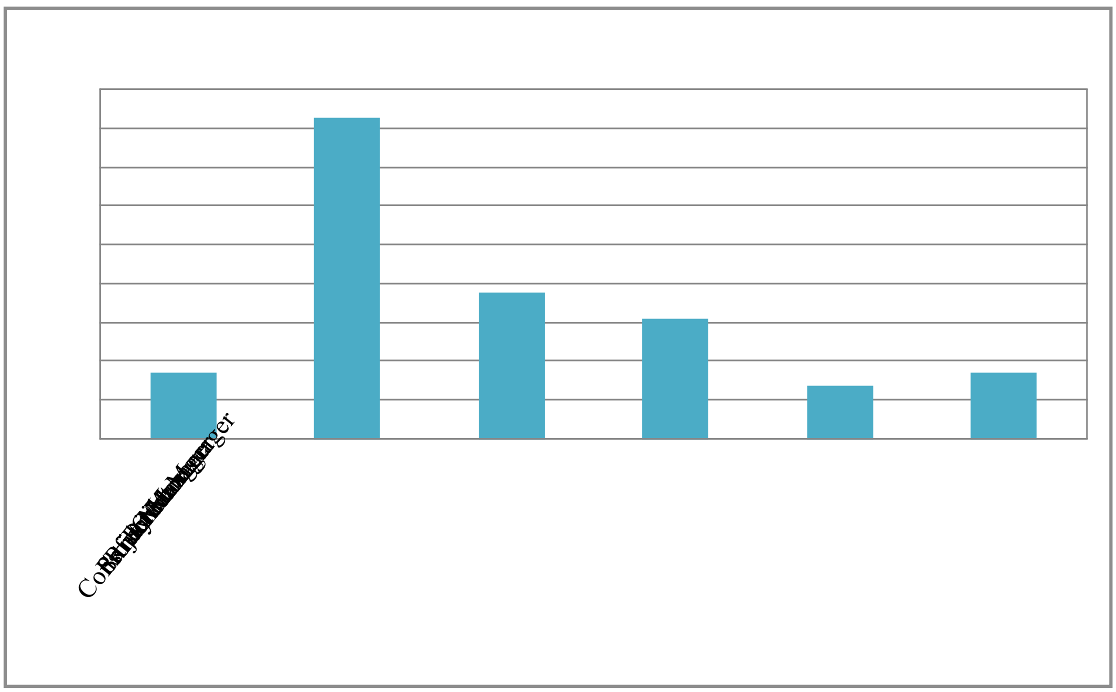

Figure 4.2: Position of the respondents in their organisation

c) Project value of the respondents

Figure 4.3 reveals that fifty two percent (52%) of the respondents are currently working on projects with a value of between R51-R100 million rand, and twenty nine percent (29%) are working on project with a value of between R11-R50 million rand. Three percent (3%) of the respondents indicated that they are working on projects with a value of between R1-R10 million rand whilst sixteen percents (16%) are working on projects that are more than R100 million rand in value.

The above percentages point out clearly that boom days of huge projects, such as soccer stadiums and highway roads projects, are over. In many construction magazines and built environment circles you will often read and hear that the construction boom has burst. This means that construction industry needs eminent intervention in terms of projects if it is to continue being one of the significant players in the South African economy.

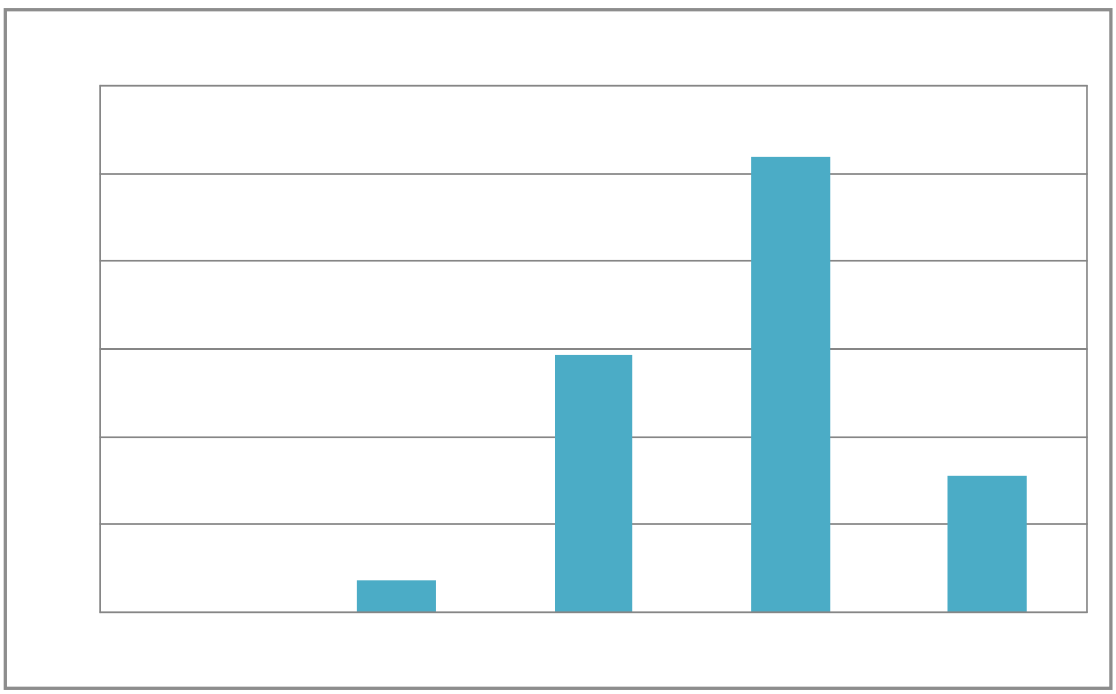

Figure 4.3: Value of the projects that the respondents are currently working on

d) Project safety management plan

The survey results show that majority of the respondents, sitting at seventy eight percent (78%), have formal safety management plan in their organisation whereas only twenty two percent (22%) have shown that they are not certain if their organisations have formal safety management plan as demonstrated in Figure 4.4.

The high number of respondents with formal safety management plan could be attributed to the statutory and Construction Industry Development Board requirements that is placed on construction contractors with at least Grade 7 CIDB rating. As stated in Chapter 2 in the literature review, principals and employees of the construction organisations can be found to be personally responsible for incidents and accidents that happen on their projects, and in a worst case scenario a criminal case may be laid against them should they be found to have transgressed legislated safety requirements.

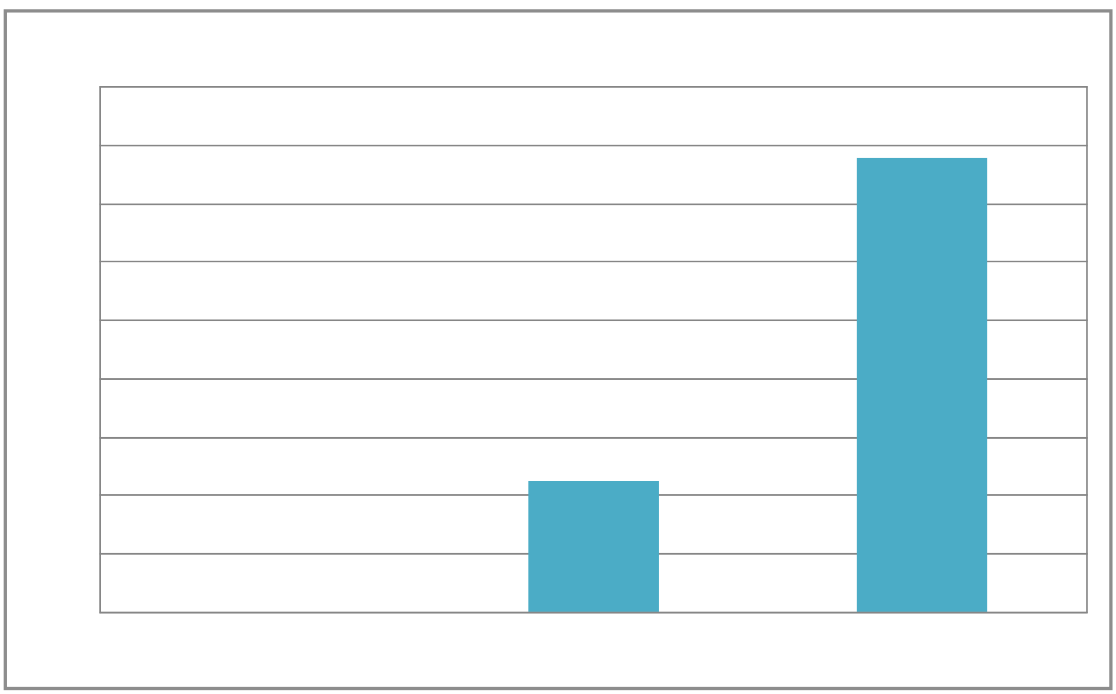

Figure 4.4: Safety management policy in the respondents' organisations

e) Project risk management plan

This question seeks to find out if organisations the respondents represent have any formal risk management policy and it was a follow up on the question under 4.2.5. Figure 4.5 indicates that twenty nine percent (29%) of the respondents do not know if their organisations have a formal risk management policy or not, whilst seventy one percent (71%) have indicated that they have formal risk management policy in their organisations.

Again, this high number of percentage of organisations with formal risk management policy could be attributed to statutory requirements. The literature review provided that construction contractors are required to have risk assessment done before any activity is performed on site.

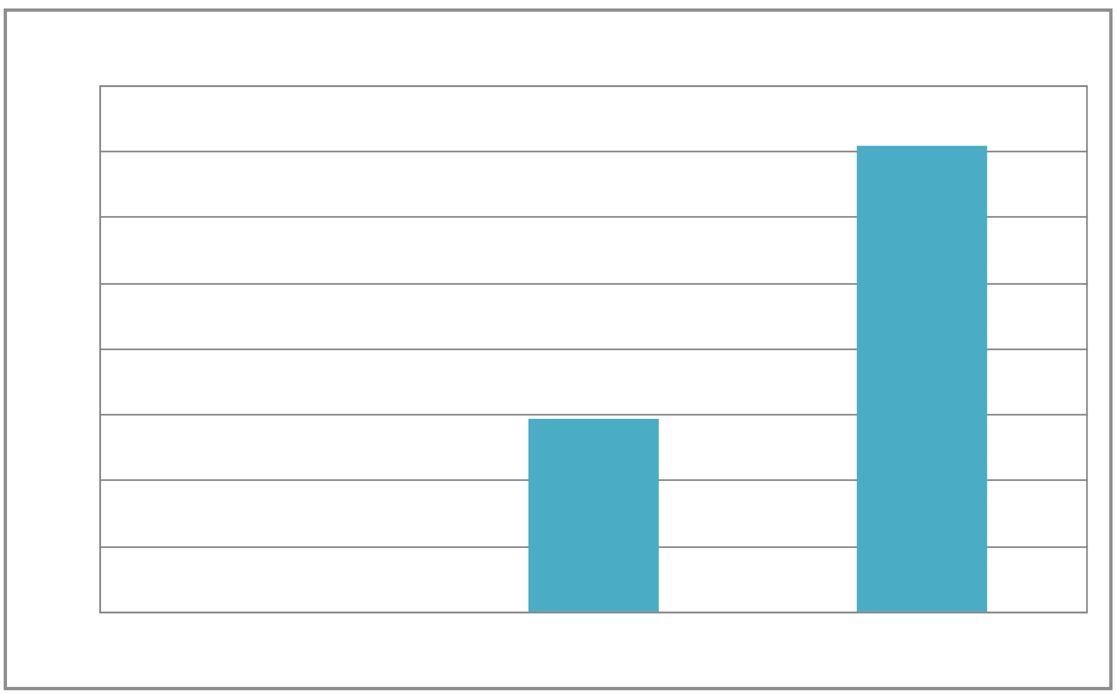

Figure 4.5: Risk management policy (RMP) in the respondents' organisations

f) Project safety risk responsibility

Figure 4.6 illustrates that only sixteen percent (16%) of the respondents indicated that the responsibility of implementing project safety risk management in their projects rests with the client, contractor and professional consultants. This means that the whole team contributes to the success and failure of the project.

