A socio-technical view of the requirements engineering process

A Thesis Submitted in Partial Fulfilment of the Degree of

DOCTOR INGENERIAE

in

ENGINEERING MANAGEMENT

at the

FACULTY OF ENGINEERING AND THE BUILT ENVIRONMENT

of the

UNIVERSITY of JOHANNESBURG

by

Annlizé Marnewick

March 2013

SUPERVISOR: PROF. JHC PRETORIUS

CO-SUPERVISOR: PROF. L PRETORIUS

Declaration

I, Annlizé L Marnewick, hereby declare that the dissertation "A socio-technical view of the requirements engineering process" submitted for the Doctor Ingeneriae: Engineering Management degree, Faculty of Engineering and the Built Environment, at the University of Johannesburg, apart from the help recognized, is my own work and has not previously been submitted to another university or institution of higher education for a degree.

Abstract

The requirements discipline is at the heart of systems engineering, software engineering and business analysis. When a solution needs to be developed, built or bought that will be useful to the users and that will achieve the intended business goals, the problem needs to be understood before a possible solution can be developed. This process of understanding the problem that needs to be solved and what the solution should achieve is referred to as the requirements process. Requirements are the input to the solution development process. If the requirements are incorrect, the developed solution will not be useful.

The purpose of this study was to discover the social behaviour of practitioners that causes the communication breakdowns during the requirements engineering process. Requirements emerge from the social interaction and communication between the requirements practitioner and the various stakeholders. The main problems with the requirements engineering process are communication and coordination breakdowns, as well as the lack of domain knowledge or understanding of the problem. These challenges are all related to the social interaction during the requirements engineering process that impacts the quality of requirements.

Researchers have made significant progress in the development of methodologies. Tools and techniques are available for improving the quality of requirements. However, in practice, requirements are still produced with errors which then leads to unsuccessful solutions to problems. The requirements engineering process is executed within a social context. These social elements should be taken into consideration to improve quality.

Based on the results collected from real-world practice as well as people's behaviour in the real world, a complete understanding of the influence on the requirements process was derived. This understanding was used to identify the social elements required during the requirements engineering process. A socio-technical view is provided of the social and the technical activities that should be facilitated by the requirements engineering process. This framework integrates the required communicative activities with the traditional requirements activity. This socio-technical framework for the requirements engineering process was developed based on a survey. The aim of this framework is to overcome the social behaviour that causes communication breakdowns and impacts on the quality of the requirements.

The research contributes to the existing requirements knowledge base. The socio-technical framework developed for the requirements process concerns the communication breakdowns continuously highlighted as a contributing factor to poor requirements, by providing the social activities required during the requirements process as guidance. Secondly, the knowledge acquired provides adequate data on requirements practice for future research. Specific focus areas for practitioners and managers on how to improve the requirements engineering process without the adoption of any new tools or methodologies are also included in the results. Additionally, practitioners' behaviour was determined. By determining these interaction and relationship patterns, communication can be improved and made more effective.

Acknowledgements

Thank you to my Father in Heaven.

A big thank you to Professor Jan-Harm Pretorius and Professor Leon Pretorius, my supervisors, for the time you took to share your thoughts and knowledge with me. The overall guidance and feedback you provided led to insights and are the start of my development as a researcher.

A word of thanks to the practitioners who did not delete the survey, but who took the time out of their busy schedules to provide input to the research process. Without their input the research would not have been possible.

A special thanks to Carl and Lyoné – without your patience and support I would never have finished this research.

CONTENTS

Figures

Tables

Abbreviations

BABOK	Business analysis body of knowledge
CBAP	Certified Business Analysis Professional
DEC	Digital Equipment Corporation
ICT	Information and communication technology
IIBA	International Institute of Business Analysis
INCOSE	International Council on Systems Engineering
LAN	Local area network
NCOSE	National Council on Systems Engineering
PARC	Palo Alto Research Center
RML	Requirements Modeling Language
TME	Technology, media and entertainment
UML	Unified Modeling Language
WWW	World Wide Web

CHAPTER 1 Introduction

1 Introduction

Technologies are used daily by customers, either in the form of a product, or an electronic device application which operates with software. Yet, these products or software applications are not necessarily what customers need and they become obsolete if they are not functioning as intended. To deliver a product or software application that is accepted and used by customers, the requirements must be well understood by the requirements engineer. Software products are error-prone, and many of these errors originate during the requirements stage.

Requirements engineering is about understanding the problem, and then solving it. To solve problems, a learning environment is required which can be defined as one in which all the team members are involved in identifying and solving problems. This allows the team to continually increase its ability to grow, learn and achieve its purpose (Senge, 2006).

Understanding problems involves human interaction (Aurum and Wohlin, 2003; Vitalari and Dickson, 1983; Kim and Grunig, 2011). A purely technical process cannot solve a problem where customers' needs are to be met (Fuentes-Fernández et al., 2010). This study investigates how human interaction factors should be taken into consideration as part of a technical process to improve the quality of requirements delivered as a result of the requirements process.

1.1 The Origination of Requirements

The requirements discipline has originated as a consequence of developments in computer systems, software applications and the impact of systems and software applications on the operational business environment. With each new computer generation, software used on these computer platforms has evolved (Moreau, 1986).

The computer itself has its origins as a consequence of development of instruments that help humans to do calculations (Zwiers, 2011; Moreau, 1986). The main events that led to the existence of computers have been summarised by Moreau (1986) and are illustrated in Figure 1.

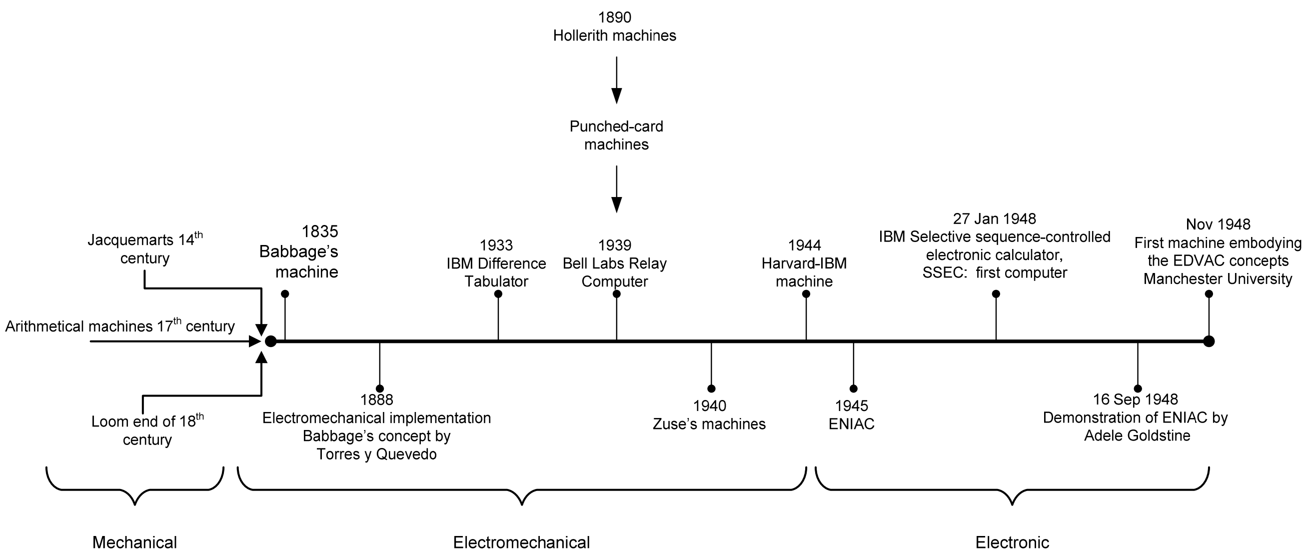

Figure 1: Main events in the history of the birth of the computer (Moreau, 1986)

The above timeline shows the main events that led to the development of computers. Being a computer meant that the instrument had at least the following four main characteristics (Moreau, 1986):

- A numerical machine able to execute a sequence of instructions without human intervention. The sequence of instructions was communicated to the machine as a program.
- An arithmetical and logic unit of the computer was designed to perform the tasks required.
- The program and data were held in memory during the execution of tasks.
- Lastly, an input and output to exchange the information with the world.

Originally computers were in a hidden world with only a few scientists having access to them in research laboratories (Campbell-Kelly, 2003). After this, the computer environment moved from a few computers on company desks to access to anyone, anywhere and any time. This evolution of computer technologies is showcased in the usage of the personal computer, the Internet and mobile phone devices (Ebert, 2008). A few events during the evolution are illustrated in Figure 2. Many developments have not been included and more complete event lists are available in literature (O'Leary and O'Leary, 2000; O'Leary and O'Leary, 2010; Moreau, 1986; Union, 2011).

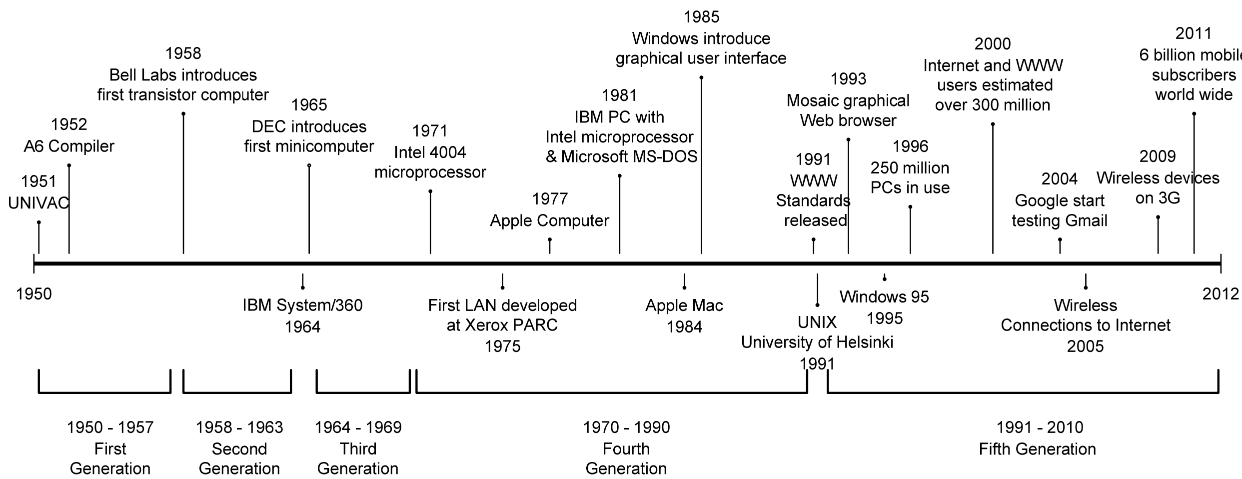

Figure 2: Evolution of computer technologies

The first generation of computers used in the 1950s was built with vacuum tubes. Punch cards were used to input and externally store data (Zwiers, 2011; O'Leary and O'Leary, 2000; Computer History Museum, 2006). The second generation of computers emerged during the late 1950s. In this generation the vacuum tubes were replaced by transistors as the main logic element. The transistor technology helped the computers to be faster and smaller than the vacuum computers (Zwiers, 2011). During this era, computer hardware was application specific (Glass, 1998). Software was written to control the basic resources of the computer hardware (Moreau, 1986). This software was provided free by the hardware vendors as the computers were worthless without it (Glass, 1998). New computers were developed every year or two as previous ones became obsolete (Glass, 1998). The software on the computers had to be rewritten as new computers were developed (Glass, 1998). Due to this need software contracting developed alongside computer hardware (Campbell-Kelly, 2003).

Due to the frequent rewriting of the software, programming languages were developed which were to cover the man-machine communication as well as the algorithms (Moreau, 1986). High-level programming languages were launched, such as FORTRAN which was developed by IBM and ALGOL. The US Department of Defense issued Cobol to deal with specific business problems (Wirth, 2008). Software and programming languages of major significance based on their usage are illustrated in Figure 3.

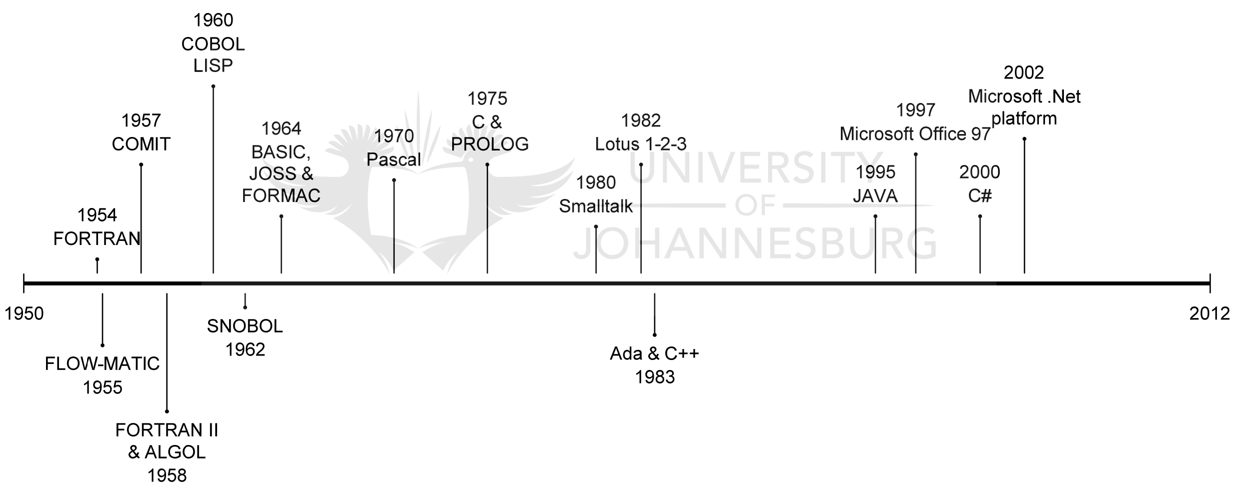

Figure 3: History timeline of software (Sammet, 1991; Wirth, 2008; O'Leary and O'Leary, 2010)

The software evolution was triggered as computers and computerised systems were developed. A multidisciplinary engineering team was established to develop an information processing system during the 1950s (Boehm, 2006). This system was known as the Semi-automatic Ground Environment (SAGE) system. The first process created to assist during the system development (Gonzales, 2005) used the same approach as that used to develop hardware in 1956 (Boehm, 2006). This was the first step in the evolution of the modern system engineering community (Gonzales, 2005). The process was top-down and formulating requirements was one of the steps. It became apparent that software was different from hardware and that modifications were much easier than in hardware, and so a “code and fix” approach soon followed compared with the thorough hardware design reviews (Boehm, 2006). The maintenance process of software was also different from that of hardware as software did not wear and tear like hardware. However, software was more people intensive than hardware and soon the demand for software surpassed the supply of hardware engineers.

During the 1960s computers migrated from closed laboratory environments to the public domain and become more accessible within the corporate market (Campbell-Kelly, 2003). Corporate software products emerged after the launch of the IBM System/360 computer. A software product was a program that could be used without modification by a large number of corporate users (Campbell-Kelly, 2003). Software products typically automated business functions such as payroll or a savings bank. Software was unbundled and charged for separately (Campbell-Kelly, 2003). This was the beginning of the software industry (Boehm, 2006). Software development positions were taken up by creative people, which often resulted in spaghetti code, which when fixed led to patched code (Boehm, 2006).

In 1968, NATO held a conference to address the difficulties that programmers faced and the term “software engineering” emerged. At this conference, it was acknowledged that the software development or programming techniques at the time were inadequate (Wirth, 2008). It was also acknowledged that more structured approaches were required for software engineering in response to the spaghetti code problems faced (Randell and Naur, 1968). In addition, to enable control and planning into larger projects a model was introduced, called the waterfall model for software engineering (Boehm, 2006). Although a requirements driven process was established in the 1950s during the development of SAGE, the waterfall model allowed the development of software in a sequence of activities where formulating requirements was the initial step (Royce, 1970). With no formal techniques in place, requirements were written in a natural language. The empirical study of Bell and Thayer (1976) provided evidence that errors in the requirements had a significant impact on the quality of the software developed from these requirements. A need for techniques to improve requirements was identified, which established requirements engineering as a subfield of software engineering in the early 1970s (Greenspan et al., 1994).

