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A Study of Uncertainty and Risk Management Practice Related to Perceived Project Complexity

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A STUDY OF UNCERTAINTY AND RISK MANAGEMENT PRACTICE RELATIVE TO PERCEIVED PROJECT COMPLEXITY

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by

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Abstract

The project management literature is extensive with reference to continued project failures and the notion that over the years projects have increased in complexity. This is accompanied by concern that prescribed industry risk management standards are not effective enough in managing uncertainty and risk, especially in complex project environments. Leading risk and project management researchers have proposed a number of approaches that they consider to have the potential to improve the management of uncertainty and risk in these environments, including the uncertainty management paradigm; explicit opportunity management; an improved approach to the evaluation and interpretation of estimates; complexity theory concepts and the explicit management of individual and organisational risk attitudes. Other researchers suggest an even wider approach to managing uncertainty and risk, such as scenario planning or frameworks that include fundamental uncertainty, ignorance and fuzziness.

The primary purpose of this research is to contribute to the understanding of the practices used by Project Managers to manage uncertainty and risk on projects of high complexity. The research questions explore the relationship between uncertainty and risk management approaches and processes and perceived project complexity; the prevalence of risk management approaches and processes considered to be 'in advance' of general prescribed industry risk management standards; and perceptions of project success in relation to uncertainty and risk management.

A post-positivist research approach was taken. The value of phenomenological elements to supplement the quantitative data in this research was considered important. Post-positivism enables this by rejecting the relativist idea of incommensurability of different perspectives. Results obtained from a survey of 73 Project Managers revealed that Project Managers implement higher level (in accordance with a framework developed for this research) uncertainty and risk management approaches and processes on projects perceived to be of greater complexity. However, most Project Managers, on projects characterised by high complexity, implement uncertainty and risk management approaches and processes at lower than the 'optimal' levels recommended by general prescribed industry risk management standards. A minority of Project Managers on projects perceived as complex are implementing uncertainty and risk management approaches and processes considered to be 'in advance' of general prescribed industry risk management standards. A positive correlation was found between uncertainty and risk management approaches and processes implemented and perceived project success on projects of high complexity. These results support findings in the literature that enhanced uncertainty and risk management approaches and processes appear to be related to project success. The empirical investigation also explores the nature of uncertainty and risk management approaches and processes considered to be 'in advance' of general prescribed industry risk management standards, together with qualitative perspectives from participating Project Managers, highlighting issues and recommendations for improving uncertainty and risk management, particularly in complex project environments.

Declaration

This thesis is submitted to Bond University in fulfillment of the requirements of the degree of Doctor of Philosophy. This thesis represents my own original work towards this research degree and contains no material which has been previously submitted for a degree or diploma at this University or any other institution, except where due acknowledgement is made.

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Conducting this research has been a long, challenging, exciting and knowledge gaining experience. Throughout this journey there have been many others who have been supportive. I'd especially like to thank those organisations and Project Managers who took the time to participate in the research. I trust that the findings will be of benefit to you and the project management discipline and that they will provide insights for further investigation into the intricacies of managing uncertainty and risk in complex project environments, to continually improve project delivery into the future.

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1. INTRODUCTION

1.1 Purpose of the Research

The creation of certainty seems to be a fundamental tendency of the human mind. Ironically though, there appears to be much evidence that our ability to manage uncertainty efficiently and effectively in many cases is severely lacking, even with the advances in this field (Gingerenzer, 2002). As Taleb (2007) suggests, "almost all social scientists have, for over a century operated under a false belief that their tools could measure uncertainty" (Taleb, 2007, p. xxii). In recent years there has been a heightened awareness of uncertainty and risk management in both the public and private sectors, particularly given the backdrop of sensational financial collapses of major corporate and banking institutions, together with significant catastrophes, such as British Petroleum's Gulf of Mexico oil spill.

The literature provides a wide array of evidence and reference to continued project failures (Atkinson, 1999; Flyvbjerg, Bruzelius, & Rothengatter, 2003; Kutsch & Hall, 2005; Kutsch, Maylor, Weyer, & Lupson, 2011; Mulcahy, 2003; Raz, Shenhar, & Dvir, 2002; Sharma, Sengupta, & Gupta, 2011; Standish Group, 2006, 2009). A few notable project failures include the massive cost overruns of the Channel Tunnel (Flyvbjerg et al., 2003); NASA's Mars Climate Orbiter loss (Sauser, Reilly, & Shenhar, 2009); Terminal 2E roof collapse at Charles de Gaulle airport (Uwe, 2006) and the cost and time overruns of the airbus A380 (Shore, 2008). There is also much rhetoric suggesting that projects have over time become more complex (Baccarini, 1996; Chang & Christensen, 1999; Hillson & Simon, 2007; Philbin, 2008; Vidal, Marl, & Bocquet, 2011; Williams, 1999). Consequently, in recent years there has been an increasing tendency to draw attention to the particular challenges posed by complex projects (Cooke-Davies, Cicmil, Crawford, & Richardson, 2007).

Uncertainty adds to the complexity of a project, so can be considered as a constituent dimension of a project (Williams, 1999). Uncertainty and complexity could be seen by some as two separate concepts, but William's (1999) view is that "uncertainty and structural complexity produce the overall difficulties and messiness of the overall project, which is considered to demonstrate the overall complexity" (Williams, 1999, p. 271).

Project management complexity is characterised by much debate, but two key concepts of project complexity are generally accepted - structural complexity (organisational and technological), with associated differentiation and interdependencies (Baccarini, 1996) and uncertainty (Williams, 1999). There are a number of project categorisation methods offered in the literature with respect to complexity. Some recent frameworks developed include measuring complexity using an Analytic Hierarchy Process (Vidal et al., 2011) and the Technological, Organisational and Environmental Framework (Bosch-Rekveldt, Jongkind, Mooi, Bakker, & Verbraeck, 2011). The Crawford-Ishikura Factor for Evaluating Roles (CIFTER), used by the Global Alliance for Project Performance Standards (GAPPS) is a practical and tested method for categorising projects according to management complexity (Aitken & Crawford, 2007). These are critically discussed in the literature review.

Project management research has shown that conventional project management approaches and practice are rational and linear, proving ineffective in successfully managing project complexity and the entire project life cycle in general (Atkinson, Crawford, & Ward, 2006; Cooke-Davies et al., 2007; Williams, 1999). More specifically, most general prescribed industry risk management standards also have a rational and linear slant (Smith & Irwin, 2006). Some literature questions the ability of such approaches to effectively deal with complexity and irrationality

(Smith & Irwin, 2006). Other criticism of the ability of current general prescribed industry risk management standards to effectively manage uncertainty and risk is made by Atkinson et al (2006), Chapman & Ward (2002, 2003b), De Meyer, Loch & Pitch (2002) and Stoelsness & Bea (2005). Chapman & Ward (2002, 2003b) emphasise the need for a move towards an 'uncertainty management paradigm' (as detailed in section 2.7). This is further endorsed by Stoelness and Bea (2005). Atkinson et al (2006) argue that the focus on uncertain events or circumstances does not facilitate consideration of aspects of variability that is driven by underlying ambiguity and lack of information. Meyer, Loch & Pitch (2002) emphasise the need to establish improved project information from the outset, developing a model with a 'rigorous language' that allows the Project Manager to judge the adequacy of project information. Of relevance to the above is the persistent tension between risk viewed as an objective fact and a subjective construction. Even though unifying these different schools of risk analysis is not easy, integration is required to develop a more complete framework for analysing and managing project 'risk' (Zhang, 2011).

In relation to the above-mentioned objective and subjective views is the debate in the literature on the definitions of risk and uncertainty. There are two key perspectives with respect to these concepts – those who view them as fundamentally different (Winch & Maytorena, 2011) and those who view them as part of a continuum from subjective to probabilistic (Atkinson et al., 2006; Sanderson, 2012; Zhang, 2011). Cognisance does need to be taken of these differing views. This thesis uses both terms throughout, with the perspective of the author of a continuum, with uncertainty characterised by subjective views and risk characterised by objective views at each end of the continuum. This perspective is supported by Atkinson (2006), Sanderson (2012) and Zhang (2011).

It has been suggested that new understandings of complex systems may help us in managing uncertainty in complex project environments (Cooke-Davies et al., 2007). The project management literature also contains concepts suggested as important to improving the management of uncertainty and risk, particularly in complex project environments. These concepts are referred to in this thesis as those 'in advance' of mainstream standards. They include explicit opportunity management (Hillson, 2002, 2004a; Olsson, 2007; Zhang, 2011), the uncertainty management paradigm (Chapman & Ward, 2003a, 2003b; Ward & Chapman, 2003), a constructively simple approach to the evaluation and interpretation of estimates (Chapman, Ward, & Harwood, 2006), risk attitude (Hellier, Lonie, Power, & Donald, 2001; Hillson & Murray-Webster, 2005, 2008; Slovic, 1987; Smallman & Smith, 2003) and complexity theory concepts (Cooke-Davies et al., 2007). Critical of probabilistic risk management approaches in particular, other researchers have taken this further and suggested wider approaches as more appropriate in the management of uncertainty and risk, notably – a sound foundation for the management of imprecision should include fundamental uncertainty, ignorance and fuzziness (Pender, 2001) and scenario planning (Schoemaker, 1995).

With projects continuing to fail (Flyvbjerg et al., 2003; Kutsch & Hall, 2005; Kutsch et al., 2011; Mulcahy, 2003; Raz et al., 2002; Sharma et al., 2011; Standish Group, 2006, 2009) and complexity increasing (Baccarini, 1996; Chang & Christensen, 1999; Hillson & Simon, 2007; Philbin, 2008; Vidal et al., 2011; Williams, 1999), effectively managing uncertainty and risk in such environments appears to be an important element towards enabling project success (Hillson & Simon, 2007; Raz et al., 2002; Zwikael & Ahn, 2011). Pivotal though, as highlighted and critiqued throughout this thesis is the need to use appropriate uncertainty and risk management approaches and processes (Atkinson et al., 2006; Chapman & Ward, 2002, 2003a, 2003b, 2004; Chapman et al., 2006; Cooke-Davies et al., 2007; De Meyer, Loch, & Pitch, 2002; Hillson, 2002; Olsson, 2007;

Pender, 2001; Shore, 2008; Smith & Irwin, 2006; Stoelsness & Bea, 2005) or perhaps even wider uncertainty and risk management approaches (Pender, 2001; Schoemaker, 1995). Besides the criticism of the ineffectiveness of general prescribed industry risk management standards (traditional mainstream risk management standards and guidelines) especially in dealing with complexity, there is also a rather confusing array of such standards and guidelines (Beck, 2004; Hanson, 2005).

There is limited evidence in the literature of empirical research focused primarily on the management of uncertainty and risk on complex projects. This is considered to be a research 'gap', specifically with respect to Project Manager's uncertainty and risk management practice in relation to their perceptions of project complexity, together with the inter-relationships between uncertainty and risk management practice and perceived project success on projects of high complexity. This is supported by the following observation that "there appears to be far more literature offering prescriptions to Project Managers on how to manage risk in projects, rather than assess the relative effectiveness of those prescriptions" (Kutsch & Hall, 2010). The combination of continued project failures, increasing project complexity and inadequate uncertainty and risk management prescription and practice culminate to establish the research problem.

Besides research within each of the variables (uncertainty and risk management; project complexity and project success) elaborated upon in the literature review, there is some specific empirical research that does address some of the inter-relationships and key elements of this gap. Notably, research on uncertainty and risk management practice and project success (Raz et al., 2002; Zwikael & Ahn, 2011); alternative uncertainty/risk management approaches and processes to prescription(Taylor, 2006) and case study research that establishes the value of considering various scenarios pertaining to the joint impacts of various uncertainties, rather than focusing on one uncertainty (Schoemaker, 1995).

This study contributes to knowledge by building on past research in the area and addressing the practical challenges and issues concerning management of uncertainty and risk in complex project environments.

As stated above this research builds on other empirical investigations, particularly the research findings of 100 projects in Israel that concluded that risk management practices are not widely used by Project Managers, but when they are used they appear to be related to project success (Raz et al., 2002); and on findings of recent international and multi-industrial research that suggests that 'risk management planning' provides effective processes to reduce uncertainty and improve project success rates (Zwikael & Ahn, 2011). The research also investigates if risk management practices do differ from risk management prescription promulgated by general prescribed industry risk management standards, as discovered in the empirical study of the risk practices of information technology Project Managers in Hong Kong (Taylor, 2006). With the literature depicting a variety of uncertainty and risk management approaches and processes that could be considered to be 'in advance' of mainstream risk management standards, this research explores the nature and use of these on projects, especially those characterised by high levels of complexity. Qualitative insights from research participants, with respect to suggested improvements in the management of uncertainty and risk are also investigated.

The following research questions were developed to address the research 'gap' and to further define the research problem, with careful attention given to ensuring that they meet the empirical criterion and that they are clear, specific, answerable and substantially relevant (Punch, 2005):-

- Are uncertainty and risk managed differently by Project Managers on projects perceived as more complex?
- What levels of general prescribed industry risk management standards are implemented by Project Managers on projects perceived to have high complexity?
- What uncertainty and risk management approaches and processes are considered to be ‘in advance’ of general prescribed industry risk management standards on projects of high complexity?
- On projects perceived to have high complexity, what proportion of Project Managers are implementing uncertainty and risk management approaches and processes considered to be ‘in advance’ of general prescribed industry risk management standards?
- On projects of high complexity, does the uncertainty and risk management approach and process implemented affect perceived project success?
- On projects of high complexity, is there a difference in perceived project success between projects where uncertainty and risk is managed at ‘high levels’ and ‘in advance’ of general prescribed industry risk management standards?

1.2 Methodology

A mixed methods approach underpinned by a post-positivist research philosophy, using predominantly quantitative methods with some qualitative elements was considered appropriate for this research. The quantitative approach provides the overall picture of the phenomenon and the qualitative aspect provides support for interpretation of the results and answers to some of the research questions. Although the approach is primarily quantitative, it is important to note that it is based on opinions and reported practice, not on objective observations. An abductive logic was determined the most appropriate, given the nature of the research and particularly as the researcher could not conclusively rely on the initial premise being correct.

The following five null hypotheses were developed to investigate the research questions stated above:

$1H_0$: Project Managers do not implement higher level uncertainty and risk management approaches and processes on projects they perceive as more complex, than on projects that they perceive as less complex.

$2H_0$: Most Project Managers, on projects they perceive to have high levels of complexity, do not implement uncertainty and risk management approaches and processes at lower than ‘optimal’ levels of general prescribed industry risk management standards.

$3H_0$: A minority of Project Managers do not implement uncertainty and risk management approaches and processes ‘in advance’ of general prescribed industry risk management standards on projects they perceive to have high levels of complexity.

$4H_0$: There is no positive correlation between uncertainty and risk management approach and process levels implemented and perceived project success by Project Managers, on projects that they perceive to be of high complexity.

$5H_0$: Perceived project success is not higher on projects of high complexity, where uncertainty and risk is managed 'in advance' of general prescribed industry risk management standards, rather than at 'high levels' of such standards.

The sampling technique used included a combination of self-selecting and snowballing. These were considered to be the most pragmatic, given the nature and characteristics of the study. A Questionnaire was developed and following a pilot survey data was collected from Project Managers between mid August to late November 2011. An extensive and wide spectrum of project management institutions, associations and networks were approached across the globe. The snowball sample was initiated with Project Managers and business contacts spread across New Zealand, Australia, South Africa and the United Kingdom. The final sample size achieved is n=73.

1.3 Structure of the thesis

Chapter 1 of this thesis provides an overview, including the purpose, methodology and thesis structure.

Chapter 2 is a review of the pertinent literature associated with the management of uncertainty in complex project environments. An account of the history of risk management shows the progress of this discipline over time, particularly highlighting the overarching debate between the use of qualitative and quantitative approaches. Increasing project complexity and evidence of continued project failures is portrayed. The rational and linear nature of the project management paradigm and traditional mainstream risk management standards and associated practice are critiqued and shown to be considered ineffective in managing uncertainty, especially in complex environments. The approaches and processes highlighted in the literature that seek to improve the management of uncertainty, especially on complex projects, are identified. The challenges of measuring project complexity and project success are introduced. The literature review provides the background for identification of the research gap to be addressed and the formulation of the research questions.

Chapter 3 outlines the null and alternate hypotheses devolved from the research questions for testing in this study. It describes the methodology used to collect and analyse the data. The research philosophy is explained and the theoretical framework set. Frameworks are established to operationalise key variables, the sampling approach is determined and the manner in which the data is statistically tested is set out.

Chapter 4 presents the statistical findings of the data. Descriptive statistics are firstly used to present the data, identifying the characteristics and suitability of the sample and a univariate description of the key research variables. This is followed by the statistical tests conducted on each hypothesis.

Chapter 5 presents the analysis and discussion. The research questions are restated and the results of the hypotheses tests briefly summarised. The research questions are analysed against the findings and the implications thereof discussed. The uncertainty and risk management approaches denoted as 'in advance' of general prescribed industry risk management standards are explored further, together with other qualitative research findings.

Chapter 6 provides a conclusion to the thesis. A summary of the findings is presented. The importance of this research as a contribution to knowledge is outlined and emphasised. The limitations of the research are highlighted and finally recommendations for future research are proposed.

2. LITERATURE REVIEW

2.1 Introduction

Underpinning this research, in order to provide the background for the identification of the research gap and to thereafter express the research problem and formulate the research questions, a comprehensive review of the relevant literature was undertaken. This review addresses the key themes, definitions, debates and challenges surrounding the management of uncertainty and risk in complex project environments. Importantly, it intends to confirm the value of this empirical research as a contribution to knowledge.

It is widely depicted in the literature that projects are continuing to fail (Atkinson, 1999; Flyvbjerg et al., 2003; Kutsch & Hall, 2005; Kutsch et al., 2011; Mulcahy, 2003; Raz et al., 2002; Sharma et al., 2011; Standish Group, 2006, 2009). A few notable project failures are as follows:-

- The Channel Tunnel project (1987-1994) was estimated to cost £2,600 million. On completion the cost had blown out to £4,650 million – a cost overrun of 80%. (Flyvbjerg et al., 2003)
- NASA's Mars Climate Orbiter was launched on schedule. It travelled in space for 9½ months before it approached the vicinity of Mars. As soon as it began its 'insertion' maneuver its signal was lost and never recovered again. (Shenhar et al., 2005)
- In 2004, less than a year after opening, Terminal 2E roof collapsed at Charles de Gaulle airport, killing four and injuring three. (Uwe, 2006)
- The Airbus A380 project was initiated in 2000. In 2006 when the aircraft was in the assembly stage in Toulouse, France a preassembled wiring harness produced in Germany failed to fit into the airframe. Production was halted, deliveries postponed for 2 years and costs were blown out significantly. (Shore, 2008)

The sections that follow in the literature review build on ways to address this critical issue, with the focus on project complexity, the management of uncertainty and risk and perceived project success.

Insights into how uncertainty and risk management has evolved over time is summarised to provide an introduction to some of the key debates and challenges faced in managing uncertainty and risk. It is revealed that there has and continues to be debate and polarisation between the use of rationally based methods (primarily quantitative) and irrationality (primarily qualitative).

The nature and definition of complex systems and specifically project complexity is investigated and described. Projects are purported to have been increasing in complexity over the years (Baccarini, 1996; Chang & Christensen, 1999; Hillson & Simon, 2007; Philbin, 2008; Vidal et al., 2011; Williams, 1999). Furthermore, it is then shown that there is significant critique in the literature, suggesting that the current project management paradigm is not effective in managing such complexity. The challenges of developing complexity measures for projects are highlighted and a number of key models presented and critically discussed.

The relationship between uncertainty, risk and complexity is discussed. The polarisation between quantitative and qualitative approaches, as mentioned above, is highlighted, with particular attention towards defining risk and uncertainty. Following this, the prominent general prescribed industry risk management standards currently used in the management of uncertainty and risk in project management are presented and critiqued. These are described by some researchers as a rather confusing array of standards and guidelines (Beck, 2004; Hanson, 2005). Critically though, the literature provides insights that question the ability of current risk management standards, with characteristic rational and linear slants, to effectively manage uncertainty in complex environments (Smith & Irwin, 2006). Key concepts seeking improved ways to manage uncertainty and risk, particularly in complex project environments are highlighted. These include explicit opportunity management, the uncertainty management paradigm, a constructively simple approach to the evaluation and interpretation of estimates, improving the management of uncertainty on 'soft' projects, risk attitude and concepts from complexity theory.

The important concepts and challenges in determining project success are then critically discussed. Traditional 'measures' of project success are identified, with the need expressed for a broader view of success criteria.

As mentioned above, the review of the literature culminates in the identification of a research 'gap', followed by the development of research questions.

2.2 History of Risk Management

In his book *Against the Gods – The Remarkable Story of Risk*, Bernstein (1996) provides some interesting insights into how risk management has evolved over time. From its conception in the Hindu-Arabic numbering system, developed over eight hundred years ago, to the establishment of the theory of probability and explosion in quantitative techniques during the Renaissance years. Bernstein (1996) contends that much of the advancement during these years forms the basis of much of the quantitative risk management theory today. However, Bernstein's story is marked throughout by the persistent tension between those who assert that the best decisions are based on quantification and numbers, determined by patterns of the past and those who base their decisions on more subjective degrees of belief about the uncertain future. Uncertainty and probability are seen as incompatible by those who are uncomfortable with subjective probabilities (Chapman et al., 2006).

Rational decision making models (based on linear decision making, where results are proportionate to cause) remained prominent until the late 20th century, apart from early critique by Frank Knight (1921) and John Maynard Keynes (1921), who questioned the ability of such an approach in the light of irrationality. Concerned with the degree to which reality differs from earlier rational decision-making models, psychologists in particular looked extensively into the nature and causes of such deviations. This research and experimentation revealed that departures from the rational model occur frequently (Bernstein, 1996).

Pioneering research in this respect was conducted by Daniel Kahneman and Amos Tversky in the late 1970's and 1980's. They developed the concept of Prospect Theory that revealed behavioural patterns that had never been recognised by proponents of rational decision-making. Through ingenious experiments they discovered that the value of a risky opportunity appears to depend far more on the reference point from which the possible loss or gain will occur than on the final value of the assets that would result. Kahneman and Tversky discovered that with a choice portrayed as a gain, most people are risk averse. When the choice is portrayed as a loss, then most people are risk takers. They used the expression "failure of invariance" to describe such inconsistent choices, when the same problem appears in different forms. These patterns were ascribed to human emotions, which the researchers believed to be responsible for destroying self-control, which they further believed to be essential for rational decision-making. Emotions were identified to be related to cognitive difficulties. At the heart of this is the difficulty people have in sampling. People use shortcuts, known as heuristics, which can lead to erroneous perceptions (Tversky & Kahneman, 1992).

The attitude of individuals and organisations has a significant influence on whether risk management delivers what it promises (Hellier et al., 2001; Slovic, 1987; Smallman & Smith, 2003). The human element introduces an additional layer of complexity into the risk process, both explicit and covert. This leads to the adoption of risk attitudes, which affect every aspect of risk management. Risk attitudes exist at individual, group, corporate and national levels. These can be assessed and described, allowing sources of bias to be diagnosed, exposing their influence on the risk process (Hillson & Murray-Webster, 2005). Although Hillson and Murray-Webster's (2005) book referenced above, entitled *Understanding and Managing Risk Attitude*, is more pragmatic rather than theoretical or research based, it does further emphasise the importance of a people centred approach for risk management. Risk attitude is further discussed in section 2.8.

Further to the 'persistent tension' between quantification and subjectivity mentioned above, Zhang (2011), in a journal paper assessing 'risk' management research conducted over the last ten years refers to two schools of 'risk' management, where 'risk' is viewed as an objective fact and subjective construction. The school where risk is viewed as an objective fact considers risks to objectively exist and to be probabilistic in epistemology. Knowledge produced from an objective risk analysis is the outcome of rational decision making. The school regarding 'risk' as a subjective construction considers 'risk' as subjective, constructed phenomena, with multiple epistemological dimensions. Therefore 'risk analyses' are not objective and natural activities, but rich in values (Zhang, 2011).

In the world, discontinuities, irregularities and volatilities appear to be proliferating rather than diminishing. In this regard Bernstein (1996) contends that as civilisation has pushed forward, nature's vagaries have mattered less and the decisions of people have mattered more. Despite the many ingenious tools that have thus far been created, Bernstein (1996) contends that much still remains unresolved. He concludes his book

'Against the Gods – The Remarkable Story of Risk' by introducing Chaos Theory and emphasising its potential contribution to the risk management discipline, due to the theory's preference towards non-linear thinking, where results are not proportionate to the cause. Complexity Theory has arisen out of Chaos Theory and its potential contribution towards risk and project management is briefly discussed later.

2.3 Complex Systems and Project Complexity

There has been and continues to be much difficulty and debate in defining complexity. Complexity is not easy to define and even among scientists there is no unique definition of complexity (Johnson, 2006).

Complexity is a system considered to have structure with variations. Chaos on the other hand, also occurs frequently and is the sensitive dependence of the final result upon initial conditions. In a chaotic world it is hard to predict which variation will arise in a given place and time. A complex world is highly structured and in a chaotic world 'we do not know what will happen next' (Goldenfield & Kadanoff, 1999). Bawden (2007) provides a slightly different perspective in his account of the terms 'complicated' and 'complex'. A 'complicated' system is referred to as knowable, with its behaviour 'theoretically predictable'. A 'complex' system on the other hand is characterised by the "inherently contingent nature of outcomes, of often synergistic interactions, between what are considered to be different parts of some form of coherent whole, making the behaviour of the whole at best exceptionally unpredictable, and at worst quite unknowable" (Bawden, 2007, p. 615). In the new science of complexity, increased complexity is to be expected as a fundamental property of complex adaptive systems. As mentioned above, a fundamental characteristic of a complex adaptive system, is counterintuitive order.

“Such systems may through selection bring themselves to the edge of chaos, a constant process of evolution, a constant adaptation. Part of the lure of the edge of chaos is optimisation of computational ability, whether the system is a cellular automation or a biological species evolving with others as part of a complex ecological community. At the edge of chaos bigger brains are built” (Lewin, 1999, p. 149).

This is particularly focused on biological sciences, but an interesting parallel could be made with the earlier noted increase in project complexity over time. Could this be a necessary requirement for technological, economic and social advancement?

Most complexity researchers would agree that a complex system should have most or all of the following:

- The system contains a collection of many interesting objects or agents.
- The objects’ / agents behaviour is affected by memory or feedback - i.e. something from the past affects something in the present, or that something in one location affects what is happening in another – a knock-on effect.
- The objects can adapt their strategies according to their history.
- The system is typically ‘open’, i.e. the system can be affected by its environment.
- The system appears to be ‘alive’ - i.e. the system evolves in a highly non-trivial and often complicated way, driven by an ecology of agents that interact and adapt under the influence of feedback.
- The system exhibits emergent phenomena, which are generally surprising and may be extreme – i.e. the system is far from equilibrium and can evolve in a complicated way all by itself.
- The emergent phenomena typically arise in the absence of any sort of central controller.

- The system shows a complicated mix of ordered and disordered behaviour.

(Johnson, 2007)

Key in the study of complex systems is understanding the indirect effects. The causal relations between early indications or incidents and later results are seldom obvious, and often very complex (Williams, Klakegg, Walker, Aderson, & Magnussen, 2012).

As conveyed in the introduction to the thesis and literature review there is much commentary that projects are getting more complex (Baccarini, 1996; Chang & Christensen, 1999; Hillson & Simon, 2007; Philbin, 2008; Vidal et al., 2011; Williams, 1999) and an increasing tendency in recent years to draw attention to the particular challenges posed by complex projects (Cooke-Davies et al., 2007). In a paper calling for the need for new paradigms in complex projects, Williams (1999) refers to a NATO Advanced Research Workshop held in Kiev, 1996 entitled 'Managing and Modelling Complex Projects'. He mentions that the workshop was based on the basic premise "that projects are becoming increasingly complex; that traditional project methods are proving inadequate; and that new methods of analysis and management are needed" (Williams, 1999, p. 269).

An early definition of project complexity was provided by Baccarini (1996).

"It is proposed that project complexity be defined as 'consisting of many varied interrelated parts' and can be operationalised in terms of differentiation and interdependency" (Baccarini, 1996, p. 202).

Baccarini (1996) identified two types of project complexity, notably organisational and technological. He stated that differentiation and interdependencies characterised in both are managed by integration – co-ordination, communication and control – and mentioned that this integration has been claimed as the '*raison d' etre*' and essential function of project management. To conclude, Baccarini (1996) emphasised that as projects become more complex there will be an increasing concern about the concept of project complexity and its influence upon the project management process.

Williams' (1999) cites Baccarini (1996) and refers to this component (organisational and technical) as 'structural complexity', relating to differentiation (the number of related parts) and interdependency (the degree of interdependency between these elements). These measures can be applied to various project dimensions. The multi-objective nature of most projects, trade-offs and a multiplicity of stakeholders also adds to structural complexity (Williams, 1999; Williams et al., 2012). However, merely counting interdependencies is not sufficient, as the nature of the interdependencies is critical (Williams, 1999). Williams (1999) references Thompson (1967) who identified 3 types of structural complexity – pooled (each element gives a discrete contribution to the project); sequential (one elements output becomes another's input); and reciprocal (each element's output becomes another's input). The reciprocal type of interdependency particularly intensifies complexity. These reciprocal interdependencies can cause dynamic feedback effects and these run counter to the assumptions made in first generation tools, such as PERT (Programme Evaluation Review Technique), which assumes steady progress throughout the project (Williams, 1999).

Further to the structural complexity curtailed above, another key element of complexity is uncertainty. Williams (1999) contends that 'uncertainty adds to the complexity of a project, so "can be viewed as a constituent dimension of project complexity"(Williams, 1999, p. 270). However, he does mention that there is a view that uncertainty and complexity are seen by some as two separate concepts. Williams' (1999) view is that uncertainty and structural complexity produce the overall "difficulties" and "messiness" of the overall project, which is considered to demonstrate the overall project complexity (Williams, 1999, p. 271).

Turner and Cochrane's (1993) well known paper classified projects by two parameters:

- How well defined are the goals?
- How well defined are the methods for achieving the goals?

Different management and project start-up methods for different types of projects are required (Turner & Cochrane, 1993).

Williams (1999) mentions that uncertainty in methods is a well known concept. Without clarity in methods there will be added structural complexity, as there will be added interdependencies, as methods are re-planned and retried. Uncertainty in goals is the other dimension of uncertainty. Turner and Cochrane (1993) identified software development projects as typical where goals are uncertain, but the methods are well known. User's requirements are challenging to specify and often change after initial prototypes are reviewed. Interfacing elements therefore need to change with the consequent cross-impacts; feedback loops and re-work – an increase in the feature of structural complexity. Williams (1999) depicts that changes and modifications resulting from uncertainty in goals increases complexity in two areas:

- The action of making changes often increases the project's (structural) complexity.
- The product complexity is often increased, thereby increasing the project complexity.

Williams (1999) identifies the following two compounding causes for an increase in a project's structural complexity. The first is driven from the relationship between product complexity and project complexity. As new products are developed they become more structurally complex, with a larger number of project elements and a greater degree of inter-element connectivity. In the above mentioned paper the author does mention that this element is based very much on anecdotal evidence and experience. The second factor compounding structural complexity is that projects have become more time constrained. There's an emphasis on 'tight' contracts, with time risks being placed on the contractor. Shorter project durations also drive projects towards parallelism and concurrency, which increases project complexity further.

Building on the 'widely accepted' model in the literature – uncertainty and structural complexity, Geraldi and Albrecht (2007) have through theoretical and empirical research identified three valuable concepts of complexity, notably faith, fact and interaction (Geraldi & Albrecht, 2007). 'Faith' relates to creating something unique and new, with high uncertainty. 'Fact' relates to dealing with large amounts of interdependent information and 'interaction' influences both faith and fact and is concerned with interfaces between locations. Geraldi and Albrecht (2007) conducted an empirical investigation of Project Managers in a plant and engineering company, investigating patterns of complexity, with respect to these concepts and taking consideration of the project lifecycle. The empirical study found that complexity of faith, fact and interaction develop in similar patterns. The predominant type of complexity perceived by Project Managers was discovered to be interaction and "people, internationality, multidisciplinary, and clients were the most important triggers of complexity" (Geraldi & Albrecht, 2007).

Philbin (2008) conducted research in the United Kingdom concerning the management of increasing complexity prevalent on technological and engineering projects. The development of tools and techniques to manage the complexity of 'system-of-systems' was confirmed as a common requirement in the responses to the survey. In this regard Philbin (2008) highlights the 'four systems view', which was developed as a tool for the management of such projects by the Imperial College. This is comprised of four descriptive frames (integrated system design; systems architecture development; systems integration; and system-of-systems management) to accommodate increasing levels of complexity. All four frames are supported by the systems theory level and linked to the enterprise level, thus emphasising the need to consider a project's business as well as technical aspects (Philbin, 2008).

Measuring Project Complexity

Further to the above discussion pertaining primarily to the characteristics and definitions of complexity, the following section provides a critical account of various models developed to measure project complexity. Some of the key models discussed are as follows:-

- Uncertainty-Complexity-Pace Model (Shenhar & Dvir, 1996)
- Technological, Organisational and Environmental framework (Bosch-Rekveldt et al., 2011)
- Analytic Hierarchy Process (Vidal et al., 2011)
- Crawford-Ishikura Factor table for evaluating roles (Aitken & Crawford, 2007).

Shenhar and Dvir (1996) established the Uncertainty-Complexity-Pace (UCP) model as a measure for project complexity. In this model complexity is defined in terms of assembly (subsystem, performing a single function); system (collection of subsystems, multiple functions); and array (widely dispersed collection systems with a common mission) (Shenhar et al., 2005).

Further to the UCP model there are a wide variety of project categorisation methods depicted in the literature. Pivotally, it is important to emphasise that project complexity is a composite attribute (Atkinson et al., 2006). Bosch-Rekveldt (2011) identifies four key project categorisation methods used by institutions in the field of project management:-

- Co-operative Research Centre's (CRI) project profile.
- Defence Matariel Organisation (Australia) methodology of Acquisition Categorisation (ACAT) framework to categorise projects.
- The Global Alliance for Project Performance Standards (GAPPS) Crawford-Ishikura Seven Factor Table for Evaluating Roles (CIFTER) based on their management complexity.
- International Project Management Association's (IPMA) evaluation table for project management complexity.

(Bosch-Rekveldt, 2011)

Rekveldt (2011) provides a useful critique of the above methods, depicting that the CRI is the simplest method, but does not address technical project management aspects. The IPMA project classification table is extensive and covers organisational and technical project management aspects in particular. CIFTER takes into account technical project management aspects, with a broad focus on the interaction between the project and the business environment. The ACAT covers project management complexity more implicitly than the IPMA model and is considered more general and less operational than IPMA (Bosch-Rekveldt, 2011).

Two recent models to measure project complexity have been developed through research – the Analytic Hierarchy Process (Vidal et al., 2011) and the Technical, Organisational and Environmental framework (Bosch-Rekveldt et al., 2011). The Analytic Hierarchy Process (concept established by Saaty, 1977, 1980, 1990) based methodology is developed by Vidal *et al* (2011). Through pair-wise comparisons project complexity is ascertained, based on project size, variety, interdependencies and context-interdependence. Through the use of the Delphi Technique to establish criteria and elements and a case study the authors maintain that the resultant complexity index overcomes the limits of existing complexity measures in that it is reliable, intuitive and user friendly. However, there are the following limitations and criticisms of the model:

- The case study carried out was within a specific context, with a low project maturity level in the firm.
- Rankings can vary with respect to the quality of pair-wise comparisons.

(Vidal et al., 2011)

Through an extensive literature review and case study investigation in the process engineering industry the Technical, Organisational and Environmental (TOE) framework for characterising project complexity is developed (Bosch-Rekveldt et al., 2011). TOE comprises 50 elements across 3 categories to provide a 'complexity footprint', with the ultimate goal being the use of the framework to better adopt the front-end development steps of projects to specific complexities.

However, the following limitations of the framework are noted by the researchers, with suggested future research.

- The qualitative character of the study, together with suggested 'data saturation'. A more industry wide survey is suggested, performed with a more quantitative character.
- A narrow focus on engineering projects in the processing industry. Further research is required to investigate the applicability of the TOE framework in different industries and on less technical projects.

(Bosch-Rekveldt et al., 2011)

The CIFTER forms part of the Global Alliance for Project Performance Standards (Global Alliance for Project Performance Standards, 2007). CIFTER is comprised of the following seven factors:-

1. Stability of the overall project context.
2. Number of distinct disciplines, methods, or approaches involved in performing the project.
3. Magnitude of legal, social, or environmental implications from performing the project.
4. Overall expected financial impact (positive or negative) on the project's stakeholders.
5. Strategic importance of the project to the organisation or organisations involved.
6. Stakeholder cohesion regarding the characteristics of the product of the project.
7. Number and variety of interfaces between the project and other organisational entities.

Each of the seven factors are rated with a point scale of 1-4, with the total number of points determining the 'level' of project management complexity.

Aitken and Crawford (2007) conducted research across a range of project types to test the CIFTER as a means of categorising projects according to project management complexity. They found positive correlations between project manager and assessor/ sponsor assessments of management complexity of projects using this instrument for assessing and prioritising projects by complexity (Aitken & Crawford, 2007). A key feature of this is the notion of complexity levels being derived from how people perceive them.

For the purposes of this research the CIFTER is considered an appropriate framework for assessing project management complexity, with its composite and broad focus. It forms part of a global standard, is based on perceptions of complexity, is used by practitioners and as depicted above, has been tested and found to have a good level of consistency of assessment by Project Managers, their supervisors and independent assessors.

2.4 The Project Management Paradigm and Complexity

As discussed above, structural complexity (Baccarini, 1996; Williams, 1999) and uncertainty (Turner & Cochrane, 1993; Williams, 1999) can be considered to be key elements of project complexity. Much uncertainty comes from the lack of a clear unambiguous goal. On complex projects problems are often subjective and interpersonal, resulting from a team of people working uncertainly towards an uncertain goal with emergent complex team behaviours (Williams et al., 2012).

Williams (1999) provides a view that classical project management techniques are unsuitable for dealing with complex projects.

Decomposition models do not account for the compounding effects when individual perturbations accumulate in a project. They cannot deal with feedback loops or account for the systemic, holistic effects, nor are they able to deal with goal and method uncertainty. He also emphasises the importance of modelling complex projects, so as to support the management function. Holistic models such as system dynamics can assist in providing a strategic overview and enable modelling of systemic effects. He mentions that network models can perhaps be improved to include stochastic effects, or the effects of management decisions and "in addition to quantitative data, there is a need to capture 'softer' ideas into project models if they are to be a representation of 'real' projects" (Williams, 1999, p. 272).

Conventional project management and practice focuses more on the procedural aspects of project life cycles, rather than on conception at the front end and support at the tail end. This ineffectiveness is further exacerbated with conventional project management's inability to deal with projects at the 'soft' end of the spectrum, where uncertainty and ambiguity are high. Different approaches for dealing with uncertainty and stakeholder expectations need to be adopted on such projects (Atkinson et al., 2006). It is therefore of concern that the rational view of project management (as the accomplishment of clearly defined goals in a specific period of time and in conformity with certain budget and quality requirements) remains dominant in most project management textbooks and discussions on the topic (Lenfle, 2011). This is discussed further in section 2.7. Besides these challenges, 'soft' skills (communication, team work, leadership, conflict management, negotiation…) are important in the management of complex projects, with people being one of the more volatile and important factors affecting complexity (Syed et al., 2010).

Cooke-Davies *etal* (2007) support the above viewpoints. They cite various researchers in the literature and maintain that the Project Management paradigm is 'rational', 'normative', 'positivist' and 'reductionist' (p 51).
"… behind this paradigm is a world view derived from Cartesian philosophy, a Newtonian understanding of the nature of reality and an enlightenment epistemology whereby the nature of the world we live in will be ultimately comprehensible through empirical research" (p52). With the view that the nature of the deep themes that are emerging from complexity theory are an expansion and enrichment of the Cartesian/ Newtonian/ Enlightenment paradigm from which project management has emerged, Cooke-Davies et al (2007) believe that this "emerging paradigm may well provide project management with the breakthroughs in practice that are being called for in the conduct of complex projects" (Cooke-Davies et al., 2007, p. 52).

Cooke-Davies et al (2007) provide a useful overview of complexity theory themes that could be of particular importance to project management. These include the butterfly effect (non-linearity), strange attractors, fractals, edge of chaos, universality of patterns and patterning in the world, dissipative structures, self organising systems, emergence, complex adaptive systems, radical unpredictability and indeterminacy.