The figure also shows that thirty one percent (31%) of the respondents claim that contractors are solely responsible for the project safety risk management in their projects whereas nineteen percent (16%) say that the client and professional consultants are responsible. Thirty four percents indicated that the custodian of the project safety risk management in their project is the client and the contractor.

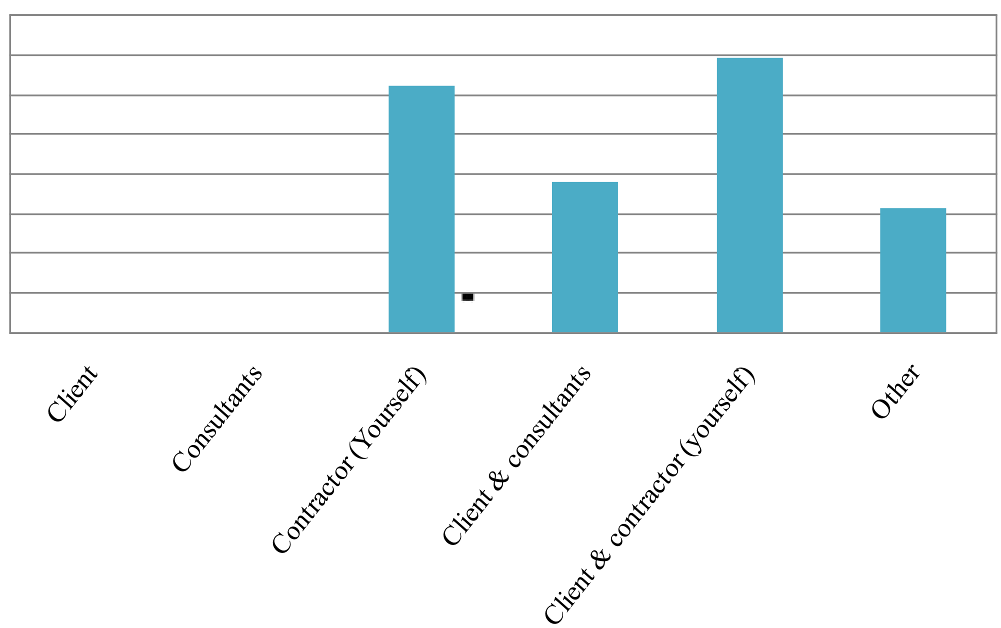

Figure 4.6: Person(s) responsible for project safety risk management in the respondents' projects

g) Project safety risk definition

Fig 4.7 indicates that forty five percent (45%) of the respondents defines project safety risk as combination of the likelihood of a hazard and the quantity measure of the uncertainty associated with estimates of various outcomes. It is important to highlight that the survey also show nine percent (9%) and ten (10%) of the respondents have prefer to define projects safety risk as the quantity measure of the uncertainty associated with estimates of various outcomes and the likelihood of a hazard respectively.

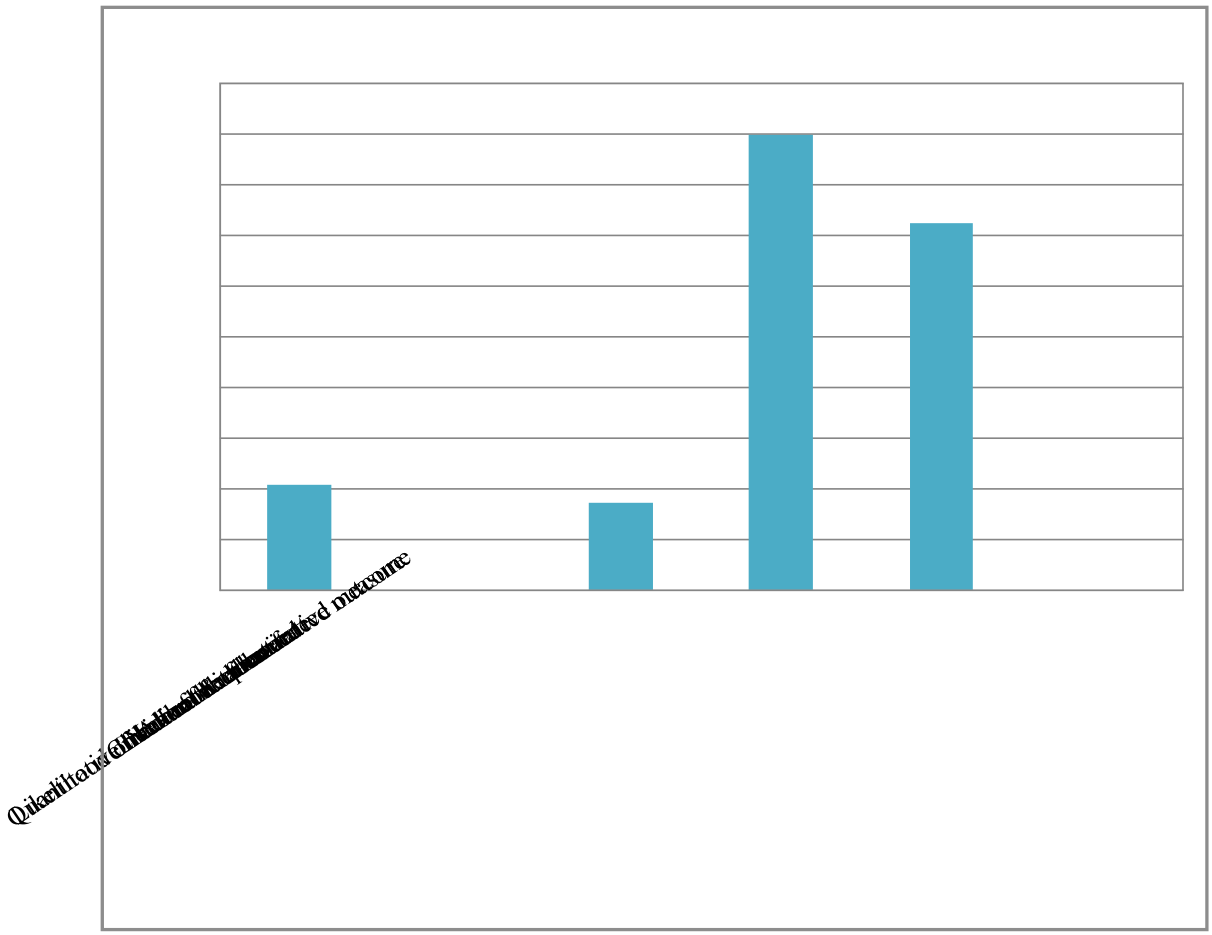

Figure 4.7: Definition of project safety risk according to the respondents

4.4 Application of Project Safety Risk Management Technique

In order to assess how risk management technique is being used to manage project safety risks by contractors in the construction industry in South Africa, respondents, irrespective of their CIDB grading, were requested to rank risk management processes according to whether they know and/or use them. The following three-point options were used to measure the contractors' knowledge and use of risk management processes as identified in the literature review:

1. Do not know.
2. Know only.
3. Know and use.

Based on the three-point options score, the following salient results were realised; Brainstorming was ranked the most known and used technique for identifying project safety risks in construction projects; when assessing project safety risk, expected monetary value was rated the most known and used technique; risk transferring was ranked as the most known and used technique for responding to project safety risks; and corrective actions has been rated the most known and used technique for monitoring project safety risks in the South African construction industry.

a) Risk identification

According to figure 4.8, forty five percent (45%) of the participants showed that they frequently identify project safety risks in their respective projects whilst seventeen percent (17%) showed that they don't do it at all. Though it is still a small percentage in relation to the amount that is spent on construction projects year after year, thirty one percent (31%) pointed out that they always identify project safety risks on their project.

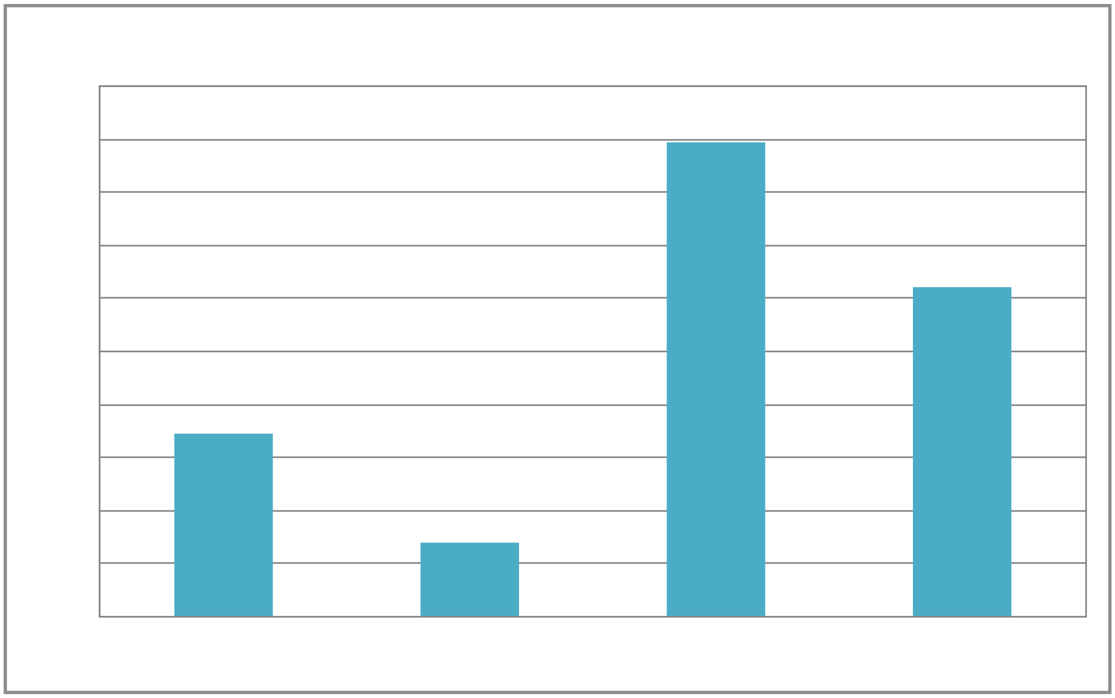

Figure 4.8: Number of respondents who identify project safety risks in their respective projects

Figure 4.9 illustrates that fifty five percent (55%) of the respondents do not know what flow charts are as a technique to identify project safety risks. The most known and used techniques were found to be brainstorming and historical data, sitting at sixty seven percent (67%) and fifty nine percent (59%) respectively. Fourteen percent of the respondents pointed out that they utilise risk management matrix and hazards identification methods in their projects.