The main events that established the requirements discipline across the three communities of systems engineering, software engineering and business analysis are illustrated in Figure 4. More detailed information about the history of system and software engineering can be found in literature (Gonzales, 2005; Brill, 1998; Ebert, 2008).

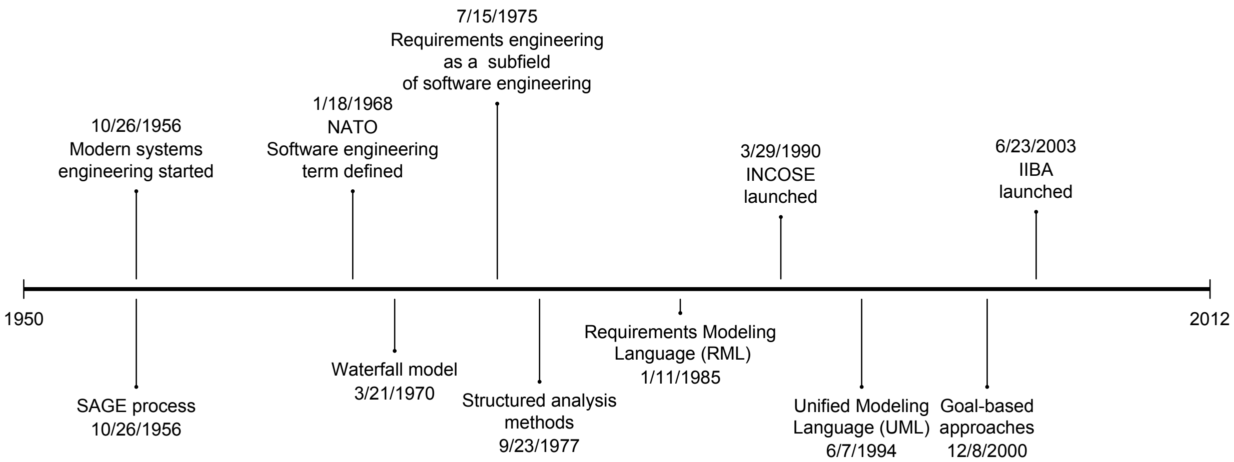

Figure 4: Requirements engineering history

In response to the code and fix approach during the 1970s, formal requirements techniques were introduced which utilised structured analysis methods such as the structured analysis and design technique (SADT) (Ross and Schoman, 1977). This method (i) defined what requirements engineering should be doing, (ii) defined the techniques required to do requirements engineering and (iii) introduced the use of graphical techniques to generate specifications that facilitated communication between all parties involved in the process. Similarly, DeMarco (1979) and Gane (1979) used data flow diagrams, data dictionaries, structured English decision tables and decision trees to generate requirements.

Typically, the starting point of these techniques was to determine the functions of a system. An alternative starting point was suggested to (i) create a model of the reality in which the system would operate and (ii) then consider the detail functions required (Jackson, 1983).

The arrival of the personal computer in the mid-1970s created an opportunity for mass-market software (Campbell-Kelly, 2003). The drive in the 1980s was to increase productivity and the reuse of software became important (Boehm, 2006). Objected-oriented methods were developed to enable software reuse and this saw the creation of Smalltalk, Java and C++ (Boehm, 2006). The focus moved to the knowledge accumulated during the requirements engineering process and not just the requirements. Software developers realised that stakeholders did not know their requirements and techniques started being developed to support the discovery of requirements, for example card sorting, laddering and repertory grids (Maiden, 2008). Greenspan et al. (1994) developed Requirements Modeling Language (RML), which supported an object-oriented approach. RML was one of the first languages to included formal semantics to address the vagueness and inaccuracy of requirements (van Lamsweerde, 2000).

The fifth generation was referred to as the “connected generation” as connectivity between computers became the norm (O'Leary and O'Leary, 2000). The development of the Internet and World Wide Web (WWW) enabled computer connectivity across the globe. Systems engineering was a well-established community and in 1990 a professional organisation (INCOSE) was formed that was dedicated to the systems engineering community (Brill, 1998). One of the main themes acknowledged by this community was that the problem to be solved must be understood before development can start (Brill, 1998).

Software became critical in the marketplace (Boehm, 2006). The usability of software by its users became very important (Boehm, 2006). Ethnography techniques were introduced in the 1990s to understand the system environment better. This approach focused on users and user interactions with systems, rather than the data itself, its structure and processing (Sommerville et al., 1992). In the late 1990s Unified Modeling Language (UML) was developed as an attempt to standardise the object-oriented languages (Zwiers, 2011). During the 2000s requirements approaches moved from the object-oriented approaches to goal-oriented approaches to help stakeholders identify their requirements (van Lamsweerde, 2000).

Computer technology enabled the business world to change quickly and to always be connected (Boehm, 2006). This had an impact on how business operated and as a consequence of the changing world business started outsourcing technology functions (Feeny and Willcocks, 1998). New roles were established within organisations to facilitate the outsourcing business model. One of these roles was the development of the business analyst (Feeny and Willcocks, 1998; Paul et al., 2010). The business analyst's responsibility is described by Paul et al. (2012) as follows:

- The business need drives the development of technology solutions.
- During the implementation of technology solutions the necessary business changes must be facilitated.
- The requirements of the technology solution must be defined accurately.

This created a third community within the requirements discipline that played an important role in addition to the system and software engineering communities. The business analysis community also launched their own professional body in 2003 called the International Institute of Business Analysis (IIBA) (IIBA, 2009).

The requirements discipline is at the heart of systems engineering, software engineering and business analysis (Gonzales, 2005). Although each of these communities has different originations and different approaches to capture requirements during solution development, an understanding of the problem is always required before a solution can be developed (Gonzales, 2005). To keep up with the fast pace of developments, the time is not always taken to understand the problem and quality is thus compromised.

The current challenges in the requirements discipline across communities are explored in the next section to validate the deterioration of quality.

1.2 The Current Challenges in the Requirements Discipline

Research in the software engineering field has been active since the late 1950s. Requirements engineering is a subfield of software engineering that deals with the first stage of software engineering. The importance of requirements engineering is acknowledged by software engineering literature (El Emam and Madhavji, 1995; Aurum and Wohlin, 2005; van Lamsweerde, 2000). Requirements are defined as the input to the software or systems engineering process. If the requirements are wrong, the project is perceived as a failure even if all other work has been done perfectly (Berenbach et al., 2009; Viller et al., 1999; Brooks, 1987). This importance has been confirmed in the past decade by the research community by holding separate requirements engineering conferences and forming requirements engineering communities.

Although the research community acknowledges the importance of requirements, the industry still faces many challenges in practice with the requirements engineering process during solution delivery (Kamata and Tamai, 2007). Industry reports, surveys and research continuously identify poor requirements as the main contributor to failed projects:

- The IAG Business Analysis Benchmark report in 2008 (Ellis, 2008) found that organisations with poor requirements and analysis capability have a ratio of three project failures for every one project success. In addition at least 40% of the information technology development budget for software, staff and external professional services will be consumed by poor requirements in average organisations using average analysts.
- Requirements and scope changes after a project has been initiated are primary reasons for project cancellation (El Emam and Koru, 2008).
- Changing requirements are one of the main reasons why runaway projects are unstable (Glass, 2003).

- A survey on risks in e-projects lists the two top risks as unstable, constantly changing requirements and poor requirements specification (Rodrigues, 2001).
- Poor requirements are identified as one of the main contributors to the failure of system implementation (Hofmann and Lehner, 2001).
- Requirements errors are the greatest source of defects and quality problems (Schwaber, 2006; Leffingwell, 1997).
- Poor specification of requirements and insufficient analysis are the source of poor cost and delivery estimations (Lederer and Prasad, 1992).
- The costs of requirements errors are high. If there are errors in the requirements that are not fixed, it has been estimated that the cost grows exponentially up to 200 times more after systems implementation (Reifer, 2007; Hooks and Farry, 2001; Boehm, 1976; Boehm, 1984; Boehm and Papaccio, 1988; Jones, 1996).

Requirements engineering is about defining the problem that must be solved in the world of the user, and then defining a solution, “the machine” (Cheng and Atlee, 2007; Jackson, 1995). If the problem in the world of the user that must be solved is not understood, the world of the user and the defined solution, “the machine”, will never become an integrated entity. To understand the problem, communication is required; requirements emerge from the social interaction and communication between the users and the requirements engineer (Siddiqi, 1996).

Previous research concluded that domain knowledge is a recurring problem during the requirements engineering process and it affects the quality of requirements (Marnewick, 2011; Marnewick et al., 2011). Although domain knowledge is a main contributing factor towards quality requirements, it is not the root cause of the quality. Rather, this is a consequence of communication and interaction not having been established effectively.

The importance of effective communication and collaboration during the requirements stage has been emphasised by many researchers (Bostrom, 1989; Robertson, 2007; Herbsleb and Mockus, 2003; Browne and Rogich, 2001; Fuentes-Fernández et al., 2010; Hartwick and Barki, 2001; Gottesdiener, 2002; Coughlan et al., 2003).
The successes of an organisation, team or project depend on the knowledge in the organisation and are represented by the relationships between the people and the organisation (Dawson, 2000). If the requirements engineer does not enable collaboration with stakeholders through relationships, knowledge could be incomplete and impact the quality of requirements (Marnewick et al., 2011). Communication between the stakeholders and the requirements engineers is highlighted by many researchers as one of the important challenges faced in practice in delivering accurate requirements:

- Communication and coordination breakdowns, i.e. how requirements have been communicated throughout the life cycle of the project (Curtis et al., 1988), result in failure.
- Sutcliff et al. (1999) also identified communication as one of the problems in the requirements process during a specific project implementation where users did not accept the developed system.

- Hofmann and Lehner (2001) found that teams that have implemented projects successfully maintain good relationships with stakeholders and constantly validate their understanding of the application domain to avoid communication breakdowns.
- Damian and Chisan (2006) proved empirically six principles to be followed during requirements engineering that lead to benefits. One of the six principles is collaboration. If there is a united effort with no communication barriers, instead of working in isolation, benefits are achieved.
- A survey by Karlsson (2007) on requirements engineering in a market-driven products environment indicated that communication gaps between the business stakeholders and the implementation team are a challenge to deal with.
- A literature survey by Kamata et al. (2007) identified a gap in the research communities' work on communication during the requirements engineering process.

Communication and collaboration are constantly identified as challenges impacting the success of engineering projects within the requirements discipline context as listed above. These challenges are all related to social interaction during the requirements engineering process. The goal of this study was to discover the social behaviour of practitioners during the requirements engineering process. The detailed objectives are discussed in the next section.

1.3 Research Objectives

The same challenges seem to be faced in requirements engineering studies. Paech et al. (2005) have summarised studies available in literature. This summary provides confirmation that communication and coordination breakdowns, lack of domain knowledge and changing and conflicting requirements are known problems during the requirements process.

The goal of this study was to discover the social behaviour during the requirements engineering process of practitioners. The aim was to identify the social behaviour that causes communication breakdowns, as communication is one of the challenges that has an impact on the quality of requirements. Social behaviour was not researched in isolation, but within the context of how the requirements engineering process is executed by practitioners. The requirements engineering process execution is included to provide the social context of each requirements activity. Literature indicates that if an effective requirements process is established, the outcomes of the process are positive (Damian and Chisan, 2006).

This study's main research objectives were:

- To explore and document how practitioners execute the requirements engineering process.
- To determine if there are any differences between how the literature suggests the requirements engineering process should be executed and how practitioners execute it. From this, insight was derived into whether improvements can be implemented during the requirements engineering process to improve outcomes positively.
- To explore the behaviour of practitioners during the requirements engineering process that causes the communication breakdowns.

1.4 Problem Statement

Although numerous methodologies, tools and techniques are available to facilitate the requirements engineering process, poor quality requirements still impact on delivering a solution that is fit for purpose and accepted by users. This phenomenon was confirmed by a recent study that found that only one in eight software projects is truly successful (McManus and Wood-Harper, 2007). In recent research, the social factors contributing to poor requirements during requirements engineering have been highlighted (Piri, 2008; Bjarnason et al., 2011). Humans are an integral part of the requirements process; a human component therefore needs to be added to the technical process to create an integrated model for practitioners.

The research hypothesis for the study was as follows:
When the requirements practitioner establishes trust relationships with stakeholders, in addition to executing the requirements engineering process activities effectively, communication improves and this leads to the increased quality of requirements.

The following hypotheses were used to determine why the requirements engineering process often produces poor quality requirements that impact the success of projects:

- Hypothesis 1: Established trust relationships between the requirements practitioner and relevant stakeholders enable communication.
- Hypothesis 2: The impact on the output of the requirements engineering process quality is positive if all activities during the process are executed effectively.
- Hypothesis 3: The output of the requirements engineering process quality is dependent on the communication established between the requirements practitioner and relevant stakeholders.

1.5 Research Design

The research design had two main inputs, followed by a design step and then publication of results. The research design is illustrated in Figure 5. The main idea was to build a solid basis of the available knowledge by doing a literature review to identify best practice, methods and standards available to practitioners. This was to determine how the requirements engineering process should be executed according to best practice.

Secondly, a survey was conducted of requirements engineering practice to understand the context in which the requirements process is executed. The purpose of this survey was to understand how requirements engineering is done in practice and whether resources are equipped to execute the process effectively.

Using both these inputs, an adapted requirements engineering process was designed based on the results of the survey. This adapted process validation was done through the analysis of results and application of existing knowledge to produce new knowledge. Results will be published to practitioners as well as the research community.

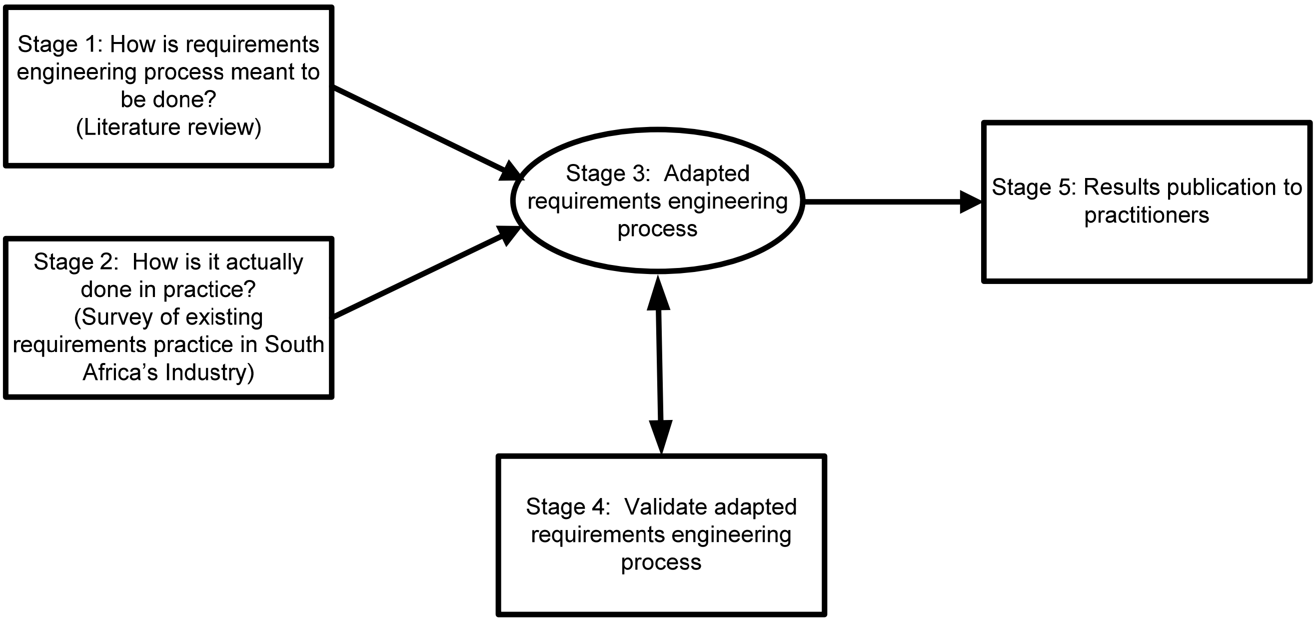

Figure 5: Research design

The detailed steps of the research process followed to facilitate the research design are explained next.