These concepts are summarised in Appendix 1**.**

2.5 Risk, Uncertainty and Traditional Risk Management Approaches in Complex Project Environments

This section focuses primarily on the definitions of uncertainty and risk, which is considered vital in the management thereof (Atkinson et al., 2006; Sanderson, 2012; Zhang, 2011). Unfortunately the terms are often misused, which leads to misunderstanding and less effective decision-making (Sanderson, 2012). The inadequacy of general prescribed industry risk management standards (defined in section 2.6) to manage uncertainty and risk in complex environments is then discussed, with reference to the potential value of complexity theory concepts in managing uncertainty and risk in such environments.

There continues to be debate in the literature with respect to the terms 'uncertainty' and 'risk'.

Identifying the characteristics uncertainty was touched on in the previous section, with reference to uncertainty in project goals and methods to achieve the goals (Turner & Cochrane, 1993). Further perspectives pertaining to uncertainty are outlined below.

Following an expression of the challenges faced by administration in coping with uncertainty Gifford etal (1979) identified two important concepts in describing uncertainty (as defined in psychological and organisational research) – information load (amount and complexity of the information received at any given time) and patterns (probabilities and risk) or randomness (inability to assign probabilities) (Gifford, Bobbit, & Slocum, 1979). Views of uncertainty expressed by Jauch and Kraft (1986) are:-

- Classical (focus on objective/ external environment)
- Transition (focus on both the external and internal dimensions)
- Process (perception of decision makers influenced by internal factors)

(Jauch & Kraft, 1986)

In research comparing the effectiveness of contractual and relational governance in constraining opportunism, Carson et al (2006) present uncertainty as consisting of ambiguity (lack of clear information about environmental variables, uncertainty of cause-effect relationships and uncertainty about available courses of action and their potential effects) and volatility (rate and unpredictability of change in an environment over time, which creates uncertainty about future conditions) (Carson, Madhok, & Wu, 2006).

Uncertainty in projects is about variability and ambiguity (Chapman et al., 2006; Ward & Chapman, 2003) - *aleatoric* uncertainty and *epistemic* uncertainty (Hillson & Murray-Webster, 2005; Olsson, 2007). Variability refers to a situation when a measurable factor can take on a range of possible values. A 'true' dice is the classic example. A throw will result in one to six and the chance of any particular number is one in six. This is *aleatoric* uncertainty. The event is defined, but the outcome is uncertain because it is variable. However, ambiguity refers to uncertainty of meaning. Here the issue is not the probability of an event producing a particular value; it's the uncertainty about the event itself, with a lack of clarity over some aspect of its existence, content or meaning. This type of uncertainty is described as *epistemic*, since there is incomplete knowledge about the situation under consideration. Both ambiguity and variability are present throughout the project life cycle, but they are particularly pronounced at the early stages of a project (Atkinson et al., 2006).

Winch and Maytorena (2011) argue that there is a fundamental difference between the concepts of uncertainty and risk. They rethink project risk management from first principles conveying the differences between *a priori* statistical probabilities and estimates, emphasising that risk is in the realm of logical quantitative analysis, while uncertainty is in the realm of judgement and intuition in entrepreneurship (Winch & Maytorena, 2011).

Perminova et al (2008) provide a perspective that risk is one of the implications of uncertainties on projects. They define uncertainty as "a context for events having a negative impact on the project's outcomes or opportunities, as events that have a beneficial impact on project performance" (Perminova, Gustafsson, & Wikstroem, 2008, p. 76).

In a critical review of risk, uncertainty and governance in mega projects Sanderson (2012) emphasises the importance of considering people's 'fundamental epistemological assumptions about decision-maker cognition and about decision-maker views on the nature of the future (risky or uncertain)'. He has a viewpoint that few texts give full consideration to the vital prior questions of whether, and if so how risk differs from uncertainty. With the terms used 'interchangeably' "there is a real danger therefore that a whole range of potentially very significant issues is silenced in the decision-making process, and a tendency to focus on operational planning and control to the detriment of strategic issues" (Sanderson, 2012, pp. 434-435). Sanderson (2012) provides suggested differences between risk and uncertainty, in which he considered the seminal contributions of Keynes (1937) and Knight (1921), together with 'clarifications and extensions' by other more recent authors. He identifies the following categories with regard to the assumptions about decision-maker views on the nature of the future:

Risk/Uncertainty Category	Decision-Makers View
Risk Category 1: *a priori* probability	The decision-makers view is that they are able to assign objective probabilities to a known range of future events on the basis of mathematically 'known chances', e.g. the probability of throwing a six when a perfect die is 1 in 6.
Risk Category 2: statistical probability	The decision-make's view is that they are able to assign objective probabilities to a known range of future events on the basis of empirical/ statistical data about such events in the past e.g. the probability of being involved in a fire.
Uncertainty Category 1: subjective probability	The decision-makers view is that they face a known range of possible future events, but lack the data necessary to assign objective probabilities to each. Instead they use expectations grounded in historical practice to estimate the subjective probability of future events.
Uncertainty Category 2: socialised	The decision-makers view is that they face a situation in which the nature and range of future events is unknown, not simply hard to understand because of a lack of relevant data. The future is inherently unknowable, because it is socially constructed and may bear little or no relation to the past or the present.

Table 1: Assumptions about decision-maker views on the nature of the future (Sanderson, 2012, p. 435)

Of key importance is Sanderson's emphasis on the consideration of people's epistemological assumptions when considering the management of risk and uncertainty. This is consistent with other researchers - (Atkinson et al., 2006; Zhang, 2011). Olsson (2007) cites Leafley (1997) who argues that although risk results from uncertainty, risk and uncertainty are not theoretically synonymous. The perspective is that there is a continuum between the two concepts depending on the degree of knowledge and calculation (Sanderson, 2012). Risk involves situations where the probability of outcomes is 'known', while uncertainty is the opposite (i.e. when the probability of outcomes is not known). Hillson (2004) provides a further perspective on the relationship between risk and uncertainty and the distinction between *aleatoric* and *epistemic* in the following couplet:

"Risk is measurable uncertainty; uncertainty is unmeasurable risk" (Hillson, 2004a)

Cognisance needs to be taken of the above debate as to the use of these concepts. As mentioned in the introduction to the thesis, this research uses both uncertainty and risk terms throughout with the author leaning towards the view of a continuum between the two concepts (as supported by Atkinson (2006), Sanderson (2012) and Zhang (2011), and the perspective that the greatest management challenges lie at the uncertainty end of the spectrum.

As with the discussion in section 2.4 above, in relation to the project management paradigm and complexity, traditional 'risk' management approaches are also considered to be of concern in project delivery, especially in relation to complex projects. It is apparent, as described later, in section 2.6, that most traditional risk management standards and guidelines have a rational and linear slant. The ability of such approaches to effectively deal with complexity and irrationality, particularly in relation to human systems is therefore questioned (Smith & Irwin, 2006). Financial performance can be generally considered an important component of most projects. In this sense existing approaches to 'risk' assessment on large scale projects provide only disconnected views of financial risk and do not adequately capture 'risk interaction and possible risk transmission mechanisms' (Brookfield & Boussabaine, 2009). Citing the work conducted by the New England Complex Systems Institute, Smith and Irwin (2006) comment that indirect effects lie at the heart of effective risk analysis and management and that "our abilities to identify and control the range of indirect effects within a complex socio-technical system have been challenged in the face of numerous catastrophic failures, policy related hazards and environmental impacts" (p223). They also mention that the issue of inter-dependence is also important to achieving effective uncertainty and risk management and that there is a growing recognition in the importance of 'soft' human issues (as opposed to technical systems) in the creation of technically-based failures.

Johnson (2006) discusses the concept of 'emergence', indicating that it is a central idea in the science of complex systems. This is defined in Appendix 1. Smith and Irwin (2006) relate 'emergence' to what they regard as the three pillars of risk management, notably, risk identification, migration and reduction. They mention that it is not enough to consider these three pillars as separate processes. Instead, the interactions between them can lead to 'risk migration' across the system. In relation to the above-mentioned pillars they believe that 'emergence' is the "fatal flaw", as it can generate conditions that exceed both the control systems that are in place and the ability of managers to deal with the conditions that emerge. Invariably the contingency plan that is in place to deal with the problems has been by-passed by the events.

The manner in which management responds to emergence can create a new cycle of problems that generate further risks. Smith and Irwin (2006) mention that decisions taken for what appears to be the most appropriate course of action can generate further consequences that are deemed to be adverse. They further emphasise that the manner in which certain risks are identified, defined and prioritised is also important.

With the above noted concerns expressed in the literature of traditional risk management standards inability to effectively deal with complexity and irrationality it is suggested by some researchers that project uncertainty and risk management will need to move beyond a linear cause and effect approach and consider the potential insights of complexity theory (Cooke-Davies et al., 2007; Smith & Irwin, 2006).

The widely accepted practice of identifying uncertainty and risk in terms of likelihood and consequences works well for frequent events. However, for infrequent rare events not encountered previously, it works less well. The new understanding of complex systems may help Project Managers to better identify, understand and manage uncertainty and risk.

2.6 Current prominent industry standards used in the management of risk on projects

The prominent risk management standards considered to be currently used in the management of projects are identified. For the purposes of this research these are referred to as the general prescribed industry risk management standards, especially as they share a common set of key processes, notably establishing the context & risk management planning; risk identification; qualitative risk analysis/ evaluation; quantitative risk analysis/ evaluation; risk response planning/ treatment; and risk monitoring & control. A risk management framework developed by Ward (2005) is described and conveyed as a useful framework to use in this research to assess uncertainty and risk management approaches implemented. Further critique of the standards is provided. In conclusion, the above-mentioned processes are depicted as important in establishing the parameters for the development of a framework to assess the implementation of risk management processes.

There is a vast array of risk management standards and guidelines. Six prominent risk management standards currently used in project management are as follows:

- Project Risk Management, Project Management Institute, Project Management Body of Knowledge (PMBoK), Chapter 11, 2004.
- Risk Management, Joint Australian/ New Zealand Standard, AS/NZS 4360:2004.
- Project Risk Analysis and Management (PRAM) Guide, UK Association for Project Management (APM), 2004.
- Risk Analysis and Management for Projects (RAMP), Institution of Civil Engineers and the Faculty and Institute of Actuaries, 2005.
- Project Risk Management, Project Management Institute, Project Management Body of Knowledge (PMBoK), Chapter 11, 2008.
- Risk Management – Principles and Guidelines, Joint Australian/ New Zealand Standard, AS/NZS ISO 31000:2009.

Such process frameworks should have an important role to play in the development of risk management 'best practice'. However, they do need to be continually subjected to constructive critique and useful features from the various frameworks should be incorporated into a more common set of basic concepts (Ward, 2005).

Ward (2005) mentions that in broad terms there is a general convergence between different guidelines and standards in respect of generic risk management process frameworks. Most incorporate the basic phases of identification, analysis, evaluation, and response selection. However, he maintains that the terminology used can vary, leading to sometimes subtle and perhaps unintended differences in emphasis and focus. Ward (2005) establishes a useful risk management development framework which is termed the "six dimensions of risk management development" (Ward, 2005). Six key dimensions of 'risk' are identified, notably the focus of attention; scope of processes; documentation; tools and techniques; parties involved and allocation of responsibilities for risk management; and resources applied to risk management. Each dimension is comprised of a range of possible approaches within each dimension. These are considered to be 'levels' of risk management practice within each dimension. Although the focus of this framework is organisational it is considered a useful framework for this research to assess risk management approach 'levels' implemented by Project Managers on projects. This is further discussed in section 3.6.2.

Further criticism from others in the literature emphasise that even with the recent proliferation of research into risk management there is still ambiguity in definitions and nomenclature pertaining to risk and uncertainty, a rather confusing array of standards and guidelines, and an ambiguous legislative mandate for risk management (Beck, 2004; Hanson, 2005).

Chapman (2006) provides a key critique on the importance and differences in framing assumptions for 'risk' and 'uncertainty' in an exploration of PMBoK (2004), PRAM (2004) and RAMP (2005). He indicates that in the development of PRAM (2004) and RAMP (2005) the most fundamental point of contention appeared to be in the definition of 'risk' and 'uncertainty'. It is shown that PMBoK's (2005) use of the Probability – Impact (PI) index limits the span of the uncertainty and risk concepts (Chapman, 2006). It is contended that PMBoK (2004) represents 'common practice' and that PRAM (2004) and RAMP (2005) represents 'best practice'. Portions of PRAM (2004) and RAMP (2005) are associated with a 'modern approach' to probabilities, including a minimalist approach (more effective descriptions of probability and impact). However, both include PI indices, which Chapman (2006) believes should be avoided, due to inconsistency in framing assumptions and because PI indices are restricted to a narrow event based view of uncertainty and risk. Furthermore, to treat an estimate as unconditional and unbiased, all three guides mentioned above need to explicitly address known-unknowns; unknown-unknowns and sources of bias. Until they do, users of these and other guides "need to understand the differences between them in terms of their position on probability" (Chapman, 2006, p. 308).

It can be argued that general prescribed risk management standards may not be appropriate for all projects. As discussed earlier and above the literature particularly expresses concerns with respect to the rational and linear slant of such standards, questioning their value in effectively managing uncertainty and risk in complex project environments. However, "making a choice not to apply formal processes requires a clear understanding of what 'best practice' formal project risk management processes could deliver…" (Chapman & Ward, 2004, p. 619). Chapman and Ward (2004) highlight the key importance of 'risk efficiency' (defined below) in attaining 'best practice', as opposed to 'common practice' (which is largely focussed on events), rather than the accumulated effect of all risk events and other sources of uncertainty, which are relevant to decision makers. Risk efficiency assesses value through comparisons of options, against risk-reward trade-offs, considering cumulative probability, expected cost and risk cost with the notion that it can deliver both lower expected cost and lower associated risk (Chapman & Ward, 2004). Project risk management guidelines should not define risk in a restrictive manner, as an 'add-on' for projects, but rather as a comprehensive 'add-in'. "All guidelines need encouragement to avoid such a stance, because simplicity is an attractive and understandable goal, but simplistic approaches to complex issues will inevitably fail" (Chapman & Ward, 2004, p. 631).

The most recent edition of the Project Management Book of Knowledge (Project Management Institute, 2008) is similar to the 2004 edition, with respect to the 'risk' management approach and processes stipulated in chapter 11. The introduction is promising, with mention made to the importance of individual and group attitudes. Unfortunately, it gets very limited mention thereafter. Furthermore, the probability-impact indices critiqued earlier are still prevalent in the qualitative risk analysis section. There is a limited and rather confusing mention to opportunity management, with no real attention to a wider uncertainty management approach. Overall the focus of the standard is still very much threat based and linear.

The most recently released risk management standard AS/NZS ISO 31000:2009 appears to an attempt to move towards an international standard. The Joint Australian/ New Zealand Committee OB-007, in the revision of AS/NZS4360:2004, decided on promoting the development of an international standard on risk management. In 2005, the International Standards Organisation (ISO) subsequently established a working group to develop the first international risk management standard, using AS/NZS 4360:2004 as the first draft (Joint Australia New Zealand ISO, 2009).

The process for managing risk is reported by the standard (AS/NZS ISO:2009) as identical as that of AS/NZS 4360:2004. The variations to the previous standard relate to risk now being defined in terms of the effect of uncertainty on objectives; a greater focus on principles organisations "must" follow to achieve effective risk management and guidance on how risk management should be implemented and integrated into organisations through continuous improvement frameworks (Joint Australia New Zealand ISO, 2009).

As mentioned above, this standard is an attempt to move towards an international standard. However, it would appear to have some way to go, as the standard was developed very much in an Australian and New Zealand context, with public consultation reported as only being in that region. The standard has some good organisational focus elements, but it unfortunately is not explicit on some important themes considered in the literature, seeking to improve the management of uncertainty – for example explicit consideration and management of individual, as well as organisational risk attitudes, the explicit management of opportunities, a wider definition of uncertainty, and consideration of epistemic uncertainty.

Having a less confusing array of standards would be advantageous, together with a deeper definition of 'risk' and 'uncertainty'. "At present users can be badly served by guides and a broader literature, which is confusing because it uses very basic words like 'risk' in different ways, and it assumes very different objectives are at stake, with very little discussion in the literature about the implications of these differences" (Chapman, 2006, p. 313). Furthermore, it appears necessary that the wider view of the uncertainty management paradigm discussed in this thesis should also be incorporated into 'risk' management guidelines, together with a more explicit focus on individual and organisational risk attitudes.

The six risk management standards identified above are considered to be the key standards currently used in the management of uncertainty and risk in the delivery of projects. For the purposes of this research these are referred to as general prescribed industry risk management standards. The key risk management approaches used and associated levels are introduced through a framework developed by Ward (2005). This framework was shown to be valuable in measuring uncertainty and risk management approaches implemented on projects. Section 3.6.1 describes this further. The key processes detailed in each of these standards consist of establishing the context/risk management planning; risk identification; qualitative risk analysis/ evaluation; quantitative risk analysis/ evaluation; risk response planning/ risk treatment; and risk monitoring and control. These are considered valuable in the development of an uncertainty and risk management process framework for this research. This is discussed in further detail in section 3.6.2.

2.7 Towards Explicit Opportunity Management, an Uncertainty Management Paradigm and Improving the Management of Uncertainty on 'Soft' Projects

Over recent years there has been a growing recognition that a threat focused risk management approach on projects is not appropriate to enhance project performance (Chapman & Ward, 2002, 2003b; De Meyer et al., 2002; Hillson, 2002; Stoelsness & Bea, 2005). Having an approach that merely aims to reduce the possibility of underperformance "is unfortunate because it results in a very limited appreciation of project uncertainty and the potential benefits of project risk management" (Chapman & Ward, 2002, p. 4).

It is important and now widely recognised that risk management should focus on both threats and opportunities (Atkinson et al., 2006; Chapman & Ward, 2002, 2003b; Hillson, 2002; Hillson & Murray-Webster, 2005; Joint Standards Australia/ Standards New Zealand, 2004; Project Management Institute, 2004). If there is a continued focus on threats then there will be a failure to consider the possible welcome effects on project performance (Chapman & Ward, 2003a). Traditional risk management as practiced tends to concentrate 'almost exclusively' on the potential negative effects of uncertainty. Subsequently, opportunities tend to be overlooked or at best addressed reactively (Hillson, 2002). Hillson (2002) therefore calls for an integrated approach to the explicit management of both threats and opportunities. Olsson (2007) concurs with this and through research concluded that risk management practice focuses mainly on threats and that existing risk management processes cannot fully manage opportunities. Olsson (2007) also notes that "existing risk management processes are developed to manage "tame" problems, leaving the 'messes' and 'wicked problems' aside" (Olsson, 2007, p. 752). Furthermore, it is suggested that three major factors are needed for managing opportunities - the ability of the project manager to develop a holistic view within the project; organisational support and interest; and the ability to understand how other organisations affect the project objectives (Olsson, 2007).

Critical of 2000 edition of the PMBOK® Guide (Project Management Institute, 2000) (at the time, but still relevant to the later editions) towards risk management with a probability focus, Pender (2001) presents a framework that deals with incomplete knowledge. This includes an expanded concept of uncertainty that acknowledges ignorance and surprise, where there is no knowledge of future states; imprecision arising from ambiguity (fuzziness) in project parameters and future states; and human limitations in information processing (Pender, 2001). Atkinson, Crawford and Ward (2006) argue that even though attention to threats and opportunities will do better, it is still focused on uncertain events or circumstances. This they argue does not facilitate consideration of aspects of variability that is driven by underlying ambiguity and lack of information. A more explicit focus on uncertainty management is required, and particular attention needs to be paid to the parties involved in a project and their respective objectives in three ways:-

1. Treat the definition of objectives as a key part of managing projects.
2. Project management should clarify and manage desired trade-offs between multiple performance objectives.
3. Ownership of uncertainty requires specific consolidation - decisions need to be made about how uncertainty and associated issues should be allocated to different parties, recognising that different parties have different objectives, perceptions of project risk and different capabilities for managing associated sources of uncertainty.

(Atkinson et al., 2006)

Chapman and Ward (2003a) provide a strong case for moving from a risk management approach that is threat focussed to an uncertainty management paradigm that focuses on both threats and opportunities. They endorse both the US Project Management Institute (PMI) and the UK Association for Project Management (APM) current standards for recognising risk in terms of threats and opportunities. However, they are critical about the limiting focus on events, conditions and circumstances, which cause effects on the achievement of project objectives. They emphasise that uncertainty management is not just about managing threats and opportunities and their implications – "it is about managing all the sources of uncertainty that give rise to and shape our perceptions of threats and opportunities" (Chapman & Ward, 2003a, p. 6). In this sense the use of the traditional term 'risk management' is at odds with this focus on both threats and opportunities and the wider view. In this respect Hillson (2004) suggests an appropriate definition of risk management as 'uncertainty that matters'. With the focus on looking at both threats and opportunities in relation to project objectives. It is still however narrow, in the sense that the wider view, as expressed by Chapman and Ward (2003b) is not highlighted. 'Uncertainty that matters' should include which parties ought to be involved, the alignment of project objectives with corporate strategic objectives, shaping the design and resource requirements, choosing and managing appropriate processes, managing the underlying trade-offs between all relevant attributes measuring performance and the implications of associated risk (Chapman & Ward, 2004).

An uncertainty management approach significantly broadens the thought processes in risk identification. A useful comparison is provided by Ward and Chapman (2003) when they allude to the potential differences in approach to a hypothetical example related to the availability of resources. They mention that a risk management approach, with a threat focus, is likely to identify the issue as 'unavailability of a key resource'. Consequently, they believe that a risk management approach would potentially respond as - 're-schedule activities' or 'obtain additional resources'. An uncertainty management perspective however, would encourage a more open ended, neutral description of all factors, which would facilitate a less constrained consideration of options. The issue is likely to be characterised as 'uncertainty about availability of a key resource'. This could then prompt questions about all factors influencing availability, characteristics of the resource, the possibility of an excess and so on.

Conventional project management (common perceptions of projects; project management practice and professional project management guidelines) does not adequately encompass all the stages of the project life cycle, particularly in minimising the role of:-

- Conception at the 'front end' of the life cycle (strategic aspects).
- Support at the 'tail end'.

(Atkinson et al., 2006)

Atkinson, Crawford and Ward (2006) note that the more procedural elements of project life cycles receive more attention from trainers of project management and in project management text books. They emphasise that it is unfortunately the front end strategic aspects that include the most important and key sources of uncertainty. In this respect it can be said that it is critical that before doing the project right, ensure that it is the right project.

"Perhaps the conventional view of project management is essentially to see the project task as a set of processes to ensure a project meets its predetermined objectives. Then the whole *raison d'être* of project management is to remove (or substantially reduce) uncertainty about meeting specified objectives. However, project management in this sense is a castle built on shifting sands if in practice objectives are unclear, contradictory, or impossible" (Atkinson et al., 2006, p. 691).

Chapman and Ward (2003a) present 5 areas where uncertainty is prevalent:

1. Variability associated with estimates.
2. Uncertainty about the basis of estimates.
3. Uncertainty about design and logistics.
4. Uncertainty about objectives and priorities.
5. Uncertainty about the fundamental relationships between project parties.

To deal with these areas of uncertainty Chapman and Ward (2003a) derived a model which they term the 'Six-W' framework – Who? Why? What? Which Way? Wherewithal? and When? - See Figure 1 below:

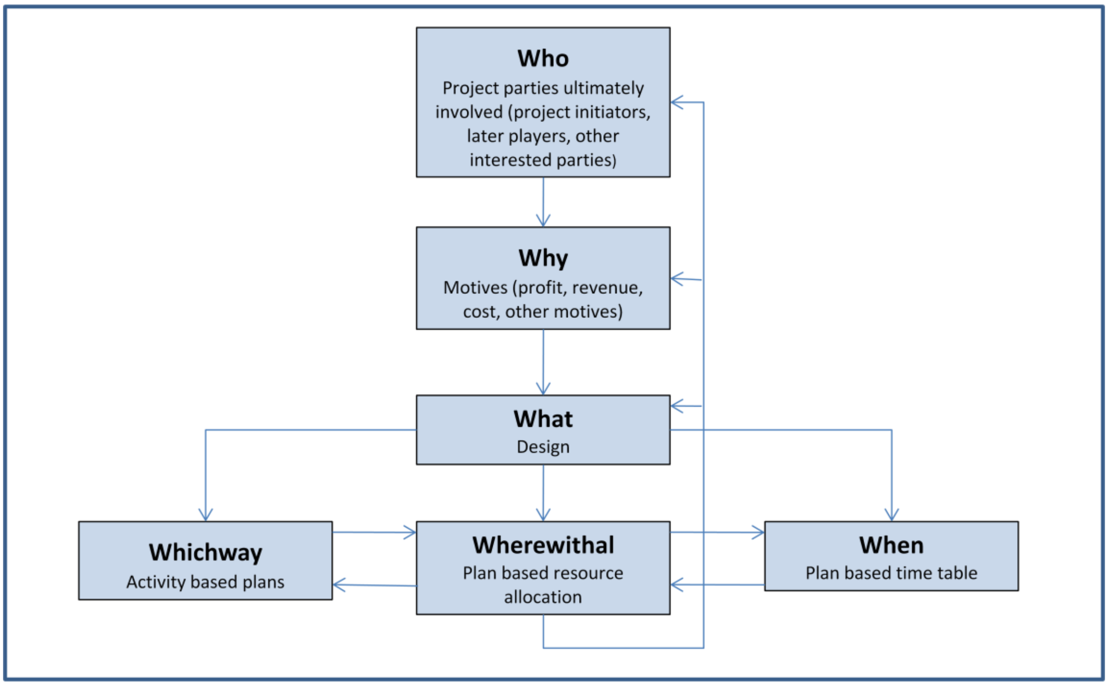

Figure 1: *The six W's of the project definition process - Based on figure 1.1, p 11* (Chapman & Ward, 2003a)

Chapman and Ward (2003) mention the flow lines are the 'roots' of uncertainty, with the arrows showing the inter-connectedness and knock–on effects. It is important to note that the highest levels of uncertainty are usually found at the early stages of the project life cycle (Atkinson et al., 2006; Chapman & Ward, 2003b; Turner & Cochrane, 1993). To address uncertainty in terms of variability and ambiguity a more explicit focus on uncertainty management is required from the outset. Chapman and Ward (2003) mention that to "realise in practical terms the advantages of this wider perspective, it is essential to see project risk management as an important extension of conventional project planning…" (Chapman & Ward, 2003a) (p13). Perhaps a more appropriate term than 'extension' is 'integration', expressing the notion that risk management is integrated fully into the planning process. 'Extension' may imply an 'add on', which is certainly not appropriate. However, Chapman and Ward (2003a) later refer to planning and risk management as "integrated and holistic" (p15), which is certainly more preferable to the earlier use of the term 'extension'.

It is also important to emphasise that uncertainty changes over time and that actors in projects can influence uncertainty through their behaviour (Jensen, Johannson, & Löfström, 2006). Uncertainty is not static and therefore needs to be carefully assessed, evaluated and managed throughout the project life-cycle.

Chapman and Ward (2003) further identify that base plans and contingency plans seek to manage and modify the future incidence and quality of threats or opportunities and their possible impact on project performance primarily through proactive planning. They do mention that this does not necessarily mean that all possible 'out-turns' will have been predicted. However, it is key that though the above-mentioned proactive focus, one should be able to more readily reactively cope with any 'nasty' surprises. Some crisis management may be necessary, no matter how effective the risk management planning is, but this should be kept to a minimum.

When confronted with unforeseeable uncertainties, Project Managers also adopt a learning, trial-and-error based strategy or a parallel approach (different solutions are developed in parallel and the best one is chosen when enough information becomes available) (Lenfle, 2011). Through a review of the 'Manhattan project' characterised by a parallel approach, Lenfle (2011) suggests that an either/or logic is over simplistic and that managers should not necessarily choose between solutions, but also combine them or add new ones throughout the project life cycle.

With respect to crisis management mentioned above, the concept of specialist teams (often referred to as 'tiger teams') is discussed in the literature. Important in this respect is that such teams integrate advanced team work with total problem solving under the concept of a temporary, focused small group of experts. The focus is on managing people to solve a broad range of problem types rather than relying on individual expert solvers (Pavlak, 2004). Research recently conducted on Project Manager's response to unexpected events identified three 'pillars' that support successful responses to unexpected events, notably (1) responsive and functioning structures at organisational level; (2) good interpersonal relationship at group level and (3) competent people at individual level (Geraldi, Kutsch, & Lee-Kelly, 2010).

The literature and guidelines emphasise the importance of the appropriate identification of risks in terms of cause-risk-effect meta-language (Hillson, 2004; Mulcahy, 2002, 2003; Project Management Institute, 2004). However, as discussed above, this approach has a narrow focus. The uncertainty management paradigm espoused by Chapman and Ward (2003, 2003a) has been shown to take this further. Inclusion of this approach in risk management standards is therefore considered to be important to improve the management of uncertainty in projects. The case for moving towards an uncertainty management paradigm has the potential to provide greater opportunity to successfully manage projects than the narrow focussed threat based approaches, and those that focus attention primarily on events, conditions or circumstances.

Furthermore, this thesis has highlighted the persistent tension between those with objective and those with subjective views towards assessing uncertainty. Chapman, Ward and Harwood (2006) address this by providing an innovative and valuable model that seeks to consider 'subjective' probabilities more deeply and broadly. The term they establish is a 'constructively simple approach to estimation'. Incorporating end-user adjustments to counter culturally driven uncertainty and bias, objective estimates, pessimistic estimates and expected value are determined through a 'first pass' and a 'second pass' (where necessary), which considers normal, abnormal and a combined probabilistic view. How this approach addresses the objectivity-subjectivity divide is best summarised as follows:

"The constructively simple approach…dismisses the classical objective view of probabilities as necessary data based in relation to a single model, which is assumed to be true. Both the classical approach and the constructively simple approach accept that 'the truth' is unknowable, but the classical approach looks to more data for more understanding, while the constructively simple approach looks to deeper modelling, structure and the input of more people who understand some aspects of what is going on, plus more data at an appropriate level of structure if it is available, with a view to a richer internally consistent synthesis of subjective and objective information" (Chapman et al., 2006, p. 113).

Also important to consider are 'hard' and 'soft' projects. 'Hard' projects are described as largely unitary, standalone projects with well defined and agreed goals and end products. 'Soft' projects are multidisciplinary and are not pre-defined. They are contested and open to negotiation throughout (Atkinson et al., 2006). Seven dimensions of hardness and softness, as referenced by Crawford and Pollack (2004) are illustrated in figure 2 below.

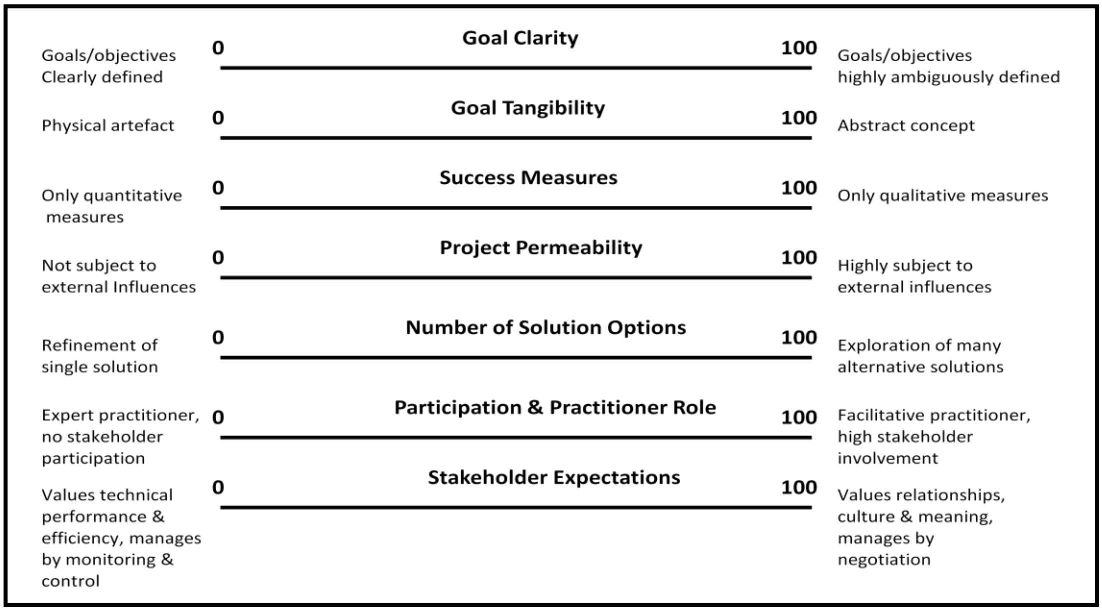

Figure 2: Depiction of 'hard' and 'soft' dimensions framework – Adapted from (Crawford & Pollack, 2004) – Fig 2 p.650

It is suggested by Atkinson, Crawford and Ward (2006) that different approaches for dealing with uncertainty need to be adopted, depending on the hard and soft dimensions. Mainstream project risk management methodologies, tools and techniques have been developed to deal with uncertainty in projects characterised at the hard end of the spectrum. Projects at the soft end of the spectrum, where uncertainty and ambiguity could be considered 'necessarily high' require different approaches and levels of performance expectation (Atkinson et al., 2006). Atkinson, Crawford and Ward (2006) cite Thiry's (2002) approach as useful on soft projects. He proposes the use of 'sense-making' and 'value analysis', particularly at the concept stage of the project.

Thiry (2002) emphasises that these strategies are an 'ambiguity reduction' process that must take place before any attempt is made at uncertainty reduction. In this respect he proposes a *value management* process that seeks to enhance value through achieving a balance between satisfaction of differing needs and resources required and *sense-making,* which is about fully understanding stakeholder needs and expectations (Thiry, 2002).

This section has outlined the importance of explicit opportunity management and the uncertainty management paradigm in the management of uncertainty and risk in projects. Furthermore, the literature has also shown that projects at the 'soft' end of the spectrum require different approaches to manage the characteristically high levels of ambiguity and uncertainty, than projects at the 'hard' end of the spectrum. The above approaches, as with the discussion on risk attitude below, are unfortunately not explicitly promulgated by general prescribed industry risk management standards. They are important in this research (with respect to the exploration and assessment of such concepts in practice) and are considered to be approaches 'in advance' of mainstream risk management standards.

2.8 Risk Attitude

As highlighted in section 2.2, the attitude of individuals and organisations has a significant influence on whether uncertainty and risk management delivers what it promises (Hellier et al., 2001; Slovic, 1987; Smallman & Smith, 2003). Risk management cannot be undertaken mechanistically. Human factors represent an important aspect of the process. The long history of organisational psychology and decision-making literature focussing on systematic biases was touched on earlier in the literature review. The research of Tversky and Kahneman in particular was highlighted. Recent research on project failures emphasises that the vocabulary of systematic biases could prove very useful in understanding how rational project management processes can be 'derailed' by the decision making process (Shore, 2008). It is therefore critical to understand the effects which the attitudes of individuals can have on the risk process (Hillson & Murray-Webster, 2005). Risk attitudes exist on a spectrum, ranging from risk-averse (those who are very comfortable in the presence of uncertainty) to risk-seeking (those who view uncertainty as a welcome change).

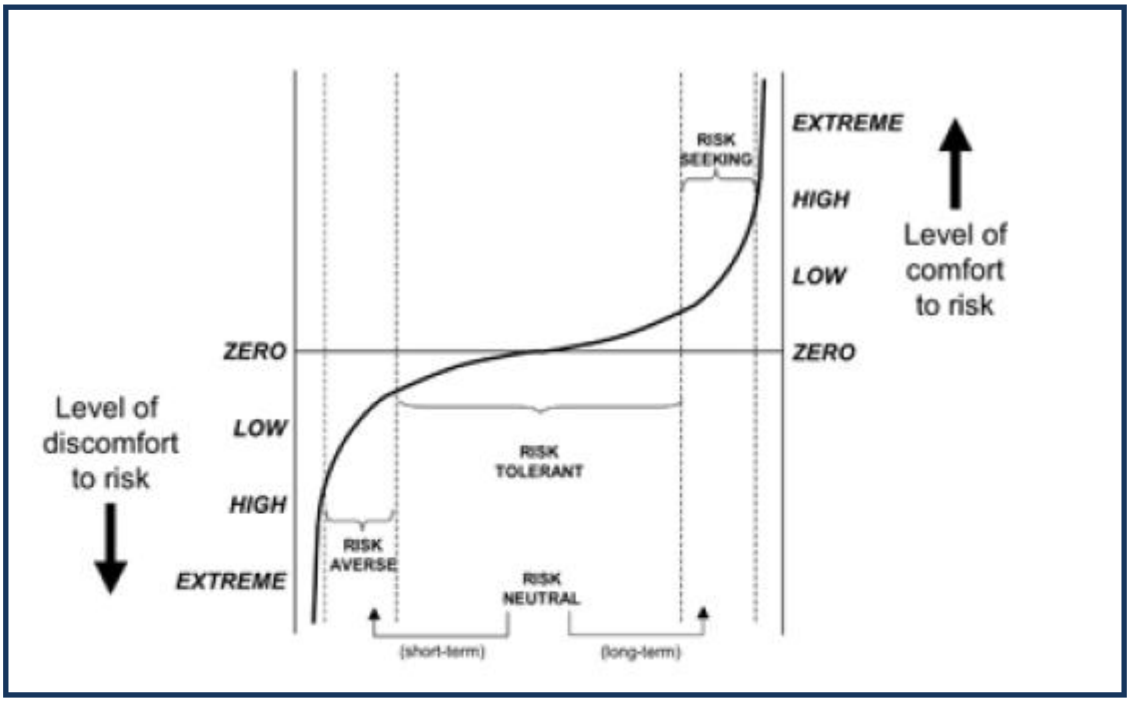

Figure 3: Spectrum of risk attitudes - Figure 3.5 (Hillson & Murray-Webster, 2005)

The general characteristics of the curve in Figure 3 above shows some important aspects of the range of risk attitudes displayed by individuals and groups when faced with uncertainty.

Hillson and Murray-Webster (2005) identify four basic risk attitudes, notably:

- Risk averse - person/group
- Risk tolerant - person/group
- Risk neutral attitude
- Risk seeking

These can be assessed and described, allowing for sources of bias to be diagnosed, exposing their influence on the risk process (Hillson & Murray-Webster, 2005).

Risk attitudes occur at a corporate/ organisational level as well. It is important for the risk management process to address this explicitly.

"Group risk attitude has a significant influence on both the decision process and the outcome and if it is left unmanaged the consequences can be unpredictable" (Hillson & Murray-Webster, 2008).

The literature on an individual's risk behaviour is extensive (Harwood, Ward, & Chapman, 2009). However, few studies investigate the risk propensity of an organisation (Harwood et al., 2009). Hillson (2004) provides some useful insights into risk attitude. Furthermore, Hillson and Murray-Webster (2008) provide a useful practitioner framework, with explicit steps enabling group risk attitude in the decision-making context to be managed proactively.

Key for this research is the importance expressed in the literature to explicitly manage risk attitude in the uncertainty and risk management process. As with the concepts highlighted in the previous section, risk attitude is largely negated by prescribed industry risk management standards. Risk attitude is therefore considered as an approach in advance of mainstream standards for the purpose of this research.

2.9 Project Success

Traditionally projects are perceived as successful when they meet time, budget and performance goals (Shenhar, Dvir, Levy, & Maltz, 2001). The Project Management Book of Knowledge, 2004 refers to project success being measured in terms of time, cost, scope, quality and customer satisfaction (Project Management Institute, 2004). This is commonly known as the 'triple constraint'. The 4th edition of the Project Management Book of Knowledge (2008) is similar, with the focus of 'performance management baselines' against project schedule, scope and cost (Project Management Institute, 2008, p. 82). "Often the scope, schedule and cost will be combined into a performance baseline that is used as an overall project baseline against which integrated performance can be measured" (Project Management Institute, 2008). There is however criticism of traditional measures of project success. De Bakker, Boonstra and Wortman (2010) point out that this criticism is based upon the underpinning assumptions of the definition that:-

- The amount of time, the budget and the project's requirements can be set at the beginning of the project.
- The project's success is the same for each stakeholder.
- The project's success can be determined at the moment the project has produced its deliverables.

(de Bakker, Boonstra, & Wortman, 2010)

There are many times when project success measured in time and budget is not sufficient, especially over a longer period of time after the project is complete. “Quite often, what seemed to be a troubled project, with extensive delays and overruns, turned out later to be a great business success” (Shenhar et al., 2001). Shenhar et al (2001) and many others cite the example of the Sydney Opera House. It took three times longer and five times the cost than anticipated. But it quickly became Australia’s most famous landmark, with few tourists wanting to leave Australia without seeing it (Shenhar et al., 2001).