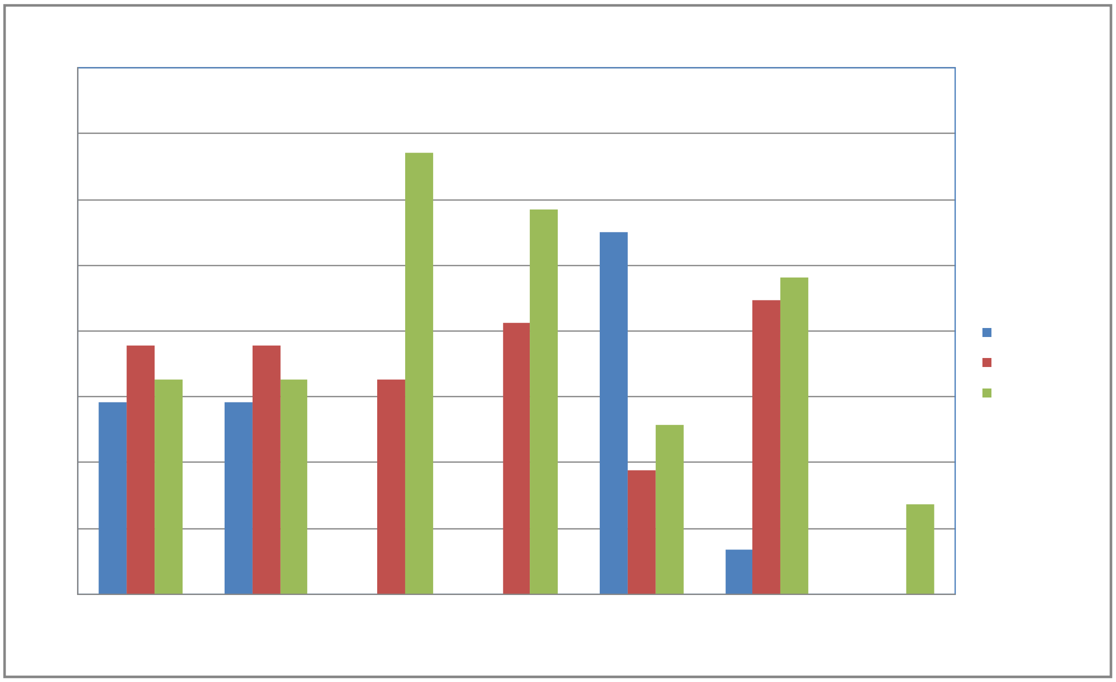

Figure 4.9: Project safety risks identification techniques used by respondents in their respective projects

b) Risk assessment

Figure 4.10 shows that twenty nine percent (29%) of the respondents always assess projects safety risks that have been identified during the projects safety risks identification process, whereas sixteen percent (16%) indicated that they do project safety risks assessment sometimes. The remaining percentage thirty six percent (36%) and nineteen percent (19%) is split between respondents who often do assessment and those who do not do it at all respectively.

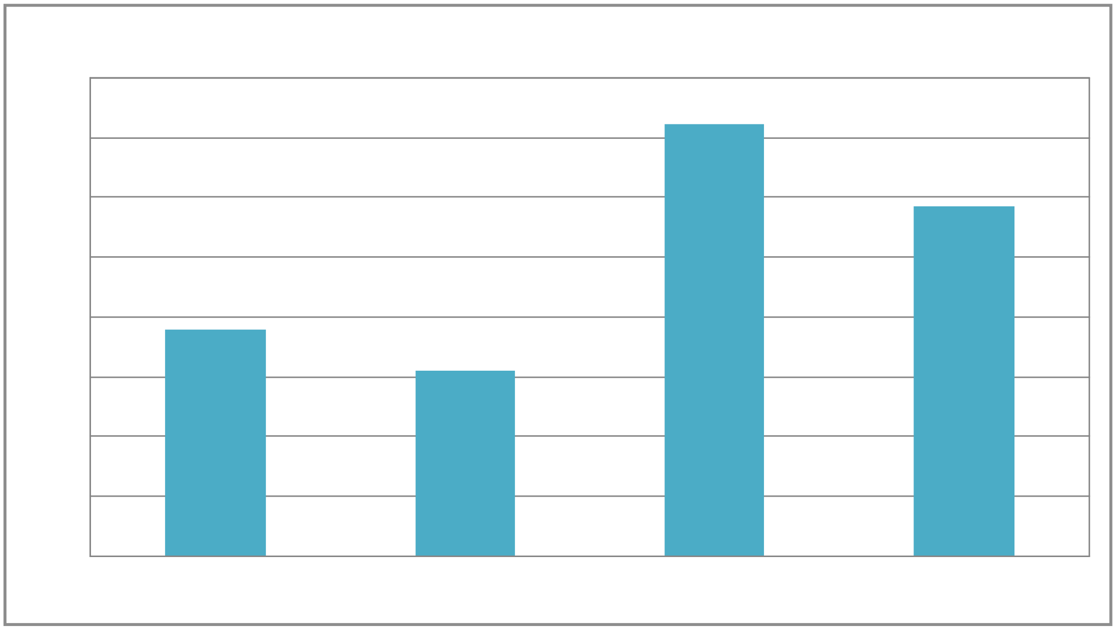

Figure 4.10: Number of respondents who assess project safety risks in their respective projects

According to Figure 4.11, sixty four percent (64%) of the respondents do not know programme evaluation and review technique as a tool that can be used to analyse project safety risks. A majority of fifty five percent (55%) respondents have pointed out that they know and use expected monetary value technique. This supports the claim on the literature review that most of the contractors use expected monetary value technique because it is easy to understand rand value losses and profits. It is also important to mention that forty three percent (43%) of the respondents know only (knowing without using) the Monte Carlo simulation technique; in fact only thirty six percent of the participants pointed out that they know and use it (Figure 4.11).

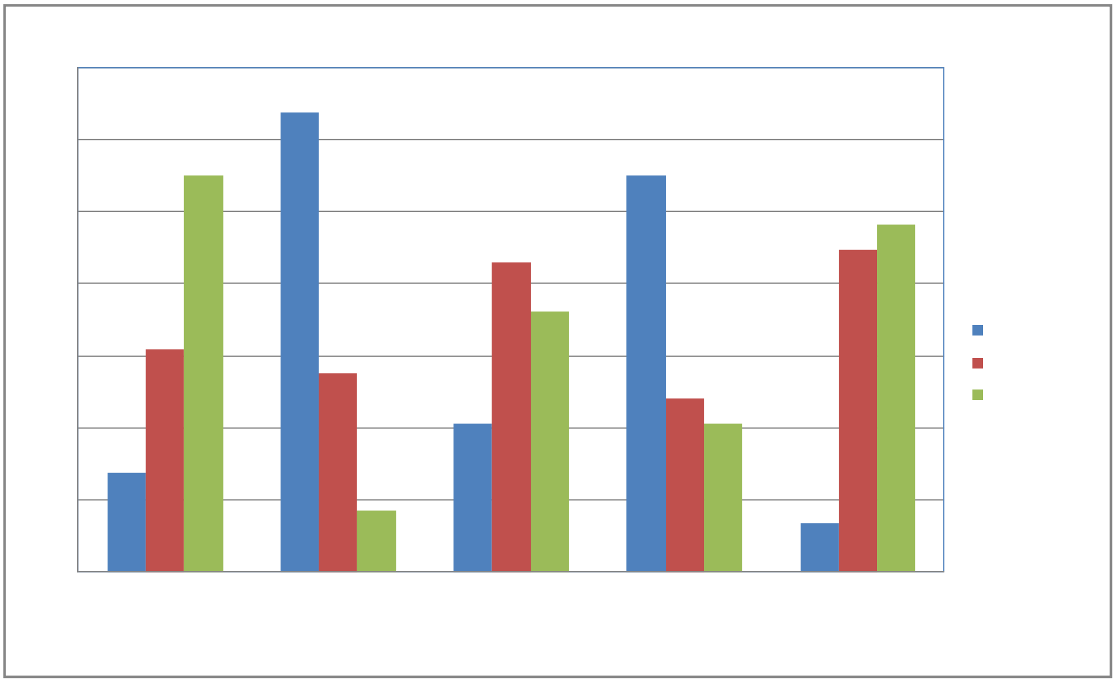

Figure 4.11: Project safety risks assessment techniques used by respondents in their respective projects

c) Risk response

Forty one percent (41%) of the respondents specified that they often respond to identified and assessed project safety risks, whereas fourteen percent (14%) indicated that they sometimes respond to projects safety risks as shown in Figure 4.12. It was intriguing to identify that seventeen percent (17%) of the respondents claim that they do not plan any response to project safety risks. Having said that, my personal opinion is that these respondents (17%) are not aware that by not planning any response strategy they are effectively accepting project safety risks that may occur in their projects, which is in a way a strategy of responding to project safety risks.

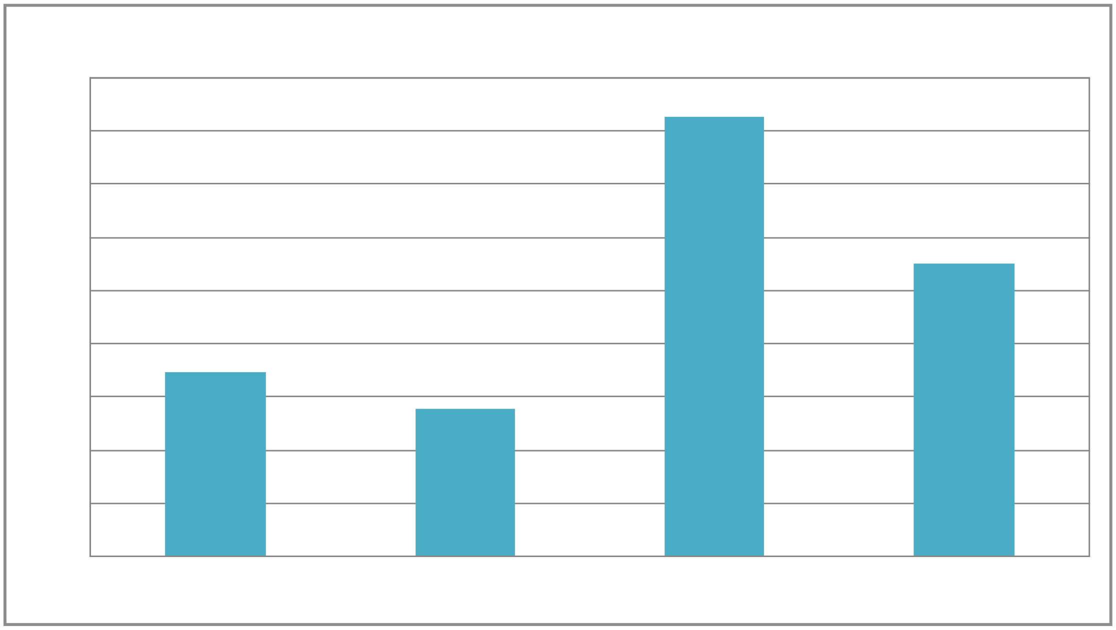

Figure 4.12: Number of respondents who respond to project safety risks in their respective projects

Figure 4.13 reveals that all five techniques used for responding to project safety risks are known by respondents. Fifty five percent (55%) of the respondents indicated that they know risk avoidance and risk sharing techniques whilst fifty seven percent, fifty two percent (52%) and forty three (43%) have pointed out that they are aware of risk acceptance, risk reduction and risk transferring strategies. As per literature review, risk transferring ranked top as the most known and used technique with fifty five percent (55%) of the respondents.