1.6 Research Process

A structured approach was followed by the researcher to find answers to the research questions (Cooper and Schindler, 2008). The starting point was to formulate the research questions based on the dilemma faced in practice (Cooper and Schindler, 2008). A literature review was done of all published work on the topic to provide the theory as background on which the research was built (Quinlan, 2011). In parallel with this, an industry review was done of the requirements discipline to determine the alignment or gaps between theory and practice.

The results of both the literature and industry review were used as input to the final process to improve the requirements process executed in practice. The research process as adapted from Quinlan (2011) and Cooper and Schindler (2008) is illustrated in Figure 6. The detailed objectives of each stage will be discussed next.

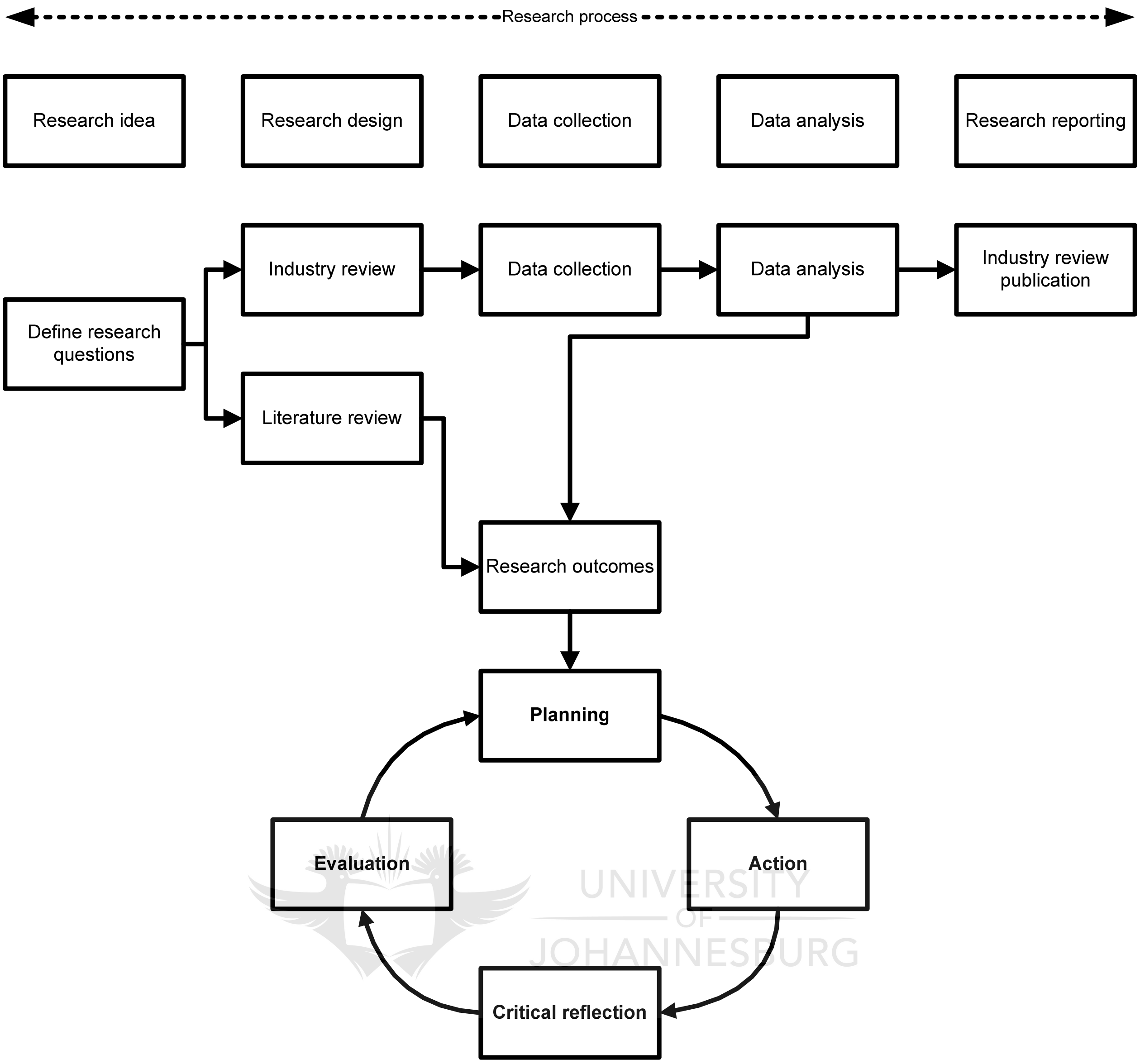

Figure 6: Research process

1.6.1 Stages 1 and 2: Literature and Industry Reviews

The literature review was done to acquire an understanding of and to confirm the body of knowledge in requirements engineering (Quinlan, 2011). The purpose of the literature review was to:

- validate the researcher's knowledge of requirements engineering
- establish what is known and what is not known in requirements engineering
- highlight gaps in the body of knowledge, i.e. confirming what the unanswered research questions are in requirements engineering.

The literature review established the basis for the research work. This was used to develop a questionnaire to understand how the requirements engineering process is executed in practice and to confirm knowledge about the current state of practice (Davis and Hickey, 2002). The knowledge of the current state of practice provided a framework of what is required in practice to ensure that any new knowledge created by the research has practical value (Davis and Hickey, 2002).

The main purpose of surveying how requirements engineering is done in practice was to:

- describe how the requirement engineering process is executed by practitioners
- establish what is used and what is not used in practice
- highlight gaps between industry and theory
- describe requirements practitioners' behaviour.

The industry review of how things are done in practice has been developed based on a theoretical framework. To ensure that the most appropriate research method was used to survey the industry, a structured approach was followed to collect and analyse data and publish the results, as illustrated in Figure 6.

Data analysis involved the data collected being reduced, summarised into a usable format and patterns in data being identified (Cooper and Schindler, 2008). The data analysis followed four stages as described by Quinlan (2011):

- Stage 1 was to engage in a descriptive analysis of the collected data.
- Stage 2 was to interpret the data.
- Stage 3 used the results of stages 1 and 2 to draw conclusions from the data.
- Stage 4 was the theorisation stage. In this stage the results from the first three stages were applied to existing knowledge to produce new theory.

From this analysis answers to the research questions were derived. It is at this stage that the degree of consistency of results with the theory was determined.

1.6.2 Stage 3: Application and Implementation

The final stage of the research was to take the results from stages 1 and 2 and improve the application of the requirements engineering process in practice (Quinlan, 2011). To improve performance in practice a cyclical process was followed to:

- plan the changes required
- implement the changes and measure the impact
- reflect on the impact of changes made
- evaluate the impact and determine its value.

1.7 Layout of the Report

Chapter 2 is a literature study that investigates what other researchers have already found in the requirements engineering discipline across communities. The scope of this review plots the landscape of current reported knowledge in terms of the requirements engineering process across all requirements communities. The existing tools, techniques and modelling methods to assist in executing activities during the requirements engineering process are evaluated. The knowledge of the factors that impact on the quality of the output of the requirements engineering process is also reviewed. Finally, the current trends in requirements research are highlighted.

In chapter 3 alternative research methods are first evaluated and a motivation for the survey as the most appropriate research method to obtain answers to the research questions is given. Secondly, the research design is explained. The research design details what questions the study answers, identifies the data relevant to answer these questions and explains how relevant data was collected and analysed (Cooper and Schindler, 2008). The questionnaire was designed to collect data in order to answer the research questions. Firstly, to describe how the requirements engineering process is executed, the practitioners were asked how the activities of the requirements engineering process are executed in practice and an attempt was made to measure the quality of the requirements delivered in practice. Secondly, data was collected about the trust relationships between the requirements practitioner and relevant stakeholders as well as about communication behaviour.

Chapter 4 contains a description and interpretation of the data collected on how the activities of the requirements engineering process are executed in practice. This generated knowledge of how the requirements engineering process is executed practically. This knowledge is used to determine if the existing requirements engineering knowledge base is actually migrated into practice by comparing the baseline with how the requirements engineering process is executed in practice.

In chapter 5 the data collected on how practitioners behave during the execution of the requirements engineering process is described and interpreted. The data describes the trust relationships between the requirements practitioner and relevant stakeholders as well as the impact of these relationships on communication.

Chapter 6 summarises the results from the industry and behaviour review. Conclusions are drawn from the results. These are used to generate new theory that can be applied to the requirements engineering process in practice.

Chapter 7 concludes this study.

1.8 Conclusion

The requirements discipline is established within the system engineering, software engineering and business analysis communities. There is an extensive knowledge base within each community on how requirements are identified and what tools and techniques are available during the execution of each activity of the requirements engineering process. Requirements engineering is about defining the problem to be solved. To successfully "solve" the problem, the problem must be understood. It is therefore vital that the input, which is requirements engineering, be done accurately. If not, all other stages or processes can be done perfectly, but the solution implementation will still fail due to poor quality requirements in the initial stage.

The importance of the requirements discipline is acknowledged across communities; however, in practice many challenges are experienced in the requirements engineering process during solution delivery. Understanding practitioners' behaviour that causes communication problems and finding solutions to these practitioners' industrial problems are required to overcome the challenges faced and thus to benefit the practitioners.

The purpose of this study was to generate knowledge about how the requirements engineering process is executed in practice, how practitioners behave during the process and if the practitioners' behaviour contributes to the challenges experienced in the process during solution delivery. This defines the existence of dependencies between the process and behaviour that would dictate what can be done to improve the requirements engineering process for practitioners.

A literature review is required to acquire and confirm the knowledge on the requirements engineering process. This literature review summarises the available knowledge on the process, and the tools, techniques and modelling methods to assist in executing activities during the process. Additionally, the challenges that impact on the quality of the requirements, which are the output of the requirements engineering process, are identified.

CHAPTER 2 Literature Review

The first stage of the research design step of the research process was to do a literature review to acquire and confirm knowledge within the requirements engineering discipline. The literature review established what is known and what is not known in requirements engineering. This framework provided insight into the body of knowledge and confirmed the unanswered research questions in requirements engineering.

The following sections provide summarised knowledge from literature on the requirements engineering process and the existing tools, techniques and modelling methods to assist in executing activities during the requirements engineering process. The knowledge of the factors that impact on the quality of the output of the requirements engineering process is also reviewed.

2 Requirements Engineering

Business change forces companies to always look for alternative ways and solutions to be more efficient in achieving their objectives.

Whether a software solution is developed or bought, to be used by users and business, the developers must understand what the product or system is intended to achieve for the user (Robertson and Robertson, 2010a). To understand these user requirements knowledge is required about the environment in which the product or system will operate, as well as about the activities performed by the users in this environment (de Oliveira et al., 2004). Different users have different pieces of knowledge about the activities performed in the environment (Wu et al., 2009). When all the pieces of knowledge are brought together, a more complete understanding of the problem in the world of the user, with all influences from the environment, can be derived. This discovery process that is performed to understand the problem that needs a solution is requirements engineering.

Requirements engineering is about solving business problems. To solve a problem in a way that the problem stays solved, one needs to know *what* problem should be solved, *why* it needs to be solved and *who* should be responsible for solving the problem (van Lamsweerde, 2009). During the 1990s Gause and Weinberg (1990) stated that the *“fledgling problem solver invariably rushes in with solutions before taking time to define the problems being solved”*.

The objective for this chapter is twofold. Firstly, it provides the theoretical framework within which the research was done and secondly, it generates a context to establish what is known and what is not known in the requirements engineering discipline.

2.1 Requirements Purpose

The purpose of requirements engineering is to maximise the likelihood that a solution development or maintenance initiative will deliver applications that function as desired. The saying "garbage in, garbage out" is a very good description for the problems experienced in requirements. Even the best requirements management practices cannot make up for inaccurate requirements (Schwaber, 2006).

The benefits of quality requirements have also been emphasised by Dorfman and IEEE standards (Dorfman, 2000; IEEE, 1998b) as follows:

- There is agreement among developers, customers and users on the problem to be solved and the acceptance criteria for the delivered system.
- A sound basis exists for resource estimation (cost, resource quantity and skills, equipment and time).
- The achievement of goals with minimum resources (less rework, fewer omissions and misunderstandings).
- There is a baseline for validation and testing.
- The implementation of the solution is facilitated for users.
- Improved system usability and maintainability.

The main purpose is to get the input to the downstream process right the first time.

2.2 What is a Requirement?

A definition of a requirement is provided by the International Institute of Business Analysis (IIBA, 2009) as:

- *"A condition or capability needed by a stakeholder to solve a problem or achieve an objective.*
- *A condition or capability that must be met or possessed by a solution or solution component to satisfy a contract, standard, specification, or other formally imposed document.*
- *A documented representation of a condition or capability as in (1) or (2)."*

The IIBA based this definition on the IEEE Standard Glossary of Software Engineering Terminology (IEEE, 1990).

A requirement is a collection of capabilities originating from users and stakeholders (organisational, legislation, and industry standards) that all must be met by the solution to solve the problem or achieve the objective (Aurum and Wohlin, 2005). Requirements are classified in many ways and the IIBA (2009) uses four main categories to classify requirements as illustrated in Table 1.

Table 1: Requirements classification (IIBA, 2009)

Requirements Classification	Description
Business Requirements	These requirements define the high-level goals, objectives and needs of the organisation.
Stakeholder Requirements	Capability required by particular stakeholder or class of stakeholders.
Solution Requirements	Functional Requirements: What capability the solution must provide the users.

	Non-functional Requirements: Requirements describing the constraints that must be taken into account to ensure the functional requirements are met.
Transition Requirements	Capabilities required ensuring a transition from the current business state to the future state. Typically these are once off and not required once transition is complete.

It is often assumed that stakeholders already know what the requirements are at the beginning of a project. As far back as the 1970s Bell and Thayer (1976) cautioned that "*requirements for a system, in enough detail for its development, do not arise naturally. Instead, they need to be engineered and have continuing review and revision*".

To collect all the capabilities required and ensure that the problem with all its influences has been understood, a discovery process needs to be facilitated. A process is a framework which provides logical steps to organise work effectively when building systems (Dittrich et al., 2002). When implementing a solution, different process models can be used to implement a possible solution throughout the solution development life cycle. The process model followed by an implementation team depends on prior experience of the resources, standard approaches used by the organisation or problem type to be solved (Sommerville, 2001). A process model in system and/or software engineering typically has the activities of specifying, designing, implementing, validating, deploying and maintaining (Sommerville, 2004). A few process models are discussed in the following section.

2.3 Engineering Processes

One of the first structured approaches developed was the waterfall process. In this model as illustrated in Figure 7, the process is executed in an orderly sequence (Leffingwell, 2011). Each stage is completed before the next stage starts (Leffingwell, 2011). Requirements are agreed, a design is created, after which the coding follows and then testing is done. The final step is integration. In practice when implementing complex systems, it is almost impossible to have requirements that do not change during the implementation life cycle (Dorfman and Thayer, 2000). The advantage of the model is that it is a simple process to manage (Sommerville, 2001).

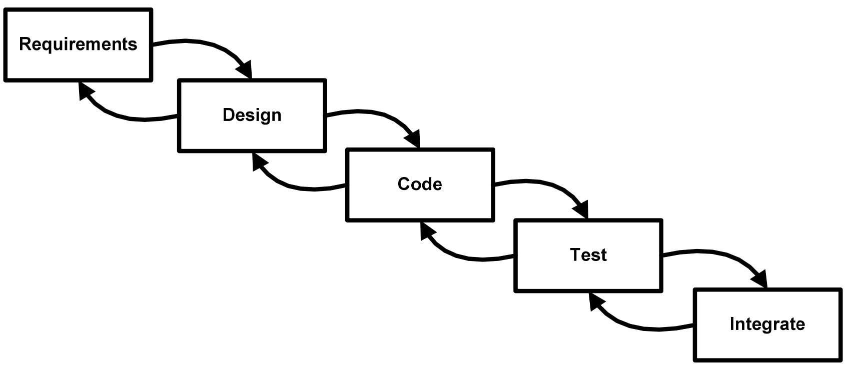

Figure 7: Waterfall model (Dorfman and Thayer, 2000)

An iterative approach is used in the waterfall model where each successive step provides feedback to a previous step (Royce, 1970). However, the waterfall model is mostly interpreted as a sequential linear process (Boehm, 2006).