With projects reported to be continually failing, focusing on IT-IS projects, Atkinson (1999) questioned this failure with respect to the criteria for success, particularly with respect to the commonly used ‘iron triangle’ – time, cost and quality. He asserted that the reason for projects to be labeled as failed could be due to the criteria used for success (Atkinson, 1999). Atkinson (1999) proposed an alternative framework to consider project success criteria, notably the ‘Square Route’. This is a shift away from the exclusive process driven criteria and consists of the following four key components:- the ‘iron-triangle’; the information system (the technical strength of the resultant system); organisational benefits and stakeholder/ community benefits (Atkinson, 1999). Furthermore, Atkinson (1999) offers a breakdown of the four success factors, providing an indicative and non-exclusive list.

Taking account of the literature, particularly the references alluded to above; an additional four factors are added to the ‘triple constraint’ measure to provide the following more balanced set of success criteria:-

- The project objectives were met? (Project Management Institute, 2008)
- The project was delivered on programme? (Project Management Institute, 2008)

- The project was delivered on budget? (Project Management Institute, 2008)
- The project scope was achieved? (Project Management Institute, 2008)
- The project quality objectives were met? (Project Management Institute, 2008)
- Client satisfaction with respect to the project delivery? (Project Management Institute, 2008)
- The project objectives were aligned to the client/ sponsors organisational goals and strategy? (de Bakker et al., 2010)
- Was there an initial commercial/ business success of the product? (Atkinson, 1999; Shenhar et al., 2001)
- Was a new product, market or technology created in preparation for future business growth? (Shenhar et al., 2001)

This is considered an appropriate set of criteria for the purpose of developing a framework for measuring perceived project success in this research. The framework is further discussed and developed in section 3.7.3.

2.10 Research, Gap, Problem and Questions

As evidenced from the critical review of the literature, projects are continuing to fail (Flyvbjerg et al., 2003; Kutsch & Hall, 2005; Kutsch et al., 2011; Mulcahy, 2003; Raz et al., 2002; Sharma et al., 2011; Standish Group, 2006, 2009) and complexity is increasing (Baccarini, 1996; Chang & Christensen, 1999; Hillson & Simon, 2007; Philbin, 2008; Vidal et al., 2011; Williams, 1999). The literature questions the ability of general prescribed industry risk management standards to effectively deal with complexity and irrationality(Smith & Irwin, 2006). Furthermore there is criticism in the literature of the ability of current general prescribed industry risk management standards to effectively manage uncertainty and risk (Atkinson et al., 2006; Chapman & Ward, 2002, 2003b; De Meyer et al., 2002; Stoelsness & Bea, 2005). Effectively managing uncertainty and risk in complex environment in particular appears to be an important element towards enabling project success (Hillson & Simon, 2007; Raz et al., 2002; Zwikael & Ahn, 2011).

The project management literature has been shown to contain concepts suggested as important to improving the management of uncertainty and risk, particularly in complex project environments. These concepts are referred to in this thesis to be 'in advance' of mainstream standards. They include explicit opportunity management (Hillson, 2002, 2004a; Olsson, 2007; Zhang, 2011), the uncertainty management paradigm (Chapman & Ward, 2003a, 2003b; Ward & Chapman, 2003), a constructively simple approach to the evaluation and interpretation of estimates (Chapman et al., 2006), risk attitude (Hellier et al., 2001; Hillson & Murray-Webster, 2005, 2008; Slovic, 1987; Smallman & Smith, 2003) and complexity theory concepts (Cooke-Davies et al., 2007). Critical of probabilistic risk management approaches in particular; other researchers have taken these further and suggested wider approaches as more appropriate in the management of uncertainty. Pender (2001) is critical of PMBoKs (2001) traditional use of probability theory. He indicates that probability-based risk management theory does not explain the important aspects of observed project management practice. He calls for an expanded framework of incomplete knowledge that includes:-

- An expanded concept of uncertainty that acknowledges ignorance or surprise, where there is no knowledge of future states.
- Imprecision arising from ambiguity (fuzziness) in project parameters and future states.
- Human limitations in information processing.

(Pender, 2001)

Pender (2001) concludes that the “underlying assumptions of the probability-based approach show limited applicability [and that] a theoretically sound foundation for the management of imprecision would include fundamental uncertainty, ignorance and fuzziness (Pender, 2001, p. 87).

Schoemaker (1995), through case study research, argues for scenario planning to help compensate for the usual errors in decision-making – overconfidence and tunnel vision. Instead of focusing on one uncertainty, scenarios explore the joint impact of various uncertainties, which ‘stand side by side as equals’ (Schoemaker, 1995).

There is limited evidence in the literature of empirical research focused primarily on the management of uncertainty and risk on complex projects. This is considered to be a research ‘gap’, specifically with respect to Project Manager’s uncertainty and risk management practice in relation to their perceptions of project complexity, together with the inter-relationships between uncertainty and risk management practice and perceived project success on projects of high complexity. This is supported by the following observation that “there appears to be far more literature offering prescriptions to Project Managers on how to manage risk in projects, rather than assess the relative effectiveness of those prescriptions” (Kutsch & Hall, 2010). The combination of continued project failures, increasing project complexity and inadequate uncertainty and risk management prescription and practice culminate to establish the research problem.

Besides research within each of the variables (uncertainty and risk management; project complexity and project success) elaborated upon in the literature review, there is some specific empirical research that does address some of the inter-relationships and key elements of this gap. Notably, research on uncertainty and risk management practice and project success (Raz et al., 2002; Zwikael & Ahn, 2011); alternative uncertainty/risk management approaches and processes to prescription (Taylor, 2006) and case study research that establishes the value of considering various scenarios pertaining to the joint impacts of various uncertainties, rather than focusing on one uncertainty (Schoemaker, 1995).

This study contributes to knowledge by expanding and building on previous research and particularly by addressing the research gap to empirically investigate the management of uncertainty and risk by Project Managers in complex project environments.

As stated above this research also seeks to build on other empirical investigations, particularly the research findings of 100 projects in Israel that concluded that risk management practices are not widely used by Project Managers, but when they are used they appear to be related to project success (Raz et al., 2002) and on valuable findings of recent international and multi-industrial research that suggests that 'risk management planning' provides effective processes to reduce uncertainty and improve project success rates (Zwikael & Ahn, 2011). The research also investigates if risk management practices do differ from risk management prescription promulgated by general prescribed industry risk management standards, as discovered in the empirical study of the risk practices of information technology Project Managers in Hong Kong (Taylor, 2006). With the literature depicting a variety of uncertainty and risk management approaches and processes that could be considered to be 'in advance' of mainstream risk management standards, this research explores the nature and use of these on projects, especially those characterised by high levels of complexity. Qualitative insights from research participants, with respect to suggested improvements in the management of uncertainty and risk, and the identification of 'advanced' uncertainty and risk approaches are also investigated.

The following research questions were developed to address the research 'gap' and to further define the research problem, with careful attention given to ensuring that they meet the empirical criterion and that they are clear, specific, answerable and substantially relevant (Punch, 2005):-

- Are uncertainty and risk managed differently by Project Managers on projects perceived as more complex?
- What levels of general prescribed industry risk management standards are implemented by Project Managers on projects perceived to have high complexity?
- What uncertainty and risk management approaches and processes are considered to be 'in advance' of general prescribed industry risk management standards on projects of high complexity?
- On projects perceived to have high complexity, what proportion of Project Managers are implementing uncertainty and risk management approaches and processes considered to be 'in advance' of general prescribed industry risk management standards?
- On projects of high complexity, does the uncertainty and risk management approach and process implemented affect perceived project success?
- On projects of high complexity, is there a difference in perceived project success between projects where uncertainty and risk is managed at 'high levels' and 'in advance' of general prescribed industry risk management standards?

2.11 Conclusion

The literature review has shown that there is extensive reference to continued project failures and to an increase in project complexity over time. Uncertainty has been highlighted as a 'constituent dimension' of project complexity. Uncertainty and risk have been defined and it has been revealed that there continues to be much debate between the subjective and objective views of uncertainty and the management thereof, with the importance of taking cognisance of epistemological assumptions when considering the management of uncertainty and risk emphasised. The effective and efficient management of uncertainty and risk in complex project environments is shown as a possible key element to enhancing project success. However, there is substantial criticism in the literature of the inability of the rational and linear project management paradigm, more broadly, and specifically the majority of traditional risk management standards to effectively manage uncertainty and risk, especially on complex projects.

The literature in the field of uncertainty/ risk management and complexity is characterised by a number of theories across a range of disciplines. Complexity theory is one key theory in this research is specifically addressed in section 2.4, with theoretical concepts expanded upon in Appendix 1. The human dimension is pivotal to the management of uncertainty and risk and is consequently addressed by a wide array of organisational, decision and behavioural theory. Important across these, as critically addressed in the literature review, is the debate between rational and irrational decision-making and associated models.

Leading project and risk management researchers have proposed a number of approaches and processes to improve the management of uncertainty and risk in projects. These have been critically reviewed.
Empirical research in the field of uncertainty and risk management, specifically in complex project environments is shown to be limited. There appears to be far more literature offering prescriptions to manage risks in projects, rather than assess the relative effectiveness of those prescriptions (Kutsch & Hall, 2010). This has been identified as the key research 'gap', specifically with respect to Project Manager's uncertainty and risk management practice in relation to their perceptions of project complexity, together with the inter-relationships between uncertainty and

risk management practice and perceived project success. The research ‘gap’ is further defined into the research problem, followed by the development of research questions. This points to the potential importance of this research and its value, as a contribution to knowledge.

The literature review and resultant research questions identify the following key research variables:- uncertainty and risk management approaches and processes; project complexity; and project success. The research methodology section that follows, takes these further in the design of frameworks to operationalise these.

3. RESEARCH METHODOLOGY

3.1 Introduction

The literature review identified the research 'gap' to empirically investigate the management of uncertainty and risk by Project Managers in complex project environments and also to build on previous research in the management of uncertainty and risk on projects. Research questions were subsequently established for this study.

This chapter presents the research design and methodology established to address the research questions. The research design process is outlined, followed by the theoretical framework and research logic. The characteristics of positivist and phenomenological paradigms are considered to arrive at a preferred research philosophy, which is post-positivist.

The research hypotheses, derived from the research questions are presented. Following this, frameworks are developed to operationalise the key research variables – project complexity, uncertainty and risk management approaches and processes and project success. The data collection process is outlined. With the variables already identified, the questionnaire design is then discussed and developed. The sampling techniques are determined and finally the intended statistical analysis approach is introduced.

3.2 Research Design

The research design process adopted in this research is identified in Figure 4 below.

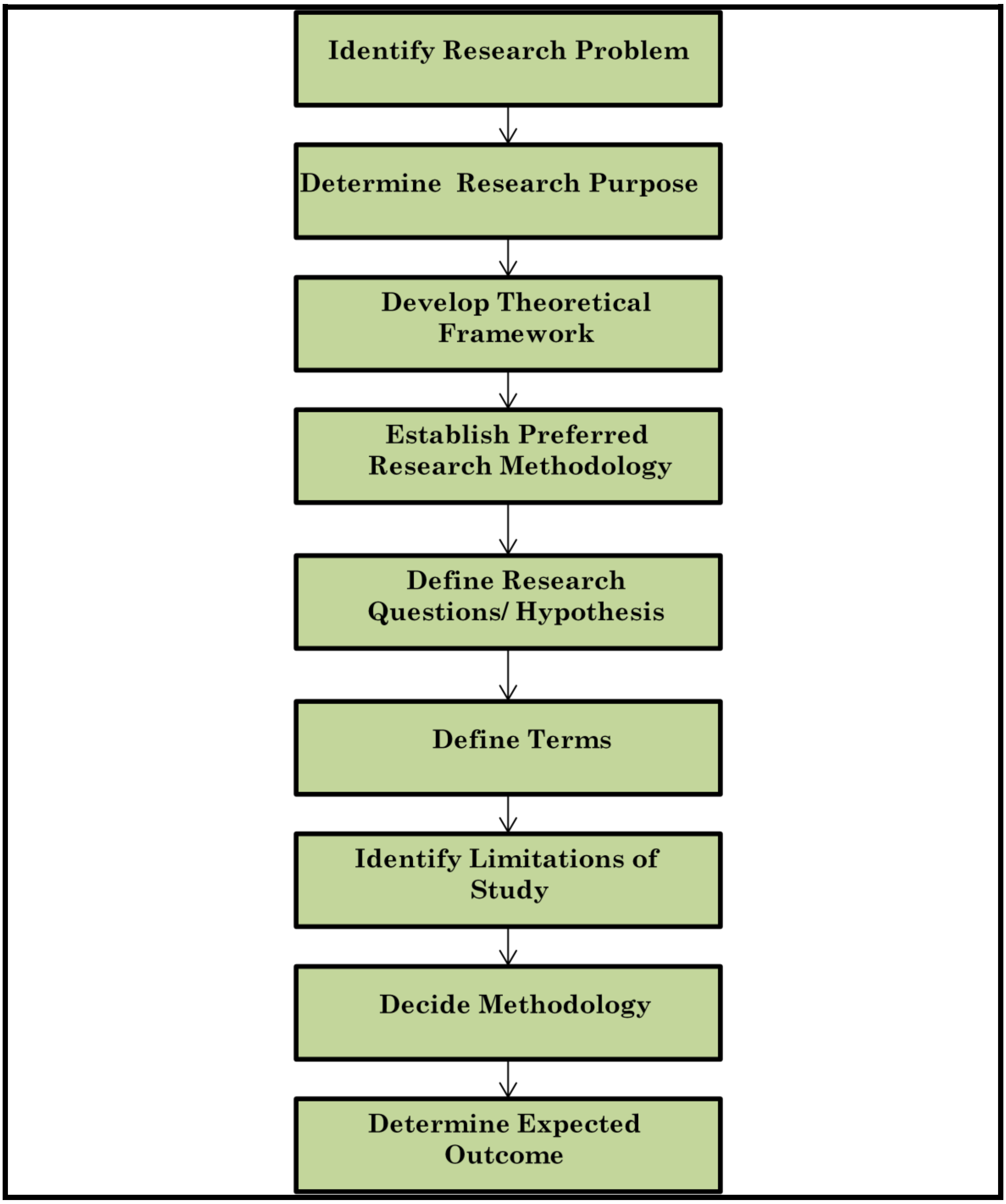

Figure 4: Overview of research design process – Adapted from figure 5.1, p115 (Hussey & Hussey, 1997)

The research gap, problem and purpose of the research have been presented and supported in chapter 1. It has been shown that there is limited empirical research focused primarily on the management of uncertainty and risk on complex projects. Furthermore, it is noted that "there appears to be far more literature offering prescriptions to manage risk in projects rather than assess the relative effectiveness of those prescriptions" (Kutsch & Hall, 2010). Projects are shown to be continually failing, getting more complex and the literature points to an inadequacy of uncertainty and risk management prescription and practice, particularly in the management of complexity, irrationality and non-linearity. It is therefore concluded that empirical research on the management of uncertainty and risk in complex project environments is considered a valuable contribution to knowledge.

The following sections address the key processes comprised in the above model:-

- Theoretical framework and research logic (section 3.3).
- Research philosophy (section 3.4).
- Research hypotheses (section 3.5).
- Frameworks to measure the key research variables – project complexity; project uncertainty and risk management approaches and processes; and project success (section 3.6).

3.3 Theoretical Framework and Research Logic

A theory is "a set of inter-related constructs (variables), definitions and propositions that presents a systematic view of phenomena by specifying relationships among variables, with the purpose of explaining natural phenomena" (Kerlinger, 1979, p64 cited in Hussey and Hussey, 1997, p123).

The theoretical framework underpinning this study is presented in the literature review through propositions that question the ability of current traditional risk management approaches to 'effectively' manage risk on complex projects (Atkinson et al., 2006; Smith & Irwin, 2006) and empirical research on the nature of and use of risk management practices on projects (Raz et al., 2002; Taylor, 2006). Furthermore, a number of researchers have also proposed that the principles contained within complexity theory may be of value in improving project delivery, as well as uncertainty and risk management in complex environments. Other approaches considered by this research to be in 'advance' of most general prescribed industry risk management standards identified in the literature include explicit opportunity management (Hillson, 2002, 2004a; Olsson, 2007; Zhang, 2011), the uncertainty management paradigm (Chapman & Ward, 2003a, 2003b; Ward & Chapman, 2003), a constructively simple approach to the evaluation and interpretation of estimates (Chapman et al., 2006), risk attitude (Hellier et al., 2001; Hillson & Murray-Webster, 2005, 2008; Slovic, 1987; Smallman & Smith, 2003) and complexity theory concepts (Cooke-Davies et al., 2007).

The logic of the research is abductive. This was determined to be the most appropriate approach to bring more insights in such a study in the context of risk, uncertainty, complexity and management practice,as the researcher could also not conclusively rely on the initial premise being correct. A major weakness in deductive reasoning is the reliance on the initial premise being correct (Shuttleworth, 2008).There is limited empirical research in the specific research area of uncertainty and risk management in complex project environments. Therefore it can be argued that abductive reasoning is the most appropriate technique for this research, as nothing is known about the research from the outset (Levin-Rozalis, 2004; Reichertz, 2004).

3.4 Research Philosophy

Fundamental to the research process is the choice of research paradigm. The two main research paradigms are positivist and phenomenological.

The positivistic paradigm is based on the approach used in the natural sciences. Explanation consists of establishing causal relationships between the variables by establishing causal laws and linking them to a deductive or integrated theory. In the positivistic paradigm social and natural worlds are both regarded as being bound by certain fixed laws of cause and effect, with variables being attributes of an entity that can change and take values that can be observed and/or measured.

Social scientists have argued against positivism claiming that the physical sciences deal with objects that are outside us, whereas the social sciences deal with action and behaviours, which are generated from within the human mind. They also argue that the inter-relationship of the investigator and what is being investigated is impossible to separate and what exists in the social and human world is what we think exists (Hussey & Hussey, 1997). Phenomenology is therefore concerned with understanding human behavior from the participants own frame of reference. The qualitative approach stresses the subjective aspects of human activity, rather than the measurement of social phenomena.

Furthermore Hussey and Hussey (1997) list the main criticisms of the positivist paradigm as follows:

- It is impossible to treat people as being separate from their social contexts and they cannot be understood without examining the perceptions they have of their own activities.
- A highly structured design imposes certain constraints on the results and may ignore more relevant and interesting findings.

- Researchers are not objective, but part of what they observe.
- Capturing complex phenomena in a single measure is misleading.

These two paradigms are at the two extremes of a continuum, but it is important to recognize that there is "considerable blurring" along this continuum. This is highlighted in figure 5 which shows the continuum of core ontological assumptions.

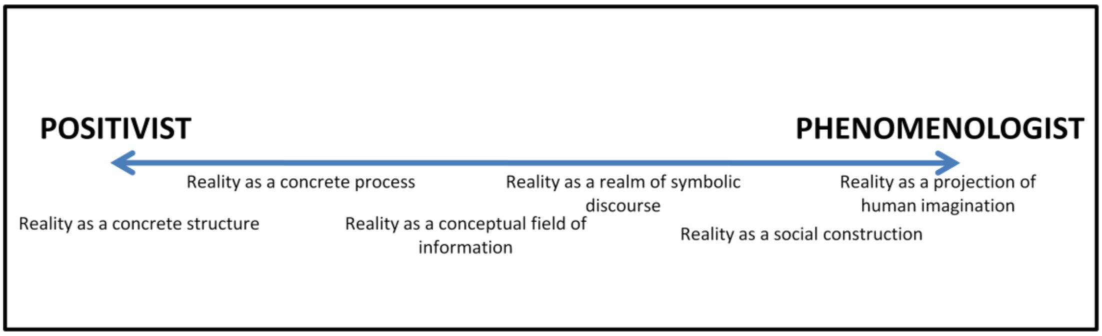

Figure 5: The continuum of core ontological assumptions - Based on figure 3.1, p51 (Hussey & Hussey, 1997)

Hussey and Hussey (1997) reference Creswell (1994) who shows the differences between the two main paradigms based on ontological (what is the nature of reality?), epistemological (what is the relationship of the researcher to that being researched?), axiological (what is the role of values?), rhetorical (what is the language of research?) and methodological (what is the process of research?) assumptions. They mention that ontological, epistemological and axiological assumptions are inter-related. If one accepts one assumption that is within the specific paradigm, then the other two complement it. With respect to the language of research (the rhetorical assumption) a positivistic study is written very much in the passive voice, whereas in a phenomenological study the immediacy of the research and the demonstration of the researcher's involvement is important. The methodological assumption is concerned with the process of research. A positivist should be concerned with ensuring that the concepts used can be operationalised i.e. described in such a way that they can be measured. In the analysis one seeks associations and causality. A phenomenologist strives to obtain different perceptions of phenomena, seeking to understand what is happening in a situation and looking for patterns which may be represented in other situations.

Data integrity refers to the characteristics of research which effect error and bias. Results currency refers to the generalisability of results. In a positivistic paradigm data is specific and precise. Rigor must be applied to ensure accuracy of measurement. In the phenomenological paradigm the emphasis is on the quality and depth of the data. Such data is referred to as ‘rich’, as it captures the richness of detail and nuance of the phenomena being studied. Hussey and Hussey (1997) state that a positivistic approach is higher in data integrity, whereas a phenomenological approach tends to be higher in results currency because they have contextual relevance across methods, paradigms, settings and time. However, Hussey and Hussey (1997) stress that in any research project the researcher will normally operate a trade-off between data integrity and results currency.

Two other important research parameters are reliability and validity. Reliability is concerned with the findings of the research. Another study should get similar results. This is very important in positivistic studies, with replication often being conducted to test reliability. In a phenomenological paradigm the view is that similar observations and interpretations can be made on different occasions and/or by different people. Validity is the extent to which the research findings accurately represent what is really happening in the situation. With a positivistic paradigm, because of the focus on precision measurement there is a danger that validity is low. However, the phenomenological paradigm is aimed at capturing the essence of the phenomenon and extracting data which is rich in explanation and analysis. A researcher attempts to get full access to the knowledge and meaning of those involved in the phenomenon and consequently validity is high.

A post-positivist approach is chosen in order to test the assertions made in the literature and obtain an overall picture of the phenomenon. The value of the phenomenological elements to supplement the quantitative data was considered important in this research. Post-positivism enables this by rejecting the relativist idea of incommensurability of different perspectives (Trochim, 2006). It enables 'objectives' to be achieved through triangulation across multiple perspectives (Trochim, 2006) and the appreciation of the different constructions and meanings that people place upon their experience (Easterby-Smith, Thorpe, & Lowe, 1991).

The qualitative elements that assist in providing further insights into the interpretation of the quantitative results include exploring the types of uncertainty and risk management approaches considered by research participants (Project Managers) to be in 'advance' of general prescribed industry risk management standards and seeking perspectives from participating Project Managers regarding the improvement of uncertainty and risk management, particularly in complex project environments. Both are included into the questionnaire as open ended questions. The purpose of this qualitative insight is to augment the quantitative data.

3.5 Research Hypotheses

The research aims to make a contribution to knowledge by drawing on the research results to make recommendations for the improved management of uncertainty and risk on projects, particularly those characterised by high levels of complexity.

With the research gap and problem identified, the following research questions were developed:-

- Are uncertainty and risk managed differently by Project Managers on projects perceived as more complex?

- What levels of general prescribed industry risk management standards are implemented by Project Managers on projects perceived to have high complexity?
- What uncertainty and risk management approaches and processes are considered to be 'in advance' of general prescribed industry risk management standards on projects of high complexity?
- On projects perceived to have high complexity, what proportion of Project Managers are implementing uncertainty and risk management approaches and processes considered to be 'in advance' of general prescribed industry risk management standards?
- On projects of high complexity, does the uncertainty and risk management approach and process implemented affect perceived project success?
- On projects of high complexity, is there a difference in perceived project success between projects where uncertainty and risk is managed at 'high levels' and 'in advance' of general prescribed industry risk management standards?

The research questions were continually reflected upon and re-formulated through the research process. Reflecting and reformulating the research question are central points of reference for assessing the appropriateness of the decisions taken at several points during the research (Flick, 2006).

The research hypotheses, developed to address the research questions are as follows:-

Hypothesis 1

$1H_0$: Project Managers do not implement higher level uncertainty and risk management approaches and processes on projects they perceive as more complex, than on projects that they perceive as less complex.

$1H_1$: Project Managers implement higher level uncertainty and risk management approaches and processes on projects they perceive as more complex than on projects that they perceive as less complex.

Hypothesis 2

$2H_0$: Most Project Managers, on projects they perceive to have high levels of complexity, do not implement uncertainty and risk management approaches and processes at lower than 'optimal' levels of general prescribed industry risk management standards.

$2H_1$: Most Project Managers, on projects they perceive to have high levels of complexity, implement uncertainty and risk management approaches and processes at lower than 'optimal' levels of general prescribed industry risk management standards.

Hypothesis 3

$3H_0$: A minority of Project Managers do not implement uncertainty and risk management approaches and processes 'in advance' of general prescribed industry risk management standards on projects they perceive to have high levels of complexity.

$3H_1$: A minority of Project Managers implement uncertainty and risk management approaches and processes 'in advance' of general prescribed industry risk management standards on projects they perceive to have high levels of complexity.

Hypothesis 4

$4H_0$: There is no positive correlation between uncertainty and risk management approach and process levels implemented and perceived project success by Project Managers, on projects that they perceive to be of high complexity.

$4H_1$: There is a positive correlation between uncertainty and risk management approach and process levels implemented and perceived project success by Project Managers on projects that they perceive to be of high complexity.

Hypothesis 5

$5H_0$: Perceived project success is not higher on projects of high complexity, where uncertainty and risk is managed 'in advance' of general prescribed industry risk management standards, rather than at 'high levels' of such standards.

$5H_1$: Perceived project success is higher on projects of high complexity, where uncertainty and risk is managed 'in advance' of general prescribed industry risk management standards, rather than at 'high levels' of such standards.

The table below provides a summary of the research problem, research questions and hypotheses.

Research Problem		Research Question		Research Hypothesis (H_0)
The combination of continued project failures, increasing project complexity and inadequate uncertainty and risk management prescription and practice	1	Are uncertainty and risk managed differently by Project Managers on projects perceived as more complex?	1	Project Managers do not implement higher level uncertainty and risk management approaches and processes on projects they perceive as more complex, than on projects that they perceive as less complex.

Research Problem		Research Question		Research Hypothesis (H_0)
	2	What levels of general prescribed industry risk management standards are implemented by Project Managers on projects perceived to have high complexity?	2	Most Project Managers, on projects they perceive to have high levels of complexity, do not implement uncertainty and risk management approaches and processes at lower than 'optimal' levels of general prescribed industry risk management standards.
	3	What uncertainty and risk management approaches and processes are considered to be in advance of general prescribed industry risk management standards on projects of high complexity?		Qualitative response through questionnaire.
	4	On projects perceived to have high complexity, what proportion of Project Managers are implementing uncertainty and risk management approaches and processes considered to be 'in advance' of general prescribed industry risk management standards?	3	A minority of Project Managers do not implement uncertainty and risk management approaches and processes 'in advance' of general prescribed industry risk management standards on projects they perceive to have high levels of complexity.
	5	On projects of high complexity, does the uncertainty and risk management approach and process implemented affect perceived project success?	4	There is no positive correlation between uncertainty and risk management approach and process levels implemented and perceived project success by Project Managers, on projects that they perceive to be of high complexity.
	6	On projects of high complexity, is there a difference in perceived project success between projects where uncertainty and risk is managed at 'high levels' and 'in advance' of general prescribed industry risk management standards?	5	Perceived project success is not higher on projects of high complexity, where uncertainty and risk is managed 'in advance' of general prescribed industry risk management standards, rather than at 'high levels' of such standards.

Table 2: Summary of Research Problem, Questions and Hypotheses

3.6 Research Variables

Drawing upon the literature frameworks are developed to operationalise the key research variables – project complexity, uncertainty and risk management approach/ processes and project success. These are outlined in sections 3.6.1, 3.6.2 and 3.6.3 below.

3.6.1 Project Complexity

The Crawford-Ishikura 7 factor table (CIFTER) described in section 2.3 of the literature review is an instrument for assessing the management complexity of projects and forms part of the Global Alliance for Project Management Standards (Global Alliance for Project Performance Standards, 2007). As outlined in section 2.3 it is considered an appropriate measure of perceived project complexity. This research therefore uses this framework to assess levels of perceived project complexity (see table 3, 4 and factor explanations).

The 7 factors, together with the descriptor and points are provided in Table 3 below.

Project Management Complexity Factor	**Descriptor and Points**			
Stability of the overall project context	Very High (1)	High (2)	Moderate (3)	Low (4)
Number of distinct disciplines, methods, or approaches involved in performing the project	Low (1)	Moderate (2)	High (3)	Very High (4)
Magnitude of legal, social, or environmental implications from performing the project	Low (1)	Moderate (2)	High (3)	Very High (4)
Overall expected financial impact (positive or negative) on the project's stakeholders	Low (1)	Moderate (2)	High (3)	Very High (4)
Strategic importance of the project to the organisation or organisations involved	Very Low (1)	Low (2)	Moderate (3)	High (4)
Stakeholder cohesion regarding the characteristics of the product of the project	High (1)	Moderate (2)	Low (3)	Very Low (4)
Number and variety of interfaces between the project and other organisational entities	Very Low (1)	Low (2)	Moderate (3)	High (4)

Table 3: Crawford-Ishikura 7 factor table (CIFTER)

This model differentiates the perceived complexity levels as follows:

- Below Level 1 – 11 points or less
- Level 1 – 12-18 points
- Level 2 – 19 points or more

In order to distinguish the higher levels of perceived project complexity, the following levels were used in this research:-

Project Complexity Level	Score
Very High	25 - 28
High	19 - 24
Medium	12 - 18
Low	0 - 11

Table 4: Perceived project complexity levels and scores

Each project management complexity factor (as shown in Table 2) has the accompanying explanation. These explanations are an important component of the CIFTER model and are described below.

1. Stability of the overall project context

The project context includes the project life-cycle, the stakeholders, the degree to which the applicable methods and approaches are known, and the wider socioeconomic environment. When the project context is unstable — phase deliverables are poorly defined, scope changes are frequent and significant, team members are coming and going, applicable laws and regulations are being modified — the project management challenge increases.

Note: some aspects of "technical complexity" such as dealing with unproven concepts would be considered here. Uncertainty in the economic or political environment would be considered here.

2. Number of distinct disciplines, methods, or approaches involved in performing the project

Most projects involve more than one management or technical discipline; some projects involve a large number of different disciplines. For example, a project to develop a new drug could include medical researchers, marketing staff, manufacturing experts, lawyers, and others. Since each discipline tends to approach its part of the project in a different way, more disciplines means a project that is relatively more difficult to manage.

Note: some aspects of "technical complexity" such as dealing with a product with many interacting elements would be considered here.

3. Magnitude of legal, social, or environmental implications from performing the project

This factor addresses the potential external impact of the project. For example, the potential for catastrophic failure means that the implications of constructing a nuclear power plant close to a major urban centre will likely be much greater than those of constructing an identical plant in a remote area. The management complexity of the urban project will be higher due to the need to deal with a larger number of stakeholders and a more diverse stakeholder population.

Note: "external impact" refers to the effect on individuals and organizations outside the performing organization. Financial considerations related to actual or potential legal liability for the performing organization would be considered in factor 4.

4. Overall expected financial impact (positive or negative) on the project's stakeholders

This factor accounts for one aspect of the traditional measure of "size," but does so in relative terms. For example, a project manager in a consumer electronics start-up is subject to more scrutiny than a project manager *doing a similarly sized project for a computer manufacturer with operations around the globe, and increased scrutiny generally means more management complexity. A subproject whose output is a necessary component of the parent project would generally receive a rating on this factor close to or equal to that of the parent project.*

Note: where the impact on different stakeholders is different, this factor should be rated according to the impact on the primary stakeholders. Financial considerations related to actual or potential legal liability incurred by the performing organization would be considered here.

5. Strategic importance of the project to the organisation or organisations involved

This factor addresses yet another aspect of "size," and again deals with it in relative rather than absolute terms. While every project should be aligned with the organisation's strategic direction, not every project can be of equal importance to the organisation or organisations involved. A subproject whose output is a necessary component of the parent project would generally receive a rating on this factor close to or equal to that of the parent project.

Note: as with financial impact, if the strategic importance for different stakeholders is different, this factor should be rated according to the strategic importance for the primary stakeholders.

6. Stakeholder cohesion regarding the characteristics of the product of the project

When all or most stakeholders are in agreement about the characteristics of the product of the project, they tend to be in agreement about the expected outcomes as well. When they are not in agreement, or when the benefits of a product with a particular set of characteristics are unknown or uncertain, the project management challenge is increased.

7. Number and variety of interfaces between the project and other organisational entities

In the same way that a large number of different disciplines on a project can create a management challenge, a large number of different organisations can as well.

Note: issues of culture and language would be addressed here. A large team could have a relatively small number of interfaces if most team members have the same employer. On the other hand, shift work might increase the rating here even though the additional shifts are technically part of the project.

3.6.2 Project Uncertainty and Risk Management Approach and Process Frameworks

To enable the measurement of the risk management approaches and processes implemented on projects, the following frameworks were established for this research.

'Risk' Management Approach Framework

The first framework is based on Ward's (2005) "Six dimensions of 'risk management' development" (p 5), which was introduced in the literature review. This has an organisational focus, but with very minor amendments is adapted to a project context. This is further operationalised with the scores noted on each of the levels associated with each dimension. Risk management approaches and processes (discussed below) are combined to provide a total risk management approach and process score and associated level. This is described in further detail following the presentation of the frameworks.

Dimension/ Levels-Scores	Level 1 (Score 1)	Level 2 (Score 2)	Level 3 (Score 3)	Level 4 (Score 4)
Focus of Attention	Threat management	Opportunity and threat management	Uncertainty management paradigm	
Scope of Processes	Ad-hoc informal processes	Some specific formal processes	Generic formal processes	Flexible, cost effective use of generic processes
Documentation	No documentation	Limited documentation	Analyses documented and reported	Documentation reported and updated throughout the project life-cycle
Tools and Techniques	Superficial (basic) qualitative analysis	Thorough qualitative analysis/ some quantification	Quantification documented and collated	Use of best practice techniques
Parties involved & allocation of responsibilities for risk management	Scattered, ad-hoc and left to individuals	Specific functions with limited roles	Risk management facilitated throughout the core project team	Risk Management facilitated wider than the core project team
Resources applied to risk management	No allocation of resources	Implicit ad-hoc allocation of resources	Explicit formal allocation of resources	

Table 5: Project uncertainty and risk management' approach framework with descriptor and points

Uncertainty and Risk Management Process Framework

A second framework, to specifically identify project risk management processes and associated tools and techniques is also established. This was discussed in the literature review and is derived from key processes presented by the following key mainstream risk management standards:-

- Project Risk Management, Project Management Institute, Project Management Body of Knowledge (PMBok), Chapter 11, 2004 (Project Management Institute, 2004).

- Risk Management, Joint Australian/ New Zealand Standard, AS/NZS 4360:2004 (Joint Standards Australia/ Standards New Zealand, 2004).
- Project Risk Analysis and Management (PRAM) Guide, UK Association for Project Management (APM), 2004 (Association for Project Management, 2004).
- Risk Analysis and Management for Projects (RAMP), Institution of Civil Engineers and the Faculty and Institute of Actuaries, 2005 (Institute of Civil Engineers and the Institute of Actuaries, 2005).
- Project Risk Management, Project Management Institute, Project Management Body of Knowledge (PMBoK), Chapter 11, 2008 (Project Management Institute, 2008).
- Risk Management – Principles and Guidelines, Joint Australian/ New Zealand Standard, AS/NZS ISO 31000:2009 (Joint Australia New Zealand ISO, 2009).

	Process	**Descriptor and Points**			
1	Establishing the Context & Risk Management Planning	Not at All (1)	Very Little (2)	Somewhat (3)	To a Great Extent (4)
2	Risk Identification	Not at All (1)	Very Little (2)	Somewhat (3)	To a Great Extent (4)
3	Qualitative Risk Analysis/Evaluation	Not at All (1)	Very Little (2)	Somewhat (3)	To a Great Extent (4)
4	Quantitative Risk Analysis/Evaluation	Not at All (1)	Very Little (2)	Somewhat (3)	To a Great Extent (4)
5	Risk response Planning/ Risk Treatment	Not at All (1)	Very Little (2)	Somewhat (3)	To a Great Extent (4)
6	Risk Monitoring & Control	Not at All (1)	Very Little (2)	Somewhat (3)	To a Great Extent (4)

Table 6: Project uncertainty and risk management process framework with descriptor and points

In the questionnaire, to aid participants, to enable a more meaningful and deeper analysis and understanding of the 'process' and to establish a greater degree of consistency with responses, a brief description of the techniques and activities that are typically promulgated by key mainstream risk management standards is provided. These are illustrated below.

Establishing the Context and Risk Management Planning

Establishing the context and risk management planning sets out the parameters within which risk will be managed on the project. It typically involves the following:

- Establishing the purpose and objectives of the Risk Management activity.
- Identification of the scope and boundaries of the application of the risk management processes.
- Setting out the risk management methodology. Documenting how to approach, plan and execute the risk management activities on the project. Including the tools and data sources that may be used and define when and how often the risk management process will be performed throughout the project lifecycle.
- Provision of a comprehensive process of systematically identifying risk to a consistent level of detail.
- Identifying the project's internal and external environment (also considering the interface between the two).
- Establishing the roles and responsibilities of the various project stakeholders participating in the risk management process.
- Developing risk criteria (i.e. the criteria against which risks will be evaluated).
- Establishing definitions of risk likelihood/ probability and impact and determining risk thresholds (i.e. what constitutes high, medium and low risks).

- Assignment of human and financial resources.

Risk Identification

Risk identification typically involves the following:

- A comprehensive and structured identification and documentation of risks that might affect the project.
- Risks are identified throughout the project lifecycle.
- The project team are involved in the process.
- Expertise input is provided where required.
- Providing a clear description of the risks, so that the cause and effects are understood and documented.
- Techniques used to identify risks can include checklists, judgements based on experience and records, brainstorming, flow charts, systems analysis, scenario analysis and systems engineering. The techniques and activities used need to be commensurate on the nature of the project under review, types of risk, the organisational context and the purposes of the risk management study.
- Expertise input is provided/ attained where required.

Qualitative Risk Analysis

Qualitative risk analysis typically involves the following:

- Assessing the priority of identified risks by considering the likelihood of them occurring and impact (consequences) on project objectives (and other factors such as schedule, scope, cost, quality) if they do occur.
- An assessment of both threats and opportunities.
- Matrices specify combinations of likelihood and impact that lead to ratings risks as low, moderate and high priority. Descriptive terms

or numeric values are used, depending on preference. Organisational thresholds are considered and inform the matrix.

- Assessments are preferably informed by factual information and data where applicable.
- Assumptions made during the analysis are stated.
- Re-assessing of qualitative risk scores throughout the project life cycle.

Quantitative Risk Analysis

Quantitative risk analysis is typically performed on the high priority risks identified through the qualitative risk analysis process. In some cases quantitative risk analysis may not necessarily be required to develop effective risk responses. Availability of time and budget and the need for qualitative and quantitative statements about risk will determine which methods to use on any particular project.

Numerical values are assigned to the risk event and used to make decisions under uncertainty. This process uses techniques such as Expected Value, Decision Tree Analysis, Sensitivity Analysis, Monte Carlo Simulation etc. to:

- Quantify the possible outcomes for the project and their probabilities.
- Assess the probability of achieving project objectives.
- Identify realistic and achievable cost, schedule and scope targets, given the project risks.
- Determine the most appropriate project management decisions under uncertainty.

Risk Evaluation and Risk Response Planning (Treatment)

Risk evaluation, risk management planning and treatment typically involve the following:

- Continued consideration of project objectives, the organisational and wider context and the extent of the threat and opportunity and associated losses and gains.
- Decision about which risks need response plans (treatment) and priorities in this respect.
- The development of appropriate plans and actions to address risk. This could include mitigation, acceptance, avoidance and transfer of threats or exploiting, sharing and enhancing opportunities.
- The selection of the most appropriate plans (treatment options) should balance the costs of implementing each option against the benefits derived from it i.e. the cost of managing risks need to be commensurate with the benefits obtained.
- The identification of residual and secondary risks and associated management plans.
- The identification of symptoms and signs of the risk's imminent occurrence.
- The identification of fallback plans, should the planned strategy and action not turn out to be fully effective and the threat occurs.
- Risk management (Treatment) plans include – proposed actions; resource requirements; responsibilities; timing; performance measures; monitoring and reporting requirements and completion of a Risk Register.

Risk Monitoring and Control

Risk Monitoring and Control typically involves the following:

- Identifying, analysing and planning for newly arising risks.