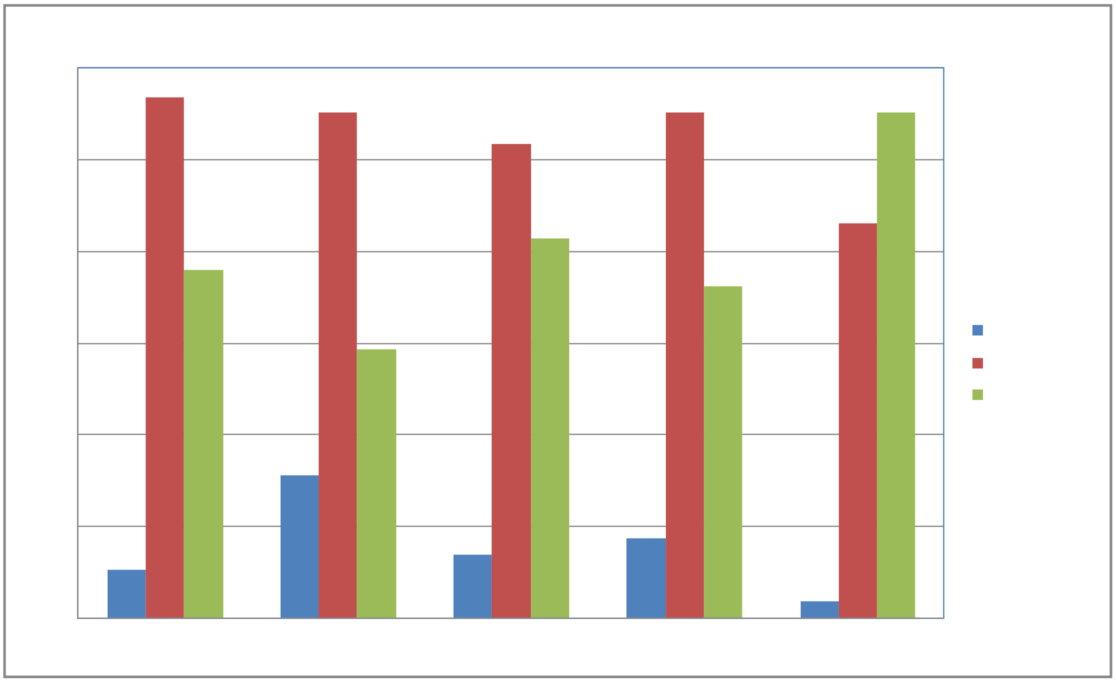

Figure 4.13: Project safety risks response techniques used by respondents in their respective projects

d) Risk monitoring

Fig 4.14 shows that twenty nine percent (29%) of the respondents indicated that they always monitor project safety risks in their projects and thirty eight percent (38%) claim that they do it most of the time. The remaining percentage is split between respondents who monitor project safety risks sometimes and the ones who do not do it at all, sitting at sixteen percent (16%) and fifteen percent (15%) respectively.

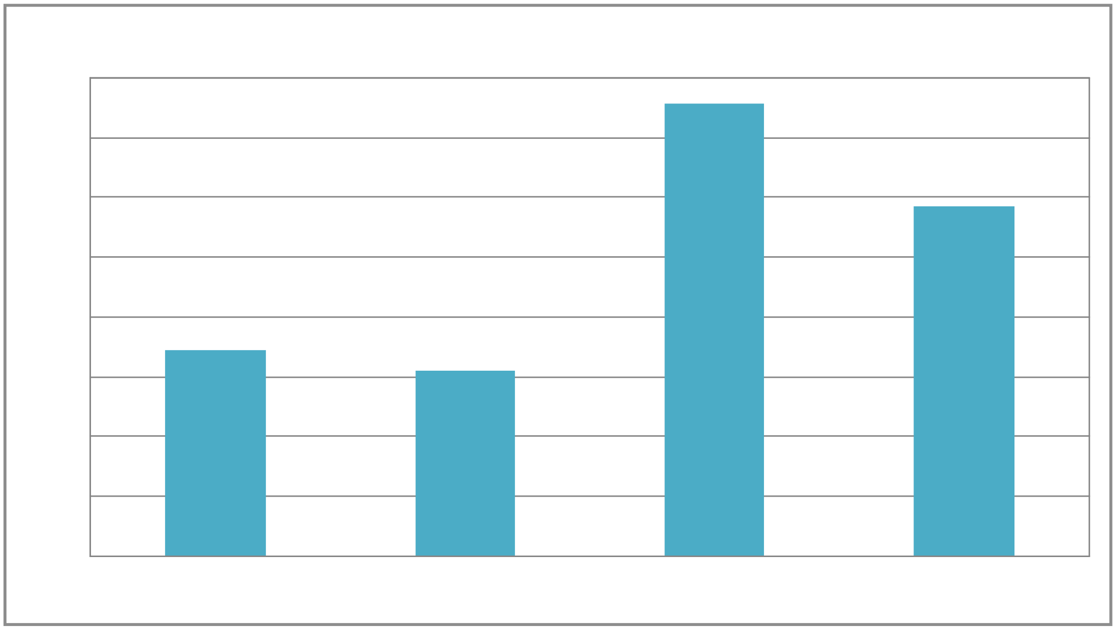

Figure 4.14: Number of respondents who monitor project safety risks in their respective projects

Figure 4.15 illustrates that most of the respondents are aware of the techniques that are used to monitor project safety risks. Milestone tracking technique rated the most with seventy one percent (71%) of the respondents, followed by risk reassessment technique with sixty seven (67%), corrective action with sixty four percent (64%) and top 10 tracking with sixty two percent (62%) techniques. In fact seventeen percent (17%) of the respondents indicated that they know and use milestone tracking technique while only twelve percent (12%) of the respondents pointed out that they do not know the technique.

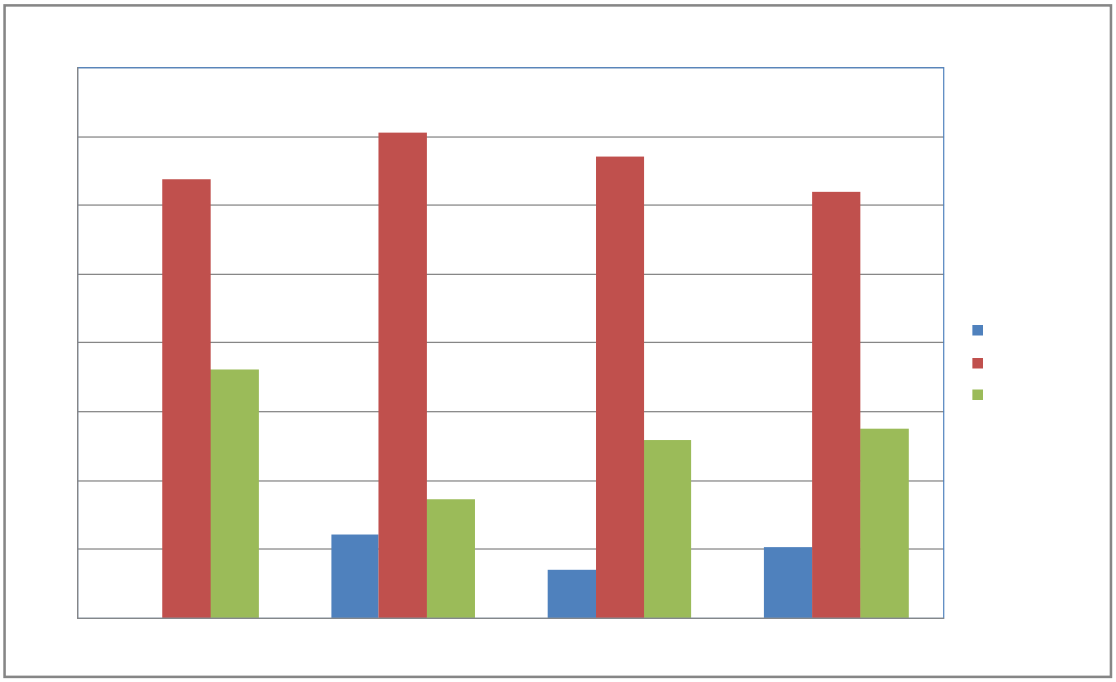

Figure 4.15: Project safety risks monitoring techniques used by respondents in their respective projects

4.5 Project Parameters

Figure 4.16 shows the impact of implementing project safety risk management process on construction project parameters of schedule, cost, quality and safety. Seventy nine percent (79%) of the respondents pointed out that the implementation of project safety risk management always resulted in good project safety performances and twenty one percent (21%) indicated that projects safety risk management often have a positive impact on project safety. This means that majority of the respondents concur that positive relationship exist between project safety risk management and project parameters.

According to Figure 4.16, project quality had the lowest rank, with fifty three percent (53%), thus twenty nine percent (29%) for always and twenty four percent (24%) for often, of respondents. This therefore means that more than half of the respondents concur that the implementation of project safety risk management results in positive outcome. Seventy four percent (74%) of the respondents pointed out that the implementation of project safety risk management process can heavily influence project schedule, while eighty four percent (84%) believed that project safety management technique has a favourable impact on project costs.

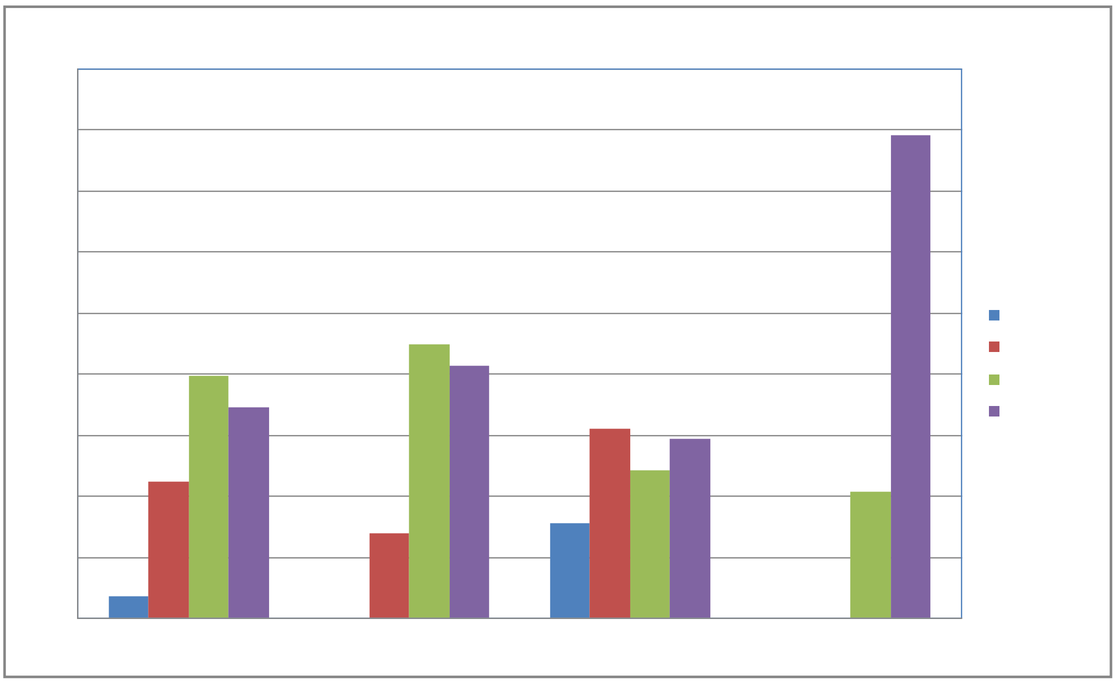

Figure 4.16: Impact of project safety risk management on projects according to the respondents

4.6 Spearman's Rank-Order Correlation Coefficient Analysis

This study utilizes Spearman rank-order correlation coefficient to establish a relationship between project safety risk management and project goals of schedule, cost, quality and safety. Irrespective of their CIDB grading, responses from all 58 contractors were ranked accordingly and then Spearman's rank-order correlation coefficient was computed. Table 4.2 illustrates the summary of computed values of the Spearman's rank-order correlation coefficient between project safety risk management and project parameters (refer to appendix B for full data for computing Spearman's rank-order correlation coefficient values).