In high-risk implementations, especially where there is complex integration with high volumes of data between multiple systems, prototyping is used. Typically only one or two interfaces are constructed of the final system to simulate volumes and response times. Users can, after the prototyping, gain a better understanding of the final system and then provide better input into the requirements. Prototyping is also used in user interface applications by creating mock-ups and getting feedback from users before finalising all user interfaces. The prototype approach is illustrated in Figure 8.

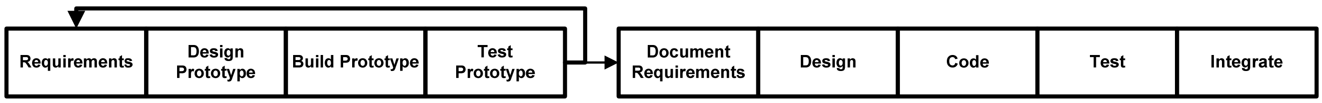

Figure 8: Prototyping life cycle model (Dorfman and Thayer, 2000)

During prototyping an initial version of the software is produced to which users are exposed. Based on their feedback, refinements are made. The users' feedback is used to gain a better understanding of the problem. It is a supportive tool to elicit input from users and validate requirements (Sommerville, 2001).

Incremental development is a combined approach between evolutionary development which makes use of prototyping and the waterfall approach (Sommerville, 2004). This approach is based on developing the system incrementally to satisfy the urgent immediate need, exposing it to the end-users and refining it with many versions until the final system is completed. The incremental iterations are displayed in Figure 9.

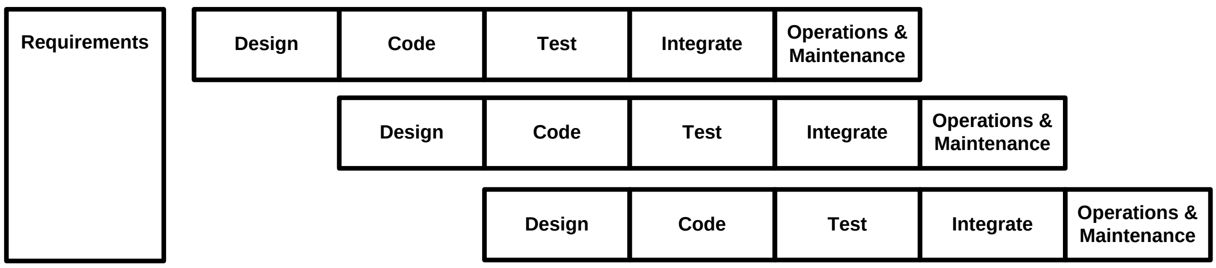

Figure 9: Incremental development model (Dorfman and Thayer, 2000)

The advantage of the incremental approach is that it allows for design changes or delays in finalisation of requirements. This could result in software that is structured inefficiently and difficult to maintain (Sommerville, 2001).

The spiral model addresses the problem of development cost estimation that cannot be done accurately. The approach followed in this model is a combination of all the other models but the main driver is risk (Boehm, 1986). The project is evaluated continuously after each phase. Each loop of the spiral in Figure 10 represents a phase in the project. After each iteration, changes can be made based on the re-evaluation. If the project needs to be terminated, this model will indicate it before all the phases have been completed.

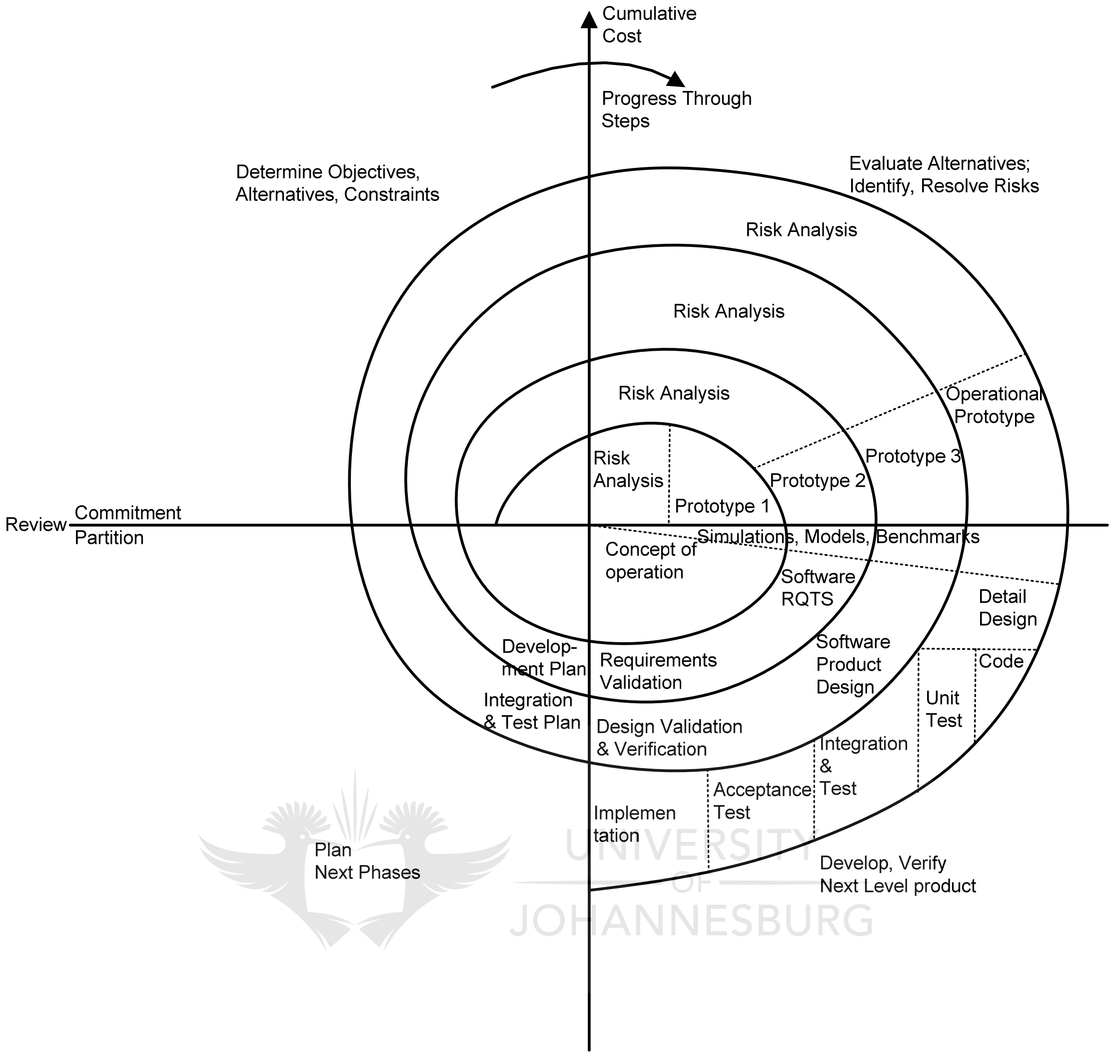

Figure 10: Spiral Model of the Software Process (Boehm, 1986)

In iterative processes a discovery-based approach is followed. This iterative nature of the process was the basis on which new agile methods were developed (Leffingwell, 2011). A number of adaptive (agile) methods are used during software development such as Adaptive Software Development, Extreme Programming, Scrum, Dynamic Systems Development Method and Crystal Methods (Leffingwell, 2011; Sillitti and Succi, 2005). An extreme high-level view of these approaches is that the code is written very quickly without detailed design, after which it is evaluated by customers in actual use and adapted after feedback. Detailed descriptions for these methods are available in literature (Sillitti and Succi, 2005; Leffingwell, 2011; Sommerville, 2004; Pinheiro, 2003).

All these agile methods share the same underlying basis which can be described by five elements (Sommerville, 2004; Leffingwell, 2011). The elements are summarised as follows:

- Collaboration: Customers are involved throughout the process. They continuously evaluate the iteration delivered and provide feedback.

- Incremental delivery: The software is developed in increments. The customer specifies the requirements that must be included in each increment.
- People, not process: Individuals are trusted to do their job in their own way without prescriptive processes.
- Change: The increments are changed as the customer dictates instead of following a plan.
- Simplicity: There is a focus on simplifying solution development as well as the process followed.

One of the best-known agile methods, extreme programming, is illustrated in Figure 11. Requirements are expressed as a user story for iteration, which are directly implemented as a series of tasks. As only the iteration in progress user story is done, the entire solutions requirements, architecture and design emerge over time during the course of the project (Leffingwell, 2011).

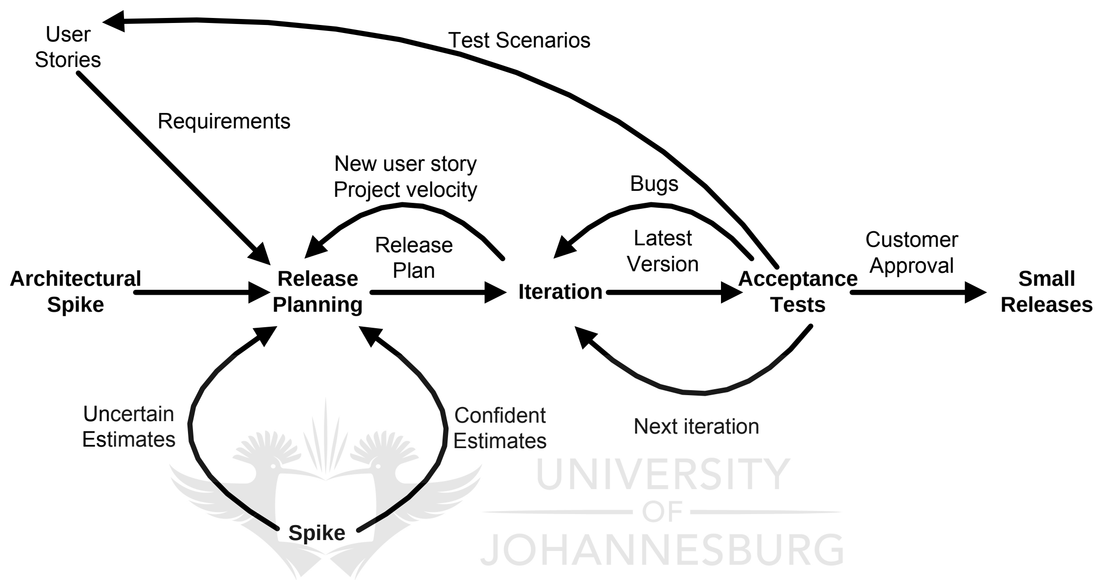

Figure 11: Extreme Programming (Leffingwell, 2011)

These agile methods could be difficult to implement in environments where the customers with the knowledge of the requirements do not have time to be part of the development process. The methods require high interaction and certain people do not have the personality to support this either (Sommerville, 2004). The agile methods are more appropriate for medium-sized problems and not suitable when solving complex problems where teams are located in different locations and the solution is not mission critical (Sommerville, 2004; van Lamsweerde, 2009).

Multiple engineering models can be applied during problem solution. During the problem solution process, the assumptions of problem complexity, the number of users with knowledge available and the type of solution required have a direct impact on which of the approaches would be most appropriate (van Lamsweerde, 2009). As emphasised by Boehm (2002), the characteristics of the problem that must be solved should be compared with those of the engineering model to determine the relative risks.

The engineering model selection will impact on how the requirements will be documented. In a small environment, with a rapidly changing marketplace where people are capable and work collaboratively agile methods would be appropriate and the requirements will be documented less formally (Boehm, 2002). In an environment where people do not work collaboratively, requirements will have to be documented formally to minimise misunderstandings (Boehm, 2002).

Although the method of requirements documentation could vary based on engineering model selection, the requirements have to be understood to solve the problem. In the next section the proposed logic steps to follow during the requirements engineering step are explored.

2.4 The Requirements Engineering Step

Requirements engineering was defined in the 1970s by Ross and Schoman (1977) as *"a careful assessment of the needs that a system is to fulfil.* [The assessment] *must say why a system is needed, based on the current and foreseen conditions, which may be internal operations or an external market. It must say what system features will serve and satisfy this context. And it must say how the system is to be constructed*".

Greenspan et al. (1994) define requirements engineering as a specification of the system that must be developed. However, before a requirements specification can be produced, an understanding is needed of the application domain in which the system will function, including the organisational environment. The specification needs to capture as much as possible of this understanding to support communication between all stakeholders, for example users, customers, developers and testers.

The above definitions all emphasise that the requirements engineering process is about transforming information from multiple sources into a formal representation called the specification document, which is used to get a common agreement of what the working solution should be doing.

The requirements engineering step in a software engineering process can be represented as its own process which has inputs, a function and outputs. A process is an organised set of activities that transform inputs to outputs to achieve a specific result (IEEE, 1990; Kotonya and Sommerville, 1998). A process serves as a guideline to solve a problem. Once a problem has been solved, a process can be documented to capture the knowledge to be reused in similar problems in future (Kotonya and Sommerville, 1998). The requirements engineering process is represented in Figure 12.

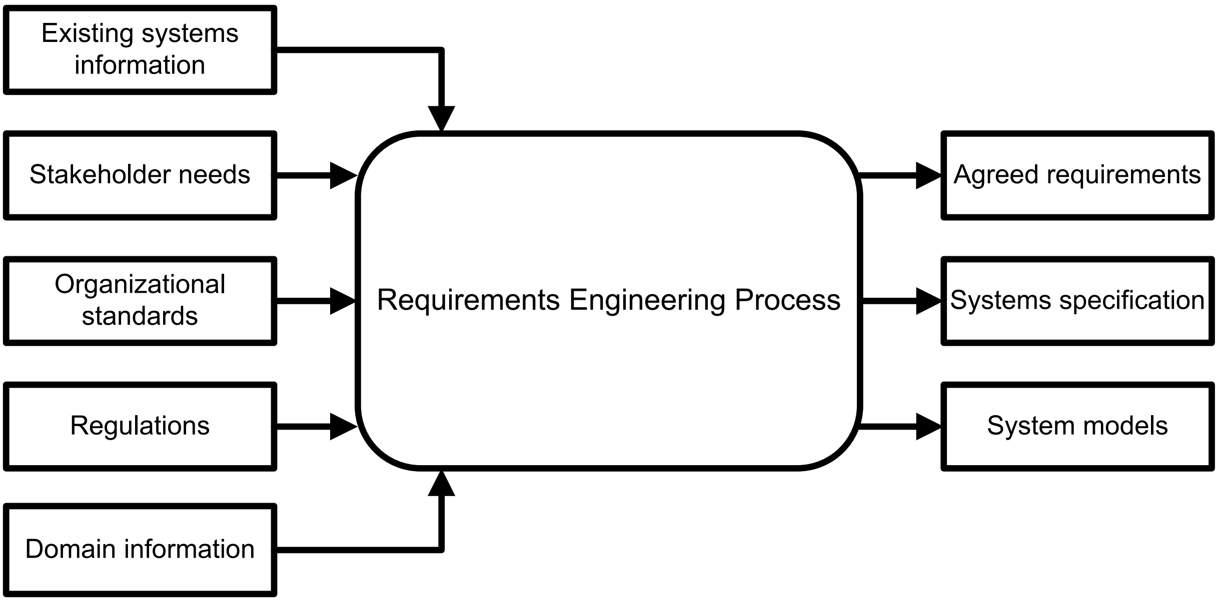

Figure 12: Inputs and outputs of the requirements engineering process (Kotonya and Sommerville, 1998)

The desired output of the requirements engineering process is commonly agreed requirements by all stakeholders presented in a specification document (Pohl, 1994). The specifications are used to facilitate the communication and should be complete to ensure that a working solution fit for purpose can be produced from requirements (NATURE, 1996). This specification document could be written in natural language or presented using formal model tools and techniques (Hsia et al., 1993).

The goals of the requirements engineering process are described by Pohl (1994) as:

- transforming unclear user needs into a complete system specification
- transforming informal knowledge into formal representations
- a common agreement on the specification out of the personal views.

To deliver requirements to enable the development of a solution that is fit for purpose, a well-defined process is required (Arthur and Gröner, 2005). The following section will explore the versions of the requirements engineering process available.