- Keeping track of identified risks and those on the watch list, reanalysing existing risks, monitoring trigger conditions for contingency plans, monitoring residual risks and reviewing the execution of risk responses, while evaluating their effectiveness.
- Other considerations during risk monitoring and control include determining if - the project assumptions are still valid; there are any changes to the risk state, with analysis of trends; proper risk management policies and procedures are being followed; contingency reserves (cost and schedule) are modified in line with the risks of the project.

The differentiation of risk management approach and process 'levels' is as follows (see Table 7):

Risk Management Approach & Processes Level	Score	%
Very High	42 - 46	≥90%
High	30 - 41	≥64% ≤89%
Medium	19 - 29	≥40% ≤63%
Low	1 - 18	≥1% ≤39%
No active management of Risk	0	0%

Table 7: Project uncertainty and risk management approach & process levels and scores

The above mentioned frameworks each have a different focus on assessing risk management implementation. Ward's framework is more explicit in identifying key risk management dimensions and associated 'levels' and has a greater strategic focus. The risk management processes framework is focussed at a process level, in line with the key processes promulgated by current mainstream risk management standards. There is minimal overlap between them, although when assessing the 'level' of implementation against risk management processes on a likert scale (as used in this research), a number of 'approach' levels, within dimensions, would be considered and subsequently influence that specific rating. However, it is considered that taking cognisance of both frameworks as a composite appears to capture risk management implementation characteristics and 'levels' more comprehensively. This research collected the data for both frameworks through the questionnaire and then combined the scores into a composite score for risk management approach and processes, as identified in Table 7. The uncertainty management paradigm is included in the Ward (2006) framework, and this research considers this approach to be 'in advance' of traditional mainstream risk management standards. This element is included in the composite levels (Table 7), consistent with the Ward (2006) framework. This research further explores the implementation of other risk management approaches considered to be 'in advance' of traditional mainstream risk management standards separately.

Table 8 below provides a differentiation that is used in this research to determine the levels of risk management approach and processes, <u>with respect to general prescribed risk management standards.</u> For the purposes of the investigation of this element, only the approaches and processes generally promulgated by mainstream risk management standards are considered. The approaches and processes depicted in Tables 5 (as mentioned above, this is a more strategic view, but also related to the processes generally promulgated by mainstream risk management standards) and 6 are both considered. However, the 'uncertainty management paradigm' approach, as highlighted in Table 5 is not included, as this is considered to be an approach that is 'in advance' of most mainstream risk management standards (see literature review).

The scores and associated levels are provided in table 8 below).

Risk Management Approach & Processes Level	Score	%
Very High	42 - 45	≥91%
High	30 - 41	≥65% ≤91%
Medium	19 - 28	≥40% ≤64%
Low	1 - 17	≥1% ≤39%
No active management of Risk	0	0%

Table 8: Project uncertainty and risk management approach & process levels and scores for mainstream risk management standards

As mentioned above, this research also explores risk management approaches and processes that are considered to be 'in advance' of mainstream risk management standards. These are discussed at length in the literature review and include the following:- explicit opportunity management (Hillson, 2002, 2004a; Olsson, 2007; Zhang, 2011), the uncertainty management paradigm (Chapman & Ward, 2003a, 2003b; Ward & Chapman, 2003), a constructively simple approach to the evaluation and interpretation of estimates (Chapman et al., 2006), risk attitude (Hellier et al., 2001; Hillson & Murray-Webster, 2005, 2008; Slovic, 1987; Smallman & Smith, 2003) and complexity theory concepts (Cooke-Davies et al., 2007). The questionnaire developed for this study requested participants to identify if they implemented approaches and processes, which they consider to be 'in advance' of mainstream industry project risk management standards? They were further requested to describe the approach taken and why?

The term, 'optimal' level of implementation of traditional mainstream risk management standards is used for the purposes of this research. With respect to this research, the term equates to the highest 'level' of risk management implementation, with respect to the framework established above (Table 8) - i.e. a score of 45. The term is used in the analysis of risk management approaches and processes implemented on projects of high complexity, which could be expected to be characterised by high 'levels' of risk management implementation with respect to traditional mainstream risk management standards.

3.6.3 Perceived Project Success

It is important to note that the measures of success used in this research are considered to be a general indication of perceived success. This is in recognition of the debate in the literature with respect to an agreed definition of project success (see literature review – section 2.9). The success 'factors' are measured as equal weightings in the framework. In project management practice success factors may not necessarily be of equal importance. However, for consistency in this research an equal weighting between factors is considered appropriate.

The following framework developed from the success criteria identified in the literature review (section 2.10) is used to determine the indicative levels of perceived project success.

	Success Factor	Descriptor and Points			
1	Project objectives were met	Not at all (1)	Very Little (2)	Somewhat (3)	To a Great Extent (4)
2	Project was delivered on programme	No (1)			Yes (4)
3	Project was delivered on budget	No (1)			Yes (4)
4	Project scope achieved	Not at all (1)	Very Little (2)	Somewhat (3)	To a Great Extent (4)
5	Project quality objectives were met	Not at all (1)	Very Little (2)	Somewhat (3)	To a Great Extent (4)
6	How would you rate the level of client satisfaction with respect to the delivery of the project	Very Low (1)	Low (2)	Moderate (3)	High (4)
7	Were the project objectives aligned to the client/sponsors organisational goals and strategy	Not at all (1)	Very Little (2)	Somewhat (3)	To a Great Extent (4)
8	Initial commercial/ business success of the delivered product?	Not at all (1)	Very Little (2)	Somewhat (3)	To a Great Extent (4)
9	A new product/ market/ technology was created in preparation for future business growth?	Not at all (1)	Very Little (2)	Somewhat (3)	To a Great Extent (4)

Table 9: Perceived project success framework

The differentiation used in this research to determine levels of perceived project success is as follows:

Perceived Project Success Level	Score	%
Very High	33 - 36	≥90%
High	27 - 32	≥73% ≤89%
Medium	14 - 26	≥37% ≤72%
Low	9 - 13	≤36%

Table 10: Perceived project success factors – scores and levels

In the data analysis it was unfortunately discovered that a number of respondents did not respond to all 9 factors. However, a larger portion of the sample responded to the factors 'commonly' used as measures of project success.

These include:

- Time (programme)
- Cost (budget)
- Scope
- Quality
- Customer satisfaction

These are referred to as the 'triple constraint' (Project Management Institute, 2004a). However, in the 2008 edition of the PMIs Guide to the Project Management Body of Knowledge this term no longer appears to be evident. Reference is made to scope, schedule and cost as key performance measures (Project Management Institute, 2008).

Both the 9-factor and the above-mentioned sample (with 5 'measures') are included in the data analysis.

The intent of this part of the survey, as discussed earlier in the thesis is to attain a general indication of perceived project success.

Table 11 below provides a summary of the research variables and associated metrics.

Research Variable	Metric
Project Complexity	Crawford-Ishikura 7 factor table (CIFTER)
Project uncertainty and Risk Management Approach and Processes	*Adapted framework – "six dimensions of risk management development" (Ward, 2005) *Framework derived from key processes promulgated by risk management standards (PMBoK, chapter 11, 2004 and 2008; AS/NZ 4360:2004; PRAM, 2004; RAMP, 2005; AS/NZS ISO 31000:2009)
Project Success	9-Factor table developed from literature review.

Table 11: Summary of research variables and metrics

3.7 Data Collection Process

The research methodology is an analytical survey and this does reflect the assumptions of the positivist paradigm with a phenomenological component. A sample of subjects is drawn from the population and studied. The key intention is to determine whether there is a relationship between the different variables – the perceived level of project complexity, the uncertainty and risk management approach and processes adopted, and perceived project success. Care was taken to minimise bias in the attempt to attain as representative a sample as possible. The practical goal established 'is to remove as much sampling bias as possible' and to 'attempt to obtain as random a sample as possible' (Cooligan, 1999).

Figure 6 below highlights the data collection process followed by this research

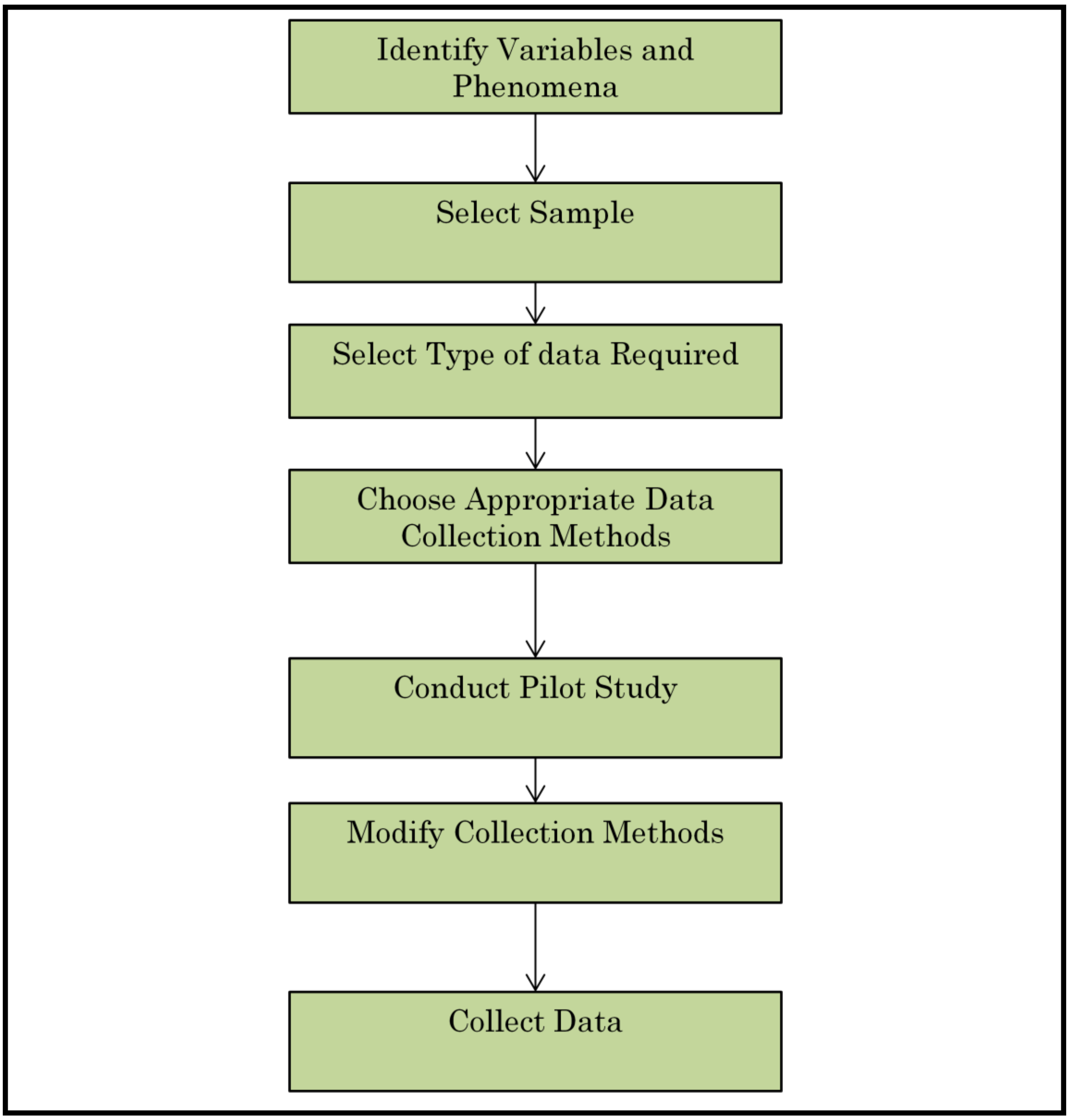

Figure 6: Overview of data collection process – Adapted from figure 6.1, p141 (Hussey & Hussey, 1997)

Research Variables

The key independent variable (can be manipulated to depict the 'values' of the dependent value) for this research is perceived project complexity level, with the dependant variable being the uncertainty and risk management approach and processes. The uncertainty and risk management approach and process variable is independent when considering the relationship with perceived project success.

Questionnaire Design

Survey questions were carefully designed in relation to this study's research questions, taking cognisance of the statistical analysis of the data. Consideration was given to attaining a good response rate. Besides sampling techniques (discussed later) a variety of techniques were used to achieve this. For example – a well written cover letter; succinct questions with simple and direct language and an offer to send a copy of the executive summary of the research findings to those who completed the questionnaires. In order to provide a copy of the executive summary and for possible follow-ups of incomplete questionnaires or further exploration of concepts identified, there was a need to know the participants name and contact details. Confidentiality was very clearly stated.

The survey questionnaire is attached as Appendix 3.

Sampling Technique

With respect to selecting data collection methods, as Hussey & Hussey (1997) points out, careful attention is given to balancing the analytical and predictive power gained from statistical analysis with the issues of sample representativeness, errors in measurement and the dangers of reductionism.

Given the nature of this research (and primarily positivist approach) the most pragmatic sampling technique was considered to be a combination of snowballing and self-selecting. Critically though, an implication of using snowballing as a sampling technique in particular, is the attainment of a non-probability sample and the inability to statistically generalise the results (Cooligan, 1999). Importantly though, snowballing and self-selecting sampling did enable the attainment of responses from Project Managers, through project management networks in particular, who are not members of project management institutions/ associations. This is discussed further below. It is also important to note that if the sample consisted of members from one professional association they might have a shared understanding of meaning of terms. Moving beyond this, one may lose this understanding, but conversely a broader view of people, not influenced by specific professional expectations and perceptions is attained.

Through an extensive survey, the combination of both snowballing and self-selecting techniques, with careful attention to avoiding bias, a fairly representative sample is believed to have been achieved (discussed further in the presentation of the findings - data description (section 4.2)).

Data was captured from Project Managers across a range of industry sectors and project types. Professional project management associations, project management networks and industry sector networks were targeted globally and approached for support in the research. Project Managers were invited to participate in a web based questionnaire. Strategies, such as provision of the executive summary of the final report and confirmed anonymity of individual and organisational details were offered in an attempt to attract research participants.

The snowball sample is particularly targeted at attaining a response from Project Managers who are not necessarily aligned to particular professional project management institutions and associations. Further to the comments above members of project management institutions/ associations may be influenced by the said institution or association's risk management standards and guidelines. However, through project management and industry sector networks it was also expected that

Project Managers who are not necessarily members of project management institutes / associations will participate in the research.

Once the questionnaire was developed it was piloted with a number of Project Managers (N=10). Explanatory letters, depicting the purpose of the research and requesting feedback on the questionnaire structure and formatting were provided (see Appendix 4). With the feedback received and follow-up interviews, the questionnaire was reviewed and amended accordingly.

The questionnaire was then placed on the web at www.surveymonkey.com (see Appendix 3). A clear statement outlined the purpose of the research and provided direction for completion, together with contacts for queries, which included the researcher, research supervisor and the Bond University senior research ethics officer. As mentioned earlier, anonymity with respect to organisational and individual details was confirmed. As mentioned above, to further entice participation, respondents were advised that they would receive an executive summary of the findings on completion of the research. Data was collected from early August to late November 2011. Responses were received from 22 August to 23 November 2011.

With respect to the self selecting sample, a wide spectrum of project management institutions/ associations and networks were contacted across the globe for support in disseminating the request to their Project Manager members for participation in the research. These are identified in Appendix 5.

The snowball sample was initially comprised of 34 Project Managers and business contacts spread across New Zealand, Australia, United Kingdom and South Africa. The response was positive, with a further spread of responses through these networks.

3.8 Statistical Analysis

The survey questions carefully address the research questions. In the design of the questionnaire, particular attention was given to the structure and organisation of the numerical data, with respect to the statistical analysis that will follow. Importantly, there was a focus on attaining and presenting data that provides a clear and unambiguous picture of what was found in the research study.

The data is primarily quantitative and ordinal in nature, with some qualitative elements. The qualitative data (particularly, suggested improvements to risk management approaches and processes) is analysed, following the statistical analysis. The quantitative data is analysed through a number of descriptive and inferential (non-parametric) statistics - a non-probability sample and ordinal data requires non-parametric statistics (Cooligan, 1999; Singh, 2006). These were carefully considered through a framework (see later discussion in data analysis section) to ensure that the most appropriate statistical tests were used. The rationale for the selection of each test is provided in section 4. The hypotheses are one-tailed (directional), which is of further importance in determining the most appropriate statistical test.

Descriptive statistics are described in section 4.3. Following reliability and validity testing and confirmation (section 4.4), statistical correlations and significance testing is then conducted on the null hypotheses (section 4.5). The test of significance finds the difference between sample means and "estimates the unlikelihood of the obtained results occurring if the null hypothesis is true" (Cooligan, 1999). On the subject of 'probability' Kerlinger's quote is still highly relevant – "Probability is an obvious and simple subject. It is a baffling and complex subject. It is a subject we know a great deal about, and a subject we know nothing about. Kindergartners can study probability and philosophers do. It is dull, it is interesting. Such contradictions are the stuff of probability" (Kerlinger, 1973).

Statistical correlations and significance tests conducted on the null hypotheses include the Spearman's Rank Correlation, Wilcoxon (T) Signed Ranks Test and the Mann-Whitney test. The Kolmogorov-Smirnov Test and One Sample Binomial test were used to test binary data for one hypothesis.

The significance level adopted for this research is at 5% ($p \leq 0.05$). Subsequently the null hypothesis will be rejected when the probability of it being true drops below 0.05. PASW Statistics v18 software was used to conduct statistical calculations.

Reliability and validity tests were carried out on the data, with respect to the key research variables – project complexity, risk management approaches and processes and project success. The Chronbach Alpha Test was conducted to determine reliability (internal consistency). Validity is also discussed and confirmed, particularly in the light of the careful and substantiated development of frameworks to 'measure' the research variables.

4. PRESENTATION OF FINDINGS

4.1 Introduction

This chapter presents the findings of the survey. The survey response and sample size is conveyed. Descriptive statistics (importantly showing the characteristics of the sample) are then provided, showing a reasonably well balanced sample for the purposes of this study (with some noted bias) and key trends of the data. The qualitative findings are then presented with respect to the use of 'advanced' uncertainty and risk management approaches and processes and Project Manager perspectives regarding improving uncertainty and risk management implementation on complex projects. Reliability and validity tests are carried out on the data, with respect to the key research variables. The Chronbach Alpha Test is conducted to determine reliability and validity is discussed and confirmed.

Finally, the research hypotheses are assessed for differences and correlation, with significance determined through a number of statistical tests. These include - Spearman's Rank Correlation, Wilcoxon (T) Signed Ranks Test, Mann-Whitney Test, Kolmogorov-Smirnov Test and the One Sample Binomial test. A summary of the statistical tests is provided.

4.2 Survey Response and Sample Size

As stated in section 3.7 (Data Collection Process) the sampling technique used for this research is a combination of snowballing and self-selecting.

A positive response was received from various 'local' branches of the project management institutes and associations. Notably and rather disappointingly no support was forthcoming from the central office of the Project Management Institute (PMI). Fortunately, a number of PMI

Chapters were very positive in conveying research participation requests to their Project Manager members. The Association for Project Management in the United Kingdom was particularly helpful, together with some other International Association for Project Management affiliates.

The response from the Project Manager networks (see section 3.7) was positive, particularly providing participation from Project Managers who are not necessarily members of formal project management institutes or associations.

85 questionnaire responses were received. However, a number were incomplete and following data validation the final sample size is 73 (N = 73). Given anecdotal evidence of the current challenges faced in attaining research participants in project management research and research generally, the final sample (especially given its descriptive characteristics) is considered an adequate response for this research. The results of this research cannot be generalised (discussed in further detail later in this chapter and in chapter 5) due to the non-probability sampling technique used. Statistical significance is attained, which can denote a 'representative' sample (Cooligan, 1999).

4.3 Descriptive Statistics

This section provides a univariate analysis of the sample data. Tables and graphs illustrate the results and trends, together with discussion.

(A) Gender profile and age assessment

The gender distribution is skewed towards a male sample of 75% and 25% female Project Managers. This is possibly due to the relatively high response to the survey from Project Managers in the construction sector, which is traditionally dominated by males. Research conducted by

Henderson and Stackman (2010) show the current breakdown for the top five project management industries is 93.5% male and 6.5% female in construction, 71% male and 29% female in consulting, 52.1% male and 47.9% female in financial services, 68.7% male and 31.3% female in information technology and 73.4% male and 26.6% female in telecommunications (Henderson & Stackman, 2010).

The age of respondents across the data set (N=73) is as follows – 18-29 (4%); 30-39 (28%); 40-49 (31%); 50-59 (26%) and 60-69 (11%). It is noticeable there are very few respondents aged less than 30, with the majority of respondents being between the ages of 30 and 59. This is to be reasonably expected, as the focus of the research is on high complexity projects, attracting more senior Project Managers, who would generally manage these and be more experienced and older.

(B) Project demographic profile

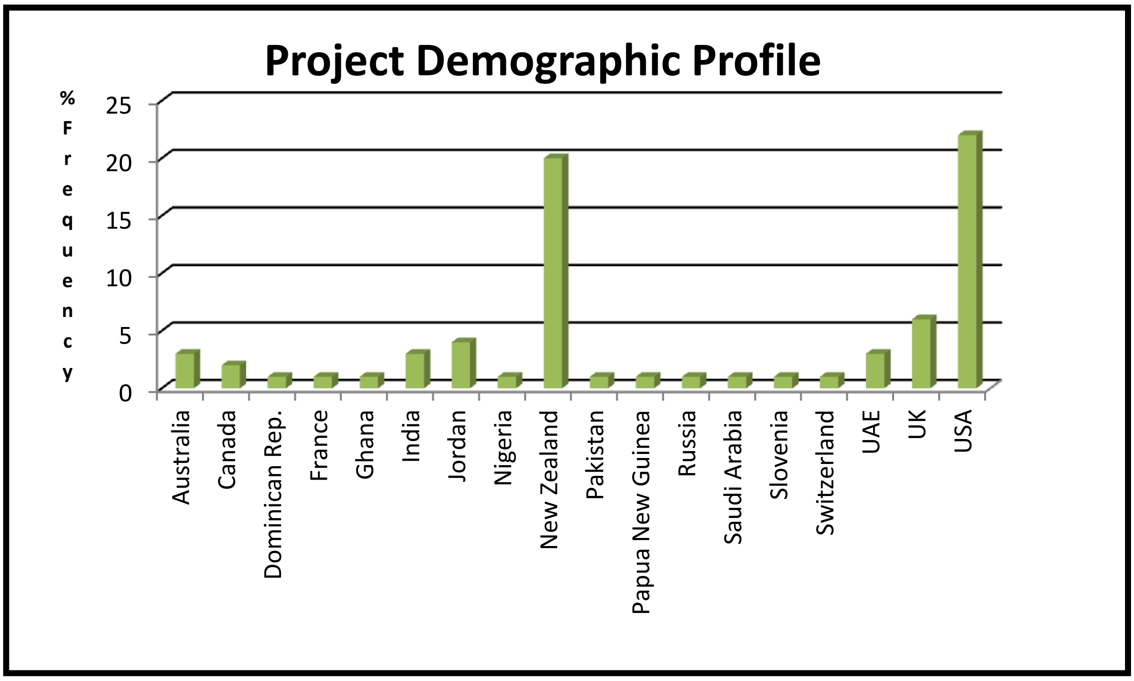

Figure 7: Project Demographic Profile

Figure 7 identifies a geographic spread of projects across 18 countries. A large proportion of responses came from USA (22%) and New Zealand (20%). A response of 6% was received from the United Kingdom and a few each from Australia, Canada, India, Jordan and the United Arab Emirates. The balance of the responses were received from the Dominican Republic, France, Ghana, Nigeria, Pakistan, Saudi Arabia, Slovenia and Switzerland. As depicted in the data collection process section (3.7), attention was given to making contact with project management associations and institutes, as well as networks globally. With the researcher being a member of the Project Management Institute (PMI) New Zealand Chapter, a favourable response was received from New Zealand, through good support from that Chapter. A good response from the USA is explained through positive support from some of the USA PMI Chapters and through web-based project management networks. The sample is skewed towards the USA and NZ. An implication of this in this research sample is a bias towards Project Managers who are members of the Project Management Institute, as supported by the PMI bias in the sample (see section 4.3 (h)). There are also likely to be further implications in terms of social, political and economic characteristics and influences. However, there is a further response from Project Managers in a number of other countries, which does provide some demographic balance to the sample, although the limitation of non-generalisability, as discussed does need to be noted.

(C) Industry sectors

Project Type	% of Sample
Automotive	6
Aerospace/ Defence	7
Construction/ Infrastructure/ Engineering	17
Education	1
Entertainment	1
Financial Services	15
Government	14
Healthcare	3
Heritage	1
IT/ Telecoms	15
Manufacturing	4
Mining/ Oil & Gas	4

Project Type	% of Sample
Not for Profit Sector	1
Pharmaceutical	1
Transportation	1
Utilities	6
	100

Table 12: Industry Sectors (% of sample)

A wide and balanced range of industry sectors and project types are reflected in the data. Industry sector responses are shown in (Table 12). Those representing a major response include information technology/telecoms, financial services, government and construction/ infrastructure/ engineering. There was also a reasonable response from the utility, mining/ oil & gas, manufacturing, healthcare, automotive and aerospace/ defense.

(D) Project types

Project Type	% of Sample
Building Security & Access Control	1
Business/ Cultural/ Financial Change Management	10
Civil Engineering	4
Conservation Management	1
Construction	15
Other Engineering	1
Equipment Supply & Installation	1
Events Management	3
Information Technology/ Systems	31
Manufacturing	6
Marketing & Sales	1
Mineral Exploration	1
New Product Development	7
Nuclear	1
Regulatory/ Compliance	1
Research & Development	4
Software Development	4
Utilities	6
	100

Table 13: Project Types (% of sample)

Project types are shown in Table 13. The largest representation is with Information Technology, accounting for 31% of the projects. Construction accounts for 15% of projects. The following projects also had a notable response – business/ cultural/ financial change management (10%), New Product Development (7%), utilities (6%), manufacturing (6%), software development (4%), research and development (4%) and civil engineering (4%). For this research it is considered a reasonable range of project types, which include those that are likely to have high levels of complexity, notably Information Technology/ Systems, New Product Development, software development, certain construction projects - e.g. (Flyvbjerg et al., 2003) and business/ financial/ cultural change management.

(E) Project Management experience

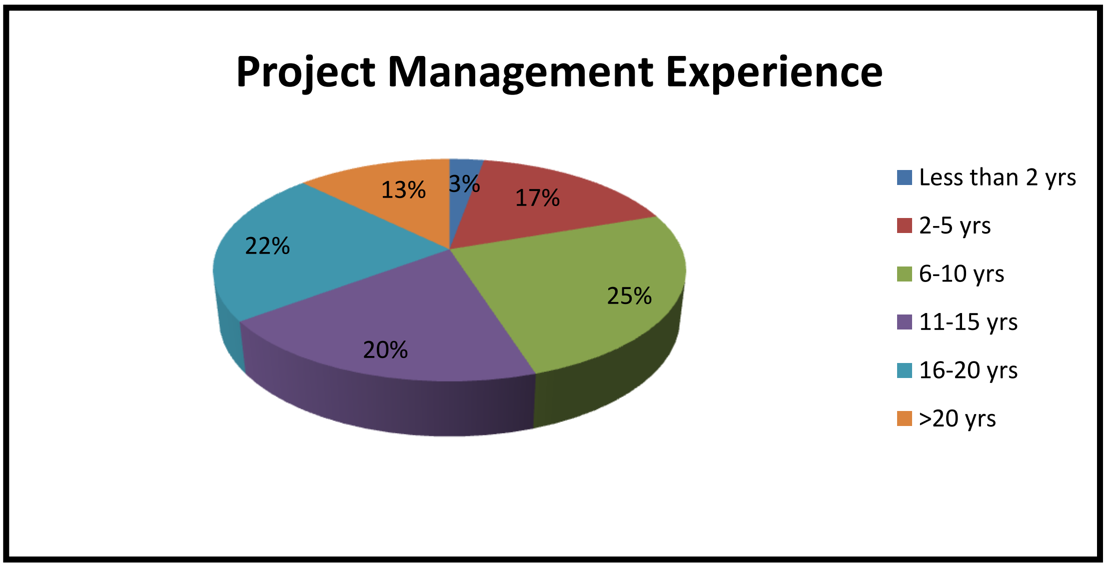

Figure 8: Project Management experience

Figure 8 illustrates that the sample is generally characterised by Project Managers with high levels of experience. 55% of the respondents have over 10 years project management experience, with 20% having less than 5 years experience. Having such experience prevalent through the sample is considered potentially advantageous for insightful and valuable views on risk management on more complex projects.

(F) Project Management and Professional Training

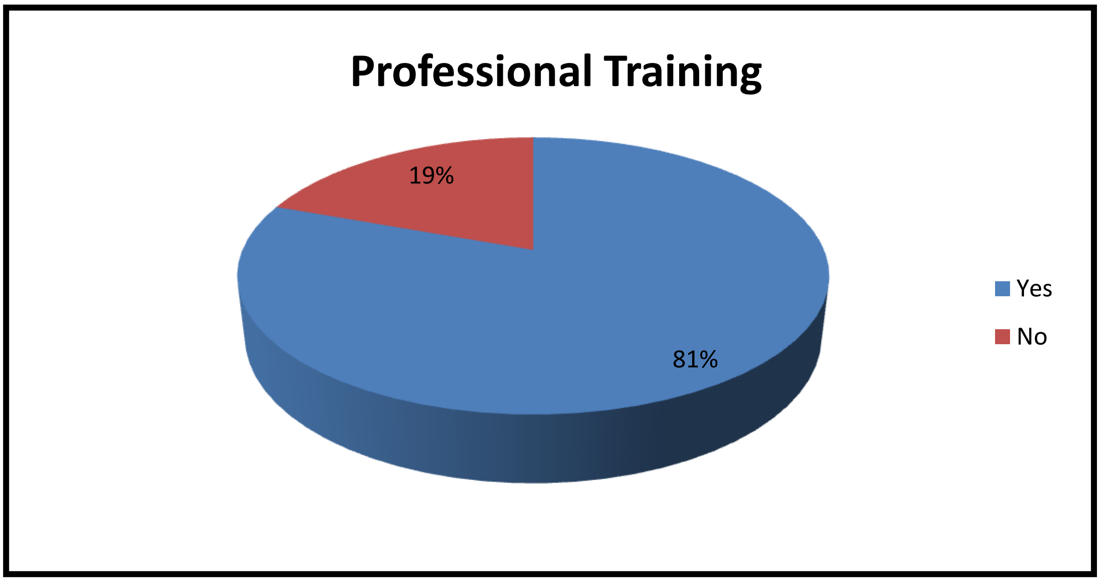

Figure 9: Professional training

Training Category	Professional Training % of "yes" sample
Project Management Professional (PMP)- Project Management Institute (PMI)	53
Other Masters Degrees (Business Administration, Eng., Systems Mgt, Psychology)	17
Masters in Project Management	8
Prince 2	6
Graduate Certificate/ Diploma in Project Management	6
PgMP-PMI	3
CAPM-PMI	3
CPPP-AIPM	1
Certified Scrum Master (Scrum Alliance)	1
Certified Scrum Practitioner (Scrum Alliance)	1
Sigma Black Belt	1
	100

Table 14: Project Management training categories

Figure 9 identifies that 81% of the Project Managers in the sample have some form of professional training. Of these, 83% have a specifically targeted project management qualification. 17% have other Masters degrees noted as Business Administration, Psychology, Systems Management and Engineering. The various training categories are provided in Table 14 above. The high number of Project Managers who have a Project Management Professional (PMI) qualification (53%), reflects the high number of respondents in the sample who are members of the PMI (76%) (see Table 14 below).

(G) Specialist Risk Management Training

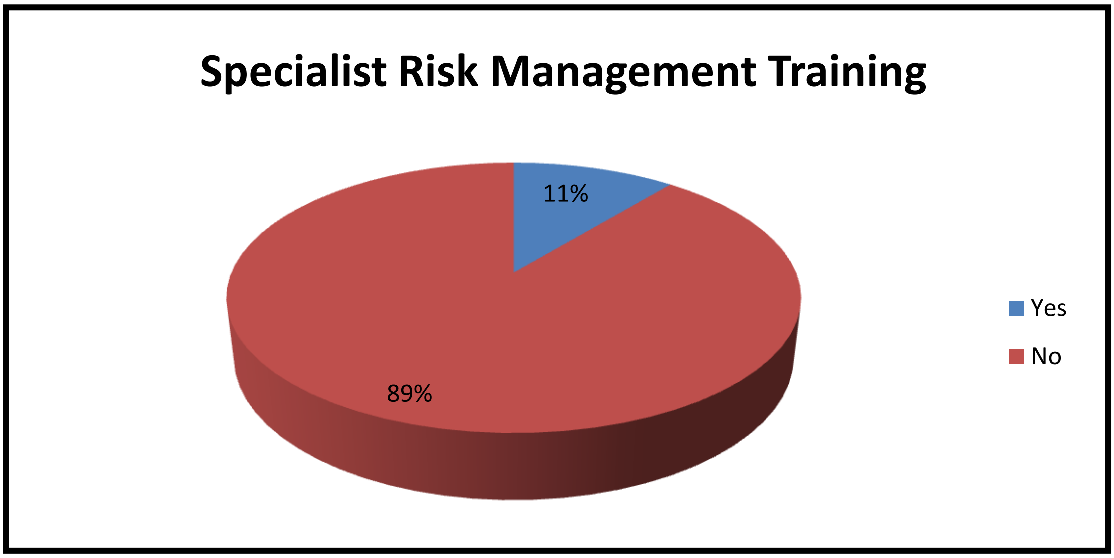

Figure 10: Specialist Risk Management training

Training Category	Training % of "yes" sample
Risk Management Certificate	50
MSc in Risk Management	12.5
In-House Risk Management Training	12.5
Self-Study	12.5
Risk Management Professional - PMI	12.5
	100

Table 15: Risk Management training categories

Very few of the respondents have received specialist/ focused risk management training, with only 11% noting to have received such training (see Figure 10 and Table 15 above). However, it is important to note that most of the project management training identified above would include a component of project risk management training. This would most likely be in line with the respective institutions risk management approach and processes.

(H) Project Management Institute/ Association Membership

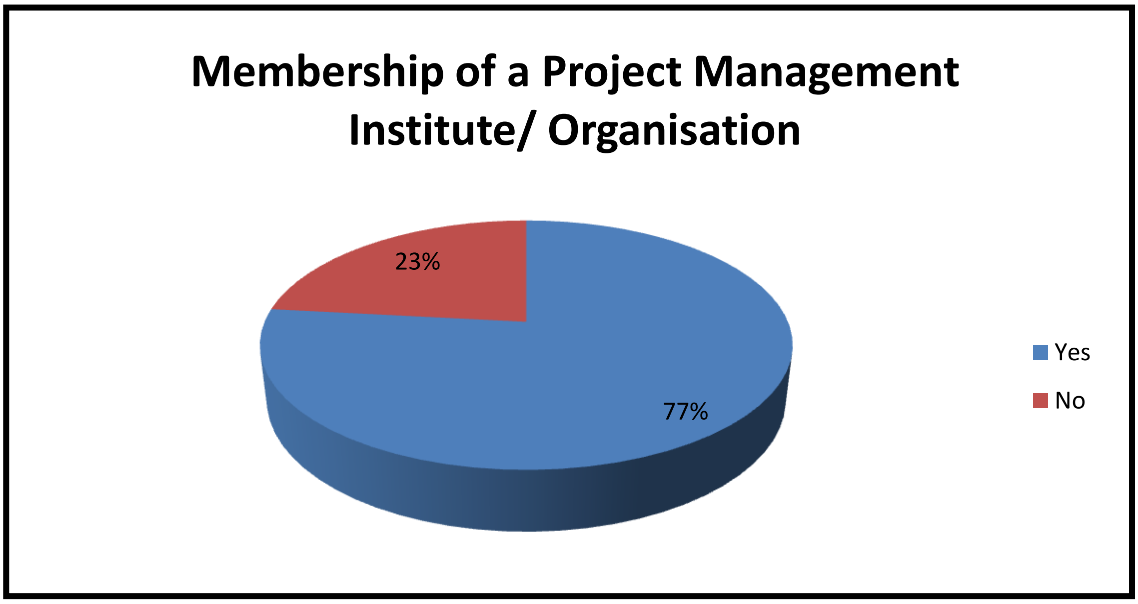

Figure 11: Membership of a project management institute/ association

Membership of Project Management Institute/ Organisation	% of "yes" sample
Project Management Institute	76
Association of Project Management (UK)	10
Other Professional Institutes	7
Russian Project Management Association	2
Association of Jordan Project Managers	2
Swiss Project Management Association	2
Project Management Associates (India)	1
	100

Table 16: Membership of project management institute/ organisation (% percentage of "yes" sample (Figure 11)

77% of the respondents indicated that they are members of a project management institute/ association. As conveyed in the research methodology, the snowball sample was a strategy to attain a representation in the sample of Project Managers who are not members of a professional project management institution/ association. 23% has been achieved, which is positive for this research. Consideration does however need to be given to the bias towards members of professional project management institutions/ associations. The professional project management institution/ association membership breakdown is provided in Table 16, showing a bias towards the Project Management Institute (PMI) at 76%. There is however also a spread of memberships across other project management institutes/ associations and other professional institutes. The views of Project Manager participants are therefore likely to be representative of the risk management guidelines and understanding of terminology provided or training by the PMI.

(I) Project Cost Values

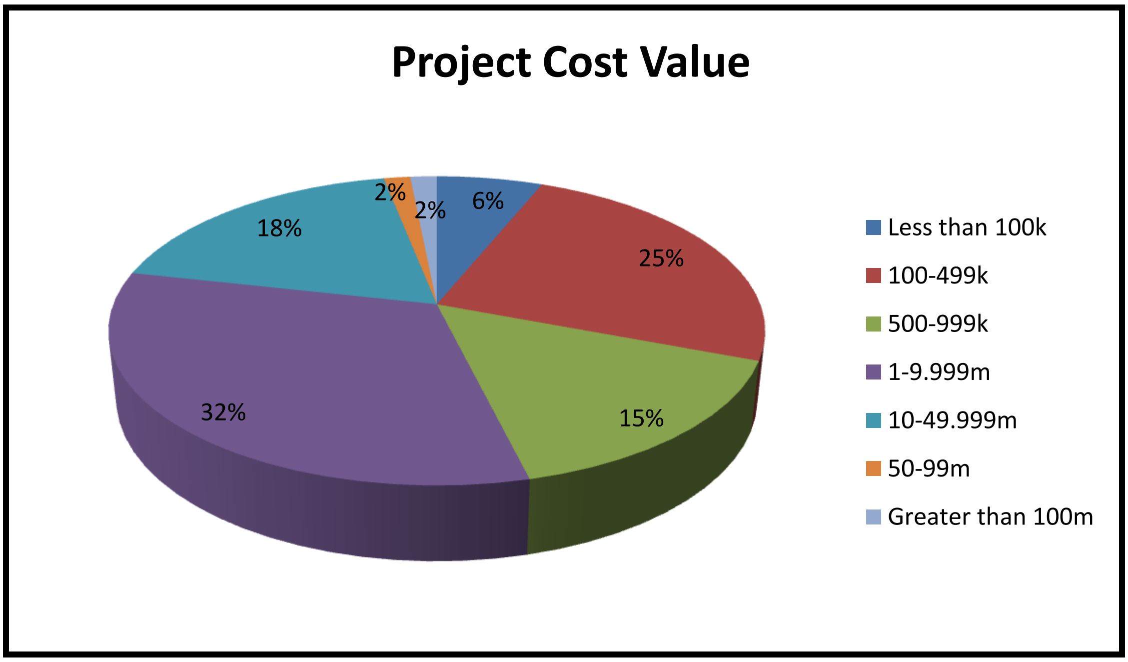

Figure 12: Project cost values (US$)

Figure 12 shows a reasonable spread of project cost values across the sample. A few (2%) projects have values of less than US$100,000.00. 40% have values between US$100,000.00 and US$999,000.00. 50% are between US$1 million and US$50 million. 2% are between US$50 million and US$ 100 million. 2% are over US$100 million.

The sample (N=73), as described above (sections 4.2 and 4.3) is considered to generally be a well balanced and directed composition of sample for the purposes of this study across demographics, gender, project management experience, age, industry sectors, project types and cost value. However, there is some bias in the sample, which as noted below should be considered:-

The institution/organisation membership sample subset is skewed towards PMI membership, but 'positively' has a good spread across a number of other institutes and associations. There is a 23% representation of Project Managers across the entire sample who are not members of project management institutes/ associations, which is good for this research, but considered globally would be a bias, with an estimated 16.5 million Project Managers worldwide and only a small percentage thereof being members of formal project management institutes/ associations.

Project Managers demographic data is skewed to New Zealand and USA, but there is also a spread across 16 other countries.