Table 4.2: Spearman's Rank-Order Correlation Coefficient

Item	**Project Parameters**	**Spearman Correlation r_s**
1	Project Schedule	0.56
2	Project Cost	0.54
3	Project Quality	0.54
4	Project Safety	0.75

Source: Author's own assessment

Table 4.2 shows that all project parameters had positive values for Spearman's rank-order correlation coefficient. This means that the relationship between project safety risk management and the project parameters of project schedule, cost, quality and safety is positive.

The highest Spearman's coefficient value of 0.75 is computed at project safety parameter followed by project schedule with a value of 0.56, and project cost and quality have same of 0.54. In other words, project safety risk management have been found to have the greatest positive impact on project safety, followed by project schedule and then project cost and project quality.

It is important to mention that had the values computed for Spearman's coefficient been zero or negative, the conclusion would have been that there is no relationship between project safety risk and project parameters or that there is a negative relationship between project safety risk and project parameters.

4.7 Research Problem

This research report sought to address the following question as outlined in Chapter 1:

a) Are construction stakeholders, with special emphasis to construction contractors, aware that project safety risk management processes can be used on construction projects to increase the overall project performance in terms of schedule, cost, quality and safety?

The literature review suggests that the implementation of project safety risk management on construction projects enables and enhances the opportunity of completing projects within its objectives of schedule, cost, quality and safety. The survey results also validated this assertion that positive relationship exists between project safety risk management and project parameters relative to schedule, cost, quality and safety.

4.8 Research Objectives

The following are the main objectives of the research report as stated in Chapter 1:

a) Investigate how risk management processes can be used to manage safety risks by construction contractors in South Africa to efficiently achieve project parameters of cost, schedule, quality and safety.

b) To develop recommendations on the way safety risk management is currently being practiced by construction contractors.

Literature review and survey results have thoroughly addressed these objectives. Therefore the objectives of the study were achieved.

4.9 Hypothesis testing

The null hypothesis and alternative hypothesis statements of the research report as stated in Chapter 1 are as follows:

Null hypothesis statement:

H_0: $\rho = 0$ (There is no relationship between project safety risk management and project parameters of cost, schedule and quality in the South African construction industry).

Alternative hypothesis statement:

H_1: $\rho \neq 0$ (There is a relationship between project safety risk management and project parameters of cost, schedule and quality in the South African construction industry).

Based on the calculations for Spearman's Rank Order Correlation of the project objectives, the following r_s values were obtained:

- Project Schedule = 0.56
- Project Cost = 0.54
- Project Quality = 0.54
- Project Safety = 0.75

In order to reject or accept null hypothesis statement, the study compares these r_s values with the $r_{s\alpha}$ values in the Spearman's Rank Table (shown in Appendix C).

The study has a data of 58 pairs, and according to the Spearman's Rank Table, to achieve a significance level of 5% ($\rho = 0.05$), the $r_{s\alpha}$ value has to be at least 0.218. The r_s values obtained for project schedule, cost, quality and safety are all bigger than $r_{s\alpha}$ value of 0.218. This means that the null hypothesis is rejected and that there is a statistically significant positive correlation between project safety risk management and project objectives.

4.10 Conclusion

The survey results can be summarised as follows:

- The overall rate of response was fifty nine percent (59%), which was found satisfactory.

- The average construction experience of the respondents was twelve years (12 years) and most of the respondents were occupying middle and senior management position. This enhanced the reliability and credibility of the survey.

- The average value of the projects the respondents are currently working on was sixty five million rand (R65 000 000.00). This means that construction boom is over and also that there is a need for eminent injection of new projects to the industry.

- Seventy eight percent (78%) and seventy one percent (71%) of the respondents indicated that they have safety and risk management policies in their companies respectively and seventy five percent (75%) of the contractors implement the project safety risk management technique in their project.

- Forty five percent (45%) of the respondents defined project safety risk as the combination of the likelihood of a hazard and the quantity measure of the uncertainty associated with estimates of various outcomes.

- Contractors believed that projects safety risk management have positive relationship with all four project parameters of schedule, cost, quality and safety as demonstrated by Spearman’s rank-order correlation coefficient values.

Chapter 5 - Conclusions and Recommendations

5.1 Conclusions

The study examines an issue that is of critical importance to the efficiency of the South African construction industry. The building and construction industry is a significant contributor in the economy of South Africa. The construction industry does not only provide the necessary infrastructure, but also provide employment to South African and global citizens.

Despite being a significant contributor to employment and gross domestic product of the South African economy, construction industry continues to deliver expensive infrastructure late and contribute disproportionate numbers of work-related injuries and fatalities. Project safety risk management is acknowledged as one of the techniques that can be implemented on construction projects to enhance performance of the South African construction contractors.

The conclusions that arise from the literature review and survey results can be summarised in this way:

i. South African construction contractors appreciate the positive impact that project safety risk management have on projects relative to project parameters of schedule, cost, quality and safety. This means that South African construction contractors are aware that adequate implementation of project safety risk management in their projects enhances chances of realising project parameters. As a result project safety risk management is an important factor that cannot be ignored by construction contractors.

ii. Construction industry contractors have formal safety and risk management plans and policies. This could be attributed to legislation and CIDB regulations that require contractors to have safety plan or policy and perform risk assessment before any activity is undertaken on a construction project. Accordingly principals and employees of construction organisations can be found to be personally responsible for incidents and accidents that happen on their projects. In worst case scenario a criminal case may be laid against these principals and employees should they be found to have transgressed legislated safety requirements.

iii. The levels of injuries and fatalities in the South African construction industry are unacceptably high. These injuries and fatalities result in cost and schedule over-runs, poor quality and safety performances. This is evident when calculating direct and indirect costs of the project safety risks. Thus negative safety culture results in poor health and safety standards that will consequently result in the reduction of productivity and efficiency.

iv. Construction industry needs eminent injection of new projects if it is to continue being a significant contributor to the South African economy.

5.2 Recommendations

Having acknowledged that construction industry is inherently risky and complex in nature it can be said that these risks can affect and influence project objectives. Therefore it is recommended that construction contractors should adopt proactive and continuous learning approaches to manage project safety risks.

At the time of writing this research report the most recent statistics report on occupational-related accidents was for the year 1999, published in 2008. As a result this study recommends that the South African government should play an essential role in publishing occupational injuries and fatalities reports. Furthermore government should also ensure that safety-related legislative regulations are strictly enforced on all construction projects.

Based on the literature review and survey results that were discussed above, it is evident that project safety risk management is an exhaustive concept that requires continuous research and development. Therefore further research is recommended in the following areas of study:

> Usually a construction projects would have four phases during its life cycle, namely planning, design, construction and operation. This research report focused mainly at the influence of project safety risk management on the objectives of construction projects during construction phase (implementation phase). Therefore future studies need to be carried out on how project safety risk management technique can be used during planning, design and operation phases of the project life cycle.

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Appendix A

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UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

26th August 2011

To Whom it may concern

This serves to confirm that Mr Joshua Maroge (Student No. 9712278N) is registered for MSc Building Project Management in the School of Construction Economics and Management; The student is required to undertaking a research report. The purposed of this research is to introduce students to research techniques. The topic of research is "**An investigation into the use of safety risk management to improve project parameters in the construction industry in South Africa**".

It would be greatly appreciated if you could provide Mr Maroge with the necessary assistance in order to complete his research.

I thank you in advance, and please feel free to contact the school should you require any further information.

Yours faithfully

M.M. Sithole

Mrs Tiny Sithole
Postgraduate Officer
School of Construction Economics and Management

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

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Dear Sir / Madam

I am studying for an MSc Building Project Management at the University of the Witwatersrand in the School of Construction Economics and Management, and currently undertaking a research entitled ***"An investigation into the use of safety risk management to improve project parameters in the construction industry in South Africa".***

I hereby request you to participate in the research by completing the attached questionnaire. The questionnaire is not asking for personal information, but seeks to establish a trend in the South African construction industry. Completed questionnaire would be used purely for academic purposes and strict confidentiality would be maintained.

For any query, please feel free to contact me or the school and ask for Dr. Harry Quainoo.

I thank you in advance.

Yours faithfully,

Joshua Maroge
University of the Witwatersrand
Mobile No.: 082 687 3235
Facsimile No.: 086 660 4664
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UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

School of Construction Economics & Management

<u>Research Report Questionnaire</u>

<u>Research topic:</u>

An investigation into the use of safety risk management to improve project parameters in the construction industry in South Africa.

The purpose of the research report questionnaire is to investigate how risk management is being used to manage project safety risks by construction contractors in South Africa to achieve project parameters of cost, schedule and quality, and develop recommendations on the way projects safety risk management is currently being practiced by construction contractors in South Africa.

- ❖ Please select and tick (√) the most appropriate answer(s).
- ❖ In the case that you cannot answer a specific question, please skip this question.
- ❖ In the case that you would like to elaborate further, please note that there is a space available at the end of the questionnaire.

1. General information

1.1 What is the Construction Industry Development Board (CIDB) grade of your company?

Grade 7	Grade 8	Grade 9

1.2 How long have you been in the construction industry and what is your position within the company.

Years in construction industry: ....

Position in the firm: ....

1.3 What is the value of the project(s) you are currently busy on?

Less than R1million	
R1million – R10million	
R10million – R50million	
R50million – R100million	
Greater than R100million	

1.4 Does your company have a formal safety management policy?

No Policy	Uncertain	Policy in Place

1.5 In relation to question 1.4, does your company have a formal risk management policy /plan (RMP)?

No RMP	Uncertain	RMP in Place

1.6 Who is responsible for risk management in your project?

Client	
Consultants	
Contractor (yourself)	
Client & consultants	
Client & contractor (yourself)	
Others (please specify)	

1.7 Do you define project safety risk as (indicate all applicable):

The likelihood of a hazard	
Choice rather than a fate	
The quantitative measure of the uncertainty associated with estimates of various outcomes	
All of the above	
None of the above (please specify)	

2. Risk Identification

2.1 Do you, either individually or as a team, determine which potential safety risks are likely to happen in your project?