2.5 Requirements Engineering Process Models

The term “requirements engineering process” is defined as the systematic process of developing requirements through an iterative co-operative process of analysing the problem, documenting the resulting observations in a variety of representation formats and checking the accuracy of the understanding gained (Loucopoulos and Karakostas, 1995; Pohl, 1996).

This definition can be illustrated by a model explained by Wiegers (2003b) that splits the requirements engineering domain into two. The initial step is requirements development to derive a complete user specification as illustrated in Figure 13.

Once the specification is produced as an output of the requirements development step, it must be agreed on by all stakeholders. This forms the baseline requirements that will be used to build the solution. Once the baseline requirements have been established and agreed on, changes should be managed to ensure that all stakeholders stay in agreement. This is presented as requirements management, the second step in the requirements domain as illustrated in Figure 13.

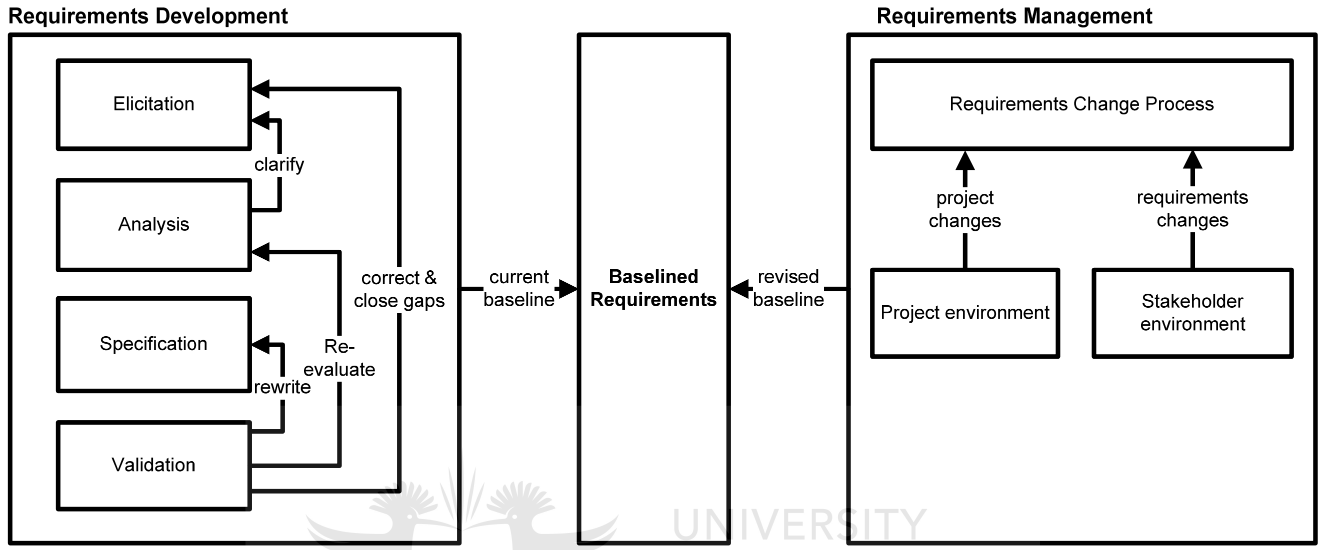

Figure 13: Requirements engineering domain (Wiegers, 2003b)

The common activities in the requirements engineering process are elicitation, analysis and documentation, negotiation and validation, and change management (Aurum and Wohlin, 2005). Several models are available to describe the requirements engineering process. Many have similar activities but they are executed in different forms, namely linear, incremental, non-linear, spiral or adaptive processes.

Macaulay (1996) describes the requirements engineering process as a linear set of activities which includes initial concept, problem analysis, feasibility and choice of options, analysis and modelling and requirements documentation.

Both incremental models by Wiegers (2003b) and Kotonya and Sommerville (1998) suggest that the activities are interconnected, incremental and iterative as illustrated in the requirements development domain of Figures 13 and 14. Requirements are elicited, and information is processed to be understood and analysed. After this the derived requirements are documented in a specification which all stakeholders will validate. Both models are executed as an iterative process which continues throughout the life cycle of the process.

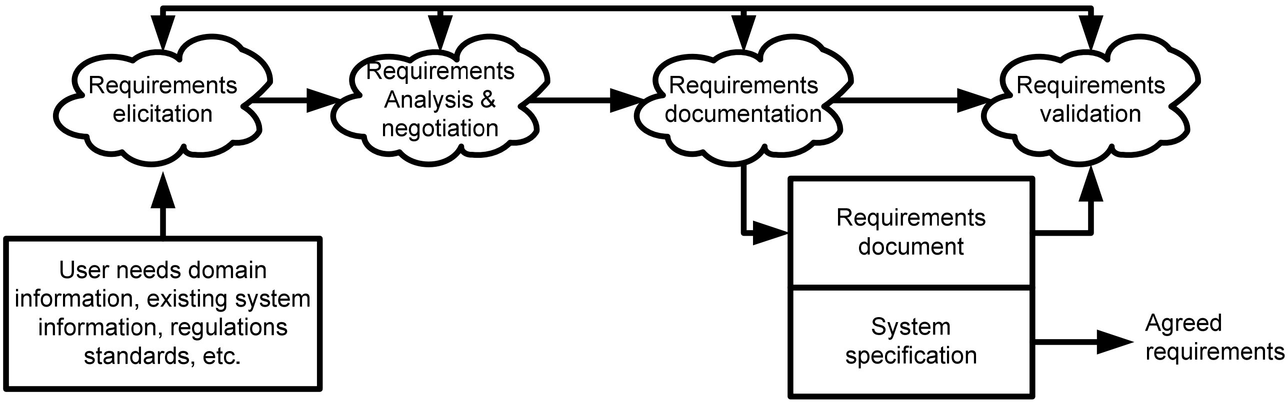

Figure 14: Linear Requirements Engineering Process Model (Kotonya and Sommerville, 1998)

A cyclical iterative model is presented by Loucopoulos and Karakostas (1995) in Figure 15. This model demonstrates interactions between activities including the user and problem domain. This is similar to the three models already discussed, but the order of the activities is non-linear and a cause-effect relationship is illustrated between the activities.

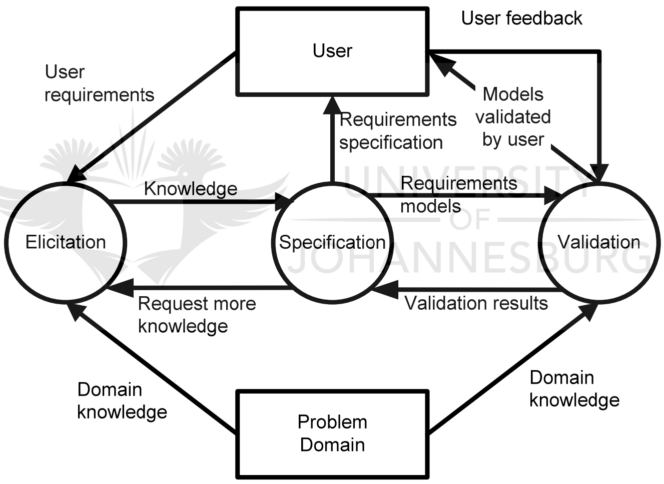

Figure 15: Requirements engineering process (Loucopoulos and Karakostas, 1995)

The requirements engineering process is represented by Van Lamsweerde (2009) as a spiral model adapted from Boehm (1986) and Kotonya and Sommerville (1998). This spiral model is illustrated in Figure 16. The spiral model represents a sequence of activities being performed iteratively. A new iteration can occur at a different stage of the life cycle of the process. At the end of each iteration, a decision determines if the requirements can be baselined, or else this process is repeated. After multiple times, a set of consolidated requirements are derived.

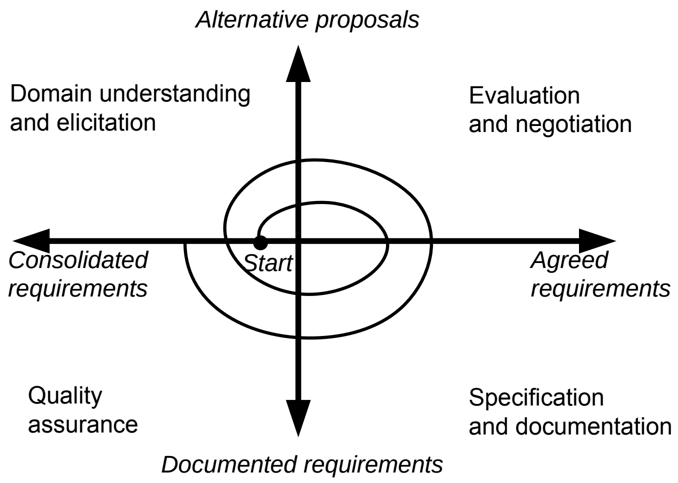

Figure 16: The requirements engineering process (van Lamsweerde, 2009)

All the models discussed deliver the desired output mentioned by Pohl (1994), which is commonly agreed requirements by all stakeholders presented in a specification document. The models described in the literature are all in line with what is expected from the function of the requirements engineering process as summarised by Boehm (1986) and Kotonya and Sommerville (1998):

- Understand the problem using information from stakeholders, regulators, organisational factors and existing systems into a set of requirements.
- Model and analyse the problem.
- Obtain agreement on the nature of the problem.
- Communicate the problem.
- Manage change as the problem evolves.

Existing studies of the requirements engineering process in practice indicate that the processes reflected in literature do not necessarily reflect the requirements engineering processes in practice.
Chatzoglou and Macaulay (1996) compared the requirements process execution by academia, software houses and industry. This study confirmed that the requirements process is an iterative one. Although the iterations are not planned for, they are triggered by problems such as lack of information, user behaviour, changes and skills of resources. This study concluded that many projects in industry do not use any methodology during the projects.

Houdek and Pohl (2000) performed a case study to determine the requirements process used in a company. They found that the requirements engineering activities as described by literature were not performed as process steps with a clear input; the activities were heavily intertwined. In another case study Martin et al. (2002) concluded that requirements engineering is not acknowledged as a process in its own right in practice, but rather as an aspect of the software process. The majority of the projects evaluated in this study followed a linear model until the prototype was completed, after which they followed an iterative nature.

Nguyen and Swatman (2003) found that requirements engineering in practice is not a systematic, smooth and incremental process. They found that the process involves both incremental building as well as reorganisation of the requirements process. This reorganisation typically happens at the point of insight and not due to a systematic process. Nguyen and Swatman (2003) found this pattern to be aligned with general problem-solving processes in other human activities and not aligned with literature describing the requirements engineering process as a cyclical one consisting of elicitation, analysis and validation. In a survey done by Neil and Laplante (2003) they found that in practice the waterfall model is used extensively in combination with prototyping.

A recent study by Hansen et al. (2009) confirms that industry recognises that determining requirements is an early task in the development process, but does not see requirements as a process following activities such as elicitation, specification, negotiation and validation.

These field studies all indicate that the requirements engineering process in practice is not defined in a structured methodological way. In most cases the process is an unstructured problem-solving activity. The purpose of each requirements engineering process activity according to literature is described in the following section.

2.6 Requirements Engineering Process Activities

The activities during the requirements engineering development process have been mentioned as elicitation, analysis, specification and validation. Before these activities can be started planning is required. What should be done during the planning to execute these activities as well how to execute each of these activities are described below, including tools, techniques and methods available to utilise during each activity.

2.6.1 Requirements Planning

As determining requirements is the first step in the problem-solving activity it provides the basis for most activities during implementation. Requirements provide the basis for project management tasks such as (van Lamsweerde, 2009; Carkenord et al., 2010):

- Scope: Definition of the problem will be solved.
- Project management: All project costs, resources and delivery times are estimated based on requirements.
- Communication: Reference documentation to all parties involved.
- Technical: All software design/architecture, testing, documentation and training manuals are based on the requirements.
- Legal: If delivery partners are used, the requirements will be linked to a contract to state what needs to be delivered.

When work is project oriented planning is the key factor to success (Carkenord, 2009). The requirements practitioner is responsible for creating a requirements management plan which is the key input to the overall project plan (Carkenord et al., 2010; Weese and Wagner, 2011). This plan should detail the following:

- How and when requirements activities, including elicitation, analysis and modelling, specification and validation, will be performed.
- Who must be involved in all the requirements activities.

- Techniques that will be used to perform the activities.
- Requirements of deliverables from each activity.
- How requirements will be communicated during the process.
- How requirements activity performance will be monitored.

If a requirements management plan is generated, work required during the requirements process is identified upfront. This can be communicated to all those involved in generating a common understanding.

2.6.2 Requirements Elicitation

Requirements elicitation is the discovery of the knowledge of the problem world in which the system will operate (van Lamsweerde, 2009). The elicitation step is very communicative (Zowghi and Coulin 2005). Requirements elicitation cannot be solved with technology; it is all about how the knowledge is acquired in the social context (Goguen and Linde, 1993). The significance of this social context would be less if technical and business resources spoke the same language (Bostrom, 1989).

The relevant knowledge about the problem is distributed among many stakeholders (Loucopoulos, 2005). Wu et al. (2009) indicate that no one user in the organisation possesses all the knowledge required for a complete set of user requirements. Each user has a piece of knowledge required to be competent in his or her work. When all the knowledge is brought together, a complete set of requirements can be derived. Hence the importance, as explained by Wu et al. (2009), of guiding and properly organising users to enable the implementation team to discover the full extent of the user requirements.

The requirements engineer is responsible for deriving a complete set of requirements from the stakeholders. Knowledge will only be exchanged once relationships have been established with stakeholders. The communication and common language established in these relationships will dictate the information exchange during elicitation (IEEE Computer Society, 2004).

Kotonya and Sommerville (1998) define requirements elicitation through four components as illustrated in Figure 17.

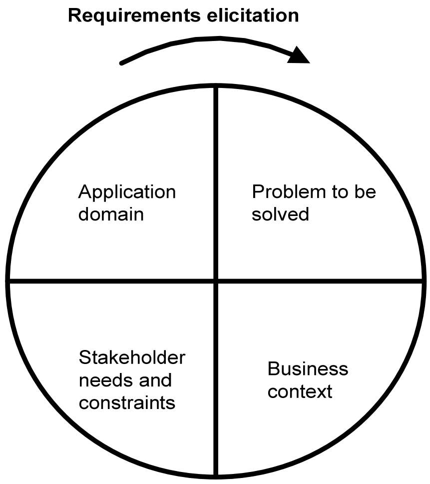

Figure 17: Components of requirements elicitation (Kotonya and Sommerville, 1998)

The first component is understanding the application domain. De Oliveira et al. (2004) mention that to generate quality requirements the following knowledge is required:

- Knowledge about the domain in which the solution will operate
- Knowledge about the activities performed in this domain

The environment needs to be explored from a political, organisational and social aspect relating to the system (Zowghi and Coulin 2005).

The second component is understanding the specific customer problem. The problem is defined by Leffingwell and Widrig (2000) as the home (problems, culture, language) of the users and stakeholders whose needs/problems must be addressed to develop a system. Complete requirements will be a result of identifying all sources of requirements including stakeholders (Zowghi and Coulin 2005). Stakeholders are the most obvious source of requirements. Current users and subject matter experts can supply information about problems experienced and new requirements (Kotonya and Sommerville, 1998). When replacing an existing system, current business processes and system documentation provide useful information about the organisation and system (Zowghi and Coulin 2005).

Thirdly, a good business understanding is required to understand how the system interacts and contributes to the business. To measure the successes of the solution, a clear understanding is required of business goals and issues (Zowghi and Coulin 2005).

Finally, an understanding of the needs of each stakeholder (end-user, manager, business department, technical architecture etc.) must be obtained to know how the system should support the business operational processes and how it will impact the world.

The literature mentions many approaches or techniques to determine the knowledge required. The following section contains a summary of the available techniques to elicit the requirements.

Requirements Elicitation Techniques

The choice of elicitation technique depends on resource availability, information required and types of problems to be solved. A summary of the techniques discussed in literature is presented in Tables 2 to 7 below. The techniques have been classified by Nuseibeh and Easterbrook (2000).