With respect to project types, the data is slightly skewed towards Information Technology and Construction. However, these can both be characterised by high levels of complexity, which is in line with the purpose of this research. Plus, there is reasonable representation and spread across a number of other project types.

Age and experience are skewed towards older and more experienced Project Managers. As mentioned above, the focus of this research is on complex projects, which are most likely managed by more experienced and experienced Project Managers. There is a good spread of age from 30-69, which is considered valuable. For the purposes of this research the age and experience demographic is therefore beneficial.

(J) Description of Key Variables

A description of the key research variables is provided below (*i-vii*). These variables are integral to the five hypotheses underpinning this research. These hypotheses are statistically analysed in section 4.4.3.

(i) Perceived Project Complexity Levels

These are measured in accordance with the framework developed from the review of the literature. See section 3.6.1.

Perceived Complexity Level	Percentage of Sample
Low	3
Medium	30
High	62
Very High	5
	100

Table 17: Perceived complexity levels

Table 17 shows that 3% of the sample is characterised by projects perceived to be of low complexity. 30% of the projects are perceived as medium complexity, 62% as high and 5% as very high in complexity. A good range of perceived project complexity levels is therefore provided across the sample, especially with the large number of projects characterised as high and very high. This is particularly valuable for the hypothesis tests, to be addressed later.

(ii) Uncertainty and Risk Management Approach/ Process levels

These are measured in accordance with the framework developed from the review of the literature. See section 3.6.2.

Uncertainty and Risk Management Approach/ Process Implementation Levels	Percentage of Sample
Very High	12
High	56
Medium	19
Low	6
No active risk management	7
	100

Table 18: Uncertainty and Risk Management approach/process levels

Uncertainty and risk management approaches and processes implemented across the entire sample (N=73) show that across all projects 12% were implemented at very high levels, 56% high, 19% medium, 6% low and on 7% of the projects there was no active risk management.

Where there was explicit risk management implemented, a wide array of standards and guidelines were used. These are portrayed in table 19 below. The standards/ guidelines most commonly used (in descending order) are:

- Project Management Body of Knowledge, Chapter 11 (Project Management Institute (PMI) – 2004, 2008
- Organisational/ Company Standard
- AS/ NZ 4360:2004
- Project Risk Analysis and Management Guide (Association of Project Management (APM))
- AS/NZS ISO31000:2009

(iii) Risk Management Standards/ Guidelines Implemented

Risk Management Standards/ Guidelines	Number of respondents explicitly managing risk
Project Mgt Body of Knowledge, Ch 11 (2004, 2008)	43
Organisation/ Company Standard	31
AS/NZ 4360:2004	15
Project Risk Analysis and Management Guide, APM, 2004	9
As/NZS ISO 31000:2009	6

Risk Management Standards/ Guidelines	Number of respondents explicitly managing risk
Eng Standards - Bridge & Road Design	1
NSW RTA Risk Management Guidelines	1
Schlumberger Oilfield Hazard & Risk Analysis	1
State of Texas Department of Information Resources Project Delivery Framework	1
ISO 14971	1
USA Utility/ Military & NASA examples of Risk Management Standards	1
Active Threat & Opportunity Management (ATOM) methodology	1

Table 19: Risk Management standards/ methodologies implemented

Table 19 shows that the relatively high percentage of Project Managers using PMI risk management guidelines (Project Management Body of Knowledge, 2004 & 2008) is consistent with the high number of PMI members responding to the survey. The relatively high number of Project Managers implementing company guidelines is also an interesting result.

(iv) Percentage of Project Managers using more than one Risk Management Standard

An interesting result is that 18% of the respondents used more than one risk management standard/ guideline in managing risks on projects. This is discussed further in Chapter 5.

(v) Project Management Institution/ Associations and Standards used - aligned to the Project Managers respective institute/ association

Project Manager respondents of two prominent project management institutions/ associations (PMI and APM) were assessed, with respect to the risk management standard/ guidelines they implemented. Prior to the research it was speculated that the project management institution/ associations respective standard would be very strongly favoured by members. The result is interesting, with 66% of the PMI member project managers implementing PMI's risk management standard and 33% of APM members implementing the APM endorsed standard. The PMI sub sample was larger at N=35. However, the APM sub sample was small at N=6, so not large enough to consider as a trend.

Institute/ Association the respective Project Manager (PMgr) belongs to	Frequency (%) of Project Managers implementing 'their' institutes standard
PMI	66
APM	33

Table 20: Frequency of Project Managers utilising their institutes risk management standards (APM & PMI)

(vi) Perceived Project Success

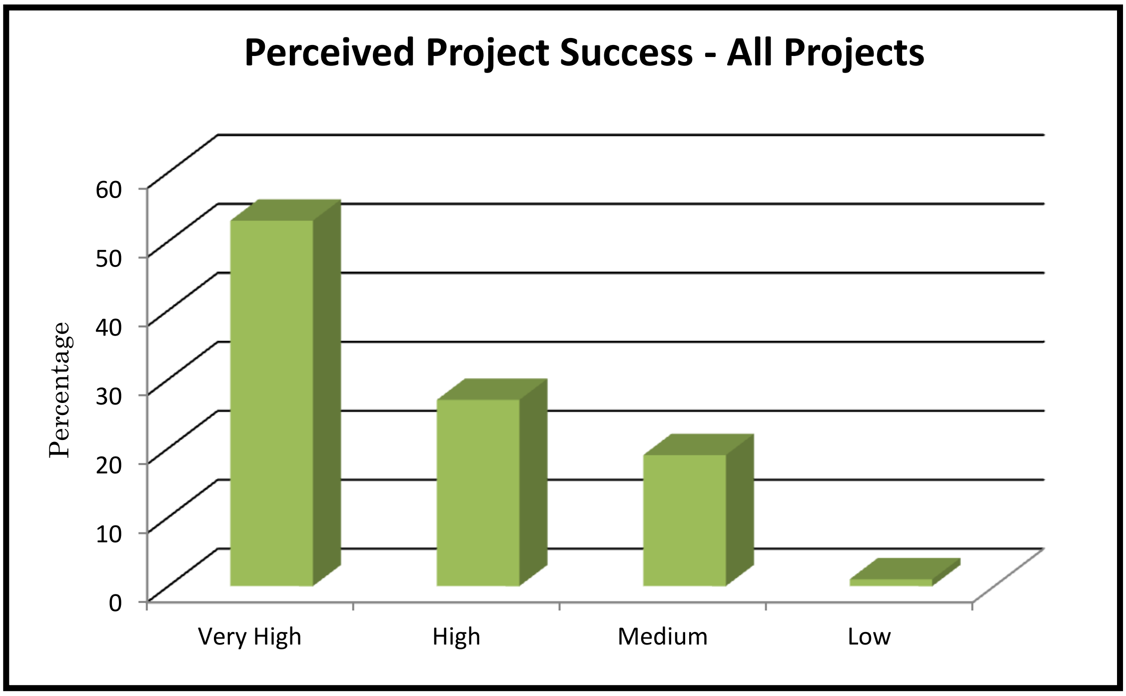

Figure 13: Perceived project success across entire sample

The perceived levels of project success, as assessed across the entire data set, depicted in Figure 13, shows that 53% of the respondents reported very high perceived levels of project success, 27% high, 19% medium and 1% a low perceived level of project success. At the outset of the research one concern in determining perceived project success was the likely bias Project Managers could have towards over rating success levels on projects they have managed. Part of the research design therefore included attaining a corresponding perception of project success from the perspective of the client/ project sponsor. Subsequently, contact details of these key project stakeholders were requested in the questionnaire for the purposes of gleaning their perspectives, as to the success of the project. The strictest confidentiality was again emphasised. Unfortunately, only a small proportion of respondents provided such contact details. Furthermore, the response rate from the clients/ project sponsors contacted to participate was also very low. Too low to be used in this research. Even though there is a likely Project Manager bias towards perceived project success, a good range of scores was attained between medium, high and very high categories of perceived project success, providing a differentiation, although it is noted that this is based on subjective judgments of participants and may be optimistic.

4.4 QUALITATIVE RESEARCH FINDINGS

As set out in the research methodology section this component of the research qualitatively (in the form of open ended questions in the questionnaire) explored the following:-

- The use of uncertainty and risk management approaches considered to be in 'advance' of general prescribed risk management standards.
- Project Managers perspectives with respect to improving uncertainty and risk management implementation on complex projects.

The findings are discussed below.

(i) 'Advanced' Uncertainty/ Risk Management Approaches and Processes and Perceived Project Complexity

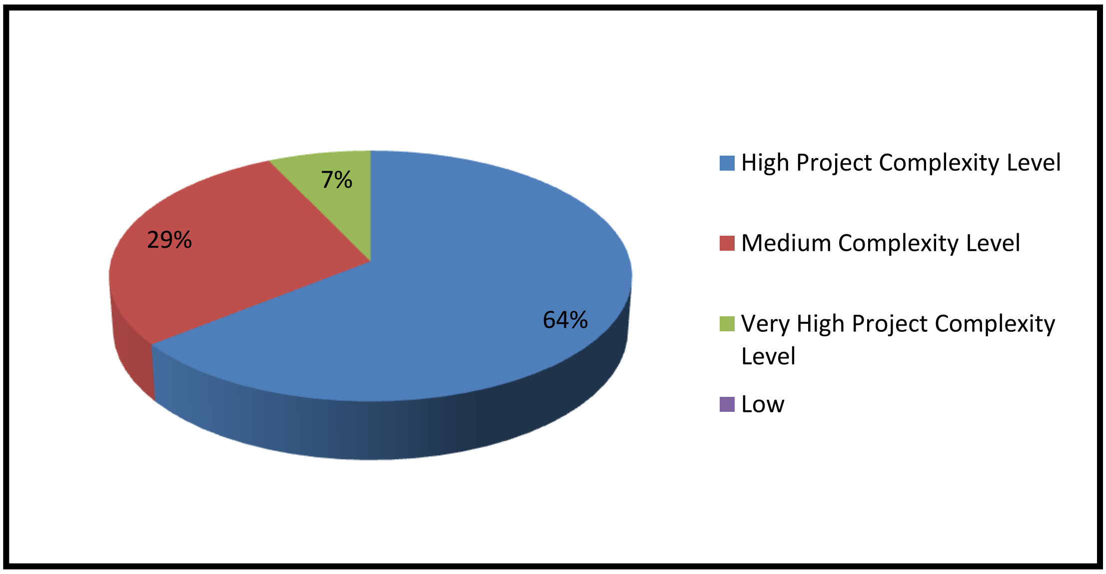

Figure 14: Advanced risk management approaches used and perceived levels of complexity (N=14)

Risk management approaches and processes considered to be 'in advance' of mainstream risk management standards were highlighted in the literature review and further defined in the research methodology. This is also analysed later in the thesis, with the particular focus on projects perceived to have high complexity. However, in this descriptive section a bi-variate assessment of the entire sample is made, with respect to the use of risk management approaches and processes perceived as 'advanced' and the corresponding perceived level of project complexity. Figure 14 above shows that risk management approaches considered to be in advance are used predominantly on projects perceived to have high levels of complexity (64%), which intuitively is to be expected. However, it does need to be noted that N=14 sub sample only equates to 19% of the entire sample (N=73) of the Project Managers using 'advanced' approaches.

(ii) Project Manager's perspectives for improving Uncertainty and Risk Management Implementation

The suggested requirements for improved uncertainty and risk management implementation qualitatively suggested by Project Manager research participants were assessed and are comprised of the following themes across the entire sample:-

- Stakeholder/ client/ customer/ sponsor involvement, buy-in and consideration of perceptions in the risk management process.
- Risk identification, assessment and planning needs to be done prior to and at the outset of the project.
- Focused risk management training and education.
- Use of appropriate expertise.
- The development of a risk taxonomy, lessons learned data base and industry specific guidelines.
- Clear and agreed lines of communication.
- Continual risk identification and monitoring of risks and response plans throughout the project lifecycle/ Allocation of more time and resources to risk management activities.
- Improved quantitative risk assessments.
- Use of more than one risk management approach.

On projects perceived as complex, the following key areas were specifically identified as in need of improvement:-

- Stakeholder/ client/ customer/ sponsor involvement, buy-in and consideration of perceptions in the risk management process.
- Risk identification, assessment and planning needs to be done prior to and at the outset of the project.
- Focused risk management training and education.
- Use of appropriate expertise.

- The development of a risk taxonomy, lessons learned data base and industry specific guidelines.

The above themes are analysed and discussed in chapter 5.

4.5 Reliability and Validity Tests

Reliability is consistency within a test or between repeated uses of it in the same circumstances. Reliability refers to the consistency or stability of a measuring instrument (Jackson, 2006). Validity concerns whether a test measures what it was created to measure i.e. it is concerned with the extent to which the measurement provides an accurate reflection of the concept (Johnson & Duberley, 2000).

Internal Consistency (Reliability) was determined using the Cronbach Alpha Test.

The strength of internal consistency from the results of a Cronbach Alpha test is summarised below in Table 21.

Cronbach Alpha	Internal Consistency
$\alpha \geq .9$	Excellent
$.9 > \alpha \geq .8$	Good
$.8 > \alpha \geq .7$	Acceptable
$.7 > \alpha \geq .6$	Questionable
$.6 > \alpha \geq .5$	Poor
$.5 < \alpha$	Unacceptable

Table 21: Accepted rule of thumb for describing internal consistency using Cronbach's Alpha (George & Mallery, 2003).

Reliability and validity tests for this research were carried out/ confirmed on the key research variables – project complexity, risk management approaches and processes and project success. Table 22 summarises the tests on each of these variables. A discussion of these results and further expansion on validity follows the table. Appendix 5 provides further details of the Cronbach Alpha tests.

Variable	Reliability/ Validity	Method for Checking	Notes and Test Results
Project Complexity	Reliability (Internal Consistency)	Cronbach Alpha Co-efficient	Crawford-Ishikura 7 factor table (CIFTER). Cronbach α = 0.673
	Validity		Validated as a project management complexity self assessment tool, through correlation between project manager and assessor/ sponsor assessments of management complexity of projects using this instrument (Aitken & Crawford, 2007).
Uncertainty & Risk Management Approaches and Processes	Reliability (Internal Consistency)	Cronbach Alpha Co-efficient	Cronbach α = 0.751
Risk Management Approach	Validity		Content validity for the risk management approach framework is attained through the framework developed by Stephen Ward - 'Six dimensions of risk management development' (Ward, 2005). See Table 3.
Risk Management Processes	Validity		Content validity for the risk management process framework is attained through general processes promulgated by the prominent international risk management standards (PMI, 2004/2008 – Chapter 11; AS/NZS 4360:2004; PRAM, 2004; RAMP, 2005; AS/NZS ISO 31000:2009).
Project Success	Reliability (internal consistency)	Cronbach Alpha Co-efficient	Cronbach α = 0.751
	Validity		Content validity is attained through the following references from the literature (Atkinson, 1999; de Bakker et al., 2010; Project Management Institute, 2004a; Shenhar et al., 2001). (Note the discussion and comments in section 2.12)

Table 22 – Reliability and validity testing

Perceived Project Complexity

Reliability (Internal Consistency)

Table 22 above shows Cronbach's alpha is 0.673, which does indicate a questionable level of internal consistency for this sample of perceived project complexity. However, this could reasonably be considered 'acceptable' as it is fairly close to the range where alpha is considered acceptable, notably $\alpha \geq .7$. Appendix 5 provides further test details.

Validity

Validity is supported by previous research, as noted in Table 22.

Uncertainty and Risk Management Approach and Processes

Reliability (Internal Consistency)

Table 22 above shows Cronbach's alpha is 0.751, which indicates an acceptable level of internal consistency for this sample of risk management approaches and processes. Appendix 5 provides further test details.

Validity

Content validity for the risk management process framework is attained through processes promulgated by the following prominent international risk management standards:

- Project Risk Management, Project Management Institute, Project Management Body of Knowledge, Chapter 11, 2004/ 2008.
- Risk Management, Joint Australian/ New Zealand Standard, AS/NZS 4360:2004.

- Project Risk Analysis and Management (PRAM) Guide, UK Association for Project Management (APM), 2004.
- Risk Analysis and Management for Projects (RAMP), Institution of Civil Engineers and the Faculty and Institute of Actuaries, 2005.
- Risk Management – Principles and Guidelines, Joint Australian/ New Zealand Standard, AS/NZS ISO 31000:2009.

Content validity for the risk management approach framework is provided by basing the measures on the framework developed by Stephen Ward, an internationally respected project and risk management expert – 'Six dimensions of risk management development' (Ward, 2005). It has an organisational focus, but with very minor modification it is considered applicable for this research in a project context.

As outlined in the research methodology (section 3.6.2) these frameworks each have a different focus on assessing 'risk' management implementation. The validity of this measuring instrument was considered in the pilot survey and there was no feedback (followed up by interviews) from participants suggesting any concerns or issues in this respect. This research collected the data for both frameworks through the questionnaire. The scores are combined into a composite score for risk management approach and processes. It is considered that as a composite, a more comprehensive indication of the 'level' of 'risk' management implementation is achieved for the purposes of this research.

Project Success

<u>Reliability (Internal Consistency)</u>

Internal Consistency (Reliability) was determined using the Cronbach Alpha Test. Two measures of the nine factors used to measure project success, notably project schedule and budget, are dichotomous and nominal in nature. The balance of the measures use a likert scale and are ordinal in nature. With respect to the dichotomous data a Kuder-Richardson co-efficient was used to determine reliability. However, co-efficient alpha is equivalent to the Kuder-Richardson 20 (KR 20) Co-efficient (SPSS, 2010). Subsequently the data is assessed using the Cronbach Alpha test. The Cronbach's alpha, considering the nine measures is 0.751, which indicates an acceptable level of internal consistency for this sample of perceived project success. Appendix 5 provides further test details.

Validity

Validity for the purposes of this investigation is attained through reference made to the literature and the attempt of this research to establish a reasonably well balanced set of criteria to measure perceived project success. The tremendous challenges faced in measuring project success are acknowledged earlier in this thesis (Atkinson, 1999; de Bakker et al., 2010; Shenhar et al., 2001). In this sense it is noted that the criteria used provide an indicative measure of perceived project success (also see discussion in the research methodology section – 3.6.3). Without the ability to attain client or project sponsors perceptions of project success (detailed in section 4.3 (vi)) it is also noted that there is a likely bias with a possible enhancement of success by Project Managers. However, as previously mentioned, this is likely to occur across the entire sample, still enabling correlations to be made.

4.6 Statistical Testing of Hypotheses

The research questions are represented by five hypotheses that are presented in section 3.5 of the thesis. This section assesses the inter-relationships between the key variables, conducting correlations and also comparing differences. Tests for statistical significance are conducted and the null hypotheses are either rejected or fail to be rejected (are retained).

It is important to note that correlation is a measure of association, whereas significance assesses how unlikely such an association was to occur.

Scattergrams are used to demonstrate the nature and strength of correlation between the key variables. Correlation co-efficients are calculated. The scale below is considered when interpreting the strength of the correlation.

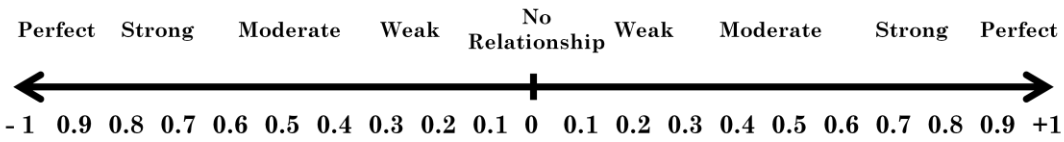

Figure 15: Scale of Correlation (Cooligan, 1999)

It is important to note that even fairly weak co-efficients, as low as 0.3 can be counted as significant if the number of pairs of values is quite high.

The table below sets out the various parametric tests and the non-parametric equivalents.

	Related Design	**Unrelated Design**	**Correlation**
Parametric	Related (or corrected) t-test	Unrelated (or uncorrected) t-test	Pearson's Product Moment Correlation Co-Efficient
Non-Parametric Equivalent	Wilcoxon Signed Ranks	Mann-Whitney U (or Wilcoxon Rank Sum)	Spearman Rank Correlation

Table 23: Parametric tests and the Non-Parametric equivalents (Cooligan, 1999)

Cooligan (1999) establishes a useful process for choosing the appropriate statistical test as follows:-

Decision 1

Does the hypothesis predict difference or correlation?

Decision 2

At what level is the measurement of the data?

Decision 3

Is the data related or unrelated?

This process is considered for each hypothesis test. Detailed statistical outputs for all tests are provided in appendix 6.

(a) Null Hypothesis 1

Project Managers do not implement higher level uncertainty and risk management approaches and processes on projects they perceive as more complex, than on projects that they perceive as less complex.

<u>Correlation</u>

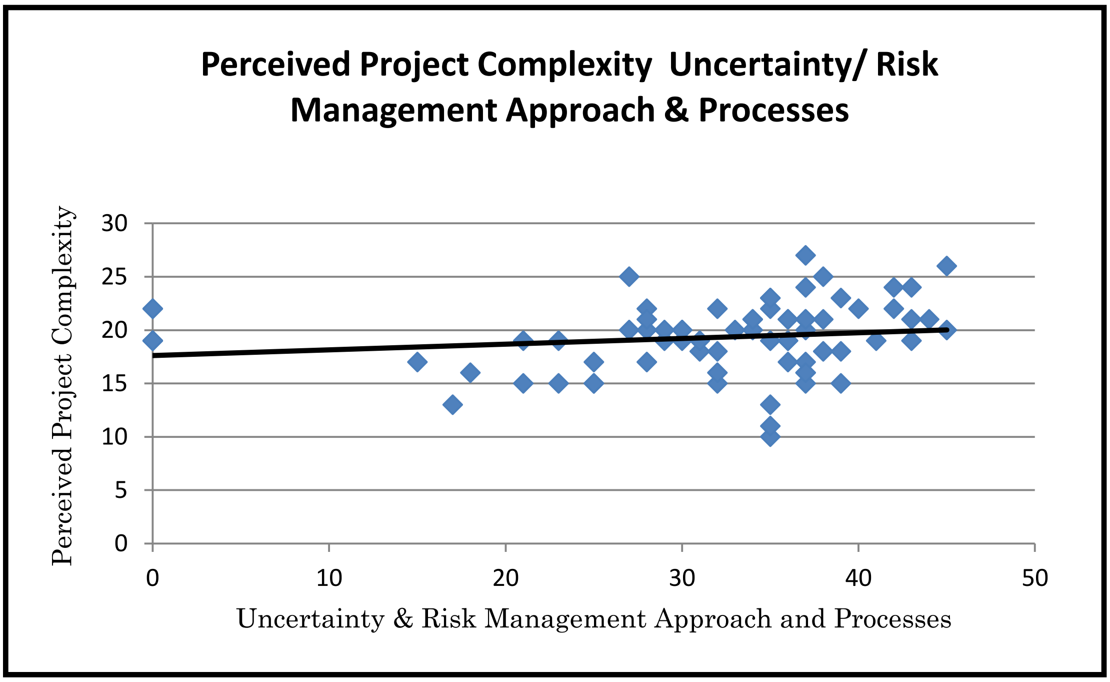

Figure 16: Correlation - Project Complexity and Uncertainty/ Risk Management Approaches and Processes implemented

The scatter chart above (Figure 16) shows a positive correlation. The correlation is however rather weak to moderate at 0.279 (see statistical calculation below). 5 responses to the survey reported that 'risk' was not explicitly managed at all on the respective projects and this is considered to reduce the strength of the correlation.

Significance Testing

Decision 1

A positive correlation is predicted between perceived project complexity and risk management approaches and processes.

Decision 2

The level of measurement is ordinal.

Decision 3

The design is related.

The most appropriate choice of statistical test is therefore the non-parametric test – Spearman's Rank Correlation. This is as follows:

$r_s = 1 - 6\sum d^2 / N(N^2-1)$

However, the Spearman's formula above is technically for use only when there are no tied ranks. If ties occur the statistic becomes a weaker estimate of what it is supposed to measure. If any values are tied the general approach is to carry out a Pearson's calculation on the pairs of ranks – $r = \sum(z_x z_y) / N-1$. The resulting co-efficient is still referred to as Spearman's r. Even though the difference between the Spearman formula and using Pearson on the ranks when there are ties is 'rather slight', especially for large samples, statisticians are correct in insisting that the formula for Spearman is not correct when ties occur (Cooligan, 1999).

The statistical calculation therefore follows this approach. With the two sets of data ranked, a Pearson's calculation was conducted for the sample N=73. The result is a correlation co-efficient of 0.279, which is as stated above, weak to moderate. Significance is p=0.008, which is significant at the 0.05 level.

It is important to note (as stated above) that of the sample of 73 there were five responses that could perhaps be considered data outliers, with no formalised risk management approach or processes adopted in the management of the respective projects. These five subsequently scored 0 for this variable and clustered away from the rest of the data. The strength of the correlation and significance increases if these five are excluded from the data set, as identified in Figure 17 below, at a correlation co-efficient of 0.362 (p= 0.001) – N=68. However, even though these five data points lie well away from the rest of the data they cannot be interpreted as outliers, as they should be considered as part of the data set, as they do display results where Project Managers did not manage risk explicitly at all. Figure 17 is therefore indicative only.

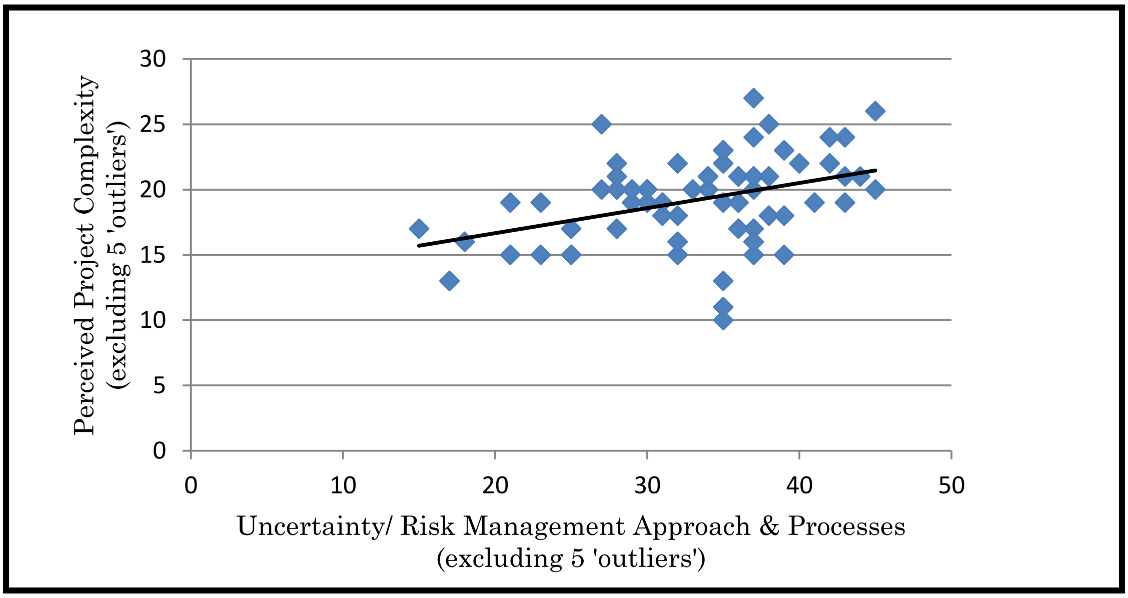

Figure 17: Project Complexity and Uncertainty/ Risk Management Approaches and Processes implemented (excluding 5 outliers)

The null hypothesis is therefore rejected.

(b) Null Hypothesis 2

Most Project Managers, on projects they perceive to have high levels of complexity, do not implement uncertainty and risk management approaches and processes at lower than 'optimal' levels of general prescribed industry risk management standards.

<u>Difference</u>

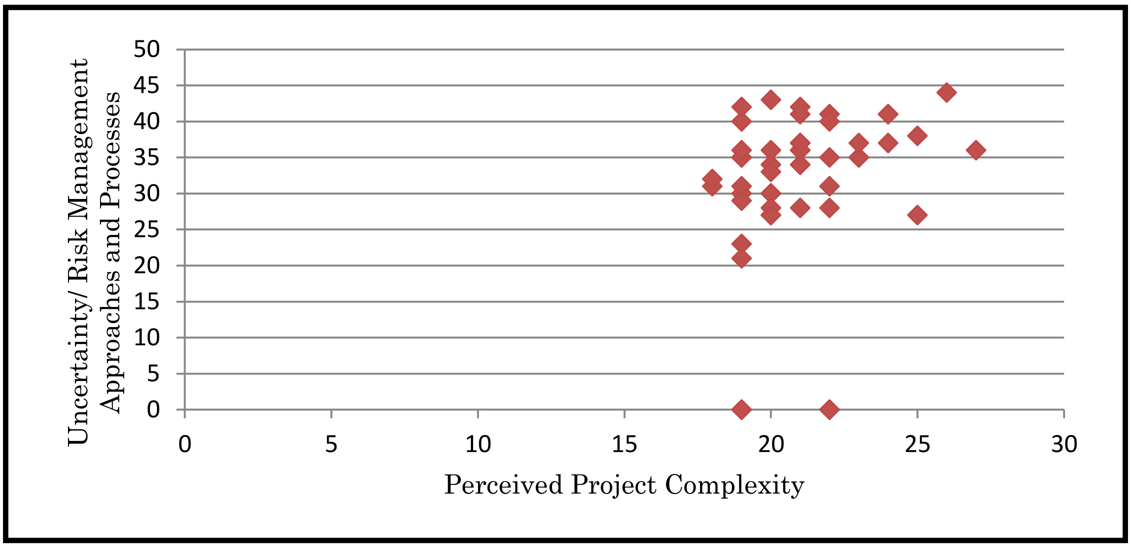

Figure 18: Levels of Uncertainty/ Risk Management approaches and processes implemented on projects of perceived high complexity ('optimal' implementation (in relation to the framework developed for this research – see section 3.6.2 and Figure 7) of general prescribed Risk Management standards equals a score of 45)

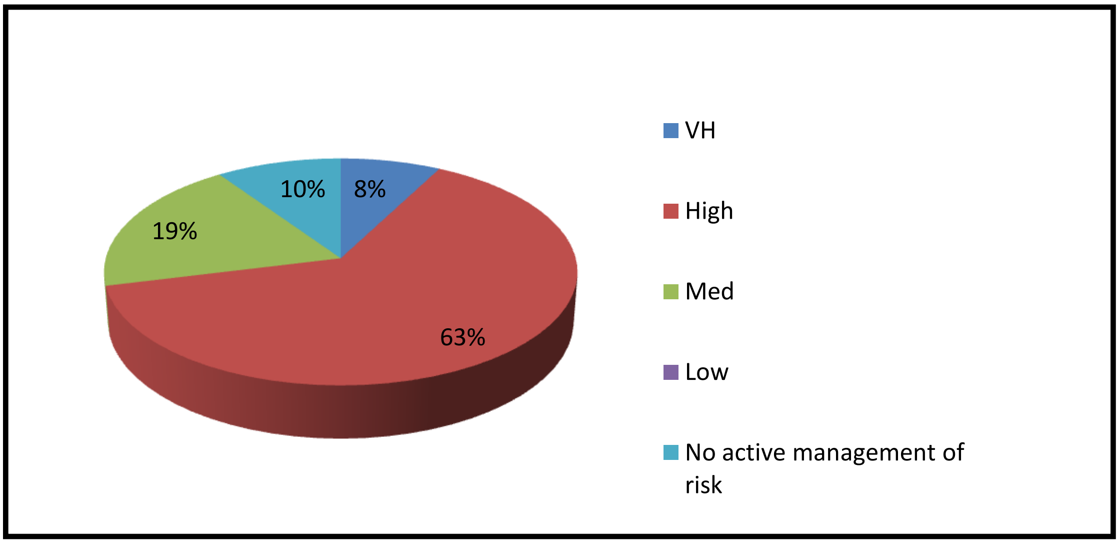

Figure 19: Frequency of the levels of implementation of Uncertainty/ Risk Management approaches and processes on projects perceived to be of high complexity

The scatter chart above (Figure 18) clearly shows that the majority of Project Managers do manage risk at levels considered less than 'optimal' risk management approaches and processes as prescribed by general industry risk management standards. This is further quantified in Figure 19 which shows that only 8% of Project Managers reported risk management approaches and processes that could be considered in line with and close to the 'optimal' implementation of general prescribed industry risk management standards. 92% of the Project Managers implement risk management at lower than 'optimal', on projects perceived to be of high complexity.

Significance Testing

Decision 1

A significant difference is predicted as stipulated in the null hypothesis above.

Decision 2

The level of measurement is ordinal.

Decision 3

The design is related.

The most appropriate choice of statistical test is therefore the non-parametric test – Wilcoxon (T) Signed Ranks Test. The difference is between the 'optimal' level of prescribed industry risk management standards and risk management approaches and processes implemented on complex projects.

The pairs of scores were ranked in the first instance. The Related samples Wilcoxon Signed Ranks Test was conducted on the sample on N=51. P=0.000, which is significant at the 0.05 level.

The null hypothesis is therefore rejected.

(c) Null Hypothesis 3

A minority of Project Managers do not implement uncertainty and risk management approaches and processes 'in advance' of general prescribed industry risk management standards on projects they perceive to have high levels of complexity.

<u>Difference</u>

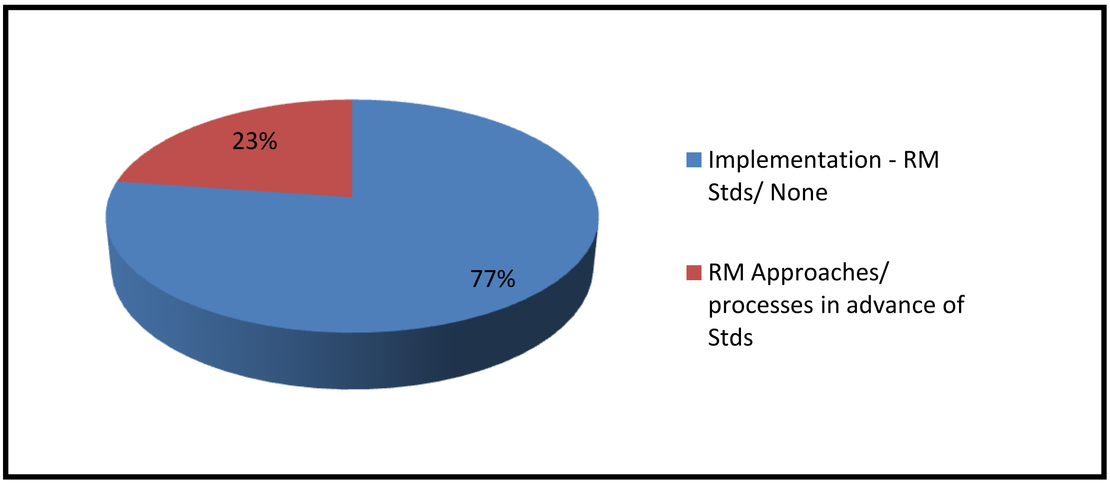

Figure 20: Frequency of Uncertainty/ Risk Management approaches and processes considered to be 'in advance' of traditional mainstream standards on projects of perceived high complexity (N=44)

Figure 20 above clearly shows that on projects perceived to have high complexity, a minority of Project Managers (23%) denoted that they implemented risk management approaches and processes that they consider to be 'in advance' of general prescribed industry risk management standards. Research participants were requested to denote if they implanted risk management approaches and process that they perceive to be in advance of risk management standards ("yes/no", with a request to denote and explain why the approach was implemented). The literature review highlights concepts that this research considers to be 'in advance' of mainstream standards. These include explicit opportunity management (Hillson, 2002, 2004a; Olsson, 2007; Zhang, 2011), the uncertainty management paradigm (Chapman & Ward, 2003a, 2003b; Ward & Chapman, 2003), a constructively simple approach to the evaluation and interpretation of estimates (Chapman et al., 2006), risk attitude (Hellier et al., 2001; Hillson & Murray-Webster, 2005, 2008; Slovic, 1987; Smallman & Smith, 2003) and complexity theory concepts (Cooke-Davies et al., 2007).

<u>Significance Testing</u>

Decision 1
A significant difference is predicted as stipulated in the null hypothesis above.

Decision 2
The level of measurement is ordinal.

Decision 3
The design is related. The test is done on 'one sample' – On projects perceived as complex, the prevalence of Project Managers managing risk at levels that they consider to be 'in advance' of mainstream risk management standards, compared to the management of 'risk' 'in-line' with the standards or perhaps not at all. The data is binary in nature.

The most appropriate choice of statistical test is considered to be the one sample Kolmogorov-Smirnov Test (parametric). A one-sample Bonomial Test was also conducted. With a sample of N=44 the Kolmogorov-Smirnov Test p=0.000 and one sample Binomial Test p=0.025, which is significant at the 0.05 level.

The null hypothesis is rejected.

(d) Null Hypothesis 4

There is no positive correlation between uncertainty and risk management approach and process levels implemented and perceived project success by Project Managers, on projects that they perceive to be of high complexity.

<u>Correlation</u>

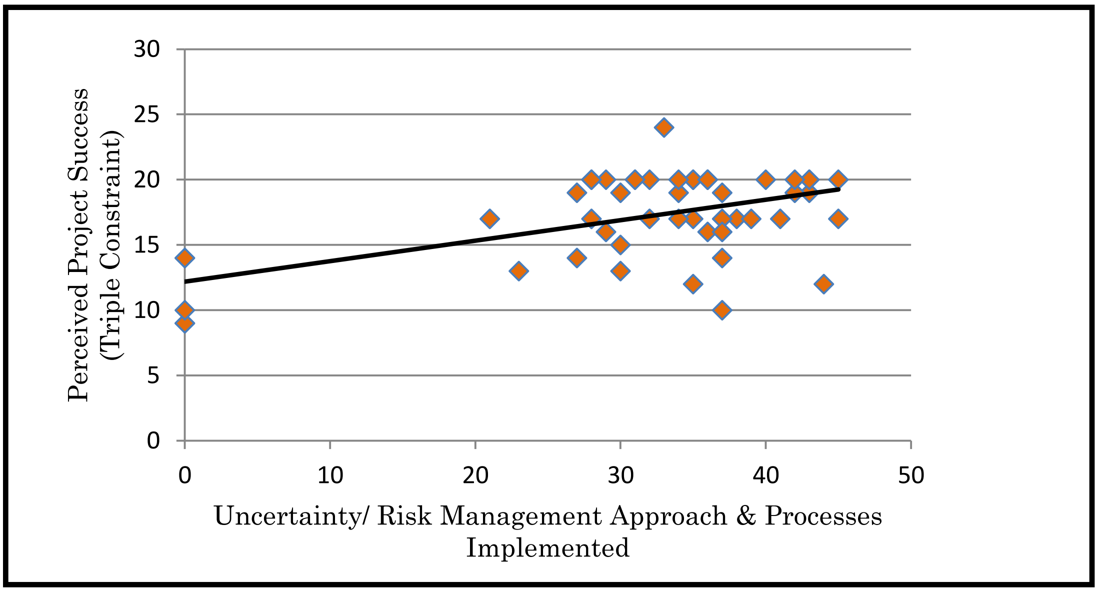

Figure 21: Levels of Uncertainty/ Risk Management Approaches/Processes Implemented and Perceived Project Success (Triple Constraint) on projects perceived to have high levels of complexity (N=50)

The scatter chart above (Fig 21) shows a moderate positive correlation (correlation co-efficient = 0.284 – see statistical calculation below).

The triple constraint, as a measure of project success was also used *albeit* an inferior measure to the additional elements considered in the literature review. The reason for this was that more of the research participants fully completed those categories. Less research participants fully completed all nine categories of the expanded definition of project success.