No (0%)	Sometimes (33%)	Often (66%)	Always (100%)

2.2 Do you know and use any of the following techniques to identify project safety risks in your project?

Structured questionnaire	Do not know		Know only		Know & use	
Structured interviews	Do not know		Know only		Know & use	
Brainstorming	Do not know		Know only		Know & use	
Historical data	Do not know		Know only		Know & use	
Zonal analysis	Do not know		Know only		Know & use	
Judgement based on experience and knowledge	Do not know		Know only		Know & use	

2.3 Please describe any other risk identification techniques used in your project.

....

....

....

....

3. Risk Assessment

3.1 Do you, either individually or as a team, quantify the likelihood of the safety risks occurring and the impact they may have on your project?

No (0%)	Sometimes (33%)	Often (66%)	Always (100%)

3.2 Do you know and use any of the following techniques used to quantify project safety risks?

Expected monetary value	Do not know		Know only		Know & use	
Statistical sums (please specify)	Do not know		Know only		Know & use	
Simulation methods	Do not know		Know only		Know & use	
Decision trees	Do not know		Know only		Know & use	
Expert judgement	Do not know		Know only		Know & use	

3.3 Please describe any other techniques used to quantify safety risks in your project.

....

....

....

....

4. Risk Response

4.1 Do you, either individually or as a team, perform risk response measures in your project to mitigate (alleviate) the consequences that may be caused by safety risks that have been identified during identification stage?

No (0%)	Sometimes (33%)	Often (66%)	Always (100%)

4.2 Do you know and use any of the following risk response measures to control safety risks in your project?

Risk acceptance[1]	Do not know		Know only		Know & use	
Risk avoidance	Do not know		Know only		Know & use	
Risk reduction	Do not know		Know only		Know & use	
Risk sharing	Do not know		Know only		Know & use	
Risk transferring[2]	Do not know		Know only		Know & use	

4.3 Please describe any other technique(s) used in your projects to respond to safety risks:

....

....

....

....

[1] The strategy is used when the project team has decided not to change the project management plan to deal with a project risk, or is unable to identify any other suitable response strategy, PMI (2008, p304).

[2] Project risk transfer involves shifting some or all of the negative impact of a threat, along with ownership of the response to a third party, PMI (2008, p303).

5. Risk Review & Monitoring

5.1 Do you, either individually or as a team, review safety risks that were identified during safety risks identification stage in your project?

No (0%)	Sometimes (33%)	Often (66%)	Always (100%)

5.2 Do you know and use any of the following techniques for monitoring and review safety risks in your project?

Corrective action	Do not know		Know only		Know & use	
Milestone tracking	Do not know		Know only		Know & use	
Risk reassessment	Do not know		Know only		Know & use	
Top 10 tracking	Do not know		Know only		Know & use	

5.3 Please describe any other technique(s) used to monitor and review safety risks in your project:

....

....

....

....

....

6. Project Parameters

6.1 Based on the experience gained over the past 5years, does the lack of safety risk management affect **project schedule**?

No (0%)	Sometimes (33%)	Often (66%)	Always (100%)

6.2 Do you think that the application of safety risk management resulted in **project schedule saving**?

No (0%)	Sometimes (33%)	Often (66%)	Always (100%)

6.3 Based on the experience gained over the past 5years, does the lack of safety risk management affect **project cost**?

No (0%)	Sometimes (33%)	Often (66%)	Always (100%)

6.4 Do you think that the application of safety risk management resulted in **project cost saving**?

No (0%)	Sometimes (33%)	Often (66%)	Always (100%)

6.5 Based on the experience gained over the past 5years, does the lack of safety risk management affect **project quality conformance**?

No (0%)	Sometimes (33%)	Often (66%)	Always (100%)

6.6 Do you think that the application of safety risk management resulted in **project quality conformance**?

No (0%)	Sometimes (33%)	Often (66%)	Always (100%)

6.7 Based on the experience gained over the past 5years, does the lack of safety risk management affect **project safety performance**?

No (0%)	Sometimes (33%)	Often (66%)	Always (100%)

6.8 Do you think that the application of safety risk management resulted in improved **project safety performance**?

No (0%)	Sometimes (33%)	Often (66%)	Always (100%)

7. General Comments

7.1 "A positive safety culture can significantly contribute to the maintenance of good safety management practice, the achievement of favourable safety performance indicators and overall success and reputation of both a project and organisation", Howarth and Watson (2009, p89). Do you agree with this statement?

No	Yes

7.2 If you wish to make comments and elaborate on any question to this study, please feel free to do this. First state the question number, followed by your comments.

....

....

....

- **Thank you very much for taking your invaluable time to fill in this questionnaire.**

- Please return it by the 30th September 2011 to **ntsandeni.maroge@students.wits.ac.za** or fax directly to Mr. Joshua Maroge at **086 660 4664.**

Appendix B

Computation of Spearman’s Rank Correlation Coefficient for Project Schedule

Respondents	Project Safety Risk Management (A)	Project Schedule Score (B)	Rank A	Rank B	d	d^2	Spearman's Rank r_s
1	100	0	29.50	1.50	28.00	784.00	0.56
2	100	0	29.50	1.50	28.00	784.00	
3	100	33	29.50	9.00	20.50	420.25	
4	100	33	29.50	9.00	20.50	420.25	
5	100	33	29.50	9.00	20.50	420.25	
6	100	33	29.50	9.00	20.50	420.25	
7	100	33	29.50	9.00	20.50	420.25	
8	100	33	29.50	9.00	20.50	420.25	
9	100	33	29.50	9.00	20.50	420.25	
10	100	33	29.50	9.00	20.50	420.25	
11	100	33	29.50	9.00	20.50	420.25	
12	100	33	29.50	9.00	20.50	420.25	
13	100	33	29.50	9.00	20.50	420.25	
14	100	33	29.50	9.00	20.50	420.25	
15	100	33	29.50	9.00	20.50	420.25	
16	100	66	29.50	27.00	2.50	6.25	
17	100	66	29.50	27.00	2.50	6.25	
18	100	66	29.50	27.00	2.50	6.25	
19	100	66	29.50	27.00	2.50	6.25	
20	100	66	29.50	27.00	2.50	6.25	
21	100	66	29.50	27.00	2.50	6.25	
22	100	66	29.50	27.00	2.50	6.25	
23	100	66	29.50	27.00	2.50	6.25	
24	100	66	29.50	27.00	2.50	6.25	
25	100	66	29.50	27.00	2.50	6.25	
26	100	66	29.50	27.00	2.50	6.25	
27	100	66	29.50	27.00	2.50	6.25	
28	100	66	29.50	27.00	2.50	6.25	
29	100	66	29.50	27.00	2.50	6.25	
30	100	66	29.50	27.00	2.50	6.25	
31	100	66	29.50	27.00	2.50	6.25	
32	100	66	29.50	27.00	2.50	6.25	
33	100	66	29.50	27.00	2.50	6.25	

34	100	66	29.50	27.00	2.50	6.25	
35	100	66	29.50	27.00	2.50	6.25	
36	100	66	29.50	27.00	2.50	6.25	
37	100	66	29.50	27.00	2.50	6.25	
38	100	66	29.50	27.00	2.50	6.25	
39	100	100	29.50	48.50	-19.00	361.00	
40	100	100	29.50	48.50	-19.00	361.00	
41	100	100	29.50	48.50	-19.00	361.00	
42	100	100	29.50	48.50	-19.00	361.00	
43	100	100	29.50	48.50	-19.00	361.00	
44	100	100	29.50	48.50	-19.00	361.00	
45	100	100	29.50	48.50	-19.00	361.00	
46	100	100	29.50	48.50	-19.00	361.00	
47	100	100	29.50	48.50	-19.00	361.00	
48	100	100	29.50	48.50	-19.00	361.00	
49	100	100	29.50	48.50	-19.00	361.00	
50	100	100	29.50	48.50	-19.00	361.00	
51	100	100	29.50	48.50	-19.00	361.00	
52	100	100	29.50	48.50	-19.00	361.00	
53	100	100	29.50	48.50	-19.00	361.00	
54	100	100	29.50	48.50	-19.00	361.00	
55	100	100	29.50	48.50	-19.00	361.00	
56	100	100	29.50	48.50	-19.00	361.00	
57	100	100	29.50	48.50	-19.00	361.00	
58	100	100	29.50	48.50	-19.00	361.00	
TOTAL						**14 395.00**	

Computation of Spearman's Rank Correlation Coefficient for Project Cost

Respondents	Project Safety Risk Management (A)	Project Schedule Score (B)	Rank A	Rank B	d	d^2	Spearman r_s
1	100	0	29.50	6.00	23.50	552.25	0.54
2	100	0	29.50	6.00	23.50	552.25	
3	100	0	29.50	6.00	23.50	552.25	
4	100	0	29.50	6.00	23.50	552.25	
5	100	0	29.50	6.00	23.50	552.25	
6	100	0	29.50	6.00	23.50	552.25	
7	100	0	29.50	6.00	23.50	552.25	
8	100	0	29.50	6.00	23.50	552.25	
9	100	0	29.50	6.00	23.50	552.25	
10	100	0	29.50	6.00	23.50	552.25	
11	100	0	29.50	6.00	23.50	552.25	
12	100	33	29.50	16.00	13.50	182.25	
13	100	33	29.50	16.00	13.50	182.25	
14	100	33	29.50	16.00	13.50	182.25	
15	100	33	29.50	16.00	13.50	182.25	
16	100	33	29.50	16.00	13.50	182.25	
17	100	33	29.50	16.00	13.50	182.25	
18	100	33	29.50	16.00	13.50	182.25	
19	100	33	29.50	16.00	13.50	182.25	
20	100	33	29.50	16.00	13.50	182.25	
21	100	66	29.50	31.00	-1.50	2.25	
22	100	66	29.50	31.00	-1.50	2.25	
23	100	66	29.50	31.00	-1.50	2.25	
24	100	66	29.50	31.00	-1.50	2.25	
25	100	66	29.50	31.00	-1.50	2.25	
26	100	66	29.50	31.00	-1.50	2.25	
27	100	66	29.50	31.00	-1.50	2.25	
28	100	66	29.50	31.00	-1.50	2.25	
29	100	66	29.50	31.00	-1.50	2.25	
30	100	66	29.50	31.00	-1.50	2.25	
31	100	66	29.50	31.00	-1.50	2.25	
32	100	66	29.50	31.00	-1.50	2.25	

33	100	66	29.50	31.00	-1.50	2.25	
34	100	66	29.50	31.00	-1.50	2.25	
35	100	66	29.50	31.00	-1.50	2.25	
36	100	66	29.50	31.00	-1.50	2.25	
37	100	66	29.50	31.00	-1.50	2.25	
38	100	66	29.50	31.00	-1.50	2.25	
39	100	66	29.50	31.00	-1.50	2.25	
40	100	66	29.50	31.00	-1.50	2.25	
41	100	66	29.50	31.00	-1.50	2.25	
42	100	100	29.50	50.00	-20.50	420.25	
43	100	100	29.50	50.00	-20.50	420.25	
44	100	100	29.50	50.00	-20.50	420.25	
45	100	100	29.50	50.00	-20.50	420.25	
46	100	100	29.50	50.00	-20.50	420.25	
47	100	100	29.50	50.00	-20.50	420.25	
48	100	100	29.50	50.00	-20.50	420.25	
49	100	100	29.50	50.00	-20.50	420.25	
50	100	100	29.50	50.00	-20.50	420.25	
51	100	100	29.50	50.00	-20.50	420.25	
52	100	100	29.50	50.00	-20.50	420.25	
53	100	100	29.50	50.00	-20.50	420.25	
54	100	100	29.50	50.00	-20.50	420.25	
55	100	100	29.50	50.00	-20.50	420.25	
56	100	100	29.50	50.00	-20.50	420.25	
57	100	100	29.50	50.00	-20.50	420.25	
58	100	100	29.50	50.00	-20.50	420.25	
TOTAL						**14 906.50**	