Table 2: Elicitation techniques - traditional approaches

Techniques	Description	Advantages	Limitations
Interviewing	One-to-one discussions with a stakeholder using unstructured or structured approaches. Structured interviews are driven by a set of predefined questions (Hansen et al., 2009).	Effective in collecting large amounts of information (Zowghi and Coulin 2005).	There is a dependency to generate the right questions for the right stakeholder (Zowghi and Coulin 2005).
Questionnaires	Submitting a list of specific questions, open and/or closed, to selected stakeholders for completion (van Lamsweerde, 2009).	Efficient way of collecting information from multiple stakeholders quickly (IIBA, 2009).	Limitation in the depth of knowledge available (Zowghi and Coulin 2005).
Document analysis	Analysis of existing documentation such as organisational charts, processes and user or other manuals of existing systems (Nuseibeh and Easterbrook, 2000).	Information about the existing context enables knowledge acquisition (IIBA, 2009).	Documentation could be out of date or non-existing (IIBA, 2009).

Table 3: Elicitation techniques - group approaches

Techniques	Description	Advantages	Limitations
Brainstorming	Brainstorming session is a gathering of interested people whose task it is to generate ideas (Robertson and Robertson, 2010a).	Promotes free thinking, allowing for innovative/creative solutions (Zowghi and Coulin 2005).	There is a dependency on participants' willingness to participate. Interpersonal politics could limit participation (IIBA, 2009).
Groupwork	Groupwork such as collaborative meetings (Gottesdiener, 2002).	Commit and involve all stakeholders and corporations (Zowghi and Coulin 2005).	Dependency on stakeholders' composition and availability. Risk of group dynamics could lead to incomplete information (van Lamsweerde, 2009).
Joint	A consensus building workshop	With correct stakeholders	Effective management of

application development	with unbiased facilitator (Nuseibeh and Easterbrook, 2000).	involved, decisions and issues can be resolved quickly (Zowghi and Coulin 2005).	sessions (Zowghi and Coulin 2005).
Requirements workshop	Different group meetings with a selected group of stakeholders to discover requirements. Group could be cross-functional with different stakeholders from different business areas or focus groups often used in market analysis (Zowghi and Coulin 2005).	Innovation and cross-functional thorough exploration generates valuable information (Hansen et al., 2009).	Potential risk for destructive conflict due to multiple stakeholders (Hansen et al., 2009).

Table 4: Elicitation techniques – exploratory approaches

Techniques	**Description**	**Advantages**	**Limitations**
Prototyping	A prototype is an initial preliminary version of a solution or system (Kotonya and Sommerville, 1998). Two types of prototypes are used: throw-away (discard after development) and evolutionary (become part of final solution).	During development of user interfaces a prototype enables stakeholders to play an active role in developing requirements (IIBA, 2009).	Prototyping is expensive to produce in terms of cost and time (Zowghi and Coulin 2005).
Domain analysis	Domain analysis specifies the basic elements of the domain, organises an understanding of the relationships among these elements and presents this understanding in a useful way (Reinhartz-Berger and Sturm, 2009).	Generates a common understanding between analyst and stakeholders. Ability to reuse requirements to validate new requirements against domain knowledge (Zowghi and Coulin 2005).	Skill required to do domain analysis (Reinhartz-Berger and Sturm, 2009).
Introspection	Requirements are developed by the analyst by imagining what system functions should be available if the analyst had done the job (Goguen and Linde, 1993).	Only effective if analyst has expert domain knowledge, understands the business goals and is an expert on how business processes are executed (Zowghi and Coulin 2005).	Requirements could be inaccurate if not validated using alternative techniques (Goguen and Linde, 1993).

Table 5: Elicitation techniques – model-based approaches

Techniques	Description	Advantages	Limitations
Goal-based approaches	Hierarchy of stakeholders' goals: High-level goals (business goals) are refined into lower level goals (technical goals) and eventually an operationalised system (Nuseibeh and Easterbrook, 2000).	Assists in managing change, as a goal analysis reveals conflicting desires or expectations, allowing the trade-offs to be managed (Yu et al., 2011).	If error is made initially, there is a decremental follow-through effect (Zowghi and Coulin 2005).
Scenarios	A storyboard which illustrates the sequence of interactions between user and system (covering who the players are, what happens, why it happens) (van Lamsweerde, 2009).	Very useful to generate common understanding, validation and during test case development (Zowghi and Coulin 2005). Shows the functionality of a use case.	The internal structure of the system is typically not addressed in a scenario (Zowghi and Coulin 2005).
Viewpoints	The requirements are described from different sets of viewpoints, for example business manager, operational user and interface data flow (Zowghi and Coulin 2005).	Requirements priority can easily be derived from the different views (Zowghi and Coulin 2005).	Viewpoints do not enable the specification of non-functional requirements (Zowghi and Coulin 2005).

Table 6: Elicitation techniques - cognitive approaches

Techniques	Description	Advantages	Limitations
Repertory grids	Stakeholders are requested to categorise and assign attributes to domain concepts. This results in a matrix modelling the system, with each element categorised (van Lamsweerde, 2009).	The similarities and differences between domain entities are easily identifiable (Zowghi and Coulin 2005).	There is a limitation of specific characteristics for complex requirements (Zowghi and Coulin 2005).
Card sorting	Card sorts are based on the belief that different people categorise the world differently. Stakeholders are provided with a set of cards. Each card is associated with a domain	The domain attributes can easily be compared across respondents (Upchurch et al., 2001).	Information derived is normally at a high level and more detail could still be required (Zowghi and Coulin 2005).

	concept. These cards are then sorted into groups according to stakeholders' own understanding. Once sorted, the stakeholders explain the rationale for groupings (Upchurch et al., 2001).		
Laddering	Stakeholders are asked prompting questions and probes; then required to arrange answers in organised structured (Nuseibeh and Easterbrook, 2000).	When domain knowledge is hierarchically structured (Upchurch et al., 2001).	Stakeholders must have the ability to express domain knowledge (Zowghi and Coulin 2005).
Protocol analysis	Protocol analysis is when a user performs an activity while talking aloud, describing actions and rationale for each action (Hansen et al., 2009).	Specific information about the process that the solution must support becomes available (Zowghi and Coulin 2005).	An overly simplistic process could be described by user overlooking detail (Hansen et al., 2009).

Table 7: Elicitation techniques - contextual approaches

Techniques	Description	Advantages	Limitations
Ethnography	Analyst participates in user activities while collecting information on activities performed through observation (Hansen et al., 2009).	Where there is a need for a new system to solve problems with processes. To understand social patterns and complex human relationships (Zowghi and Coulin 2005).	Consumes significant time or resources (Hansen et al., 2009).
Observation	Analyst observes without interference how activities are performed in domain (Zowghi and Coulin 2005).	Can lead to detailed information (Zowghi and Coulin 2005).	Analyst requires skill to understand and interpret actions (Zowghi and Coulin 2005).
Apprenticing	Analyst performs actual task under supervision of expert rather than observing (Zowghi and Coulin 2005).	Spends time working with an expert, especially if specialist has difficulty explaining (Robertson and Robertson, 2010a).	Consumes significant time or resources (Hansen et al., 2009).

Tables 1 to 7 list many elicitation techniques, but these techniques cannot all be used together. Guidelines on how to choose the appropriate elicitation technique are provided by Robertson and Robertson (2010a), Robertson (2001), Maiden and Rugg (1996) and Zowghi and Coulin (2005).

2.6.3 Requirements Analysis

The analysis activity during the requirements engineering process is to analyse all information elicited and generate a list of potential requirements (Hickey and Davis, 2004). As mentioned by the IEEE Computer Society (2004), Van Lamsweerde (2009) and Sommerville (2001), the activities involved during analysis are classification, negotiation including conflict resolution, prioritisation and requirements checking.

The objective of the requirements analysis step is to increase understanding, identify problems and search for inconsistencies in the list of requirements produced (Kotonya and Sommerville, 1998; Hickey and Davis, 2004). Models are generated to understand requirements. Various modelling techniques or notations are available. Nuseibeh and Easterbrook (2000) suggest general categories for requirements modelling as follows:

- Enterprise modelling deals with understanding the organisation context.
- Behaviour modelling deals with the dynamic or functional behaviour of stakeholders or systems.
- Data modelling is used where systems generate large volumes of information to understand the information that the system must present.
- Domain modelling is used to generate descriptions about the world in which the system will be operating.

Each category of modelling approaches is discussed in more detail below.

2.6.3.1 Enterprise Modelling Approaches

These modelling approaches present the purpose of the system and express the behaviour of the system in terms of goals, tasks and resources. Agent-based models as well as goal-oriented models are typically used to do enterprise models. Descriptions of some modelling approaches are provided with some examples in Table 8.

Table 8: Enterprise modelling approaches

Model Category	**Description**	**Examples**	**Sample**
Goal-oriented models	Goal modelling focuses requirements analysis on the agents within an organisation, their goals and the interdependencies between those goals. This provides information on why a new system is needed (Yu et al., 2009).	Knowledge Acquisition in Automated Specification (KAOS). Non-functional requirements framework has five elements which determine the degree to which each non-functional requirement has been addressed (Mylopoulos et al., 1992).	KAOS (Dardenne et al., 1993). For application to non-functional requirements framework, refer to Mylopoulos et al. (1992 and 1999).

Agent-based models	Modelling of complex systems	i* organisational modelling framework presents the organisation as a network of social actors with freedom of action and dependency on others to achieve goals, execute tasks and obtain resources (Pastor et al., 2011). Tropos generates models to provide an understanding of the environment where the system must operate, including interactions that should occur between software and human agents (Bresciani et al., 2004).	i* consists of two models: strategic dependency model representing the intentional level, and the strategic rational model representing the rational level. For detail on these models refer to Cares et al. (2011).

2.6.3.2 Behaviour Modelling Approaches

A wide range of behaviour modelling methods are available, including state models, structural models, activity models, object-oriented models and formal models. Descriptions of behaviour modelling approaches are provided with some examples in Tables 9 to 13.

Table 9: Behaviour modelling approaches - state models

Model Category	**Description**	**Examples**	**Sample**
State models	Modelling the system as a set of distinct states and transition between the states. The transition from one state to another is due to an external trigger (Hansen et al., 2009; Machado et al., 2005).	Finite state machines model the behaviour of a system in time. The system can only be in one state at a time, based on a trigger event that the state changes (Brand and Zafiropulo, 1983; Cooling, 1991). Petri nets are mainly applied to model states of concurrent processes (Zurawski and MengChu, 1994).	Refer to Figure 18..

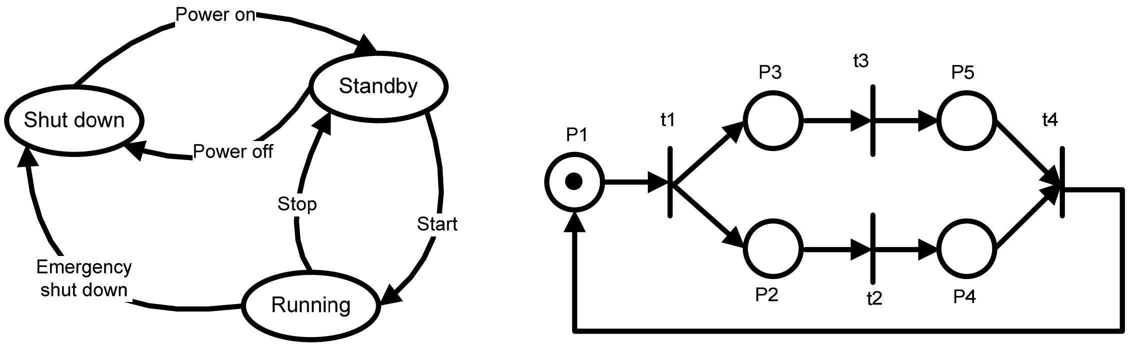

Figure 18: State transition and Petri nets diagrams (Cooling, 1991; Zurawski and MengChu, 1994)

Table 10: Behaviour modelling approaches - structural models

Model Category	Description	Examples	Sample
Structural models	Systems are modelled based on structural features of application domain (Hansen et al., 2009).	Structured analysis and design technique (SADT) (Ross and Schoman, 1977; Ross, 1977). SADT decomposes a problem into a set of hierarchical diagrams. A high-level overview diagram represents the total system. Each lower level diagram shows detail about a higher level component. Each lower level diagram connects into higher level component of the model, thus preserving the logical relationship of each component to the total system.	SADT notation is presented in Figure 19. There is always an input, an activity that is controlled or data to facilitate the process. The mechanism represents the algorithm used by the process to produce output (Kotonya and c347641045 \h 131).

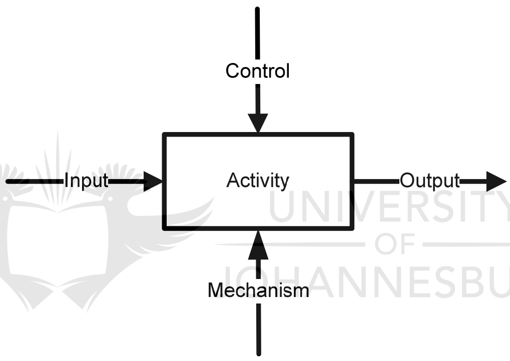

Figure 19: SADT notation

Table 11: Behaviour modelling approaches - activity models

Model Category	Description	Examples	Sample
Activity models	Modelling of the system as a collection of activities related by data or dependencies (Hansen et al., 2009; Machado et al., 2005).	Data flow diagrams are used to model activities or processes and the transactions (data) that flow between these (Cooling, 1991; DeMarco, 1979). Flow charts are used to model the flow among activities. They give the sequence of operations of well-defined activities with no dependency on external triggers (Machado et al., 2005).	Data flow diagram shows X is transformed into Y by process P1 (which requires access to data source to do its work). Refer to Figure 20.

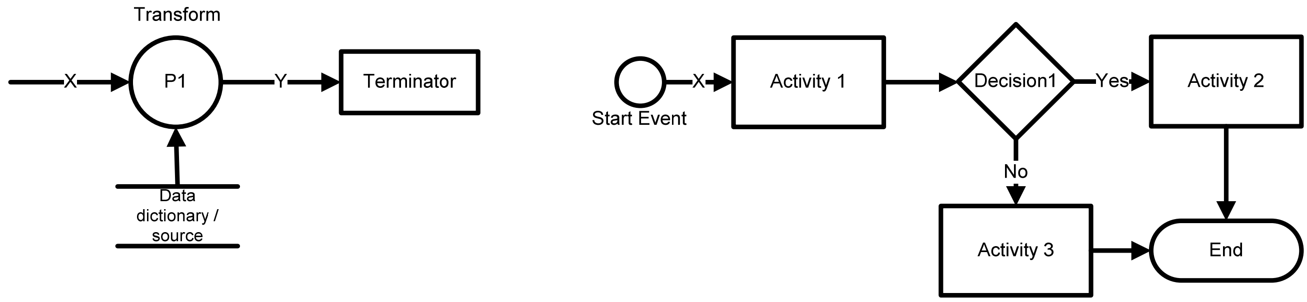

Figure 20: Data flow diagram and flow chart convention (DeMarco, 1979; Leffingwell and Widrig, 2000)

Table 12: Behaviour modelling approaches – object-oriented models

Model Category	**Description**	**Examples**	**Sample**
Object-oriented models	Modelling the problem domain by means of objects by identifying information about it, including attributes, services and relationships between objects (Van Vliet, 2008).	Model the problem as a set of interrelated, interacting objects that support reusability (Sutcliffe, 1991).	Object modelling technique (OMT) generated three models during analysis: object model, dynamic model and functional model. The object model models the structure of the problem world, the dynamic model shows the behaviour of the system and the functional model shows the functional derivation of values (Rumbaugh et al., 1991). Unified Modeling Language (UML) (Zwiers, 2011; Sutcliffe, 1991).

Table 13: Behaviour modelling approaches - formal models

Model Category	**Description**	**Examples**	**Sample**
Formal models	Models specified and constructed on mathematically based models to ensure precision (Cooling, 1991).	For a method to be formal, it must have a well-defined mathematical basis or language defined. For a detailed discussion on formal methods refer to Wing (1990) and Parnas (2009).	Trace function method (Parnas, 2009).