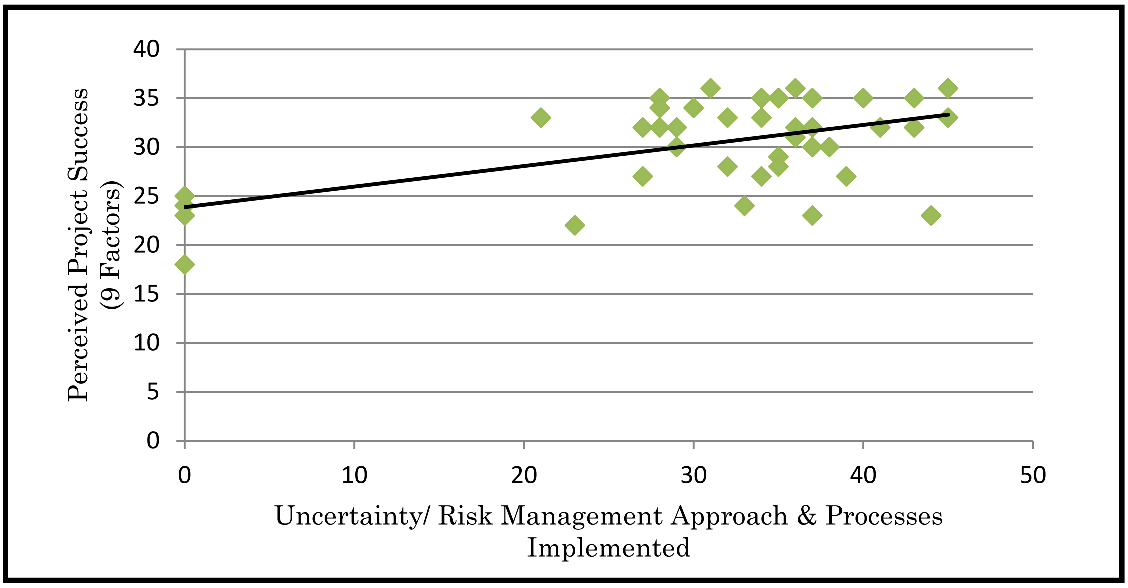

Figure 22: Levels of Uncertainty/ Risk Management Approaches/Processes Implemented and Perceived Project Success (9-Factors) on projects perceived to have high levels of complexity (N=41)

Figure 22 shows a moderate positive correlation (correlation coefficient = 0.299 – see statistical calculation below)

<u>Significance Testing</u>

Decision 1

A positive correlation is predicted between levels of risk management approaches/processes implemented and perceived success by project managers.

Decision 2

The level of measurement is ordinal.

Decision 3

The design is related.

The most appropriate choice of statistical test is therefore the non-parametric test – Spearman's Rank Correlation. This is as follows:

$r_s = 1- 6\sum d^2/N(N^2-1)$

However, there are tied ranks and as outlined in the statistical testing of the first hypothesis the Spearman's formula is technically for use only when there are no tied ranks. The general approach will therefore be to carry out a Pearson's calculation on the pairs of ranks – $r = \sum(z_x z_y)/N\text{-}1$. The resulting co-efficient will still be referred to as Spearman's r.

With the two sets of data ranked a Pearson's calculation was conducted using PASW Statistics v18 software. For the triple constraint sample N=50 the result is a correlation co-efficient of 0.284, which is as stated above, weak to moderate. Significance is p=0.023, which is significant at the 0.05 level. For the 9-factor sample N=41 the result is a correlation co-efficient of 0.299, which is as stated above, weak to moderate. Significance is p=0.029, which is significant at the 0.05 level.

The null hypothesis is rejected.

(e) Null Hypothesis 5

Perceived project success is not higher on projects of high complexity, where uncertainty and risk is managed 'in advance' of general prescribed industry risk management standards, rather than at 'high levels' of such standards.

Difference

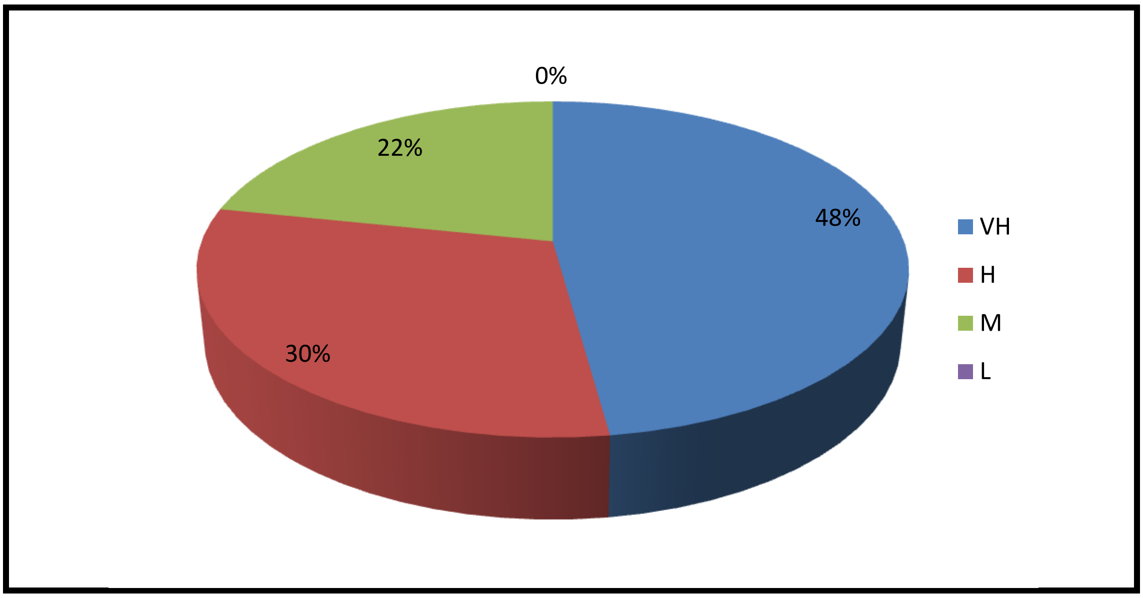

Figure 23: Perceived project success (triple constraint) on complex projects where uncertainty/ risk management approaches and procedures were implemented at high levels of mainstream risk management standards (N=27)

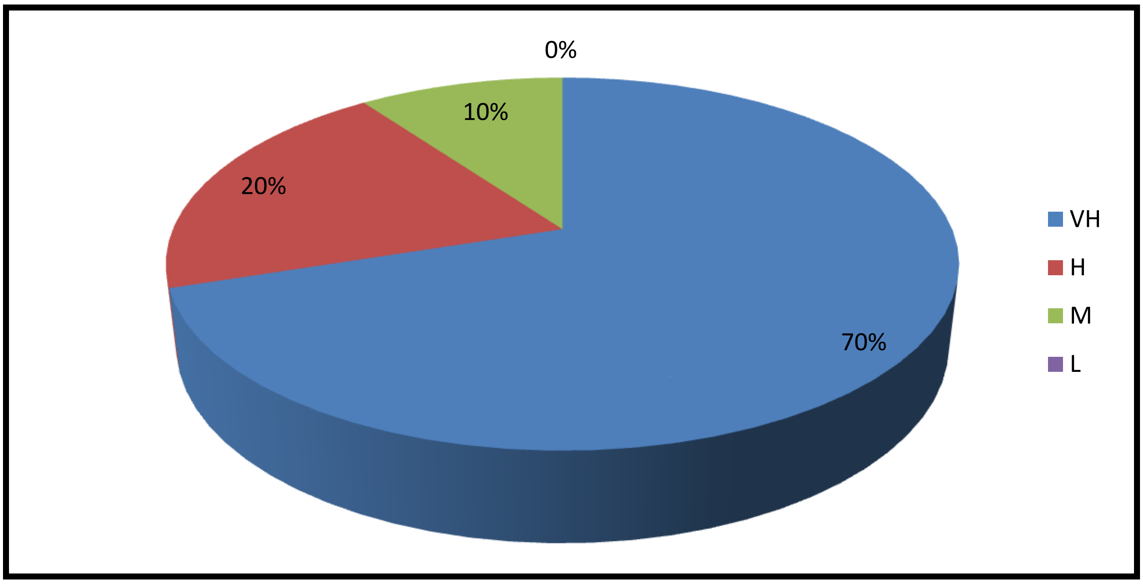

Figure 24: Perceived project success (triple constraint) on complex projects where uncertainty/ risk management approaches and procedures implemented were considered to be 'in advance' of mainstream risk management standards (N=10)

Figures 23 and 24 above show a difference in the perceived success of projects. The 'triple constraint' was used an indicative project measure due to a larger sample, when compared to the 9-factor project success measure. Those characterised by uncertainty and risk management approaches that are considered to be 'in advance' of mainstream standards have higher levels of perceived project success than those projects characterised by uncertainty and risk management implemented at high levels of mainstream standards. 70% of projects where project managers used risk approaches and processes in advance of mainstream standards are considered to be at very high levels of success, compared to only 48% on those projects characteristic of high levels of mainstream standards.

With independent samples, the Mann-Whitney (non-parametric) was used to calculate the statistic. With the sample N=37, p=0.897 which is not significant at the 0.05 level.

The null hypothesis is retained.

4.6 Summary of Statistical Tests and Results

Table 24 below provides a summary of the statistical tests carried out, together with the results.

H_0	Null Hypothesis	Statistical Tests Conducted	Result	Conclusion
$1H_0$	Project Managers do not implement higher level uncertainty and risk management approaches and processes on projects they perceive as more complex, than on projects that they perceive as less complex.	Spearman's Rank Correlation	*Correlation Co-efficient = 0.279 *Significance P=0.008 *Significant at 0.05 level *Null Hypothesis rejected	Project Managers implement higher level uncertainty and risk management approaches/ processes on projects they perceive as more complex.
$2H_0$	Most Project Managers, on projects they perceive to have high levels of complexity, do not implement uncertainty and risk management approaches and processes at lower	Wilcoxon (T) Signed Ranks Test	*P = 0.000 which is significant at 0.05 level *Null Hypothesis rejected	On projects perceived as complex, most Project Managers implement uncertainty and risk management approaches and processes at lower than 'optimal' levels

H_0	Null Hypothesis	Statistical Tests Conducted	Result	Conclusion
	than 'optimal' levels of general prescribed industry risk management standards.			of general prescribed industry risk management standards.
$3H_0$	A minority of Project Managers do not implement uncertainty and risk management approaches and processes 'in advance' of general prescribed industry risk management standards on projects they perceive to have high levels of complexity.	Kolmogorov-Smirnov Test One-sample Bonomial Test	*P=0.000 *P=0.25 *Significant at 0.05 level *Null Hypothesis rejected	On projects perceived as complex, a minority of Project Managers implement uncertainty and risk management approaches/ processes 'in advance' of general prescribed industry risk management standards.
$4H_0$	There is no positive correlation between uncertainty and risk management approach and process levels implemented and perceived project success by Project Managers, on projects that they perceive to be of high complexity.	Spearman's Rank Correlation	*Correlation Co-efficient = 0.299 *Significant p=0.029 *Significant at 0.05 level *Null Hypothesis rejected	On projects perceived as complex, perceived project success increases with the implementation of increasing levels of uncertainty and risk management approaches/ processes.
$5H_0$	Perceived project success is not higher on projects of high complexity, where uncertainty and risk is managed 'in advance' of general prescribed industry risk management standards, rather than at 'high levels' of such standards.	Mann-Whitney Test	* P=0.897 * Not significant at the 0.05 level *The Null Hypothesis is retained.	With the Null Hypothesis retained it cannot be concluded that on projects of high complexity, perceived project success is not higher, where uncertainty and risk is managed 'in advance' of general prescribed industry risk management standards than at 'high levels' of such standards.

Table 24 – Summary of statistical tests carried out

5. RESEARCH ANALYSIS AND DISCUSSION

5.1 Introduction

The overarching requirement for this research was developed through evidence in the literature of continued project failures (Flyvbjerg et al., 2003; Mulcahy, 2003; Raz et al., 2002; Standish Group, 2006, 2009) and the notion that current mainstream risk management standards appear ineffective in managing uncertainty on projects of high complexity in particular (Chapman & Ward, 2002, 2003b; De Meyer et al., 2002; Johnson, 2006; Smith & Irwin, 2006). Furthermore, there is criticism of mainstream project and risk management standards ineffectiveness to manage 'soft' projects and a call for alternative management approaches in this respect (Atkinson et al., 2006).

The literature provides some empirical evidence of project risk management practices differing from risk management prescription (Taylor, 2006) and that risk management practices are not widely used by project managers, but when they are used they appear to be related to project success (Raz et al., 2002). The literature also suggests for the consideration and use of complexity theory concepts in the management of projects characterised by high levels of complexity (Cooke-Davies et al., 2007). Other uncertainty and risk management approaches developed by leading project and risk management researchers are identified in the literature. This research introduced and discussed these in the literature review, concluding that they are potentially 'in advance' of most traditional mainstream risk management standards and as motivated in the literature, could be important approaches towards improving the management of uncertainty and risk on complex projects.

Following the identification of the research 'gap', with respect to Project Manager's uncertainty and risk management practice in relation to their perceptions of project complexity, together with the inter-relationships between uncertainty and risk management practice and perceived success, research questions were developed. Hypotheses were devolved from these research questions (see table 2).

The research analysis critically discusses the research findings, with respect to the research questions. Both univariate and bivariate data findings are analysed. The results of the hypotheses tests are re-iterated and the statistical results of each Null Hypothesis conveyed and discussed. An analysis of the key descriptive statistics and the qualitative research findings is provided. In conclusion there is a critical review of the research findings against the research questions and the implications thereof.

5.2 Results of the Hypothesis Testing

Null Hypothesis 1

Project Managers do not implement higher level uncertainty and risk management approaches and processes on projects they perceive as more complex, than on projects that Project Managers perceive as less complex.

The Null Hypothesis is rejected.

The test statistic used was a Pearson's Product Moment Correlation Co-Efficient, against the following variables – perceived project complexity and risk management approach and process levels. A positive correlation was established and significance at the $p \leq 0.05$ level was achieved.

The research finding is that Project Managers do implement higher level risk management approaches and processes on projects they perceive as more complex than on projects that they perceive as less complex. This matches an intuition that this is current practice. However, the correlation co-efficient is low at 0.279, which indicates a fairly weak relationship.

Null Hypothesis 2

Most Project Managers, on projects they perceive to have high levels of complexity, do not implement uncertainty and risk management approaches and processes at lower then 'optimal' levels of general prescribed industry risk management standards.

<u>The Null Hypothesis is rejected.</u>

The test statistic used was the Wilcoxon (T) Signed Ranks Test. The difference being between the 'optimal' level of prescribed industry risk management standards and uncertainty/ risk management approaches and processes implemented on complex projects. A significant result is achieved at the $p \leq 0.05$ level.

The research finding is that Most Project Managers, on projects they perceive to have high levels of complexity, are implementing risk management approaches and processes at lower then 'optimal' levels of general prescribed industry risk management standards.

The frequency of the levels of implemented risk management approaches and processes (Figure 19) identifies that on projects perceived to have high complexity, only 8% of the respondents reported implementing such approaches and processes at very high levels, which according to the framework established could be considered as 'optimal', with respect to mainstream risk management standards prescription. The bivariate analysis is graphically represented in Figure 18, clearly showing that on projects of high complexity most Project Managers are implementing risk management approaches and processes at below 'optimal' levels.

Null Hypothesis 3

A minority of Project Managers do not implement uncertainty and risk management approaches and processes 'in advance' of general prescribed industry risk management standards on projects they perceive to have high levels of complexity.

<u>The Null Hypothesis is rejected.</u>

The test statistic used was the Kolmogorov-Smirnov Test, as well as a one sample Binomial Test. The difference was significant at the $p \leq 0.05$ level.

The research finding is that a minority of Project Managers implement risk management approaches and processes 'in advance' of general prescribed industry risk management standards on projects they perceive to have high levels of complexity.

The literature review outlines risk management approaches and processes, which this research considers to be 'in advance' of general prescribed industry risk management standards. These are further identified in the research methodology. Research participants responded with their perceptions in this respect. These were validated in relation to their description of risk management approaches and process implemented.

Figure 20 illustrates the frequency, with 23% of the Project Managers on high complex projects identifying risk management approaches and processes considered to be 'in advance' of general prescribed industry risk management standards.

Null Hypothesis 4

There is no positive correlation between uncertainty and risk management approach and process levels implemented and perceived project success by Project Managers, on projects that they perceive to be of high complexity.

<u>The Null Hypothesis is rejected.</u>

The test statistic used was a Pearson's Product Moment Correlation Co-Efficient against the following variables – perceived project success and risk management approach and process levels. A positive correlation was established and significance at the $p \leq 0.05$ level was achieved.

The research finding is that there is a positive correlation between risk management approach and process levels implemented and perceived project success by Project Managers on projects that they perceive to be of high complexity. However, the correlation co-efficient is fairly low at 0.299, which indicates a moderate to weak relationship.

Null Hypothesis 5

Perceived project success is not higher on projects of high complexity, where uncertainty and risk is managed 'in advance' of general prescribed industry risk management standards, rather than at 'high levels' of such standards.

The Null Hypothesis is retained.

The Mann-Whitney (non-parametric) test was used (with independent samples) to calculate the statistic. With the sample N=37, p=0.897 which is not significant at the 0.05 level.

The research finding therefore cannot reject the null hypothesis that on projects characterised by high level complexity, where risk management approaches and processes implemented are in advance of mainstream risk management standards, perceived project success is not higher than on those projects of similar complexity, where risk management approaches and processes implemented are equivalent to a high level implementation of mainstream standards.

Figures 23 and 24 show a difference. 70% of projects where Project Managers used risk approaches and processes 'in advance' of mainstream standards are perceived to be at very high levels of success, compared to only 48% on those projects characterised by the implementation of high levels of mainstream risk management standards.

5.3 Analysis and Discussion of Key Descriptive Statistics and Qualitative Research Findings

The key descriptive statistics and qualitative insights augment the quantitative findings of this research. The following section analyses and discusses the key findings of the descriptive statistics. The qualitative research findings are then critically analysed, with respect to 'advanced' uncertainty and risk management approaches implemented and research participants' perspectives regarding improvements to uncertainty and risk management approaches and processes, particularly in complex project environments.

Key Descriptive Statistics

This section analyses and discusses the key findings from the descriptive statistics analysis.

(A) Risk Management Training

A high proportion of the Project Managers in the sample have received professional training – 81%. The training categories are highlighted in Table 12, with project management specific training comprising 87%. The Project Management Institute (PMI) is the highest training provider, which is most likely due to the bias in the sample skewed towards PMI membership, as identified and discussed in the univariate analysis. There is however a number of other project management training programmes identified, such as Prince 2, Masters/ Graduate Certificates/ Diploma's in Project Management, Certified Practicing Project Practitioner (CPPP)-AIPM, Certified Scrum Master/ Practitioner (Scrum Alliance) and Sigma Black Belt.

Specific risk management training is shown to be limited, with only 11% of the entire research sample identifying some form of risk management training. These include an MSc in Risk Management, risk management certificates, in-house risk management training, self-study and a Risk Management Professional (PMI). Within project management training, especially the various institutes/ associations general project management accreditation programmes there is a component of risk management training. This training would in most cases be aligned to the respective institute/ association risk management approach.

This research has revealed very few risk management approaches and processes that are considered to be in 'advance' of general prescribed industry risk management standards. It is apparent therefore that large numbers of Project Managers continue to receive training in and exposure to the very risk management approaches and processes that are criticised in the literature. Possibly with more Project Managers being exposed to other forms of risk management training, greater momentum could be made towards change.

(B) Risk Management Standards and Guidelines Implemented

The sample identifies a wide spectrum of standards/ guidelines implemented. The PMI guideline (Chapter 11 – 2004, 2008) is dominant, with AS/NZS 4360:2004, RAMP 2004 and AS/NZS ISO 31000:2009 also being identified, amongst others. However, an interesting response is that a large number of Project Managers are using their respective organisational and company standards. Some are identified by respondents as being based on general prescribed industry risk management standards, whilst others did not specify. The low response in the survey to risk management approaches and responses considered 'in advance' would suggest that the organisational guidelines are perhaps similar to general prescribed industry risk management standards. But it should be noted that it is perfectly reasonable that there are a number of responses reporting approaches 'in advance' of general prescribed industry risk management standards.

(C) Frequency of Project Managers Implementing their respective Institute/ Association Risk Management Standard/ Guideline

Project Manager members from PMI and APM were assessed to determine the frequency they implemented their own institutes/ associations risk management guidelines. The APM sample is too small at N=6 to be of much significance. A reasonable sample was received from PMI members (N=35) to provide an indicative result. Interestingly, only 66% of the PMI members reported using PMI's guidelines, compared to 33% from APM. This could be influenced by 31% of Project Managers across the sample reporting they use organisational/ company standards. Future research for the project management discipline in seeking to improve the management of uncertainty on projects could further investigate what risk management standards/ guidelines Project Managers are using? Why? When?

(D) Frequency of Project Managers using more than one Risk Management Standard/ Guideline

Across the sample (N=73) it was discovered that 18% of Project Managers use more than one 'risk' management standard. Is there a discontent with any one standard being sufficient and appropriate? This is another area that future research could explore?

<u>Qualitative Research Findings</u>

As outlined in the research methodology section, qualitative insights were sought through the research to explore uncertainty and risk management approaches implemented in 'advance' of general prescribed industry risk management standards and also to ascertain the perspectives of participating Project Managers, as to the necessary improvements to the uncertainty and risk management approaches implemented on complex projects. The analysis and discussion is provided below.

(A) Uncertainty and Risk Management Approaches 'in Advance' of General Prescribed Industry Risk Management Standards

The testing of null hypothesis 3 concludes that a minority of Project Managers implement risk management approaches and processes 'in advance' of general prescribed industry risk management standards on projects they perceive to have high levels of complexity.

The research requested Project Managers to identify approaches and processes that were implemented, which they consider to be 'in advance' of general prescribed industry risk management standards. This is considered an important exploratory component of this research, where possible improved 'risk' management approaches and processes are identified and discussed.

The analysis of the entire data sample identifies that 19% of the respondents perceive their approaches and processes to be 'in advance' of general prescribed industry risk management standards.

The breakdown of the implementation of such approaches, with respect to perceived complexity is depicted in Figure 14 earlier. This shows that risk management approaches and processes considered to be 'in advance' are mostly implemented on projects perceived to have high levels of complexity. This intuitively is to be expected.

Across the entire sample, risk management approaches and processes identified by respondents as 'in advance' are as follows:-

- Uncertainty management paradigm
- Explicit opportunity investigation
- Explicit assessment and management of risk attitudes
- Explicit consideration of organisational risk appetite
- Use of complex adaptive methods

'Advanced' Uncertainty/ Risk Management Approach	Frequency of Response (Number of Respondents)
Uncertainty management paradigm	12
Explicit opportunity investigation	1
Explicit assessment and management of risk attitudes	2
Explicit consideration of organisational risk appetite	1
Use of complex adaptive methods	1

Table 25: Response from survey of the advanced uncertainty/ risk management approaches implemented (N=14)

It is important to note that a qualitative response was sought from participants in the form of an open ended question. However, the uncertainty management paradigm is a concept expressed in Ward's (2005) framework, used by this research to determine the uncertainty/ risk management approach implemented. The potential influence of this depiction was dealt with through cross validation, as discussed further below. Table 25 shows that of the 19% of those research participants across the entire sample who indicated implementing risk management at levels considered to be 'in advance' of general prescribed industry risk management standards, the predominant approach is identified as the uncertainty management paradigm. Furthermore, the other approaches identified were only noted by two Project Managers. So, besides the implementation of an uncertainty management approach, there are a negligible number of other 'advanced' approaches implemented across the sample.

It is noted however that there is the possibility that some of the participants who identified having implemented the uncertainty management paradigm may have identified this through 'uncertainty management' name recognition and did not actually implement the uncertainty management paradigm as presented by Chapman and Ward (2003a, 2003b). However, there was a cross-reference validation conducted with the responses received from a later question in the questionnaire, which requested participant Project Managers to qualitatively depict the uncertainty and risk management approaches/ processes they implemented that they consider to be 'in advance' of mainstream risk management standards. Only those respondents who qualitatively depicted the uncertainty management paradigm as an advanced approach used to this question (N=12) were considered to have implemented the approach. As stated above, there still remains a likelihood that of the 12 responses received a few may not have implemented the paradigm as proposed by Chapman and Ward (2003a, 2003b). This is a limitation in this research and is identified in section 6.3. This would not affect the research finding, with respect to Null Hypothesis 3.

In the survey, participants were requested to provide further details regarding the approaches taken and why? There was limited commentary here, but a few interesting insights were provided from those who responded “yes” to implementing ‘advanced’ approaches.

With respect to risk attitude, one respondent emphasised the importance of careful consideration to cultural perspectives. Narration was suggested as an effective technique to “share subjective feelings”. This is consistent with the requirement for the improved management of subjective facets to enable the more effective management of projects, which is an extremely strong theme in the literature (Atkinson et al., 2006; Chapman, 2006; Cooke-Davies et al., 2007; Crawford & Pollack, 2004; Hellier et al., 2001; Hillson & Murray-Webster, 2005, 2008; Slovic, 1987; Zhang, 2011).

On another project it was reported that complex adaptive methods were used due to a “black swan event”. This is often used as a synonym for an unforeseen negative event of significance. Taleb (2008) describes a black swan event as having the following three attributes:

1. It is an ‘outlier’. It lies outside the realm of regular expectations.
2. It carries extreme impact.
3. Human nature ‘concocts’ explanations for its occurrence after the fact retrospectively, making it explainable and predictable.

(Taleb, 2007)

It was reported that reactive and adaptive risk management was required to address the unforeseen event. It was further emphasised that the key focus was to stay as close to the original intent, as stipulated in the business case, whilst making progress, as efficiently as possible under the circumstances. The respondent made the following recommendation for improvement of risk management in this respect:-

"Explicit education and use of complex adaptive methods to all the project team - and the stakeholders, many of whom saw risk as a reputational threat only, responding to circumstances accordingly. I can think of only one stakeholder who asked - how can I help?"

The relevant literature addressing complex adaptive systems includes Cooke-Davies etal (2007), Lewin (1999) and Taleb (2007).

(B) Project Manager Perspectives – Improving Uncertainty and Risk Management Implementation

The research questionnaire asked respondents to state how they would improve on risk management implementation on similar future projects. A positive response (N=47) was received to this. The key recommendations are grouped according to key themes below, with the most prevalent recommendations towards the top of the list. These recommendations are across the spectrum of perceived complexity. As this thesis has a distinct focus on projects of high complexity, responses were also compared to the respective Project Manager rating of perceived project complexity. Comments relating to projects characterised by high levels of perceived complexity are highlighted, following the presentation of the recommendations below.

(i) Stakeholder/ client/ customer/ sponsor involvement, buy-in and perceptions in the risk management process

A number of respondents raised this as an item that needs to be improved upon. A few quotations received from Project Manager research participants below illustrate this theme.

“Clients didn’t want to be bothered with risks. Instead [they] wanted [the Project Manager] to handle all the risks and just get the project done”.

“Our stakeholders didn’t want to be 'bothered' with risks. Instead they wanted IT to handle all issues and risks and just get the project done. Stakeholder input was important in some of the decision making. In the future more direct involvement by the stakeholders in their project should be required.”

“Continuous review & improvement procedures in conjunction with project sponsors and the whole team to ensure that all risks are firstly thought of, and secondly actively mitigated by the whole team, rather than risks being thought of by one or two members of the team and mitigated by ad hoc members.”

“Make sure a full understanding of the touch points from the perspective of each client are identified”.

“Integrate risk management [into the management of the project]. Develop methods (eg narration) to share subjective views and ‘bad’ feelings”.

In the risk management process, key stakeholders need to be well informed about the risks on the project and also play an important and active role in the risk management process. Comments were made suggesting that this is an issue, with key stakeholders in a number of projects not being active enough in the process. Also, of importance are some comments surrounding the requirement to consider and manage perceptions towards risk. This is related to the need for the improved management of risk attitude on projects, which is a key theme expressed in the literature review (Bernstein, 1996; Gingerenzer, 2002; Hellier et al., 2001; Hillson & Murray-Webster, 2005, 2008; Slovic, 1987; Smallman & Smith, 2003).

(ii) Use of appropriate expertise

The use of appropriate expertise in the uncertainty and risk management process was conveyed as important.

“The lesson from this would be to get external help as a sanity check as early as possible, particularly where the technology involved is new to the organisation and/or simply new technology”.

“…Include resources who are not only experts in risk management but also [those who] understand the business and technology domain of the project. Prior experience in similar projects across industries or [the] same industry also helps.”

“It would also be helpful to assign a resource who is knowledgeable about risk management tools and techniques to the project team".

Appropriate expertise needs to be used in the management of risk on projects. The use of skilled risk management practitioners to enhance risk management implementation was raised. However, it was also noted that it is not only risk management experts who need to be involved, but also those people who understand the business and the technological domain of the project. An interesting link can be made with the denoted and quantified low rates of risk management training – 11% of sample (N=73) (see Fig 10 – section 4.3(G)) and the qualitative response advocating for increased risk management training for Project Managers and other project stakeholders. This could perhaps form the basis of future research into what uncertainty/ risk management expertise is appropriate for project delivery? When should an uncertainty/ risk management ‘expert’ be used to manage the uncertainty and risk management process on a project?

(iii) Risk identification, assessment and planning needs to be done prior to (e.g. strategic planning, business case development) and at the outset of the project

The need for upfront uncertainty and risk management was identified. Not only at the outset of the project, but also as part of strategic planning and business case development.

"…[early identification of risks] rather than during project execution, as [risks] are manifested".

"Recognise risk [and] that [a] proper ROI calculation may not have been done during concept planning, such that the ongoing support costs for the delivered system may exceed corporate benefit."

"Through better upfront loading of the project and addressing potential risks ahead of project execution, rather than during project execution as they manifested."

"Conduct detailed risk management along with the business case in the initial phases of the project".

"Develop a comprehensive risk register and management plan for the entire project i.e. from business case through construction."

Risk management needs to be done along with the business case and in the initial phases of the project. Careful attention needs to be given to assumptions made in the business case, when identifying uncertainties and risks.

(iv) Focused risk management training and education

The requirement for risk management training and education was identified. It was raised that this is not only for Project Managers, but also for project team members.

“Training [is required] for the project team on risk management, since most of the team members [had] not heard about risk management”.

“…To focus on risk management I think requires behavioural & cultural changes, not just the process and therefore training and actually carrying our risk management should include educating the people involved. For example, most of the people I deal with are engineers or similar and do not see risk management as something that applies to them”.

“Explicit education …. to all the project team - and the stakeholders, many of whom saw risk as a reputational threat only, responding to circumstances accordingly”.

As discussed in (ii) above, the univariate findings revealed that only 11% of the research sample have participated in specialist risk management training. Furthermore, the qualitative feedback from participant Project Managers provides further insights into these low levels, pointing to a need for increased training for Project Managers.

(v) Clear and agreed lines of communication

The following quotes illustrate the perspective for clear and agreed lines of communication.

"Risk Management was very ad-hoc…I only took over the project within the last few months of its implementation. The project was floundering and very little was being achieved. There was a complete communication breakdown and even though some risk had been identified nothing had been put in place to mitigate that risk. [A] communication plan was developed along with risk management [and] regular risk reviews via weekly steering committee meeting."

"…Initially there was a struggle for lines of reporting/ PM team structure…this was probably the greatest challenge in establishing the overall risk plan... clarifying and maintaining good lines of communication and reporting. Once this was completed the team was functioning as a team. All the rest fell into place and the risk identification, planning and scheduling did its job [to the] completion of the project."

The need for clear lines of communication was depicted as important. Risk management planning, identification, assessment, response planning and monitoring will not be ineffective without this in place. This is a requirement as set out by most of the general prescribed industry risk management standards.

(vi) Continual risk identification and monitoring of risks and response plans throughout the project lifecycle/ Allocation of more time and resources to risk management activities

One response outlined this with respect to outward looking project risks, for example social-legal factors. It was mentioned that on this particular project these were well identified early on in the project, but "negated later on as the team was focused on the internal project detail."

Other responses in this respect included:-

“Ensure the project team implement risk monitoring and migration strategies.”

“… as the project progressed the team became involved in the detail of our internal activities and less aware of impending legal and social changes that had risk impacts.”

“Allocation of more time and resource to focus on risk management.”

The management of uncertainty and risk throughout the project lifecycle, as well as resourcing are key requirements expressed in general prescribed industry risk management standards.

(vii) Improved quantitative assessments

Improved quantitative risk analysis was identified with the following comment.

“Undertake a higher level of quantitative assessment of data of some of the high priority risks, as opposed to relying on qualitative assessment only.”

Most general prescribed industry risk management standards include the process of quantitative risk assessment/ analysis, with guidelines as to when to carry out quantitative risk assessment/ analysis, together with a depiction of various techniques. An important paper providing insights into the use of estimates in quantification, as discussed in the literature review is Chapman et al (2006) – minimising the effects of dysfunctional corporate culture in estimation and evaluation proceses : A constructively

simple approach, International Journal of Project Management, 24(2), 106-115.

(viii) Development of a risk taxonomy, lessons learned database and industry specific guidelines

One Project Manager pointed out that specific risk related information is typically held by limited parties who have been in the industry a long time as consultants - "There could be more industry specific risks highlighted as a standard within the Dairy industry. This has typically been held by limited parties who have been in the industry a long time as consultants."

Other comments included the following:-

"… develop a formal approach including post-project risk analysis and knowledge base formation in order to identify and better understand future risks & their influence more precisely".

Capturing lessons learnt is an important element in project management (Project Management Institute, 2008). This enables areas to be identified and improved upon later in the project cycle and/ or on future projects. The literature conveys risk taxonomy's as valuable in assisting the uncertainty/ risk management process (Mulcahy, 2003). However, project teams should not be over-reliant on these and should also be cognisant of differences across projects and identify uncertainty and risk accordingly.

(ix) Use of more than one risk management approach (standard)

The following was raised by one respondent - "In the future I will focus on [implementing more than one risk approach] on the same project to make sure that the results [are improved]."

There were interestingly a number of Project Managers in the sample who depicted implementing more than one standard (as discussed in the descriptive analysis – section 4.3 (iv). Exploring this in further detail could be quite valuable research in the search for improvements to mainstream standards. Why do Project managers choose more than one standard? What are the strengths and weaknesses of the various standards?

To conclude the above perspectives from Project Managers, the following quote from one Project Manager perhaps provides a poignant summary and a link to the literature, which calls for improvements to the current practice in the management of uncertainty on projects:-

"I would describe the state of risk management in Project Management as in need of vast improvement requiring much work to be done in the area of decision making and uncertainty."

In terms of projects perceived to be of high complexity, the most important areas for improvement in risk management practice identified by research participants include (from most strongly to least strongly represented) stakeholder/ client/ customer/ sponsor involvement, buy-in and perceptions in the risk management process; risk identification, assessment and planning needs to be done prior to and at the outset of the project lifecycle; focused risk management training and education; use of appropriate expertise; and the development of a risk taxonomy, lessons learned data base and industry specific guidelines.

The perspectives above provided by experienced Project Managers, the insights from the qualitative findings regarding the use of 'advanced' uncertainty/ risk management approaches and the key findings of the univariate analysis are a rich source of information. This has been shown to augment the findings of the quantitative data and to provide further insights to the research. This has further enabled the identification of a number of research opportunities, which can further expand on the findings of this research.

5.4 Review of the Research Questions against the Findings and Implications

RQ1 Are uncertainty and risk managed differently by Project Managers on projects perceived as more complex?

The first null hypothesis in particular explored this question. Through the testing of this hypothesis it is concluded that the answer to this question is 'yes'. It is shown that on projects perceived to be higher in complexity, Project Managers are implementing higher levels of risk management approaches and processes than on projects that are perceived as less complex. Intuitively, at the outset of the research this was thought to possibly be a likely result. However, given continued project failures reported in the literature there was some doubt. It is noted earlier that the correlation between the variables, perceived project complexity and risk management approaches and processes is low, denoting a rather weak degree of relationship. The analysis has also provided evidence that on projects of greater complexity, approaches and processes considered to be 'in advance' of general prescribed industry risk management standards are implemented more prevalently than on projects of lesser complexity.

The findings of this research, with respect to the analysis of uncertainty and risk management approaches/ processes and perceived project success on complex projects suggests an enhancement of project success with a corresponding improvement of uncertainty and risk management approaches and processes. This supports similar empirical findings from previous research - (Raz et al., 2002; Zwikael & Ahn, 2011). Also see later discussion.

It could be conceived that a mere strengthening of the relationship (perceived project complexity and risk management approach/ processes) is what should be strived for on future projects. Some strengthening is preferable, but there are elements that need to be considered. It is important to note that there is still a requirement for uncertainty and risk to be managed at 'reasonable' levels on projects of lower complexity, so a 'perfect' correlation cannot be achieved. In seeking improvements to managing uncertainty and risk on complex projects, given the strong criticism in the literature of the inability of general prescribed industry risk management standards to deal with complexity, it is important that improvements are sought beyond the 'confines' of current risk management standards. Cognisance needs to be given to the literature that seeks improved approaches to manage uncertainty and risk - (Atkinson et al., 2006; Chapman & Ward, 2002, 2003a; De Meyer et al., 2002; Hillson, 2002; Johnson, 2006; Smith & Irwin, 2006; Stoelsness & Bea, 2005).

RQ2 What 'levels' of general prescribed industry risk management standards are implemented by Project Managers on projects perceived to have high complexity?

This research question is important, particularly as there is substantial criticism in the literature of the ineffectiveness of most general prescribed industry risk management standards in managing uncertainty and risk, particularly on complex projects (Atkinson et al., 2006; Chapman & Ward, 2002, 2003a; De Meyer et al., 2002; Hillson, 2002; Johnson, 2006; Smith & Irwin, 2006; Stoelsness & Bea, 2005). The following statement is also pertinent in this respect – "there appears to be far more literature offering prescriptions to Project Managers on how to manage risk in projects, rather than assess the relative effectiveness of those prescriptions" (Kutsch & Hall, 2010, p. 254). This research attempts to contribute to this by assessing perceived project success against risk management implementation, as addressed in the discussion pertaining to RQ5

Investigating whether general prescribed industry risk management standards are being implemented at ‘high’ or ‘low’ levels is considered by this research to be an important ‘first-step’. If it is found for example that standards are being implemented at extremely low levels against prescription, then a further question could be – are the general prescribed industry risk management standards perhaps ineffective, due to the fact that they are not being implemented appropriately?

The emphasis of the research question is on complex projects, so it could be expected that higher levels of risk management are implemented on projects of higher perceived complexity. A further question to consider, in line with the critique in the literature with respect to the ineffectiveness of general prescribed industry risk management standards - Is the standard’s perceived ineffectiveness preventing progression to higher levels of implementation of the standard?
Importantly though, the second null hypothesis investigated this on projects of high perceived complexity, assessing ‘optimal’ levels of uncertainty and risk management implementation, as promulgated by general prescribed industry risk management standards. This was assessed through the framework developed for this research. It was discovered that very few Project Managers are implementing risk management at ‘optimal’ levels. 8% of the sample are considered to do so. 63% of the Projects Managers reported implementing high levels, 19% medium and 10% low levels of implementation. This suggests a requirement for further research investigating impediments to implementing uncertainty and risk management in projects, particularly complex projects. An area that also requires further research in line with calls in the literature for assessing the effectiveness of current uncertainty and risk management prescriptions (Kutsch & Hall, 2010).

RQ3 Are the uncertainty and risk management approaches and processes considered to be 'in advance' of general prescribed industry risk management standards on projects of high complexity?

The literature review identified a number of uncertainty and risk management approaches that could be considered to be 'in advance' of general prescribed industry risk management standards (Chapman & Ward, 2002, 2003a, 2003b; Chapman et al., 2006; Cooke-Davies et al., 2007; Hellier et al., 2001; Hillson, 2002, 2004a; Hillson & Murray-Webster, 2005, 2008; Slovic, 1987; Smallman & Smith, 2003; Zhang, 2011). It was explained earlier that this question was explored by requesting participants to qualitatively denote and describe the uncertainty and risk management approaches and processes implemented that they consider to be in advance of general prescribed industry risk management standards. This question was established with the anticipation (hope) that a 'treasure trove' of advanced approaches, in line with those portrayed in the literature and perhaps even 'new' approaches may be discovered.

The research question is answered by research participants with the depiction of some 'advanced' approaches matching concepts presented in the literature. This provides further evidence of uncertainty and risk management practices differing from the prescription of standards (Taylor, 2006). However, as highlighted earlier, the response was low (N=14), with the implementation of the uncertainty management paradigm identified and explicit management of risk attitudes mentioned, together with explicit opportunity investigation, explicit consideration of organisational risk appetite and the use of complex adaptive methods (see Table 25). This low number of 'advanced' uncertainty and risk management approaches implemented on complex projects is perhaps related to the finding in the univariate analysis, depicting low levels of risk management training and the qualitative analysis where Project Managers conveyed a perspective that increased risk management training is required.

RQ4 On projects perceived to have high complexity, what proportion of Project Managers are implementing uncertainty and risk management approaches and processes considered to be 'in advance' of general prescribed industry risk management standards?

This research question is important, because for a number of years the research literature has been proposing various approaches to uncertainty and risk management that is considered by this research to be 'in advance' of general prescribed industry risk management standards With the criticism of the standards inability to effectively manage uncertainty and risk, especially in complex project environments, these approaches could be innovative ways to more effectively manage uncertainty and risk on projects across the 'hard' and 'soft' spectrums.

The finding of hypothesis 3 confirms that only 19% (N=14) of the entire research sample reported using approaches and processes 'in advance' of general prescribed industry risk management standards, whilst on projects characteristed by high levels of complexity, 23% of the Project Managers reported using 'advanced' approaches. Furthermore, as discussed earlier, there is not a wide spectrum of 'advanced' approaches across the sample. One respondent reported implementing five approaches, another two, whilst the balance of respondents each identified one only.