<u>Computation of Spearman's Rank Correlation Coefficient for Project Quality</u>

Respondents	Project Safety Risk Management (A)	Project Schedule Score (B)	Rank A	Rank B	d	d^2	Spearman r_s
1	100	0	29.50	4.50	25.00	625.00	0.5405888
2	100	0	29.50	4.50	25.00	625.00	
3	100	0	29.50	4.50	25.00	625.00	
4	100	0	29.50	4.50	25.00	625.00	
5	100	0	29.50	4.50	25.00	625.00	
6	100	0	29.50	4.50	25.00	625.00	
7	100	0	29.50	4.50	25.00	625.00	
8	100	0	29.50	4.50	25.00	625.00	
9	100	33	29.50	19.00	10.50	110.25	
10	100	33	29.50	19.00	10.50	110.25	
11	100	33	29.50	19.00	10.50	110.25	
12	100	33	29.50	19.00	10.50	110.25	
13	100	33	29.50	19.00	10.50	110.25	
14	100	33	29.50	19.00	10.50	110.25	
15	100	33	29.50	19.00	10.50	110.25	
16	100	33	29.50	19.00	10.50	110.25	
17	100	33	29.50	19.00	10.50	110.25	
18	100	33	29.50	19.00	10.50	110.25	
19	100	33	29.50	19.00	10.50	110.25	
20	100	33	29.50	19.00	10.50	110.25	
21	100	33	29.50	19.00	10.50	110.25	
22	100	33	29.50	19.00	10.50	110.25	
23	100	33	29.50	19.00	10.50	110.25	
24	100	33	29.50	19.00	10.50	110.25	
25	100	33	29.50	19.00	10.50	110.25	
26	100	33	29.50	19.00	10.50	110.25	
27	100	33	29.50	19.00	10.50	110.25	
28	100	33	29.50	19.00	10.50	110.25	
29	100	33	29.50	19.00	10.50	110.25	
30	100	66	29.50	37.00	-7.50	56.25	
31	100	66	29.50	37.00	-7.50	56.25	
32	100	66	29.50	37.00	-7.50	56.25	

33	100	66	29.50	37.00	-7.50	56.25	
34	100	66	29.50	37.00	-7.50	56.25	
35	100	66	29.50	37.00	-7.50	56.25	
36	100	66	29.50	37.00	-7.50	56.25	
37	100	66	29.50	37.00	-7.50	56.25	
38	100	66	29.50	37.00	-7.50	56.25	
39	100	66	29.50	37.00	-7.50	56.25	
40	100	66	29.50	37.00	-7.50	56.25	
41	100	66	29.50	37.00	-7.50	56.25	
42	100	66	29.50	37.00	-7.50	56.25	
43	100	66	29.50	37.00	-7.50	56.25	
44	100	66	29.50	37.00	-7.50	56.25	
45	100	100	29.50	51.50	-22.00	484.00	
46	100	100	29.50	51.50	-22.00	484.00	
47	100	100	29.50	51.50	-22.00	484.00	
48	100	100	29.50	51.50	-22.00	484.00	
49	100	100	29.50	51.50	-22.00	484.00	
50	100	100	29.50	51.50	-22.00	484.00	
51	100	100	29.50	51.50	-22.00	484.00	
52	100	100	29.50	51.50	-22.00	484.00	
53	100	100	29.50	51.50	-22.00	484.00	
54	100	100	29.50	51.50	-22.00	484.00	
55	100	100	29.50	51.50	-22.00	484.00	
56	100	100	29.50	51.50	-22.00	484.00	
57	100	100	29.50	51.50	-22.00	484.00	
58	100	100	29.50	51.50	-22.00	484.00	
TOTAL						**14 935.00**	

Computation of Spearman's Rank Correlation Coefficient for Project Safety

Respondents	Project Safety Risk Management (A)	Project Schedule Score (B)	Rank A	Rank B	d	d^2	Spearman r_s
1	100	66	29.50	6.50	23.00	529.00	0.75
2	100	66	29.50	6.50	23.00	529.00	
3	100	66	29.50	6.50	23.00	529.00	
4	100	66	29.50	6.50	23.00	529.00	
5	100	66	29.50	6.50	23.00	529.00	
6	100	66	29.50	6.50	23.00	529.00	
7	100	66	29.50	6.50	23.00	529.00	
8	100	66	29.50	6.50	23.00	529.00	
9	100	66	29.50	6.50	23.00	529.00	
10	100	66	29.50	6.50	23.00	529.00	
11	100	66	29.50	6.50	23.00	529.00	
12	100	66	29.50	6.50	23.00	529.00	
13	100	100	29.50	35.5	-6.00	36.00	
14	100	100	29.50	35.5	-6.00	36.00	
15	100	100	29.50	35.5	-6.00	36.00	
16	100	100	29.50	35.5	-6.00	36.00	
17	100	100	29.50	35.5	-6.00	36.00	
18	100	100	29.50	35.5	-6.00	36.00	
19	100	100	29.50	35.5	-6.00	36.00	
20	100	100	29.50	35.5	-6.00	36.00	
21	100	100	29.50	35.5	-6.00	36.00	
22	100	100	29.50	35.5	-6.00	36.00	
23	100	100	29.50	35.5	-6.00	36.00	
24	100	100	29.50	35.5	-6.00	36.00	
25	100	100	29.50	35.5	-6.00	36.00	
26	100	100	29.50	35.5	-6.00	36.00	
27	100	100	29.50	35.5	-6.00	36.00	
28	100	100	29.50	35.5	-6.00	36.00	
29	100	100	29.50	35.5	-6.00	36.00	
30	100	100	29.50	35.5	-6.00	36.00	
31	100	100	29.50	35.5	-6.00	36.00	
32	100	100	29.50	35.5	-6.00	36.00	

33	100	100	29.50	35.5	-6.00	36.00	
34	100	100	29.50	35.5	-6.00	36.00	
35	100	100	29.50	35.5	-6.00	36.00	
36	100	100	29.50	35.5	-6.00	36.00	
37	100	100	29.50	35.5	-6.00	36.00	
38	100	100	29.50	35.5	-6.00	36.00	
39	100	100	29.50	35.5	-6.00	36.00	
40	100	100	29.50	35.5	-6.00	36.00	
41	100	100	29.50	35.5	-6.00	36.00	
42	100	100	29.50	35.5	-6.00	36.00	
43	100	100	29.50	35.5	-6.00	36.00	
44	100	100	29.50	35.5	-6.00	36.00	
45	100	100	29.50	35.5	-6.00	36.00	
46	100	100	29.50	35.5	-6.00	36.00	
47	100	100	29.50	35.5	-6.00	36.00	
48	100	100	29.50	35.5	-6.00	36.00	
49	100	100	29.50	35.5	-6.00	36.00	
50	100	100	29.50	35.5	-6.00	36.00	
51	100	100	29.50	35.5	-6.00	36.00	
52	100	100	29.50	35.5	-6.00	36.00	
53	100	100	29.50	35.5	-6.00	36.00	
54	100	100	29.50	35.5	-6.00	36.00	
55	100	100	29.50	35.5	-6.00	36.00	
56	100	100	29.50	35.5	-6.00	36.00	
57	100	100	29.50	35.5	-6.00	36.00	
58	100	100	29.50	35.5	-6.00	36.00	
TOTAL						**8 004.00**	

Computation of Mean and Standard Deviation values for Project Schedule

Respondents	Score X	Mean M	Score - Mean X - M	(Score - Mean)^2 (X - M)^2	Variance	Standard Variance
1	0	68.05	-68.05	4631.04	802.54	28.33
2	0	68.05	-68.05	4631.04		
3	33	68.05	-35.05	1228.62		
4	33	68.05	-35.05	1228.62		
5	33	68.05	-35.05	1228.62		
6	33	68.05	-35.05	1228.62		
7	33	68.05	-35.05	1228.62		
8	33	68.05	-35.05	1228.62		
9	33	68.05	-35.05	1228.62		
10	33	68.05	-35.05	1228.62		
11	33	68.05	-35.05	1228.62		
12	33	68.05	-35.05	1228.62		
13	33	68.05	-35.05	1228.62		
14	33	68.05	-35.05	1228.62		
15	33	68.05	-35.05	1228.62		
16	66	68.05	-2.05	4.21		
17	66	68.05	-2.05	4.21		
18	66	68.05	-2.05	4.21		
19	66	68.05	-2.05	4.21		
20	66	68.05	-2.05	4.21		
21	66	68.05	-2.05	4.21		
22	66	68.05	-2.05	4.21		
23	66	68.05	-2.05	4.21		
24	66	68.05	-2.05	4.21		
25	66	68.05	-2.05	4.21		
26	66	68.05	-2.05	4.21		
27	66	68.05	-2.05	4.21		
28	66	68.05	-2.05	4.21		
29	66	68.05	-2.05	4.21		
30	66	68.05	-2.05	4.21		
31	66	68.05	-2.05	4.21		
32	66	68.05	-2.05	4.21		
33	66	68.05	-2.05	4.21		
34	66	68.05	-2.05	4.21		

35	66	68.05	-2.05	4.21		
36	66	68.05	-2.05	4.21		
37	66	68.05	-2.05	4.21		
38	66	68.05	-2.05	4.21		
39	100	68.05	31.95	1020.69		
40	100	68.05	31.95	1020.69		
41	100	68.05	31.95	1020.69		
42	100	68.05	31.95	1020.69		
43	100	68.05	31.95	1020.69		
44	100	68.05	31.95	1020.69		
45	100	68.05	31.95	1020.69		
46	100	68.05	31.95	1020.69		
47	100	68.05	31.95	1020.69		
48	100	68.05	31.95	1020.69		
49	100	68.05	31.95	1020.69		
50	100	68.05	31.95	1020.69		
51	100	68.05	31.95	1020.69		
52	100	68.05	31.95	1020.69		
53	100	68.05	31.95	1020.69		
54	100	68.05	31.95	1020.69		
55	100	68.05	31.95	1020.69		
56	100	68.05	31.95	1020.69		
57	100	68.05	31.95	1020.69		
58	100	68.05	31.95	1020.69		
TOTAL	**3 947**			**45 744.84**		