2.6.3.3 Data Modelling

Data modelling is used to provide identification of all data elements within a system, including their attributes and the logical relationships between data elements.

Table 14: Data modelling approaches

Model Category	Description	Examples	Sample
Data-oriented models	Modelling of the system as a collection of data related by an attribute (Machado et al., 2005).	Entity relationship diagrams (ERDs) reflect items in the problem domain that are defined as entities. These entities have data values associated with them.	Refer to Figure 21 which illustrates a requirement using an entity relationship model.

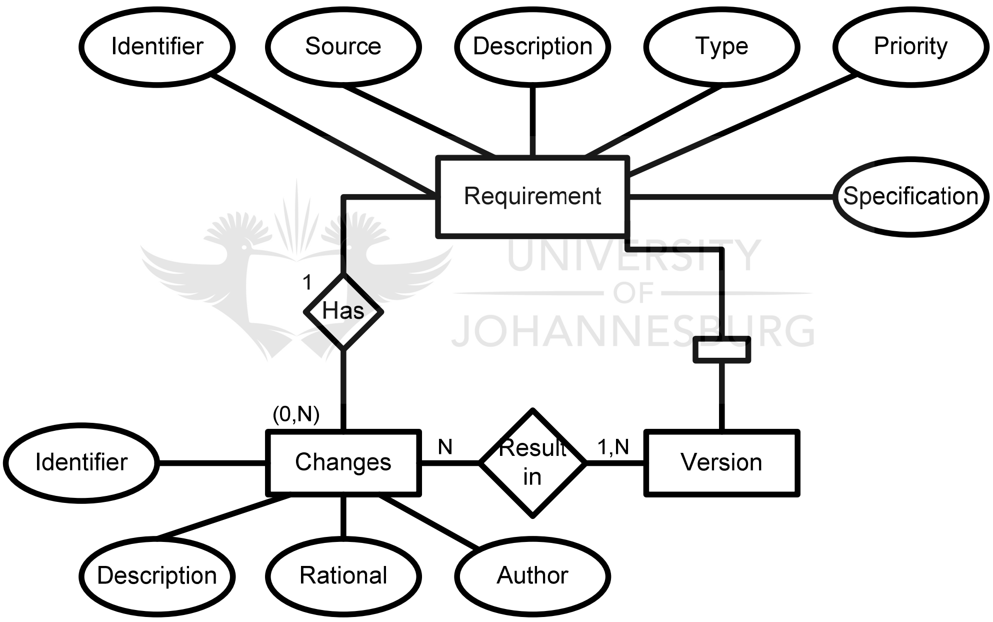

Figure 21: Data model of a requirement (Kotonya and Sommerville, 1998)

2.6.3.4 Domain Modelling

The domain model is created to be used by resources to understand each other's vocabularies and key concepts of the problem domain (Easterbrook, 1993).

Table 15: Domain modelling approaches

Model Category	Description	Examples	Sample
Domain models	Generating conceptual models of a problem domain used to create a shared understanding between resources (Easterbrook, 1993).	Multiple view approach generates conceptual models for the problem, each from a different view (Easterbrook, 1993; Machado et al., 2005).	Illustration of domain modelling is available (Easterbrook, 1993; Machado et al., 2005; Piho et al., 2011).

Tables 8 to 15 provide an overview of the modelling techniques available. These techniques provide the ability during the generation of requirements specification to express requirements more formally (Machado et al., 2005). The modelling techniques assist during analysis in establishing whether the solution proposed would be feasible, otherwise alternative solutions should be presented and the best options based on risks and goals should be agreed upon.

2.6.4 Requirements Specification

Once all information has been elicited and requirements have been analysed and modelled, the findings from these two activities should be documented in the specification document. The specification produced can be generated in various formats or languages. Natural language is often used as it is preferred by stakeholders compared to formal semantic language that has to be learned (Hansen et al., 2009; Hsia et al., 1993).

Many best practice templates are available to provide guidelines on what information should be presented in the requirements specification (Robertson and Robertson, 2010b; IEEE, 1998a; IEEE, 1998b). To achieve the benefits as discussed in 2.1, the quality of requirements is important. Quality elements of a specification have been detailed by standards available as summarised in Table 16 (IEEE, 1998b; IIBA, 2009; IEEE, 1998a).

Table 16: Characteristics of quality requirements

Quality Characteristics	Description
Correct	Accurate description of the functionality to be delivered. The correctness is validated by the source of the requirement, typically the stakeholder (Wiegers, 1999).
Unambiguous	Requirement must only have a single interpretation. All stakeholders should have a common understanding (Denger and Olsson, 2005; Robertson and Robertson, 2010a).
Complete	All requirements should be present in specification required to ensure a working solution fit for purpose by user (Denger and Olsson, 2005).
Consistent	No requirement should conflict with other requirements or with higher level

	system or business requirements. Disagreements among requirements must be resolved before development can proceed (Wiegers, 1999).
Ranked for importance and/or stability	All requirements should be prioritised based on importance or stability. Stability is expressed in terms of expected changes associated with requirement (IEEE, 1998b). To prioritise factors, refer to Robertson and Robertson (2010a).
Verifiable	For each requirement there should be a machine or human process to test if the requirement has been properly implemented (Denger and Olsson, 2005).
Modifiable	The specification of requirements must be done in such a way that there is a history of changes made to each requirement. Changes to requirements should be allowed for in an easy way, for example uniquely labelled and expressed separately from other requirements (Wiegers, 1999).
Traceable	Each requirement should be linked back to its source of origin (Wiegers, 1999).

Quality of requirements is complex to measure (Denger and Olsson, 2005). There are various guidelines and checklists to validate the quality of requirements (Firesmith, 2005; Wiegers, 1999; Sommerville and Sawyer, 1997; Heck and Parviainen, 2008; Denger and Olsson, 2005). However, poor quality requirements are still constantly identified as one of the main contributors to failed projects (El Emam and Koru, 2008; Ellis, 2008; Glass, 2003; Rodrigues, 2001; Ferrari and Madhavji, 2008).

2.6.5 Requirements Validation

The output of the requirements engineering process is commonly agreed requirements by all stakeholders presented in a specification document. Once the specification is produced as an output of the requirements development step, it must be agreed on by all stakeholders. This forms the baseline requirements that will be used to build the solution.

The priority of each requirement should be discussed by and agreed on with the stakeholders to identify the most important requirements with the greatest impact on solving the problem. Techniques that are available are discussed by Berander and Andrews (2005), Hansen et al. (2009) and Cheng and Atlee (2009). The requirements must be validated for completeness and conflicts and should reflect what needs to be done to solve the stakeholders' problem.

As many stakeholders could be involved, this is an iterative process. The typical results of a validation process are a list of problems with agreed upon actions that must be resolved (Kotonya and Sommerville, 1998). This iterative process should continue until all the relevant stakeholders are in agreement that the requirements reflect their need correctly and accurately.

As explained, once a baseline set of requirements have been agreed on, requirements must be managed and changes should be analysed based on the impact they will have on the solution. The following sections detail what tools and professional body standards are available to assist practitioners during the execution of the requirements process.

2.7 Requirements Tools

Requirements tools assist in facilitating consistency and efficiency during the requirements process (Carrillo de Gea et al., 2011). There are many tools in the current marketplace which give different types of support to the requirements activities of elicit, specify, analyse, validate and manage. Careful consideration of the purpose of use should be given before a tool is purchased. Some guidelines to consider when purchasing a tool to facilitate the requirements process are provided by Schwaber (2006). A list of tools available in the market has been generated, using three sources listed in Table 17. See the list of requirements tools in Table 56 in APPENDIX A.

Table 17: Requirements tools surveys

Database Source	URL
Volere	www.volere.co.uk/tools.htm
Incose	http://www.incose.org/ProductsPubs/products/rmsurvey.aspx
IEEE (Carrillo de Gea et al., 2011)	www.um.es/giisw/EN/re-tools-survey

Each of these tools listed has different strengths supporting the requirements development stage or requirements management stage of the process. Tools only assist in tracking requirements documentation but cannot improve requirements quality. The next section will detail the guidelines provided by the professional bodies within each community as good practice.

2.8 Professional Bodies for the Requirements Discipline

The requirements discipline is utilised by multiple communities to capture, specify and manage requirements. Systems engineering has its roots in the development of large military applications, with requirements at the heart of systems engineering (Gonzales, 2005). The fundamental belief of systems engineering is that software is a *component* of the system. The fundamental belief of software engineering is that software *is* the system (Gonzales, 2005). Software engineering developed during the 1950s when writing software no longer required an understanding of hardware (Gonzales, 2005). The last community where the requirements discipline is utilised is the business analyst community. Business analysis is defined as the set of tasks and techniques used to work as a liaison among stakeholders in order to understand the structure, policies and operations of an organisation, and to recommend solutions that enable the organisation to achieve its goals (IIBA, 2009; Carkenord et al., 2010).

As a consequence of these multiple communities, of which the requirements discipline forms part, various professional body guidelines have been developed for the requirements discipline. The IIBA represents the business analyst community, INCOSE represents the systems engineering community and SWEBOK represents the software engineering community.

The requirements discipline is evolving with these communities influencing one another. All these communities provide guidelines on how to execute the requirements engineering process when solving a problem. In the following sections the requirements knowledge areas within each body of knowledge throughout these three communities are described.

2.8.1 Business Analysis Body of Knowledge (BABOK)

The IIBA BABOK (IIBA, 2009) guide prescribes six knowledge areas that must be understood by a practitioner during the requirements engineering process. The six knowledge areas and the relationship between them are illustrated in Figure 22. The tasks prescribed by each area are not presented by the project phase or intended to be performed in a linear fashion; they merely provide guidelines to what tasks should be performed (IIBA, 2009).

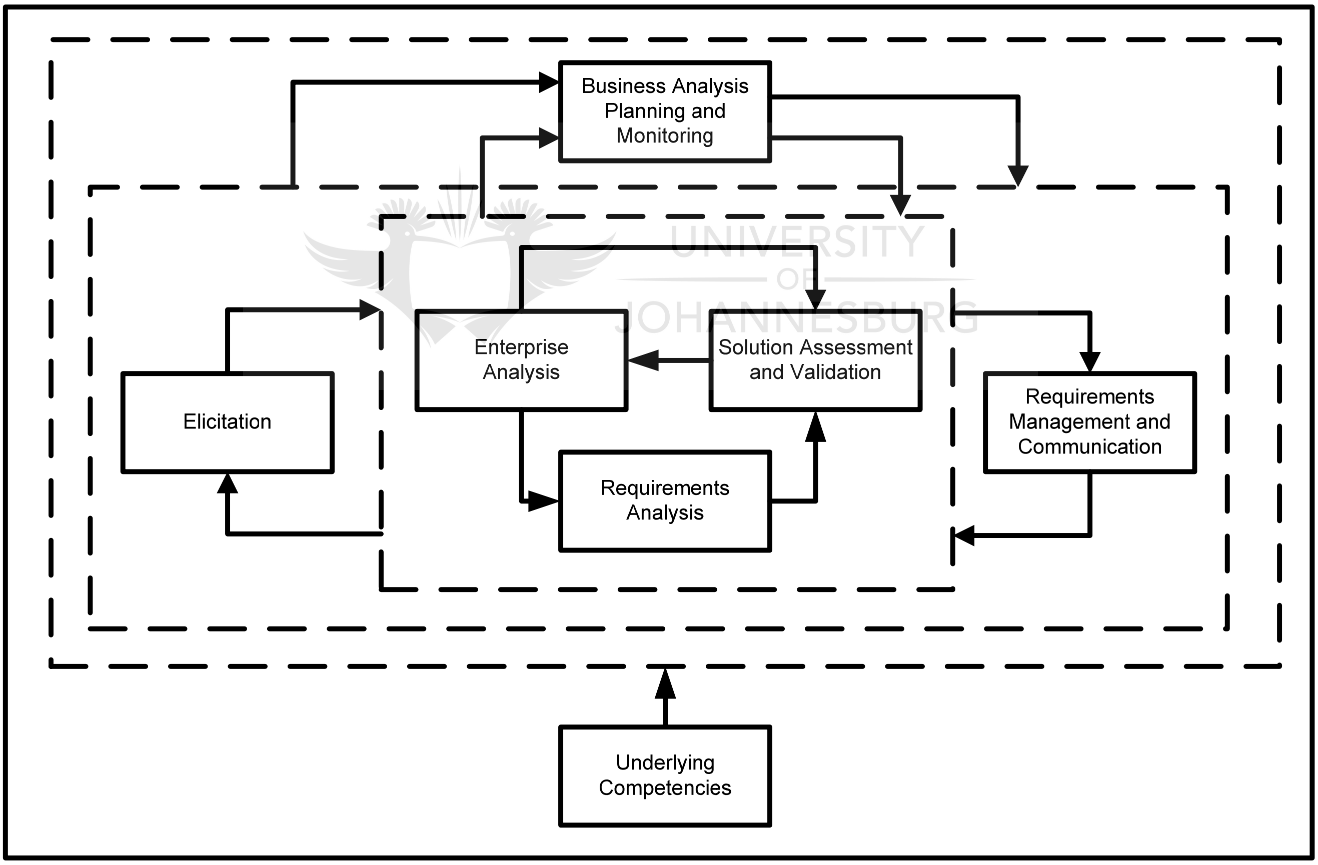

Figure 22: IIBA relationships between knowledge areas (IIBA, 2009)

Business analysis planning and monitoring cover the tasks required to plan the requirements process that will be appropriate. Elicitation defines how to collaborate with identified stakeholders in order to identify a complete set of requirements. Tasks required for managing changes and conflicts are prescribed by the knowledge area of requirements management and communication. Enterprise analysis focuses on tasks required to identify the business needs driving the project or initiative. The requirements analysis knowledge area lists tasks required to evolve from elicited information to prioritised requirements. Finally the solution assessment and validation knowledge area explains what is required to ensure that the solution is fit for purpose. The detailed tasks as prescribed by the IIBA are summarised in Table 18.

Table 18: IIBA knowledge area task list (IIBA, 2009)

IIBA Knowledge Area	**Tasks**
Business analysis planning & monitoring	• Determine how requirements will be approached • Stakeholder analysis • Define and determine requirements activities • Plan how the requirements will communicate with stakeholders • Plan requirements development process • Manage & report analysis effort
Elicitation	• Build an elicitation schedule • Meet with stakeholders to conduct elicitation • Document & record elicitation results • Confirm elicitation results with key stakeholders
Requirements management & communication	• Manage the scope & requirements • Manage requirements traceability • Maintain requirements reuse • Prepare requirements base • Communicate requirements
Enterprise analysis	• Define & understand problem • Assess capability gaps • Determine feasible business solution approach • Describe solution scope • Develop business case for proposed solution
Requirements analysis	• Prioritise importance of requirements • Organise requirements • Specify and model requirements • Define assumptions & constraints • Verify requirements • Validate requirements
Solution assessment & validation	• Assess proposed solution • Allocate stakeholders and solution requirements • Assess organisation readiness • Define transitional requirements • Validate solution • Evaluate solution performance

2.8.2 Software Engineering Body of Knowledge (SWEBOK)

Requirements are presented as the first knowledge area in the Software Engineering Body of Knowledge (SWEBOK) for software engineering, as illustrated in Figure 23.