This finding is important and a challenge for the project management discipline, as how best to explore and incorporate such innovative approaches presented through research, into general prescribed industry risk management standards? Further to the above, the univariate analysis, together with recommendations provided by Project Manager research participants could provide some insights into possible strategies. These could perhaps include:-

- Training/ knowledge sharing to expose Project Managers, institutions/ associations and other key stakeholders to other uncertainty and risk management approaches/ processes, besides those prescribed by their respective institute.
- Project risk management researchers continuing to influence Project Managers, project management institutions and associations through publications and presentations, together with continued 'effective' participation in the development of risk management standards.
- Further empirical research, showing the benefits on complex projects in particular, of alternative (to mainstream standards) uncertainty and risk management approaches.

RQ5 On projects of high complexity, does the uncertainty and risk management approach and process implemented affect perceived project success?

This was considered a key question to establish a correlation between the level of risk management implemented on complex projects and perceived project success. Statistically a correlation of moderate strength was achieved, with significance.

This suggests that on projects of high complexity, higher levels of risk management implementation contribute positively towards achieving higher levels of project success. Similar empirical findings have been suggested by Raz et al (2002) and Zikael & Ahn (2011), as highlighted in the literature review. A key suggestion with this finding is that continuing to show the value of improved uncertainty/ risk management towards enabling enhanced project outcomes is critical to gleaning acceptance of uncertainty and risk management approaches from the project management discipline and key project stakeholders. It is suggested that further empirical investigation is required to build on this and other empirical findings. It is a challenging area of research, but a necessary one.

RQ6 On projects of high complexity, is there a difference in perceived project success between projects where uncertainty and risk is managed at 'high levels' and 'in advance' of general prescribed industry risk management standards?

The intent of this research question was to investigate the differences on complex projects of perceived success between uncertainty and risk managed at high levels of general prescribed industry risk management standards and uncertainty and risk managed using approaches considered to be 'in advance' of that. Again, an attempt to show the benefit of approaches that are alternative to prescribed standards. As reported, a difference is shown, with 48% of those implementing risk at high levels of general prescribed industry risk management standards (N=27) reporting perceived success as very high, compared to 70% for the 'in advance' sample (N=10).

Unfortunately a non significant result was achieved through statistical analysis and the null hypothesis is therefore retained. The low sample of those using 'in advance' approaches and processes is considered a key issue leading to a non-significant result. However, even with a non-significant result, the difference shown in this research is hoped to be a catalyst for further research to be conducted, to perhaps achieve a significant result to empirically highlight the value of using some of the innovative uncertainty and risk management approaches presented in the literature.

5.5 Conclusion

The results of the statistical tests on the 5 Null Hypotheses have been stated and the implications thereof discussed. The key univariate descriptive findings have been discussed, with an analysis of risk management training; risk management standards and guidelines implemented; the frequency of Project Managers implementing their respective institute/ association's risk management standard/ guideline; and the frequency with which Project Managers use more than one risk management standard. The qualitative insights of the sample have been highlighted and discussed, notably the nature and frequency of 'advanced' uncertainty and risk management approaches implemented and the perspectives of Project Managers pertaining to the key improvements required in the management of uncertainty and risk on complex projects in particular. This data and analysis augmented the quantitative analysis and provided further insights, highlighting some possible inter-relationships and identifying areas for future research. Finally, an analysis of the research results against the research questions was provided.

6. CONCLUSION

6.1 Introduction

The key purpose of this research was to investigate the relationship between uncertainty and risk management approaches and processes and perceived project complexity; the prevalence of uncertainty and risk management approaches and processes considered to be 'in advance' of general prescribed industry risk management; and perceptions of project success in relation to uncertainty and risk management practice. An extensive review of the literature was undertaken. It points to continued project failures (Flyvbjerg et al., 2003; Mulcahy, 2003; Raz et al., 2002; Sharma et al., 2011; Standish Group, 2006, 2009), increasing project complexity over time (Baccarini, 1996; Chang & Christensen, 1999; Philbin, 2008; Williams, 1999) and concern that general prescribed industry risk management standards are not effective in managing uncertainty and risk, particularly in complex project environments (Atkinson et al., 2006; Cooke-Davies et al., 2007; Smith & Irwin, 2006; Williams, 1999; Zhang, 2011). The literature also proposes a number of approaches that are considered to be 'in advance' of general prescribed industry risk management standards, notably explicit opportunity management (Hillson, 2002, 2004a; Olsson, 2007; Zhang, 2011), the uncertainty management paradigm (Chapman & Ward, 2003a, 2003b; Ward & Chapman, 2003), a constructively simple approach to the evaluation and interpretation of estimates (Chapman et al., 2006), risk attitude (Hellier et al., 2001; Hillson & Murray-Webster, 2005, 2008; Slovic, 1987; Smallman & Smith, 2003) and complexity theory concepts (Cooke-Davies et al., 2007).

The literature review provided limited evidence of empirical research focused primarily on the management of uncertainty and risk on complex projects. This is considered to be a research 'gap', specifically with respect to Project Manager's uncertainty and risk management practice in relation to their perceptions of project complexity, together with the inter-relationships between uncertainty and risk management practice and perceived project success on projects of high complexity. This is also supported by the following observation that "there appears to be far more literature offering prescriptions to Project Managers on how to manage risk in projects, rather than assess the relative effectiveness of those prescriptions" (Kutsch & Hall, 2010). The combination of continued project failures, increasing project complexity and inadequate uncertainty and risk management prescription and practice culminate to establish the research problem.

The following six research questions were developed to guide this research:-

- Are uncertainty and risk managed differently by Project Managers on projects perceived as more complex?
- What levels of general prescribed industry risk management standards are implemented by Project Managers on projects perceived to have high complexity?
- What uncertainty and risk management approaches and processes are considered to be 'in advance' of general prescribed industry risk management standards on projects of high complexity?
- On projects perceived to have high complexity, what proportion of Project Managers are implementing uncertainty and risk management approaches and processes considered to be 'in advance' of general prescribed industry risk management standards?
- On projects of high complexity, does the uncertainty and risk management approach and process implemented affect perceived project success?
- On projects of high complexity, is there a difference in perceived project success between projects where uncertainty and risk is

managed at 'high levels' and 'in advance' of general prescribed industry risk management standards?

Five hypotheses were derived from the research questions to operationalise the key research variables – perceived project complexity; uncertainty and risk management approaches and processes; and perceived project success.

A post-positivist research philosophy, including both quantitative and qualitative elements was adopted, with a questionnaire distributed to Project Managers using a combination of self-selecting and snowballing sampling techniques. Following the questionnaire design, pilot survey and review, the questionnaire was placed on the web and data was collected over a four month period towards the end of 2011. A final survey sample of N=73 was realised.

The conclusion to this thesis provides a summary of the research findings. The contribution that this research makes to knowledge is then described and argued. Finally, limitations of the study are highlighted and recommendations for future research are suggested.

6.2 Summary of Findings

Table 26 below summarises the results of the research hypotheses tests.

Number	Hypotheses	Finding	Conclusion
$1H_0$	Project Managers do not implement higher level uncertainty and risk management approaches and processes on projects they perceive as more complex, than on projects that they perceive as less complex.	Reject Null Hypothesis	Project Managers implement higher level uncertainty and risk management approaches/ processes on projects they perceive as more complex.

Number	Hypotheses	Finding	Conclusion
$2H_0$	Most Project Managers, on projects they perceive to have high levels of complexity, do not implement uncertainty and risk management approaches and processes at lower than 'optimal' levels of general prescribed industry risk management standards.	Reject Null Hypothesis	On projects perceived as complex, most Project Managers implement uncertainty and risk management approaches and processes at lower than 'optimal' levels of general prescribed industry risk management standards.
$3H_0$	A minority of Project Managers do not implement uncertainty and risk management approaches and processes 'in advance' of general prescribed industry risk management standards on projects they perceive to have high levels of complexity.	Reject Null Hypothesis	On projects perceived as complex a minority of Project Managers implement uncertainty and risk management approaches/ processes 'in advance' of general prescribed industry risk management standards.
$4H_0$	There is no positive correlation between uncertainty and risk management approach and process levels implemented and perceived project success by Project Managers, on projects that they perceive to be of high complexity.	Reject Null Hypothesis	On projects perceived as complex, perceived project success increases with the implementation of increasing levels of uncertainty and risk management approaches/ processes.
$5H_0$	Perceived project success is not higher on projects of high complexity, where uncertainty and risk is managed 'in advance' of general prescribed industry risk management standards, rather than at 'high levels' of such standards.	Null Hypothesis Retained	With the Null Hypothesis retained it cannot be concluded that on projects of high complexity, perceived project success is not higher, where uncertainty and risk is managed 'in advance' of general prescribed industry risk management standards than at 'high levels' of such standards.

Table 26: Summary of Hypotheses Testing

Overall the study addresses the research gap by providing empirical insight into the actual use of uncertainty and risk management approaches against all of the six research questions, concluding that:-

- Project Managers do implement higher level uncertainty and risk management approaches and processes on projects they perceive as more complex than on projects that they perceive as less complex.
- Most Project Managers, on projects they perceive to have high levels of complexity, implement uncertainty and risk management approaches and processes at lower then 'optimal' levels of general prescribed industry risk management standards.
- A minority of Project Managers implement uncertainty and risk management approaches and processes 'in advance' of general prescribed industry risk management standards on projects they perceive to have high levels of complexity. This builds on similar empirical findings in the literature - (Taylor, 2006).
- There is a positive correlation between uncertainty and risk management approach and process levels implemented and perceived project success by Project Managers on projects that they perceive to be of high complexity. This confirms similar empirical findings in the literature - (Raz et al., 2002; Zwikael & Ahn, 2011).
- A difference is shown in the data that on projects characterised by high level complexity, where uncertainty and risk management approaches and processes implemented are 'in advance' of mainstream risk management standards, perceived project success is not higher than on those projects of similar complexity, where uncertainty and risk management approaches and processes implemented are equivalent to a high level implementation of mainstream standards. However, a statistically significant result could not be attained and the null hypothesis is not rejected.

6.3 Contributions – The importance of the Research

An important finding of this research is that on complex projects there is a suggested enhancement of project success with higher 'levels' of uncertainty and risk management implementation. This is consistent with other empirical research, notably Raz et al (2002) and Zwikael & Ahn (2011). Another important finding is that most Project Managers are implementing higher 'levels' of uncertainty and risk management approaches and processes on projects perceived as more complex. This is encouraging. However, this needs to be tempered with the further finding of this research that on complex projects most Project Managers are implementing uncertainty and risk management approaches and processes at lower than 'optimal' levels of general prescribed industry risk management standards, together with the finding that very few are implementing uncertainty and risk management approaches considered in the literature to be 'in advance' of general prescribed industry risk management standards.

These findings are important and also challenging when considering the general criticism in the literature relating to the ineffectiveness of most general prescribed industry risk management standards in managing uncertainty and risk, particularly in complex project environments (Atkinson et al., 2006; Beck, 2004; Chapman, 2006; Chapman & Ward, 2002, 2003b; Chapman et al., 2006; Johnson, 2006; Smith & Irwin, 2006; Ward & Chapman, 2003; Williams, 1999; Zhang, 2011); the reference in the literature to alternative uncertainty and risk management concepts to those prescribed by current risk management standards - explicit opportunity management (Hillson, 2002, 2004a; Olsson, 2007; Zhang, 2011); the uncertainty management paradigm (Chapman & Ward, 2003a, 2003b; Ward & Chapman, 2003); a constructively simple approach to the evaluation and interpretation of estimates (Chapman et al., 2006); risk attitude (Hellier et al., 2001; Hillson & Murray-Webster, 2005, 2008;

Slovic, 1987; Smallman & Smith, 2003), complexity theory concepts (Cooke-Davies et al., 2007) - and wider alternative concepts suggested in the literature, notably the management of 'imprecision' should include fundamental uncertainty, ignorance and fuzziness (Pender, 2001) and scenario planning (Schoemaker, 1995). The challenge is the need to further understand the impediments to lower than 'optimal' implementation and the low uptake in alternative approaches to managing uncertainty and risk.

The research investigated differences in perceived project success on complex projects between approaches considered to be at a high 'level' of of general prescribed industry risk management standards and those considered to be 'in advance' of general prescribed industry risk management standards. A difference is shown in that 48% of those implementing at high levels of general prescribed industry risk management standards (N=27) reported perceived success as very high compared to 70% for the 'in advance' sample (N=10). Unfortunately however, this was not statistically significant. This is an area recommended as important for future research, as it could empirically substantiate suggestions from the literature.

In addition to the main research conclusions, there were other quantitative and qualitative findings that are considered important towards progressing the improvement of uncertainty and risk management practice on complex projects, as well as the general prescribed risk management standards that underpin current practice. The univariate analysis revealed that there are a number of Project Managers (18%) across the entire sample (N=73) using more than one general prescribed industry risk management standard in the management of uncertainty and risk on projects. There is also evidence of very limited specific risk management training, with only 11% of the Project Managers across the entire sample (N=73) reporting having participated in such training. The requirement for risk management training was a key theme that was identified by Project Managers, with respect to their perspectives concerning improvements in the management of uncertainty and risk on projects.

As mentioned, the Project Managers participating in the research provided further valuable qualitative perspectives that build on the quantitative data findings. On projects perceived as complex, the following key areas were specifically identified as in need of improvement:-

- Stakeholder/ client/ customer/ sponsor involvement, buy-in and consideration of perceptions in the risk management process.
- Risk identification, assessment and planning needs to be done prior to and at the outset of the project.
- Focused risk management training and education.
- Use of appropriate expertise.
- The development of a risk taxonomy, lessons learned data base and industry specific guidelines.

Besides the requirement expressed for focused 'risk' management training, the importance of improving the management of perceptions of 'risk' was raised by a few research participant Project Managers. This is consistent with the identification of the management of risk attitude as a strong theme expressed in the literature (Bernstein, 1996; Gingerenzer, 2002; Hellier et al., 2001; Hillson & Murray-Webster, 2005, 2008; Slovic, 1987; Smallman & Smith, 2003).

This empirical study has addressed the research 'gap' by providing further understanding of the management of uncertainty and risk by Project Managers in complex project environments, as well as contributing to the observation that "there appears to be far more literature offering prescriptions to Project Managers on how to manage risk in projects, rather than assess the relative effectiveness of those prescriptions" (Kutsch & Hall, 2010). With the high failure rates of projects shown in the literature, together with the characteristic uncertainty of projects of high complexity, the findings of this research are considered significant in demonstrating the scope and benefits of using more innovative and higher levels of uncertainty and risk management in project delivery. The findings and implications summarised above are considered to contribute to enhancing knowledge of uncertainty and risk management in the context of complex projects. They provide value in guiding project uncertainty and risk management practice, but perhaps more importantly to the key institutions and associations that influence the project management discipline. Uncertainty and risk are a fundamental aspect of the management of projects. This research is seen as a guiding step towards improved practice and further empirical research in this field. The main research findings and insights should provide direction and be a catalyst in this respect.

6.4 Limitations of this Research

The limitations of this research are provided below.

- A combination of snowballing and self-selecting (non-probability) sampling method was determined to be the most pragmatic, given the nature and scope of the study. Statistical tests were primarily non-parametric. Even though there was a strong focus on limiting bias, as outlined in the research methodology, the results cannot be statistically generalised. However, it is considered that this should not detract from the value of this research.
- The sample size of N=73 is considered appropriate for this research. However, there is some bias in the demographic, project type and

project management association/ institution (data subset), which is a limitation.

- The research philosophy pursued in this research was post-positivist. The quantitative data was supported by qualitative insights. Greater insights into the 'soft' factors of managing uncertainty and risk and greater 'richness' could be attained by using a more phenomenologically based approach.
- As discussed in the thesis there is the possibility that some of the participants who identified having implemented the uncertainty management paradigm may have identified this through 'uncertainty management' name recognition and did not actually implement the uncertainty management paradigm, as presented by Chapman and Ward (2003a, 2003b). There was a cross-reference validation conducted with the responses received from a later question in the questionnaire, which requested participant Project Managers to convey whether they considered the risk management approaches/ processes implemented to be 'in advance' of mainstream risk management standards. Explanations were further sought from participants who answered 'yes'. This did help to further clarify the implementation of the uncertainty management paradigm. However, there still remains a likelihood that of the 12 responses received; a few may not have implemented the paradigm, as proposed by Chapman and Ward (2003a, 2003b). This is a limitation in this research and is identified in section 6.3. This would not affect the research finding, with respect to Null Hypothesis 3.
- The bias in perceived project success (as identified in the thesis) is a limitation in the research.

6.5 Recommendations for future Research

Building on the findings from this study, the following further research is recommended.

- Empirical research in the management of uncertainty and risk in complex project environments using a more phenomenological research approach, to gain deeper insights and address potential bias.
- Identification of barriers to the adoption (by Project Managers and project management institutions/ associations) and implementation of improved uncertainty and risk management approaches? How can those barriers be overcome? This would build on recent research regarding 'barriers' to the implementation of risk management on projects (Kutsch & Hall, 2005, 2010).
- Why are certain Project Mangers using more than one risk management standard when implementing projects? What elements of the various risk management standards are considered effective/ ineffective? Would one international project risk management standard be advantageous? What would it contain? If there is merit in one international standard, how could it be achieved?
- What levels of risk management proficiency do (and should) Project Managers have? Is there a requirement for enhancement of their skills in this area? On what types of projects are specialist risk managers engaged? Why? How frequently? What risk management approaches and processes are they using? Are there benefits in using them, with respect to project outcomes?
- How can complexity theory concepts be practically applied to uncertainty management? Empirical research in the use of such concepts should provide further insights.

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Appendix 1

Complexity Theory Concepts

Complexity Theory Concepts

As mentioned in this thesis, the science of complex systems may provide a new perspective for the science of risk management (Johnson, 2006).

"Complexity theory can be defined broadly as the study of how order, structure, pattern and novelty arise from extremely complicated, apparently chaotic systems and conversely, how complex behaviour and structure emerges from simple underlying rules" (Cooke-Davies et al., 2007, p. 52). Complexity theory includes earlier fields of study collectively known as chaos theory and has arisen from the research conducted in life sciences, physical sciences and mathematics.

Some of the key themes contained within complexity theory include: the butterfly effect; strange attractors; fractals; edge of chaos; universality; dissipative structures; self organising systems; emergence; complex adaptive systems; indeterminacy and complex responsive processes of relating. A brief summary of these themes, some of which could have exciting prospects for project and risk management, is provided below. A substantial portion of this is derived from Cooke-Davies, Cicmil et al (2007).

Nonlinearity – The butterfly effect (developed by Meteorologist, Edward Lorenz in the 1960s), sensitive dependence on initial conditions, strange/ multiple attractors, adaptive systems and transformation. The notion of choice introduced as a complex dynamical system is not mechanical and has capacity to respond to its environment in more than one way. As Cooke-Davies et al (2007) put it - one can do the same thing several times and get different results. Small variations can lead to big changes.

The Butterfly Effect

The 'butterfly effect' was developed by meteorologist Edward Lorenz in the mid 1960s. It was a time when a number of scientists were becoming disenchanted about the basic assumptions of linearity that had been used as the basis of much science for around three centuries, even though such a Newtonian view had unlocked many mysteries.

In 1963 when Edward Lorenz was using computers to simulate weather systems he discovered how non-linearity affects the weather, through the principle of 'sensitive dependence on initial conditions'. This discovery showing how minute changes can have major and unpredictable consequences became known as the "butterfly effect". The analogy being that a flap of a butterfly's wings in Brazil may set-off a Tornado in Texas.

Strange Attractors

David Ruelle and Flovis Takens developed the notion of strange attractors whilst they were studying turbulence in fluids in 1971. The recurring patterns that they discovered explained why apparently chaotic systems (such as weather) display recurring and quasi-predictable features. This enabled scientists studying the behaviour of dynamical systems in nature to discover that complex systems can follow a number of qualitatively different attractors, depending on initial conditions and external influences, showing a difference from simple deterministic chaos.

Fractals

This term was coined by Benoit Madelbrot in the early 1980's and used to describe irregular shapes that repeat themselves in nature. This is rooted in algebra and with the concept of self similarity – the property of certain objects to repeat themselves on different scales and sizes. Fractal geometry is about the whole system and not just about its component parts. It explains mathematically how it is possible to see the same pattern recurring at both a small scale (for example, a leaf) and at a larger scale (for example, the plant as a whole).

Edge of Chaos

The concept of the edge of chaos is derived from the life sciences and studies in the evolution and behaviour of living dynamical systems, where such systems manage to demonstrate elements of both chaotic and orderly behaviour.

Stuart Kauffman [get this ref], a prominent biologist working in this field uses the different states of water to illustrate this. When water exists as ice it is in orderly state. Where it is a stream, it is chaotic. However, in its intermediate form of gas, it offers the best opportunities for the development of complex activities (Cooke-Davies et al., 2007).

Scientists at the Santa Fe Institute have studied ant colonies, which provide evidence of the critical balance between order and chaos, the central principle of the edge of chaos. Ants as individuals exhibit chaotic tendencies, continually switching between frantic activity and inactivity. However, the colony as a whole exhibits a pattern of behaviour that is both rhythmic and orderly.

Universality

This relates to the observation that repetitive patterns occur in the most diverse and unlikely fields. An example illustrated by mathematician Ian Stewart in 1996 (as cited by Cooke-Davies et al (2007)) is the period doubling factor derived by physicist Mitch Feigenbaum in the 1970's, whereby the number 4.669 is associated with period doubling in a number of fields. Another is the fact that with nearly all flowers, the number of petals is one of the numbers that makes up the Fibonacci series of numbers i.e. 3,5,8,13,34,55,89.

The revelation of such repetitive patterns has become known as the principle of universality.

Dissipative Structures

This relates to the work of physicist Ilya Prigogine in the field of thermodynamics. He demonstrated that systems reach points of irreversible change (bifurcations), where the state of the system changes in ways that are impossible to predict. Not because of inadequacies of information, but simply because the outcome is inherently unpredictable. This has led to more general studies of dissipative structures (more commonly known as complex dynamical systems), recognising the potential that these systems have for producing unpredictable behaviour (Cooke-Davies et al., 2007) (p54). Progogine (1997) provided this interesting comment as referenced by Cooke-Davies etal (2007) – "Is the future given, or is it under perpetual construction" (p54).

Self Organising Systems

Prigogines work has been taken forward in the study of spontaneous self organisation. Examples of complex dynamical systems that seem capable of self-organisation and exercising choice in a manner that makes them inherently unpredictable include hurricanes, living cells and human self-organisation. The commonality in these systems is that they exchange matter and energy and remain far from equilibrium. Feedback loops in such systems ensure rich patterns. The production of complex behaviours from rule-based behaviour and feedback allows such systems to be simulated on modern high powered computers. (Cooke-Davies et al., 2007)

Emergence

Emergence is another characteristic of complex dynamical systems. Self-organising systems exchange matter and energy with their environment and this enables them to remain in a state that is not in equilibrium. This enables spontaneous behaviour to give rise to new patterns. Such characteristics allow shoals, for example, to respond to predators and for organisms to adapt to life in different climatic conditions, from those within which they evolved. In doing so characteristics and patterns emerge that are different in kind as well as degree from the characteristics and patterns of the constituent parts. Such emergent properties of living systems allow 'novelty' and 'innovation' and accounts for how diversity and variety arise in order to 'allow' evolution. (Cooke-Davies et al., 2007)

"The universe in its persistent becoming is richer than all our dreamings" (Kauffman, 2000, p.139; cited in Cooke-Davies et al, 2007, p. 55).

Complex Adaptive Systems

Complex Adaptive Systems arise from Self-Organising Systems and emergence (Cooke-Davies et al., 2007). Complex Adaptive Systems differ from Self-Organising Systems in that they have the ability to learn from their experience. Cooke-Davies et al (2007) cite McMillan (2004) [pp 30-31] who distinguished between a laser beam, which is a Self-Organising System and a human brain, which is a Complex Adaptive System.

Indeterminacy

Cooke-Davies et al (2007) mention that the characteristic of indeterminacy is challenging the Cartesian/ Newtonian/ Enlightenment paradigm, with the recognition of inherent indeterminacy of the future of complex dynamical systems and thus of the physical universe itself. Cooke-Davies et al (2007) show the characteristic of indeterminacy across various fields of endeavour. They cite Wittgenstein (1953) who rejecting his earlier ideas reached in Tractus, published in 1921, and concluded that it was impossible to define the conditions that are necessary and sufficient in any lower order characteristic, to fully account for the higher-level definition. An example provided is that one cannot precisely predict the next number in even the best defined mathematical series of numbers, until the series is complete. This can never happen if the series is infinite.

The implications of this paradigm are fundamental for science and the study of project management (Cooke-Davies et al., 2007). Cooke-Davies et al (2007) quote Auyang's (1999) summary of the foundations of scientific complexity – systems theories. Auyang (1999) states that science reveals the complexity unfolding in all dimensions and features emerging at all scales and levels in the universe. Auyang comments that "the more we know the more we become aware of how much we do not know".

Cooke-Davies et al (2007) state that by no means would all scientists working in the field of complexity science theory agree with the notion that determinism (the 'clockwork' universe) and indeterminism are mutually exclusive. "It is not a question of replacing one simplistic philosophy with another - rather it is a recognition of paradox underpinning the very nature of reality" (Cooke-Davies et al., 2007) (p56).

Complex Responsive Processes of Relating

Cooke-Davies et al (2007) identify complex processes of relating as a "theoretical concept within the conceptual palette of complexity thinking in particular" (p56). They mention that Stacey (2001,2003), Stacey, Griffin and Shaw (2000), Fonseca (2002) and Streatfield (2001) argue for this "on the basis of the problematic capacity of other theoretical approaches to address complexity and paradox in contemporary organisations". Cooke-Davies et al (2007) convey that complex responsive processes of relating suggest the following:

- Particular ways of speaking about complexity of organisations, organising, managing and knowing.
- The reflexive nature of humans.
- The responsive and participative nature of humans and the radical unpredictability of their evolution and outcomes over time.

Methodologically this concept puts emphasis on the interaction among people in organisations and is concerned with the question of how patterned themes of conversations in local situations constitute and are simultaneously constituted by power relations in organisations, and how the potential transformation of these conversational patterns can induce change, trigger learning, and create new knowledge.

Complex responsive processes of relating acknowledges the advantages of a processual approach over a systemic perspective in understanding complex and chaotic patterns of relating among individuals and groups over time, which simultaneously constitute and are constituted by a wider organisational system. Cooke-Davies et al (2007) maintain that this is one main area of difference between complex adaptive systems and responsive processes of relating.

Cooke-Davies et al (2007) further cite Stacey (2003) who states that complex responsive processes of relating; social structures and individual personalities largely emerge without overall intention of an agent in the interaction through symbols and gestures. They mention that Stacey (2003) argues that the reason the individual and social structures are emerging at the same time.

Under the Complex Responsive Processes of Relating (CRPR) theory, organisation is an emergent property of many individuals interacting through their complex responsive processes of relating centred on the use of language simultaneously for conversation and to negotiate social status and power relationships. Central to the theory is the recognition that communication is a complex process involving both words that are spoken and the responses they elicit – the chain of responses that provide the context for an individual conversation or an element of it. The CRPR concept respects the notion of a distinction between the individual and the group. It's argued that it is more useful to think of individuals relating to each other through the complex process of vocalised and non-vocalised communication. (Cooke-Davies et al., 2007)

The future is seen from the perspective of being under perpetual construction by the movement of human interaction itself. In the process of responding in the medium of symbols, artefacts, feelings and the unconscious, novelty can be created or emerge.

"The concept of CRPR refocuses attention on the reflexive monitoring of interaction by agents/ actors and the radical unpredictability and uncontrollability of the outcomes of action and intersubjective relating" (Cooke-Davies et al., 2007) (pg57). Cooke-Davies mention further that as flocking is an emergent property of essential bird behaviour, so organisation and knowledge are emergent properties of the essential human behaviour of communicating- of complex responsive processes of relating.

The CRPR concept views managerial practice, skills and competencies in a particular way. Normative/ rational perspectives take the methodological position of the objective observer (manager) standing outside the organisation, understood as a system, and thinks in terms of controlling it. Cooke-Davies etal (2007) state that in the CRPR perspective, the manager is assumed to him/ herself to be a participant in these processes of relating, continuously engaged in emergent enquiry into what they are doing and what steps to take next.

The concept of CRPR refocuses attention on the reflexive monitoring of interaction by agents/ actors and the radical unpredictability and uncontrollability of action and intersubjective relating.

Appendix 2

Scoring examples for CIFTER categories

A. Social/public services project: develop a three-hour employee orientation program for a municipal department.

Factor	**Rating**	**Discussion**
1. Stability	1	Very high — requirements are clear, limited scope, stakeholders unlikely to change
2. Number of methods	1	Low — only one discipline involved
3. Implications	1	Low — might be some legal implications if content violated discrimination laws; no discernible environmental or social impact
4. Financial impact	1	Low — insignificant; no revenue and funds were budgeted
5. Strategic importance	1	Very low — orientation is important but not strategic
6. Stakeholder cohesion	1	High — management and team are in agreement about scope
7. Project interfaces	1	Very low — few interfaces and those are quite similar

B. Social/public services project: develop and implement a new science curriculum for the final, pre-university year in all schools in a state or province.

Factor	**Rating**	**Discussion**
1. Stability	3	Moderate — while many aspects of the project context are quite stable, the sensitivity of the issue and the visibility of the project means that stakeholder identification and management will be challenging
2. Number of methods	2	Moderate — disciplines include curriculum design, subject matter expertise, teacher professional development, marketing, and communications
3. Implications	3	High — environmental implications are low, but social and legal implications are significant
4. Financial impact	2	Moderate — cost is small relative to overall schools budget

Factor	Rating	Discussion
5. Strategic importance	4	High — this is the first new curriculum development project in several years; this project must go well or later projects will be severely challenged
6. Stakeholder cohesion	3	Low — resistance to new curriculum is evident among some stakeholders
7. Project interfaces	3	Moderate — numbers and variety are both moderate; project must interface with multiple units of the state or provincial education department, with organisations representing different school providers, and with teachers unions, school boards, parent associations, special interest groups, and others

C. Information Technology project: implement a software package upgrade in a single business functional area.

Factor	Rating	Discussion
1. Stability	1	Very high — requirements are clear, limited scope, stakeholders unlikely to change
2. Number of methods	1	Low — one primary discipline; limited involvement of others
3. Implications	1	Low — no real discernible impact in any area
4. Financial impact	1	Low — cost is small for functional unit; revenue is small for provider; probability of an overrun is slight
5. Strategic importance	1	Very low — operational project with limited strategic impact
6. Stakeholder cohesion	1	High — everyone agrees upgrade is necessary
7. Project interfaces	1	Very low — few interfaces and those are quite similar

D. Engineering and Construction project: construction management for a small addition to a local school done mostly during summer vacation.

Factor	Rating	Discussion
1. Stability	1	Very high — requirements are clear, limited scope, stakeholders unlikely to change
2. Number of methods	1	Low — relatively simple design; number of trades involved limited
3. Implications	1	Low — no significant impact in any area
4. Financial impact	2	Moderate — significant expenditure for the school district but supported by bond issue; smallish project for the contractor
5. Strategic importance	2	Low — needed to accommodate expected influx of students from nearby residential development
6. Stakeholder cohesion	1	High — district board, school management, and neighbours all supportive
7. Project interfaces	1	Very low — school board and neighbourhood council

E. Engineering and Construction project: construction management of the renovation of a 30 storey hotel for an international hotel chain.

Factor	Rating	Discussion
1. Stability	3	Moderate — project duration is quite long and there is likelihood of turnover among key stakeholders; owner's co-ordinator has little power to make decisions
2. Number of methods	3	High — relatively complex project involving core disciplines such as engineering, plumbing, and HVAC, as well as specialists in interior design, landscape design, and artwork installations
3. Implications	2	Moderate — mostly environmental as the site is relatively large; neighbouring plots may be affected
4. Financial impact	2	Moderate — financial impact on the chain is limited, but this is a major project for the prime contractor
5. Strategic importance	3	Moderate — important first step in the chain's plans to establish foothold in rapidly developing region

Factor	Rating	Discussion
6. Stakeholder cohesion	4	Very low — while basic specifications have been agreed, there are many details to be worked out and many conflicting requirements
7. Project interfaces	3	Moderate — project is fairly large and involves many specialties

Appendix 3

Survey Questionnaire

Management of Risk on Projects

1. Introduction and Explanatory Statement

Thank you for participating in this survey.

This is a Post Graduate Research Project with the purpose of investigating how risk is managed by Project Managers on projects of varying complexity, to assess the perceived effectiveness of these approaches, including prescribed industry risk management standards, and to make recommendations for the improvement of risk management approaches on complex projects in particular.

Project Managers who are willing to participate in this research and complete this questionnaire are very much appreciated. This should take approximately 30-45 minutes to complete and can be done at your convenience, before 28 OCTOBER 2011.

We are looking for accounts of both 'successful' and 'less successful' projects. This will be valuable in helping to achieve the overall intent, to recommend ways in which to improve the management of risk and project delivery.

IN COMPLETING THIS SURVEY PLEASE SELECT ONE PROJECT THAT YOU PROJECT MANAGED AND WAS COMPLETED WITHIN THE LAST 2 YEARS.

Individual details and responses will be held in the STRICTEST CONFIDENCE. No findings, which could identify any specific project, individual participant or organisation will be published. Only the combined results of all the participants will be published. A sample of respondents will be contacted for data validation. Project name, personal details, client and organisational information is optional to provide.

A component of the research is assessing perceptions of project success. Client/ Sponsor's details are requested to ascertain their perceptions in this respect. The absolute confidentiality, as outlined above, will be adhered to for those who are prepared to provide such details.

All participants fully completing the survey by 28 October 2011 will be sent a copy of an executive summary of the final research report by email.

Please click on the 'Done' button when you have completed the survey.

If you have any queries please contact:

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Student Investigator - Craig Harvett
Supervisor - Professor Lynn Crawford

Should you have any concerns with regard to the conduct or nature of this research, please feel free to contact:
Senior Research Ethics Officer
Bond University Human Research Ethics Committee
c/o BURCS
Bond University
QLD 4229
Tel: 07 5595 4194
Fax: 07 5595 1120
Email: buhrec@bond.edu.au

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Management of Risk on Projects

2. General Information

1. Project Name?
(Note that the project needs to have been completed within the last two years. Also, as mentioned in the introduction, the information provided by you regarding this project will remain strictly confidential)

***2. Project Start Date?**

	Year	Month
Start Date		

Other (Year)

***3. Project Completion Date?**

	Year	Month
Completion Date		

***4. Location of the project?**

City/Town:

State/Province:

Country:

***5. In what industry sector was the project conducted?**

- ○ Aerospace/defense
- ○ Automotive
- ○ Construction/Infrastructure/Engineering
- ○ Financial Services
- ○ Government
- ○ IT/Telecommunications
- ○ Pharmaceutical
- ○ Utilities
- ○ Other (specify below)

Other (please specify)

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*6. Identify the Project Type?

- Advertising
- Construction (Building)
- Civil
- Energy
- Events Management
- Financial
- Human Resources
- Information Systems
- Information Technology
- Manufacturing
- Marketing
- Mining
- New Product Development
- Research and Development
- Software Development
- Sport and Recreation
- Utilities
- Other (specify below)

Other (please specify)

Management of Risk on Projects

***7. Total Project Cost?**

Please convert the currency into United States Dollars, calculated at the time of completing this questionnaire (see xe-universal currency converter - http://www.xe.com/ucc/) and then tick the corresponding Total Project Cost box below. Furthermore, please identify the total poject cost in the "Local Currency" text box at the end of this question.

- ◯ Less than US$100,000
- ◯ US$100,000 to US$499,000
- ◯ US$500,000 to US$999,000
- ◯ US$1,000,000 to US$9,999,999
- ◯ US$10,000,000 to US$49,999,999
- ◯ US$50,000,000 to US$99,000,000
- ◯ Greater than US$100,000,000

Project Cost in Local Currency (please specify below)

***8. The number of years Project Management experience you have?**

- ◯ Less than Two years
- ◯ Two to Five years
- ◯ Six to Ten years
- ◯ Eleven to Fifteen years
- ◯ Sixteen to Twenty years
- ◯ Greater than Twenty years

***9. Your Age?**

- ◯ 17 or under
- ◯ 18-29
- ◯ 30-39
- ◯ 40-49
- ◯ 50-59
- ◯ 60-69
- ◯ 70-79
- ◯ 80+

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***10. Your Gender?**

- ◯ Male
- ◯ Female

***11. Do you have formal Project Management training?**

- ◯ Yes
- ◯ No

***12. If you do have formal Project Management training,i.e. 'YES' answer to the question above, then please can you tick the corresponding certifications & qualifications that apply below and provide the details of others if applicable. If your answer to Q 11 was 'NO' then please tick N/A.**

- ☐ PMI-CAPM
- ☐ PMI-PMP
- ☐ PMI-PgMP
- ☐ PMI-RMP
- ☐ PMI-SP
- ☐ IPMA Level A
- ☐ IPMA Level B
- ☐ IPMA Level C
- ☐ IPMA Level D
- ☐ PRINCE 2
- ☐ AIPM-CPPP
- ☐ AIPM-CPPM
- ☐ AIPM-CPPD
- ☐ Certificate IV in Project Management
- ☐ Diploma in Project management
- ☐ Advanced Diploma of Project Management
- ☐ Bachelors degree in Project Management
- ☐ Graduate Certificate in Project Management
- ☐ Graduate or Postgraduate Diploma in Project Management
- ☐ Masters in Project Management
- ☐ MBA
- ☐ PhD (Project Management)
- ☐ Doctorate in Project Management
- ☐ Other (specify below)

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- [ ] N/A

Other (please specify)

*13. Do you have any formal Risk Management training?

- ( ) Yes
- ( ) No

*14. If you do have formal Risk Management training, i.e. 'YES' answer to the question above, then please can you tick the corresponding certifications & qualifications that apply below and provide the details of other if applicable.
If your answer to the above is 'NO' then tick N/A.

- [ ] Risk Certificate - Level 1 (APM)
- [ ] Risk Certificate - Level 2 (APM)
- [ ] Advanced Risk Management (IIL)
- [ ] Risk Management Professional (PMI)
- [ ] Associate Professional Risk Manager - PRMI
- [ ] Professional Risk Manager (PRM) - PRMI
- [ ] Risk Management in Financial Services (IRM)
- [ ] International Diploma in Risk Management (IRM)
- [ ] MA/ MSc in Risk Management
- [ ] PhD in Risk Management
- [ ] Doctorate in Risk Management
- [ ] Other (specify below)
- [ ] N/A

Other (please specify)

*15. Are you a member of a professional Project Management and/or Risk Management institution and/or other professional institution? If 'yes', please provide the details in question 16.

- ( ) Yes
- ( ) No

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16. If you are a member of a Professional Project Management and/or Risk Management Institute and/or other Professional Institution (i.e. 'Yes' to Q15 above) then please can you tick the corresponding institution(s) that apply below and provide the details of other if applicable (denoting if it is a Project Management or Risk Management Institute or other Institution (briefly describe)). If you answered 'No' to Q15 then please tick N/A.