Computation of Mean and Standard Deviation values for Project Cost

Respondents	Score X	Mean M	Score - Mean X - M	(Score - Mean)^2 (X - M)^2	Variance	Standard Variance
1	33	75.52	-42.52	1807.72	547.41	23.40
2	33	75.52	-42.52	1807.72		
3	33	75.52	-42.52	1807.72		
4	33	75.52	-42.52	1807.72		
5	33	75.52	-42.52	1807.72		
6	33	75.52	-42.52	1807.72		
7	33	75.52	-42.52	1807.72		
8	33	75.52	-42.52	1807.72		
9	66	75.52	-9.52	90.58		
10	66	75.52	-9.52	90.58		
11	66	75.52	-9.52	90.58		
12	66	75.52	-9.52	90.58		
13	66	75.52	-9.52	90.58		
14	66	75.52	-9.52	90.58		
15	66	75.52	-9.52	90.58		
16	66	75.52	-9.52	90.58		
17	66	75.52	-9.52	90.58		
18	66	75.52	-9.52	90.58		
19	66	75.52	-9.52	90.58		
20	66	75.52	-9.52	90.58		
21	66	75.52	-9.52	90.58		
22	66	75.52	-9.52	90.58		
23	66	75.52	-9.52	90.58		
24	66	75.52	-9.52	90.58		
25	66	75.52	-9.52	90.58		
26	66	75.52	-9.52	90.58		
27	66	75.52	-9.52	90.58		
28	66	75.52	-9.52	90.58		
29	66	75.52	-9.52	90.58		
30	66	75.52	-9.52	90.58		
31	66	75.52	-9.52	90.58		
32	66	75.52	-9.52	90.58		
33	66	75.52	-9.52	90.58		
34	66	75.52	-9.52	90.58		

35	100	75.52	24.48	599.41		
36	100	75.52	24.48	599.41		
37	100	75.52	24.48	599.41		
38	100	75.52	24.48	599.41		
39	100	75.52	24.48	599.41		
40	100	75.52	24.48	599.41		
41	100	75.52	24.48	599.41		
42	100	75.52	24.48	599.41		
43	100	75.52	24.48	599.41		
44	100	75.52	24.48	599.41		
45	100	75.52	24.48	599.41		
46	100	75.52	24.48	599.41		
47	100	75.52	24.48	599.41		
48	100	75.52	24.48	599.41		
49	100	75.52	24.48	599.41		
50	100	75.52	24.48	599.41		
51	100	75.52	24.48	599.41		
52	100	75.52	24.48	599.41		
53	100	75.52	24.48	599.41		
54	100	75.52	24.48	599.41		
55	100	75.52	24.48	599.41		
56	100	75.52	24.48	599.41		
57	100	75.52	24.48	599.41		
58	100	75.52	24.48	599.41		
TOTAL	**4 380**			**31 202.48**		

Computation of Mean and Standard Deviation values for Project Quality

Respondents	Score X	Mean M	Score - Mean X - M	(Score - Mean)^2 (X - M)^2	Variance	Standard Variance
1	0	55.48	-55.48	3078.34	1263.90	35.55
2	0	55.48	-55.48	3078.34		
3	0	55.48	-55.48	3078.34		
4	0	55.48	-55.48	3078.34		
5	0	55.48	-55.48	3078.34		
6	0	55.48	-55.48	3078.34		
7	0	55.48	-55.48	3078.34		
8	0	55.48	-55.48	3078.34		
9	0	55.48	-55.48	3078.34		
10	33	55.48	-22.48	505.47		
11	33	55.48	-22.48	505.47		
12	33	55.48	-22.48	505.47		
13	33	55.48	-22.48	505.47		
14	33	55.48	-22.48	505.47		
15	33	55.48	-22.48	505.47		
16	33	55.48	-22.48	505.47		
17	33	55.48	-22.48	505.47		
18	33	55.48	-22.48	505.47		
19	33	55.48	-22.48	505.47		
20	33	55.48	-22.48	505.47		
21	33	55.48	-22.48	505.47		
22	33	55.48	-22.48	505.47		
23	33	55.48	-22.48	505.47		
24	33	55.48	-22.48	505.47		
25	33	55.48	-22.48	505.47		
26	33	55.48	-22.48	505.47		
27	33	55.48	-22.48	505.47		
28	66	55.48	10.52	110.61		
29	66	55.48	10.52	110.61		
30	66	55.48	10.52	110.61		
31	66	55.48	10.52	110.61		
32	66	55.48	10.52	110.61		
33	66	55.48	10.52	110.61		
34	66	55.48	10.52	110.61		

35	66	55.48	10.52	110.61		
36	66	55.48	10.52	110.61		
37	66	55.48	10.52	110.61		
38	66	55.48	10.52	110.61		
39	66	55.48	10.52	110.61		
40	66	55.48	10.52	110.61		
41	66	55.48	10.52	110.61		
42	100	55.48	44.52	1981.78		
43	100	55.48	44.52	1981.78		
44	100	55.48	44.52	1981.78		
45	100	55.48	44.52	1981.78		
46	100	55.48	44.52	1981.78		
47	100	55.48	44.52	1981.78		
48	100	55.48	44.52	1981.78		
49	100	55.48	44.52	1981.78		
50	100	55.48	44.52	1981.78		
51	100	55.48	44.52	1981.78		
52	100	55.48	44.52	1981.78		
53	100	55.48	44.52	1981.78		
54	100	55.48	44.52	1981.78		
55	100	55.48	44.52	1981.78		
56	100	55.48	44.52	1981.78		
57	100	55.48	44.52	1981.78		
58	100	55.48	44.52	1981.78		
TOTAL	**3 218**			**72 042.48**		

Computation of Mean and Standard Deviation values for Project Safety

Respondents	Score X	Mean M	Score - Mean X - M	(Score - Mean)^2 (X - M)^2	Variance	Standard Variance
1	66	92.97	-26.97	727.14	193.02	13.89
2	66	92.97	-26.97	727.14		
3	66	92.97	-26.97	727.14		
4	66	92.97	-26.97	727.14		
5	66	92.97	-26.97	727.14		
6	66	92.97	-26.97	727.14		
7	66	92.97	-26.97	727.14		
8	66	92.97	-26.97	727.14		
9	66	92.97	-26.97	727.14		
10	66	92.97	-26.97	727.14		
11	66	92.97	-26.97	727.14		
12	66	92.97	-26.97	727.14		
13	100	92.97	7.03	49.48		
14	100	92.97	7.03	49.48		
15	100	92.97	7.03	49.48		
16	100	92.97	7.03	49.48		
17	100	92.97	7.03	49.48		
18	100	92.97	7.03	49.48		
19	100	92.97	7.03	49.48		
20	100	92.97	7.03	49.48		
21	100	92.97	7.03	49.48		
22	100	92.97	7.03	49.48		
23	100	92.97	7.03	49.48		
24	100	92.97	7.03	49.48		
25	100	92.97	7.03	49.48		
26	100	92.97	7.03	49.48		
27	100	92.97	7.03	49.48		
28	100	92.97	7.03	49.48		
29	100	92.97	7.03	49.48		
30	100	92.97	7.03	49.48		
31	100	92.97	7.03	49.48		
32	100	92.97	7.03	49.48		
33	100	92.97	7.03	49.48		
34	100	92.97	7.03	49.48		

35	100	92.97	7.03	49.48		
36	100	92.97	7.03	49.48		
37	100	92.97	7.03	49.48		
38	100	92.97	7.03	49.48		
39	100	92.97	7.03	49.48		
40	100	92.97	7.03	49.48		
41	100	92.97	7.03	49.48		
42	100	92.97	7.03	49.48		
43	100	92.97	7.03	49.48		
44	100	92.97	7.03	49.48		
45	100	92.97	7.03	49.48		
46	100	92.97	7.03	49.48		
47	100	92.97	7.03	49.48		
48	100	92.97	7.03	49.48		
49	100	92.97	7.03	49.48		
50	100	92.97	7.03	49.48		
51	100	92.97	7.03	49.48		
52	100	92.97	7.03	49.48		
53	100	92.97	7.03	49.48		
54	100	92.97	7.03	49.48		
55	100	92.97	7.03	49.48		
56	100	92.97	7.03	49.48		
57	100	92.97	7.03	49.48		
58	100	92.97	7.03	49.48		
TOTAL	**5 392**			**11 001.93**		

Appendix C

Upper Critical Values of Spearman's Rank Correlation Coefficient R_S

n	Nominal α					
	0.1	**0.05**	**0.025**	**0.01**	**0.005**	**0.001**
4	1	1	-	-	-	-
5	0.8	0.9	1	1	-	-
6	0.657	0.829	0.886	0.943	1	-
7	0.571	0.714	0.786	0.893	0.929	1
8	0.524	0.643	0.738	0.833	0.881	0.952
9	0.483	0.6	0.7	0.783	0.833	0.917
10	0.455	0.564	0.648	0.745	0.794	0.879
11	0.427	0.536	0.618	0.709	0.755	0.845
12	0.406	0.503	0.587	0.678	0.727	0.818
13	0.385	0.484	0.56	0.648	0.703	0.791
14	0.367	0.464	0.538	0.626	0.679	0.771
15	0.354	0.446	0.521	0.604	0.654	0.75
16	0.341	0.429	0.503	0.582	0.635	0.729
17	0.328	0.414	0.488	0.566	0.618	0.711
18	0.317	0.401	0.472	0.55	0.6	0.692
19	0.309	0.391	0.46	0.535	0.584	0.675
20	0.299	0.38	0.447	0.522	0.57	0.662
21	0.292	0.37	0.436	0.509	0.556	0.647
22	0.284	0.361	0.425	0.497	0.544	0.633
23	0.278	0.353	0.416	0.486	0.532	0.621
24	0.271	0.344	0.407	0.476	0.521	0.609
25	0.265	0.337	0.398	0.466	0.511	0.597
26	0.259	0.331	0.39	0.457	0.501	0.586
27	0.255	0.324	0.383	0.449	0.492	0.576
28	0.25	0.318	0.375	0.441	0.483	0.567
29	0.245	0.312	0.368	0.433	0.475	0.558
30	0.24	0.306	0.362	0.425	0.467	0.549
31	0.236	0.301	0.356	0.419	0.459	0.54
32	0.232	0.296	0.35	0.412	0.452	0.532
33	0.229	0.291	0.345	0.405	0.446	0.525
34	0.225	0.287	0.34	0.4	0.439	0.517
35	0.222	0.283	0.335	0.394	0.433	0.51
36	0.219	0.279	0.33	0.388	0.427	0.503
37	0.215	0.275	0.325	0.383	0.421	0.497

38	0.212	0.271	0.321	0.378	0.415	0.491
39	0.21	0.267	0.317	0.373	0.41	0.485
40	0.207	0.264	0.313	0.368	0.405	0.479
41	0.204	0.261	0.309	0.364	0.4	0.473
42	0.202	0.257	0.305	0.359	0.396	0.468
43	0.199	0.254	0.301	0.355	0.391	0.462
44	0.197	0.251	0.298	0.351	0.386	0.457
45	0.194	0.248	0.294	0.347	0.382	0.452
46	0.192	0.246	0.291	0.343	0.378	0.448
47	0.19	0.243	0.288	0.34	0.374	0.443
48	0.188	0.24	0.285	0.336	0.37	0.439
49	0.186	0.238	0.282	0.333	0.366	0.434
50	0.184	0.235	0.279	0.329	0.363	0.43
51	0.182	0.233	0.276	0.326	0.359	0.426
52	0.18	0.231	0.274	0.323	0.356	0.422
53	0.179	0.228	0.271	0.32	0.352	0.418
54	0.177	0.226	0.268	0.317	0.349	0.414
55	0.175	0.224	0.266	0.314	0.346	0.411
56	0.174	0.222	0.264	0.311	0.343	0.407
57	0.172	0.22	0.261	0.308	0.34	0.404
58	0.171	0.218	0.259	0.306	0.337	0.4
59	0.169	0.216	0.257	0.303	0.334	0.397
60	0.168	0.214	0.255	0.301	0.331	0.394

Source: Cabilio and Masaro, 2001, p.83.