- ☐ Project Management Institute (PMI)
- ☐ American Society for the Advancement of Project Management (ASAPM)
- ☐ Associatian Espania de Ingeniera de Proyectos (AEIPRO)
- ☐ Association for Project Management (APM-UK))
- ☐ Association for Project Management - South Africa (APM-SA)
- ☐ Association Francophone de Management de Projet (AFITEP)
- ☐ Associaç Portuguesa de Gestao de Projectos (APOGEP)
- ☐ Associatiozone Nazionale di Implantistica Industriale
- ☐ Australian Institute of Project Management (AIPM)
- ☐ Azerbaijan Project Management Association (AzPMA)
- ☐ Brazilian Association for Project Management
- ☐ Bulgarian Project Management Association (BPMA)
- ☐ Croatian Association for Project Mangement
- ☐ Cyprus Project Management Society (CMPS)
- ☐ Danish Project Management Association
- ☐ GPM Deutsche Gesellschaft für Projektmanagement E.V.
- ☐ Institute of Project management Ireland
- ☐ IPMA - NL (Netherlands)
- ☐ Iran Project Management Association
- ☐ Kazakhstan Project Management Association
- ☐ Kosova Association for Quality Management Standards, Certification & Confirmation (QK)
- ☐ Latvian National Project Management Association
- ☐ LPVA - Lithuanian Project Management Association
- ☐ Management Engineering Society (MES)
- ☐ Mexican Project Engineering Association (AMIP)
- ☐ Moroccan Association Managers of Project (MPMA)
- ☐ Network of Project Managers in Greece (PM-Greece)
- ☐ Norwegian Association of Project Management (NFP)
- ☐ Peruvian Association for Project Management
- ☐ Project Management Associates (India)

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- [ ] Project Management Association of Canada
- [ ] Project Management Association of Czech Republic (SPR)
- [ ] Project Management Association of Hungary (FOVOCZ)
- [ ] Project Management Association of Iceland (VSF)
- [ ] Project Management Association of Nepal (PMAN)
- [ ] Project Management Association of Slovakia (SPPR)
- [ ] Project Management Association of Zambia (PMZambia)
- [ ] Project Management Research Committee China (PMRC)
- [ ] Project Management Romania
- [ ] Project Management South Africa (PMSA)
- [ ] Projekt Management Austria
- [ ] Russian Project Management Association (SOVNET)
- [ ] Serbian Project Mangement asiciation (YUPMA)
- [ ] Slovenian Project Management Association (ZPM)
- [ ] SMAP Association Francaise pour l'avancement du Management de Projet
- [ ] Stowarzyszenie Project Management Polska
- [ ] Svenskt Projektforum (Swedish Project Management Association)
- [ ] Swiss Project Management Association (SMP)
- [ ] Taiwan Project Management Association, China (TPMA)
- [ ] Turkish Project Management Association (TrPMA)
- [ ] Ukranian Project Management Association (UMPA)
- [ ] Institute of Risk Management (IRM)
- [ ] Professional Risk Manager's International Association (PRMIA)
- [ ] The New Zealand Society for Risk Management (NZSRM)
- [ ] Other (specify below)
- [ ] N/A

Other (please specify)

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3. Nature of the Project

For each of the following factors below (Q17-23) please depict which rating best reflects the project.
At the bottom of each question is commentary for you to consider, with respect to the project. Furthermore, for further guidance,at the end of this page (after Q23), a few examples of scoring ratings are provided, with respect to hypothetical projects. You can scroll down to peruse these examples to guide you in your scoring.

***17. Stability of the overall project context?**

- ◯ Very High
- ◯ High
- ◯ Moderate
- ◯ Low

The project context includes the project life-cycle, the stakeholders, the degree to which the applicable methods and approaches are known, and the wider socioeconomic environment. When the project is unstable - phase deliverables are poorly defined, scope changes are frequent and significant, team members are coming and going, applicable laws and regulations are being modified - the project management challenge increases. Note - some aspects of "technical complexity", such as dealing with unproven concepts would be considered here. Uncertainty in the economic and political environment would also be considered here.

***18. Number of distinct disciplines, methods or approaches involved in performing the project?**

- ◯ Very High
- ◯ High
- ◯ Moderate
- ◯ Low

Most projects involve more than one management or technical discipline; some projects involve a large number of different disciplines. For example, a project to develop a new drug could include medical researchers, marketing staff, manufacturing experts, lawyers and others. Since each discipline tends to approach its part in a different way, more disciplines means a project that is relatively more difficult to manage. Note - some aspects of "technical complexity" such as dealing with a product with many interacting elements would be considered here.

***19. Magnitude of legal, social, or environmental implications from performing the project?**

- ◯ Very High
- ◯ High
- ◯ Moderate
- ◯ Low

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This factor addresses the potential external impact of the project. For example, the potential for catastrophic failure means that the implications of constructing a nuclear power plant close to a major urban centre will likely be much greater than those of constructing an identical plant in a remote area. The management complexity of the urban project will be higher, due to need to deal with a larger number of stakeholders and a more diverse stakeholder population. Note - "external impact" refers to the effect on individuals and organisations outside the performing organisation. Financial considerations related to actual or potential legal liability for the performing organisation would be considered in the factor in the following question.

***20. Overall expected financial impact (positive or negative) on the project's stakeholders?**

- ◯ Very High
- ◯ High
- ◯ Moderate
- ◯ Low

This factor accounts for one aspect of the traditional measure of "size", but does so in relative terms. For example, a project manager in a consumer electronics start-up is subject to more scrutiny than with a project manager doing a similarly sized project for a computer manufacturer with operations around the globe, and increased scrutiny generally means more management complexity. Note - where the impact on different stakeholders is different, this factor should be rated according to the impact on the primary stakeholders. Financial considerations related to actual or potential legal liability incurred by the performing organisation would be considered here.

***21. Strategic importance of the project to the organisation or organisations involved?**

- ◯ High
- ◯ Moderate
- ◯ Low
- ◯ Very Low

This factor addresses yet another aspect of "size", and again deals with it in relative rather than absolute terms. While every project should be aligned with the organisation's strategic direction, not every project can be of equal importance to the organisation or organisations' involved. Note - as with financial impact, if the strategic importance for different stakeholders is different, this factor should be rated according to the strategic importance for the primary stakeholders.

***22. Stakeholder cohesion regarding the characteristics of the product of the project?**

- ◯ High
- ◯ Moderate
- ◯ Low
- ◯ Very Low

When all or most stakeholders are in agreement about the characteristics of the project, they tend to be in agreement about the expected outcomes as well. When they are not in agreement, or when the benefits of a product with a particular set of characteristics are unknown or uncertain, the project management challenge is increased.

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***23. Number and variety of interfaces between the project and other organisational entities?**

- ◯ High
- ◯ Moderate
- ◯ Low
- ◯ Very Low

In the same way that a large number of disciplines on a project can create a management challenge, a large number of different organisations can as well. Note - issues of culture and language would be addressed here. A large team could have a relatively small number of interfaces if most team members have the same employer. On the other hand shift work might increase the rating here, even though the additional shifts are technically part of the project.

Management of Risk on Projects

NATURE OF THE PROJECT - EXAMPLES - SCORING FACTORS

A. Social/public services project: develop a three-hour employee orientation program for a municipal department.

1. Stability
Rating - Very High (requirements are clear, limited scope, stakeholders unlikely to change)
2. Number of Disciplines, Methods or Approaches
Rating - Low (only one discipline involved)
3. Implications
Rating - Low (might be some legal implications if content violated discrimination laws; no discernible environmental or social impact)
4. Financial Impact
Rating - Low (insignificant; no revenue and funds were budgeted)
5. Strategic Importance
Rating - Very low (orientation is important but not strategic)
6. Stakeholder Cohesion
Rating - High (management and team are in agreement about scope)
7. Project Interfaces
Rating - Very low (few interfaces and those are quite similar)

B. Social/public services project: develop and implement a new science curriculum for the final, pre-university year in all schools in a state or province.

1. Stability
Rating - Moderate (while many aspects of the project context are quite stable, the sensitivity of the issue and the visibility of the project means that stakeholder identification and management will be challenging)
2. Number of Disciplines, Methods or Approaches
Rating - Moderate (disciplines include curriculum design, subject matter expertise, teacher professional development, marketing, and communications)
3. Implications
Rating - High (environmental implications are low, but social and legal implications are significant)
4. Financial impact
Rating - Moderate (cost is small relative to overall schools budget)
5. Strategic Importance
Rating - High (this is the first new curriculum development project in several years; this project must go well or later projects will be severely challenged)
6. Stakeholder Cohesion
Rating - Low (resistance to new curriculum is evident among some stakeholders)
7. Project Interfaces
Rating - Moderate (numbers and variety are both moderate; project must interface with multiple units of the state or provincial education department, with organisations representing different school providers, and with teachers unions, school boards, parent associations, special interest groups, and others)

C. Information Technology project: implement a software package upgrade in a single business functional area.

1. Stability
Rating - Very high (requirements are clear, limited scope, stakeholders unlikely to change)
2. Number of Disciplines, Methods or Approaches
Rating - Low (one primary discipline; limited involvement of others)
3. Implications
Rating - Low (no real discernible impact in any area)
4. Financial Impact
Rating - Low (cost is small for functional unit; revenue is small for provider; probability of an overrun is slight)
5. Strategic Importance
Rating - Very low (operational project with limited strategic impact)
6. Stakeholder Cohesion
Rating - High (everyone agrees upgrade is necessary)
7. Project Interfaces
Rating - Very low (few interfaces and those are quite similar)

D. Engineering and Construction project: Construction management for a small addition to a local school done mostly during summer

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vacation.

1. Stability
Rating - Very high (requirements are clear, limited scope, stakeholders unlikely to change)
2. Number of Disciplines, Methods or Approaches
Rating - Low (relatively simple design; number of trades involved limited)
3. Implications
Rating - Low (no significant impact in any area)
4. Financial Impact
Rating - Moderate (significant expenditure for the school district but supported by bond issue; smallish project for the contractor)
5. Strategic importance
Rating - Low (needed to accommodate expected influx of students from nearby residential development)
6. Stakeholder Cohesion
Rating - High (district board, school management, and neighbours all supportive)
7. Project Interfaces
Rating - Very low

E. Engineering and Construction project: construction management of the renovation of a 30 storey hotel for an international hotel chain.

1. Stability
Rating - Moderate (project duration is quite long and there is likelihood of turnover among key stakeholders; owner's co-ordinator has little power to make decisions)
2. Number of Methods
Rating - High (relatively complex project involving core disciplines such as engineering, plumbing, and HVAC, as well as specialists in interior design, landscape design, and artwork installations)
3. Implications
Rating - Moderate (mostly environmental as the site is relatively large; neighbouring plots may be affected)
4. Financial Impact
Rating - Moderate (financial impact on the chain is limited, but this is a major project for the prime contractor)
5. Strategic Importance
Rating - Moderate (important first step in the chain's plans to establish foothold in rapidly developing region
6. Stakeholder cohesion)
Rating - Very low (while basic specifications have been agreed, there are many details to be worked out and many conflicting requirements)
7. Project interfaces
Rating - Moderate (project is fairly large and involves many specialties)

Management of Risk on Projects

4. Risk Management Approach and Processes

***24. Were risks actively managed on the project?**

- ◯ Yes
- ◯ No

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Management of Risk on Projects

5. Risk Management Approach

For each of the following questions please mark the one description that best characterises the Risk Management approach taken on the project.
If the answer to the above question (Q 24) was 'No', then tick Not Applicable (N/A) for each.

***25. What was the key focus of risk management attention?**

- ◯ Uncertainty Management Paradigm
- ◯ Opportunity & Threat Management
- ◯ Threat Management
- ◯ N/A

***26. Scope of Risk Management Processes?**

- ◯ Flexible, cost effective use of generic resources
- ◯ Generic formal processes
- ◯ Some specific formal processes
- ◯ Ad hoc informal processes
- ◯ N/A

***27. Level of Risk Management documentation?**

- ◯ Documentation reported and updated throughout the project lifecycle
- ◯ Analyses documented and reported
- ◯ Limited documentation
- ◯ No documentation
- ◯ N/A

***28. Tools and Techniques used?**

- ◯ Use of best practice techniques
- ◯ Quantification documented and collated
- ◯ Thorough qualitative analysis/ some quantification
- ◯ Basic qualitative process
- ◯ N/A

Management of Risk on Projects

***29. Parties involved & allocation of responsibilities in the Risk Management Process?**

- ◯ Risk Management facilitated wider than the core project team
- ◯ Risk Management facilitated throughout the project team
- ◯ Specific functions with limited roles
- ◯ Scattered, ad hoc and left to individuals
- ◯ N/A

***30. Resources applied to Risk Management?**

- ◯ Explicit formal allocation of resources
- ◯ Implicit ad hoc allocation of resources
- ◯ No allocation of resources
- ◯ N/A

Management of Risk on Projects

6. Risk Management Processes

For each of the Risk Management processes identified below, please indicate the choice that best characterises the degree of implementation on the project.

To aid your assessment, for each process (below the question) there is a brief description of the techniques and activities that are typically promulgated by key industry risk management standards.

If the answer to the above question (Q 24) was 'No', then tick Not Applicable (N/A) for each.

***31. Establishing the Context and Risk Management Planning?**

- ◯ To a great extent
- ◯ Somewhat
- ◯ Very little
- ◯ Not at all
- ◯ N/A

Establishing the context and Risk Management Planning sets out the parameters within which risk will be managed on the project. It typically involves the following:

- Establishing the purpose and objectives of the Risk Management activity.
- Identification of the scope and boundaries of the application of the risk management processes.
- Setting out the risk management methodology. Documenting how to approach, plan and execute the risk management activities on the project? Including the tools and data sources that may be used and define when and how often the risk management process will be performed throughout the project lifecycle?
- Provision of a comprehensive process of systematically identifying risk to a consistent level of detail.
- Identifying the project's internal and external environment (also considering the interface between the two).
- Establishing the roles and responsibilities of the various project stakeholders participating in the risk management process.
- Developing risk criteria (i.e. the criteria against which risks will be evaluated).
- Establishing definitions of risk likelihood/ probability and impact and determining risk thresholds (i.e. what constitutes high, medium and low risks).
- Assignment of human and financial resources.

***32. Risk Identification?**

- ◯ To a great extent
- ◯ Somewhat
- ◯ Very little
- ◯ Not at all
- ◯ N/A

Management of Risk on Projects

Risk identification typically involves the following:

• A comprehensive and structured identification and documentation of risks that might affect the project.
• Risks are identified throughout the project life cycle.
• The project team are involved in the process.
• Expertise input is provided where required.
• Providing a clear description of the risks, so that the cause and effects are understood and documented.
• Techniques used to identify risks can include checklists, judgments based on experience and records, brainstorming, flow charts, systems analysis, scenario analysis and systems engineering. The techniques and activities used need to be commensurate to the nature of the project under review, types of risk, the organisational context and the purposes of the risk management study.
• Expertise input is provided/ attained where required.

*33. Qualitative Risk Analysis?

- ◯ To a great extent
- ◯ Somewhat
- ◯ Very Little
- ◯ Not at all
- ◯ N/A

Qualitative risk analysis typically involves the following:

• Assessing the priority of identified risks by considering the likelihood of them occurring and impact (consequences) on project objectives (including factors such as schedule, scope, cost, quality) if they do occur.
• An assessment of both threats and opportunities.
• Matrices specify combinations of likelihood and impact that lead to ratings risks as low, moderate and high priority. Descriptive terms or numeric values are used, depending on preference. Organisational thresholds are considered and inform the matrix.
• Assessments are preferably informed by factual information and data where applicable.
• Assumptions made during the analysis are stated.
• Re-assessing of qualitative risk scores throughout the project life cycle.

*34. Quantitative Risk Analysis?

- ◯ To a great extent
- ◯ Somewhat
- ◯ Very little
- ◯ Not at all
- ◯ N/A

Quantitative risk analysis is typically performed on the high priority risks identified through the qualitative risk analysis process. In some cases quantitative risk analysis may not necessarily be required to develop effective risk responses. Availability of time and budget and the need for qualitative and quantitative statements about risk will determine which methods to use on any particular project.

Numerical values are assigned to the risk event and used to make decisions under uncertainty. This process uses techniques such as Expected Value, Decision Tree Analysis, Sensitivity Analysis, Monte Carlo Simulation etc. to:

• Quantify the possible outcomes for the project and their probabilities
• Assess the probability of achieving project objectives
• Identify realistic and achievable cost, schedule and scope targets, given the project risks
• Determine the most appropriate project management decisions under uncertainty.

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Management of Risk on Projects

*35. Risk Evaluation and Risk Response Planning (Treatment)?

- ◯ To a great extent
- ◯ Somewhat
- ◯ Very Little
- ◯ Not at all
- ◯ N/A

Risk evaluation, risk management planning and treatment typically involves the following:

• Continued consideration of project objectives, the organisational and wider context and the extent of the threat and opportunity and associated losses and gains.
• Decision about which risks need response plans (treatment) and priorities in this respect.
• The development of appropriate plans and actions to address risk. This could include mitigation, acceptance, avoidance and transfer of threats or exploiting, sharing and enhancing opportunities.
• The selection of the most appropriate plans (treatment options) should balance the costs of implementing each option against the benefits derived from it i.e. the cost of managing risks need to be commensurate with the benefits obtained.
• The identification of residual and secondary risks and associated management plans.
• The identification of symptoms and signs of the risk's imminent occurrence.
• The identification of fallback plans, should the planned strategy and action not turn out to be fully effective and the threat occurs.
• Risk Response Plans (Treatment) include – proposed actions; resource requirements; responsibilities; timing; performance measures; monitoring and reporting requirements and the completion of a Risk Register.

*36. Risk Monitoring and Control?

- ◯ To a great extent
- ◯ Somewhat
- ◯ Very Little
- ◯ Not at all
- ◯ N/A

Risk Monitoring and Control typically involves the following:

• Identifying, analysing and planning for newly arising risks
• Keeping track of identified risks and those on the watch list, reanalysing existing risks, monitoring trigger conditions for contingency plans, monitoring residual risks and reviewing the execution of risk responses, while evaluating their effectiveness.
• Other considerations during risk monitoring and control include determining if - the project assumptions are still valid; there are any changes to the risk state, with analysis of trends; proper risk management policies and procedures are being followed; contingency reserves (cost and schedule) are modified in line with the risks of the project.

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Management of Risk on Projects

***37. What Standard/ Policy/ Guidelines did you base your Risk Management approach on? Please tick those that are applicable.**

- [ ] Australian/ New Zealand Risk Management Standard 4360:2004
- [ ] Project Management Body of Knowledge, Chapter 11, 2004
- [ ] Project Risk Analysis and Management Guide, APM, 2004
- [ ] Risk Management - Principles and Guidelines - AS/NZS ISO 31000:2009
- [ ] Organisational/ Company standard (if it is based on particular industry standard(s), please denote this within the the "other" section below)
- [ ] Other (specify below)
- [ ] N/A

Other

***38. Why did you choose the Standard/ Policy/ Guidelines selected in the Question above?**

- [ ] Company Policy
- [ ] Client Requirement
- [ ] Promulgated by the institute of which I am a member
- [ ] Personnel preference
- [ ] Other (specify below)
- [ ] N/A

Other (please specify)

Management of Risk on Projects

***39. Were other Risk Management approaches and processes used on the project, which you would consider to be 'in advance' of mainstream industry project Risk Management Standards?**

- ◯ Yes
- ◯ No
- ◯ Don't Know

If Yes, can you please describe the approach taken and why?

40. Considering your project, how could the focus and activities implemented within the risk management approach and processes be improved for similar projects in the future?

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Management of Risk on Projects

7. Project Success

The following questions relate to the success of the project. Please respond to these by denoting the most applicable response thereto.

***41. The project objectives were met?**

- To a great extent
- Somewhat
- Very little
- Not at all

***42. The project was delivered on programme?**

- Yes
- No

***43. The project was delivered on budget?**

- Yes
- No

***44. The project scope was achieved?**

- To a great extent
- Somewhat
- Very little
- Not at all

***45. The project's quality objectives were met?**

- To a great extent
- Somewhat
- Very little
- Not at all

***46. How would you rate the level of client satisfaction with respect to the delivery of the project?**

- High
- Moderate
- Low
- Very Low

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Management of Risk on Projects

***47. Were the project objectives aligned to the client's/ sponsor's organisational goals and strategy?**

- ◯ To a great extent
- ◯ Somewhat
- ◯ Very little
- ◯ Not at all
- ◯ Don't Know

***48. Initial commercial/ business success of the delivered 'product'?**

- ◯ To a great extent
- ◯ Somewhat
- ◯ Very little
- ◯ Not at all
- ◯ Don't Know
- ◯ Too early to tell

***49. A new product/ market/ technology was created in preparation for future business growth?**

- ◯ To a great extent
- ◯ Somewhat
- ◯ Very little
- ◯ Not at all
- ◯ Don't Know

Management of Risk on Projects

8. Concluding Questions

***50. Do you think that the management of risk on the project played a 'key' role in contributing towards improved project delivery? If risks were not actively managed on the project - i.e.'No' to Q 24, then answer N/A.**

- ◯ Yes
- ◯ No
- ◯ N/A

***51. If your answer to the question above (Q 50) is 'No', then please indicate why, by ticking the appropriate response and briefly elaborating in 'other', if necessary? Answer N/A if the answer to Q 50 is 'Yes' or 'N/A'**

- ◯ The risk management approach and processes used on the project were INADEQUATE and consequently not a key factor to improved project delivery (under 'other' please briefly identify the factors/ elements that were key to enabling improved project delivery)
- ◯ The risk management approach and processes used on the project were ADEQUATE but not key to improved project delivery (under other please briefly identify the factors/ elements that were key to enabling improved project delivery
- ◯ The risk management approach and processes used on the project were inadequate and a key factor contributing to the project not being successful in certain areas or an overall failure
- ◯ N/A

Other (please specify)

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Management of Risk on Projects

52. Please provide your contact details below. This is only to be used for data validation and clarification purposes. Individual details remain strictly confidential.

Name:	
Company:	
Address 1:	
Address 2:	
City/Town:	
State/Province:	
ZIP/Postal Code:	
Country:	
Email Address:	
Phone Number:	

53. Please provide the Client/Sponsor's contact details for the project, so that they can be invited to provide their perceptions on project delivery. As stated above, individual, company and project names will remain STRICTLY CONFIDENTIAL.

Name:	
Company:	
Address 1:	
Address 2:	
City/Town:	
State/Province:	
ZIP/Postal Code:	
Country:	
Email Address:	
Phone Number:	

QUESTIONNAIRE COMPLETE - CONCLUDING NOTES

A sincere thanks for participating in this research aimed at improving the management of risk on complex projects.
All participants fully completing the survey by 28 October 2011 will be sent an executive summary of the final research report by email. To receive this please ensure your contact email address is provided in Q 52.
Please click "Done" to submit and exit the survey.

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Appendix 4

Pilot Explanatory Letter

Dear XXXX

Research – Risk Management and Project Complexity - Pilot Survey

Thank you for participating in a pilot survey of this research.

The purpose of this research is to investigate how risk is managed by Project Managers on projects of varying complexity, to assess the perceived effectiveness of these approaches, including prescribed industry risk management standards, and to make recommendations for the improvement of risk management approaches and processes on complex projects in particular.

The on-line questionnaire to be completed by Project Managers should take approximately 30-45 minutes to complete and can be done at your convenience. If you can complete it by 24 June 2011 it will be appreciated.

Please follow this link to the questionnaire or cut and paste it to your browser:

http://www.surveymonkey.com/s/T9RMDG7

The introduction to the questionnaire further outlines the purpose of the research and provides guidance and information.

Once you have completed the questionnaire, if you have feedback with respect to issues you encountered and/or suggestions for improvements to the questionnaire please can you do so with a response to this email.

An assessment of completed questionnaires and feedback received will be conducted. Necessary improvements will be made. Following this it is expected that the survey will be launched in early July 2011.

Again, thank you for your assistance in participating in this pilot.

Kind regards

Craig Harvett

Appendix 5

Project Management Institutions / Associations and Networks approached for participation in the research

The following project management institutions / associations were approached:

- International Project Management Association (IPMA)
- Australian Institute of Project Management
- Azerbaijan Project Management Association (AzPMA)
- Project Management Research Committee China (PMRC)
- Project Management Associates (India)
- Iran Project Management Association
- Kazakhstan Project Management Association
- PMAN-Project Management Association of Nepal
- Taiwan Project Management Association, China (TPMA)
- Management Engineering Society (MES) (Egypt)
- Moroccan Association Managers of Project (MPMA)
- Project Management South Africa (PMSA)
- Project Management Association of Zambia
- Project Management Austria
- Bulgarian Project Management Association (BPMA)
- Croatian Association for Project Management
- Cyprus Project Management Society (CPMS)
- Project Management Association Czech Republic (SPR)
- Danish Project Management Association
- Project Management Association Finland (PMAF)
- Association Francophone de Management de Projet (AFITEP)
- GPM Deutsche Gesellschaft für Projektmanagement E.V.
- Network of Project Managers in Greece (PM-Greece)
- Project Management Association Hungary (FOVOSZ)
- Project Management Association of Iceland (VSF)
- Institute of Project Management Ireland
- Associazone Nazionale di Implantistica Industriale (Italy)
- Kosova Association for Quality- Management, Standards, Certification and Confirmation (QK)

- Latvian National Project Management Association
- LPVA – Lithuanian Project Management Association
- IPMA-NL (Netherlands)
- Norwegian Association of Project Management (NFP)
- Stowarzyszenie Project Management Polska (Poland)
- Associaçao Portuguesa de Gestao de Projectos (APOGEP) (Portugese)
- Project Management Romania
- Russian Project Management Associaion (SOVNET)
- Serbian Project Management Association – YUPMA
- Project Management Association of Slovakia (SPPR)
- Slovenian Project Management Association (ZPM)
- Asociacion Espanola de Ingenieria de Proyectos (AEIPRO)
- Svenskt Projektforum (Swedish Project Management Association)
- Swiss Project Management Association (spm)
- Turkish Project Management Association (TrPMA)
- Association for Project Management (APM)
- Ukrainian Project Management Association (UPMA)
- Project Management Institute (PMI)
- PMI Chapters (Asia-Pacific - 29 Chapters)
- PMI Chapters (Europe, Middle East, Africa, Latin America - 65 Chapters)
- PMI Chapters (USA, Canada, Caribbean - 180 Chapters)

The following project management networks were approached:

- LinkedIn PM Forum
- PMI Aerospace and Defence
- PMI Pharmaceutical Community of Practice
- PMI RM Community of Practice
- PMI Innovation & New Product Development Community of Practice
- PMI Project Risk Management Community of Practice
- PMI Facebook
- Project Managers.Net
- Leishman Associates (organisers of IMPA International Project Manager's conference held in Brisbane Australia in October 2011 – invite to participate in the research placed on the conference website)
- Complexity Institute (www Linkedin group)
- Roeder Consulting – PM Group (www Linkedin group)
- New England Complex Systems Institute
- PM Link (www Linkedin group)
- PM Network (www Linkedin group)
- Lean Agile Development community (www Linkedin group)
- Complexity & Project Management (www Linkedin group)
- Project Management Group SP (www Linkedin group)

Appendix 6

Cronbach Alpha Test Results - Internal Consistency

Perceived Project Complexity

Case Processing Summary

		N	%
Cases	Valid	80	100.0
	Excluded	0	.0
	Total	80	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.673	.684	7

Item Statistics

	Mean	Std. Deviation	N
VAR00001	2.5375	.82591	80
VAR00002	2.2750	.79516	80
VAR00003	2.4875	1.04329	80
VAR00004	2.1625	.86337	80
VAR00005	1.3500	.61829	80
VAR00006	1.9375	.89079	80
VAR00007	1.7875	.77449	80

VAR00001 = Stability of the overall project context?

VAR00002 = Number of distinct disciplines, methods or approaches involved in performing the project?

VAR00003 = Magnitude of legal, social, or environmental implications from performing the project?

VAR00004 = Overall expected financial impact (positive or negative) on the project's stakeholders?

VAR00005 = Strategic importance of the project to the organisation or organisations involved?

VAR00006 = Stakeholder cohesion regarding the characteristics of the product of the project?

VAR00007 = Number and variety of interfaces between the project and other organisational entities?

Inter-Item Correlation Matrix

	VAR00001	VAR00002	VAR00003	VAR00004	VAR00005	VAR00006	VAR00007
VAR00001	1.000	.042	.015	.142	-.051	.390	-.037
VAR00002	.042	1.000	.416	.432	.394	.293	.343
VAR00003	.015	.416	1.000	.318	.340	.074	.412
VAR00004	.142	.432	.318	1.000	.390	.129	.355
VAR00005	-.051	.394	.340	.390	1.000	.063	.474
VAR00006	.390	.293	.074	.129	.063	1.000	.017
VAR00007	-.037	.343	.412	.355	.474	.017	1.000

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
VAR00001	12.0000	10.203	.144	.186	.701
VAR00002	12.2625	8.449	.554	.367	.590
VAR00003	12.0500	8.023	.429	.269	.626
VAR00004	12.3750	8.440	.490	.290	.606
VAR00005	13.1875	9.547	.449	.322	.629
VAR00006	12.6000	9.433	.259	.235	.675
VAR00007	12.7500	9.051	.428	.320	.627

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
14.5375	11.644	3.41235	7

Risk Management Approach and Processes

Case Processing Summary

		N	%
Cases	Valid	66	100.0
	Excludeda	0	.0
	Total	66	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.751	.759	12

Item Statistics

	Mean	Std. Deviation	N
VAR00001	2.0758	.86488	66
VAR00002	1.5303	.68432	66
VAR00003	1.7121	.85512	66
VAR00004	2.3939	.95883	66
VAR00005	2.0303	.91095	66
VAR00006	1.8030	.82685	66
VAR00007	2.0152	.75432	66
VAR00008	2.4394	.93032	66
VAR00009	1.9697	1.00720	66
VAR00010	2.6364	1.15873	66
VAR00011	2.0758	1.02748	66
VAR00012	1.8030	.63778	66

VAR00001 = Establishing the Context and Risk Management Planning?

VAR00002 = Risk Identification?

VAR00003 = Qualitative Risk Analysis?

VAR00004 = Quantitative Risk Analysis?

VAR00005 = Risk Evaluation and Risk Response Planning (Treatment)?

VAR00006 = Risk Monitoring and Control?

VAR00007 = What was the key focus of risk management attention?

VAR00008 = Scope of Risk Management Processes?

VAR00009 = Level of Risk Management documentation?

VAR00010 = Tools and Techniques used?

VAR00011 = Parties involved & allocation of responsibilities in the Risk Management Process?

VAR00012 = Resources applied to Risk Management?

Inter-Item Correlation Matrix

	VAR00001	VAR00002	VAR00003	VAR00004	VAR00005	VAR00006	VAR00007	VAR00008	VAR00009	VAR00010	VAR00011	VAR00012
VAR00001	1.000	.451	.488	.316	.544	.473	.234	.130	-.086	.212	.063	-.056
VAR00002	.451	1.000	.817	.474	.714	.622	.133	-.082	-.133	.169	-.036	-.109
VAR00003	.488	.817	1.000	.478	.742	.615	.150	-.032	-.135	.095	-.080	-.134
VAR00004	.316	.474	.478	1.000	.497	.313	.141	-.025	-.019	.214	-.093	.003
VAR00005	.544	.714	.742	.497	1.000	.682	.044	.002	-.150	.098	-.167	-.148
VAR00006	.473	.622	.615	.313	.682	1.000	.128	-.006	-.155	.181	-.055	-.075
VAR00007	.234	.133	.150	.141	.044	.128	1.000	.210	.264	.288	.415	.294
VAR00008	.130	-.082	-.032	-.025	.002	-.006	.210	1.000	.113	.293	.303	.330
VAR00009	-.086	-.133	-.135	-.019	-.150	-.155	.264	.113	1.000	.439	.537	.517
VAR00010	.212	.169	.095	.214	.098	.181	.288	.293	.439	1.000	.450	.339
VAR00011	.063	-.036	-.080	-.093	-.167	-.055	.415	.303	.537	.450	1.000	.493
VAR00012	-.056	-.109	-.134	.003	-.148	-.075	.294	.330	.517	.339	.493	1.000

Risk Management Processes

Case Processing Summary

		N	%
Cases	Valid	69	98.6
	Excludeda	1	1.4
	Total	70	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.875	.881	6

Item Statistics

	Mean	Std. Deviation	N
VAR00001	2.1304	.87301	69
VAR00002	1.5362	.67692	69
VAR00003	1.7101	.84194	69
VAR00004	2.3768	.92516	69
VAR00005	2.0000	.85749	69
VAR00006	1.8116	.80942	69

VAR00001 = Establishing the Context and Risk Management Planning?

VAR00002 = Risk Identification?

VAR00003 = Qualitative Risk Analysis?

VAR00004 = Quantitative Risk Analysis?

VAR00005 = Risk Evaluation and Risk Response Planning (Treatment)?

VAR00006 = Risk Monitoring and Control?

Inter-Item Correlation Matrix

	VAR00001	VAR00002	VAR00003	VAR00004	VAR00005	VAR00006
VAR00001	1.000	.477	.492	.357	.589	.535
VAR00002	.477	1.000	.819	.448	.709	.617
VAR00003	.492	.819	1.000	.463	.754	.609
VAR00004	.357	.448	.463	1.000	.463	.293
VAR00005	.589	.709	.754	.463	1.000	.657
VAR00006	.535	.617	.609	.293	.657	1.000

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
VAR00001	9.4348	11.132	.601	.395	.867
VAR00002	10.0290	11.382	.779	.704	.842
VAR00003	9.8551	10.390	.792	.735	.833
VAR00004	9.1884	11.508	.483	.267	.889
VAR00005	9.5652	10.220	.810	.676	.829
VAR00006	9.7536	11.130	.669	.511	.855

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
11.5652	15.396	3.92383	6

Risk Management Approach

Case Processing Summary

		N	%
Cases	Valid	66	100.0
	Excludeda	0	.0
	Total	66	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.756	.765	6

Item Statistics

	Mean	Std. Deviation	N
VAR00001	2.0152	.75432	66
VAR00002	2.4394	.93032	66
VAR00003	1.9697	1.00720	66
VAR00004	2.6364	1.15873	66
VAR00005	2.0758	1.02748	66
VAR00006	1.8030	.63778	66

VAR00001 = What was the key focus of risk management attention?

VAR00002 = Scope of Risk Management Processes?

VAR00003 = Level of Risk Management documentation?

VAR00004 = Tools and Techniques used?

VAR00005 = Parties involved & allocation of responsibilities in the Risk Management Process?

VAR00006 = Resources applied to Risk Management?

Inter-Item Correlation Matrix

	VAR00001	VAR00002	VAR00003	VAR00004	VAR00005	VAR00006
VAR00001	1.000	.210	.264	.288	.415	.294
VAR00002	.210	1.000	.113	.293	.303	.330
VAR00003	.264	.113	1.000	.439	.537	.517
VAR00004	.288	.293	.439	1.000	.450	.339
VAR00005	.415	.303	.537	.450	1.000	.493
VAR00006	.294	.330	.517	.339	.493	1.000

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
VAR00001	10.9242	11.517	.415	.196	.742
VAR00002	10.5000	11.238	.338	.190	.762
VAR00003	10.9697	9.784	.542	.427	.708
VAR00004	10.3030	9.138	.533	.296	.715
VAR00005	10.8636	9.104	.653	.448	.674
VAR00006	11.1364	11.320	.579	.380	.715

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
12.9394	14.212	3.76983	6

Project Success - 9 Factors

Case Processing Summary

		N	%
Cases	Valid	60	100.0
	Excludeda	0	.0
	Total	60	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.751	.790	9

Item Statistics

	Mean	Std. Deviation	N
VAR00001	1.4333	.64746	60
VAR00002	5.3167	.46910	60
VAR00003	5.3000	.46212	60
VAR00004	1.3167	.53652	60
VAR00005	1.4333	.49972	60
VAR00006	1.5000	.65094	60
VAR00007	1.3500	.54695	60
VAR00008	1.8833	.94046	60
VAR00009	2.3000	1.09390	60

VAR00001 = Project objectives (Likert Scale)

VAR00002 = Project on programme ("yes"/"no") - dichotomous & nominal data

VAR00003 = Project on budget ("yes"/"no") - dichotomos & nominal data

VAR00004 = Project scope (Likert Scale)

VAR00005 = Project quality objectives (Likert scale)

VAR00006 = Client satisfaction (Likert scale)

VAR00007 = Objectives aligned to sponsor/ client's goals and strategy (Likert Scale)

VAR00008 = Initial commercial success (Likert scale)

VAR00009 = A new product or technology (Likert scale)

Inter-Item Correlation Matrix

	VAR1	VAR2	VAR3	VAR4	VAR5	VAR6	VAR7	VAR8	VAR9
VAR1	1.000	.210	.125	.623	.510	.523	.570	.224	.220
VAR2	.210	1.000	.180	.336	.345	.250	.023	-.069	-.023
VAR3	.125	.180	1.000	.226	.161	.282	.181	.121	.221
VAR4	.623	.336	.226	1.000	.554	.607	.482	.242	.182
VAR5	.510	.345	.161	.554	1.000	.521	.304	.254	.130
VAR6	.523	.250	.282	.607	.521	1.000	.452	.401	.167
VAR7	.570	.023	.181	.482	.304	.452	1.000	.509	.331
VAR8	.224	-.069	.121	.242	.254	.401	.509	1.000	.216
VAR9	.220	-.023	.221	.182	.130	.167	.331	.216	1.000

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
VAR00001	20.4000	9.803	.590	.540	.703
VAR00002	16.5167	11.779	.191	.212	.757
VAR00003	16.5333	11.473	.297	.137	.746
VAR00004	20.5167	10.152	.636	.556	.703
VAR00005	20.4000	10.617	.537	.425	.718
VAR00006	20.3333	9.616	.638	.505	.695
VAR00007	20.4833	10.118	.632	.524	.703
VAR00008	19.9500	9.472	.390	.351	.743
VAR00009	19.5333	9.473	.289	.147	.781

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
21.8333	12.616	3.55188	9

Appendix 7

Statistical Testing on Hypotheses - Outputs

Null Hypothesis 1

H_0: Project Manager's do not implement higher level risk management approaches and processes on projects they perceive as more complex, than on projects that Project Manager's perceive as less complex.

		Perceived Project Complexity VAR00001	Risk Management Approach and Processes VAR00002
VAR00001	Pearson Correlation	1	.279**
	Sig. (1-tailed)		.008
	N	73	73
VAR00002	Pearson Correlation	.279**	1
	Sig. (1-tailed)	.008	
	N	73	73

**. Correlation is significant at the 0.01 level (1-tailed).

Correlation co-efficient and significance calculation – project complexity and risk management approach & processes

Excluding 5 sets of data, where respondents reported no explicit manage of 'risk' on the project

		Perceived Project Complexity VAR00001	Risk Management Approach and Processes VAR00002
VAR00001	Pearson Correlation	1	.362**
	Sig. (1-tailed)		.001
	N	68	68
VAR00002	Pearson Correlation	.362**	1
	Sig. (1-tailed)	.001	
	N	68	68

**. Correlation is significant at the 0.01 level (1-tailed).

Correlation co-efficient and significance calculation – project complexity and risk management approach & processes (excluding 5 data points)

Null Hypothesis 2

H_0: Most Project Managers, on projects they perceive to have high levels of complexity, do not implement risk management approaches and processes at lower then 'optimal' levels of general prescribed industry risk management standards.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between VAR00001 and VAR00002 equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Hypothesis Test Summary - Wilcoxon (T) Signed Ranks Test – on projects perceived as highly complex - differences between optimal prescribed industry risk management standards and Project Managers implementation of risk management approaches and processes.
VAR00001 Optimal prescribed industry risk management standard
VAR00002 Project Managers implementation of risk management approaches and processes

Null Hypothesis 3

H_0: A minority of Project Managers do not implement risk management approaches and processes 'in advance' of general prescribed industry risk management standards on projects they perceive to have high levels of complexity.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of VAR00001 is normal with mean 1.333 and standard deviation 0.476.	One-Sample Kolmogorov-Smirnov Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Hypothesis Test Summary – One-Sample Kolmogorov-Smirnov Test – Prevalence of Project Manager's managing risk on projects perceived as complex, at levels that they consider to be in advance of mainstream risk management standards.
VAR00001 Risk management approaches 'in advance' of general prescribed industry risk management standards

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The categories defined by VAR00002 = N and Y occur with probabilities 0.5 and 0.5.	One-Sample Binomial Test	.025	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Hypothesis Test Summary – One-Sample Binomial Test – Prevalence of Project Manager's managing risk on projects perceived as complex, at levels that they consider to be 'in advance' of mainstream risk management standards.
VAR00002 Risk management approaches 'in advance' of general prescribed industry risk management standards

Null Hypothesis 4

H_0: There is no positive correlation between risk management approach and process levels implemented and perceived project success by Project Manager's on projects that they perceive to be of high complexity.

		Risk Management approach and Process level VAR00001	Perceived Project Success VAR00002
VAR00001	Pearson Correlation	1	.284*
	Sig. (1-tailed)		.023
	N	50	50
VAR00002	Pearson Correlation	.284*	1
	Sig. (1-tailed)	.023	
	N	50	50

*. Correlation is significant at the 0.05 level (1-tailed).

Correlation co-efficient and significance calculation –Risk management approach & processes and perceived project success (triple constraint) on projects of high complexity

		Risk Management approach and Process level VAR00001	Perceived Project Success VAR00002
VAR00001	Pearson Correlation	1	.299*
	Sig. (1-tailed)		.029
	N	41	41
VAR00002	Pearson Correlation	.299*	1
	Sig. (1-tailed)	.029	
	N	41	41

*. Correlation is significant at the 0.05 level (1-tailed).

Correlation co-efficient and significance calculation – Risk management approach & processes and perceived project success (9-factors) on projects of high complexity

Null Hypothesis 5

H_0: Perceived project success is not higher on projects of high complexity, where uncertainty and risk is managed 'in advance' of general prescribed industry risk management standards, rather than at 'high levels' of such standards.

Mann-Whitney Test

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of VAR00002 is the same across categories of VAR00001.	Independent-Samples Mann-Whitney U Test	.897	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.