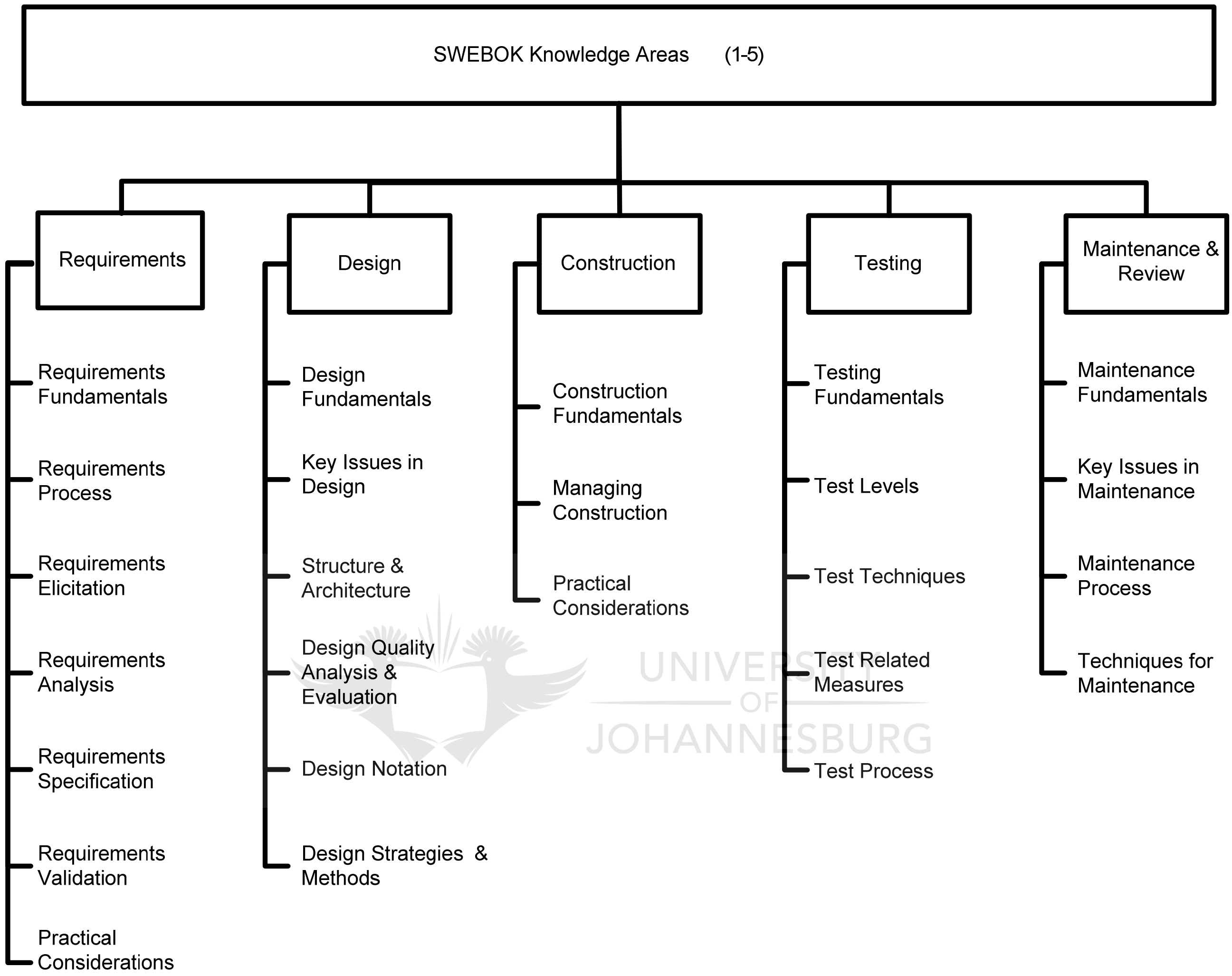

Figure 23: SWEBOK knowledge areas (IEEE Computer Society, 2004)

The sub-areas that should be covered under requirements in order to solve the problem are listed in Table 19 based on the SWEBOK guidelines (IEEE Computer Society, 2004).

Table 19: SWEBOK requirements knowledge area task list (IEEE Computer Society, 2004)

SWEBOK Requirements Knowledge Area	Tasks
Requirements Fundamentals	• Definition of a Requirement • Product and Process Requirements • Functional and Non-functional Requirements • Emergent Properties

	• Quantifiable Requirements • System Requirements and Software Requirements
Requirements Process	• Process Models • Process Actors • Process Support and Management • Process Quality and Improvement
Requirements Elicitation	• Requirements Sources • Elicitation Techniques
Requirements Analysis	• Requirements Classification • Conceptual Modelling • Architectural Design and Requirements Allocation • Requirements Negotiation
Requirements Specification	• System Definition Document • Systems Requirements Specification
Requirements Validation	• Requirements Reviews • Prototyping • Model Validation • Acceptance Tests
Practical Considerations	• Iterative Nature of Requirements Process • Change Management • Requirements Attributes • Requirements Tracing • Measuring Requirements

2.8.3 INCOSE Systems Engineering Handbook

INCOSE handbook guidelines follow the process of focus groups as prescribed by ISO/IEC 15288 standards for systems engineering. An overview of the systems life cycle process is presented in Figure 24.

Two technical processes guidelines provided by INCOSE during the systems engineering process are relevant to requirements engineering. These two technical processes are:

- the stakeholder requirements definition process
- the requirements analysis process.

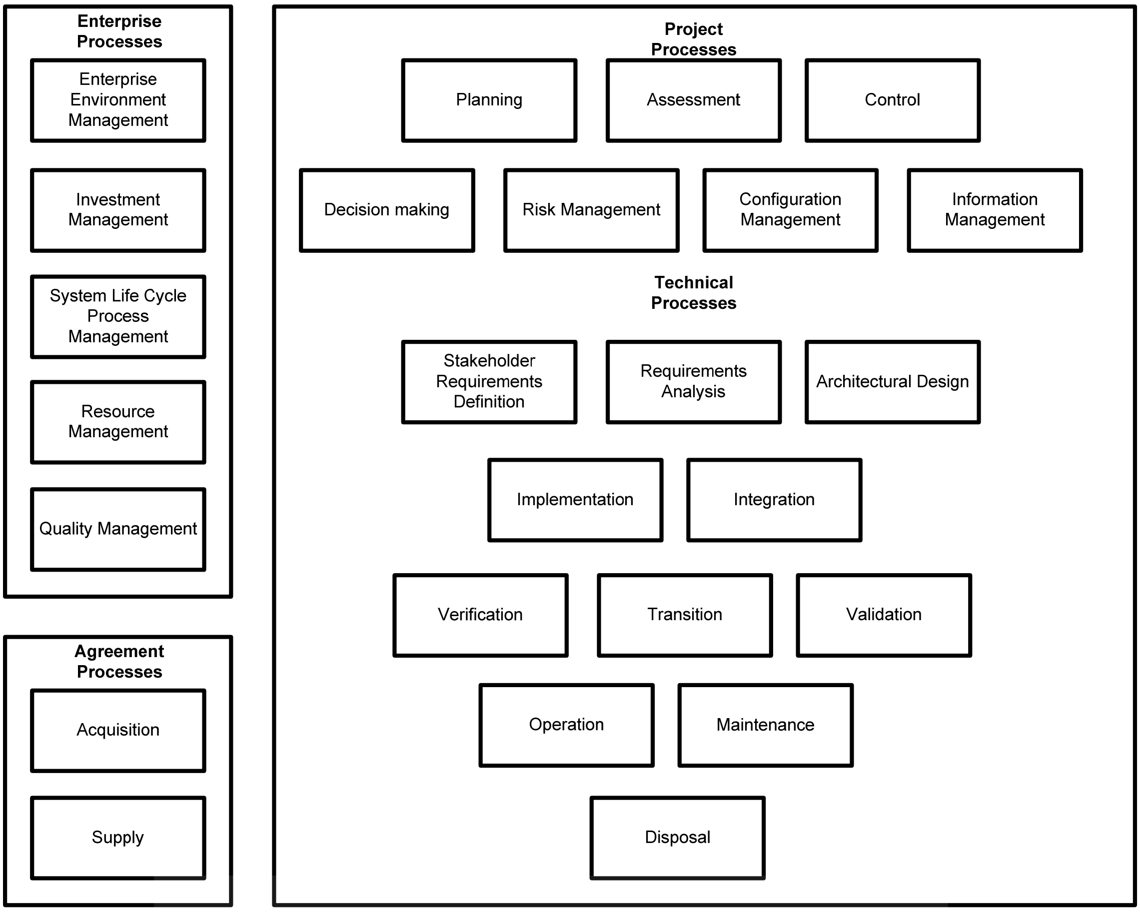

Figure 24: System life cycle process overview as per ISO/IEC 15288 (INCOSE, 2007)

The two technical processes that relate to requirements engineering provide a set of activities that should be done in order to solve the problem. These activities are listed in Table 20 and are based on the INCOSE guidelines (INCOSE, 2007).

Table 20: INCOSE requirements processes activities (INCOSE, 2007)

INCOSE Technical Processes	Activities
Stakeholder Requirements Definition	• Identify stakeholders who will have an interest in the system throughout its entire life cycle. • Elicit requirements. • Define constraints. • Establish critical and desired system performance. • Establish measures of effectiveness and suitability. • Analyse requirements. • Negotiate modifications to resolve unrealizable or impractical requirements. • Validate, record, and maintain stakeholder requirements throughout the system life cycle.

	• Establish and maintain a traceability matrix.
Requirements Analysis Process	• Define and specify the functional boundary and performance. ▪ Selected Standards – identify standards required to meet quality. ▪ System Boundaries. ▪ External Interfaces – functional and design interfaces to interacting systems, platforms, and/or humans external to the system boundary. ▪ Utilization Environment(s) – identify all environmental factors (natural or induced) that may affect system performance, impact users. ▪ Life Cycle Process Requirements – conditions or design factors that facilitate and foster efficient and cost-effective life cycle functions (i.e. Production, Deployment, Transition, Operation, Maintenance, Reengineering/Upgrade, and Disposal). ▪ Design considerations – including human systems integration (manpower, personnel, training, human factors engineering, environment, safety, occupational health, survivability, habitability), system security requirements (e.g. information assurance, anti-tamper provisions), and potential environmental impact. ▪ Define design constraints including physical limitations. ▪ Define Verification Criteria to ensure verifiable requirements. ▪ Maintain continuity of configuration control and traceability.

Because the requirements discipline is present across different communities, there are different guidelines although there is some overlap. The IIBA includes a planning activity as part of the requirements process, as does SWEBOK. INCOSE has a project process covering project planning, but does not include requirements engineering process planning. INCOSE as well as IIBA also have their own certification which a practitioner can obtain. Attempts have been started to suggest general guidelines for a requirements practitioner such as certification (IREB, 2006).

A summary was presented of knowledge available from literature about the requirements engineering process, the tools, techniques and modelling methods and guidelines. In the following section the knowledge of the known challenges that impact on the quality of the output of the requirements engineering process is evaluated.

2.9 The Factors Impacting on Requirements Process Output

The importance of requirements engineering is acknowledged and detailed knowledge is available. However, many challenges in practice are experienced with the requirements engineering process and quality requirements are not always delivered as an output of the process (El Emam and Koru, 2008; Kamata and Tamai, 2007; Schwaber, 2006). Below are the main challenges experienced during the requirements engineering process.

Paech et al. (2005) have summarised studies reviewed in literature to establish what the problems with the requirements engineering process are. The main problems with the requirements engineering process confirmed in multiple studies are:

- communication and coordination breakdowns
- lack of domain knowledge, i.e. understanding the problem in the world
- changing and conflicting requirements.

Two additional problems emerged from the Paech summary (Paech et al., 2005):

- Tools used during the requirements engineering process create problems due to benefits not being clear, tool integration, adaptation and selection within the environment.
- Non-existing documentation.

Communication and coordination breakdowns have been raised in literature as challenges during the requirements engineering process by multiple authors (Curtis et al., 1988; Karlsson et al., 2007; Sutcliff et al., 1999; Bjarnason et al., 2011). Additionally, Kamata et al. (2007) identify a gap in the research communities' work on communication during the requirements engineering process. Hofmann and Lehner (2001) found that teams that have implemented projects successfully maintain good relationships with stakeholders and constantly validate their understanding of the application domain to avoid communication breakdowns.

A recent study focusing on African practice concluded that the establishment of a trust relationship between stakeholders and the requirements engineer is essential. Without trust there is no communication, and without communication there is no domain knowledge transfer (Marnewick et al., 2011). Trust is also mentioned as one of seven key success factors during requirements collaboration by Hoffmann and Lescher (2009).

The majority of challenges faced during the requirements engineering process relates to social interaction challenges and not technical challenges (Ramachandran et al., 2011; Fuentes-Fernández et al., 2010). The context in which the requirements engineering process is performed is a human activity system. Requirements emerge from the social interaction and communication between the users and the requirements engineer (Siddiqi, 1996). The importance of effective communication to ensure a mutual understanding between the cross-functional team involved during the requirements engineering process have been emphasised over time (Penzenstadler et al., 2009; Rupp, 2006; Siau and Tan, 2005; Damian and Zowghi, 2003; Hartwick and Barki, 2001; Fisher, 1999; Al-Rawas and Easterbrook, 1996; Holtzblatt and Beyer, 1995; Bostrom, 1989).

Collaboration and negotiation between the requirements engineer and stakeholders provide the building blocks for strong relationships that allow for an interactive and involved requirements engineering process (Coughlan et al., 2003; Holtzblatt and Beyer, 1995).

To conclude the literature description of the requirements engineering process, suggested future research trends for the requirements discipline are presented in the following section.

2.10 Requirements Engineering Research Trends

Cheng and Atlee (2009) produce a list of future requirements engineering research focuses, as illustrated in Table 21.

Table 21: Current and future research directions (Cheng and Atlee, 2009)

Research facilitating the Use of Requirements Engineering Techniques	Improvements to the Current State of the Art of RE Techniques – Assurance	Emerging Needs
• Effectiveness of requirements engineering technologies supporting more evaluation-based research • Methodologies and tools • Requirements reuse • Globalisation	• Quality - improve the assurance of the overall system • Increased security to support increased mobile access • Tolerance to support increased dependency on technologies	• Scale of solution • Tighter integration between systems including software, hardware and people • Self-management

To generate knowledge for these research focuses identified by Cheng and Atlee (2009), themes have been identified from literature of how future research should be approached.

- Establish collaborative partnerships between researchers and practitioners to increase industry relevance of research outcomes as well as to share industry data to understand practitioners' real problems (Cheng and Atlee, 2009; Zowghi and Coulin 2005; Hansen et al., 2009).
- Documentation of empirical research on how well requirements engineering research addresses industrial problems. Practitioners need evidence to motivate any changes in their requirements practices (Cheng and Atlee, 2009; Zowghi and Coulin 2005).
- Establish requirements engineering repositories in order to share best practices, sample artefacts and store requirements patterns for reuse (Cheng and Atlee, 2009).

2.11 Conclusion

The purpose of the literature review was to confirm and acquire knowledge of the requirements engineering process. This summarised the available knowledge on the requirements engineering process, the existing tools, techniques and modelling methods to assist in executing activities during the requirements engineering process. Additionally, the challenges that impact on the quality of the requirements, the output of the requirements engineering process, were reviewed. The chapter concluded with suggested future research trends that should be considered by researchers.

The literature confirms the extensive body of knowledge available in literature. This body of knowledge within the requirements discipline is found across multiple communities with diverse backgrounds and origins. The output of the requirements engineering process is found in literature to be delivering poor quality. The factors identified in literature that impact on the quality of requirements are related mainly to human interaction.

Although this body of knowledge is comprehensive, it is not clear if this knowledge is known by practitioners, or if it is in use by practitioners and relevant to practitioners' real-life problems. This knowledge can be used to determine whether the existing requirements engineering knowledge from literature is used in practice, by comparing the baseline to how the requirements engineering process is executed in practice. Understanding how practitioners do things will contribute to the existing body of knowledge and has been raised as a hotspot for research.

The description of how the requirements engineering process is executed by practitioners will establish whether existing tools, techniques and modelling methods are actually used by practitioners. In addition, communication is a challenge faced across communities in which the requirements discipline is executed. Social studies show that if trust is not present in a relationship, effective communication will not take place (Zeffane et al., 2011). The existence and level of trust relationships between a requirements practitioner and relevant stakeholders could provide insight regarding potential to deliver quality requirements. The most appropriate research method should be used to obtain a description of how the requirements engineering process is executed by practitioners as well as how practitioners behave during the execution of the process. The research methods to assist in selecting the most appropriate method and defining a process to follow will be evaluated.

CHAPTER 3 Research Approach

The research design step of the research process had two parallel objectives, namely to build a solid basis of the available knowledge through a literature review and in parallel with this, an industry review. The industry review explores and describes how practitioners execute the requirements engineering process. The industry and literature review knowledge will be compared to determine if the existing requirements engineering knowledge from literature is actually migrated into practice.

In the following sections alternative research methods are evaluated and a motivation is given for selecting a survey as the most appropriate method to obtain answers to the research questions. Secondly, the survey process during the research is explained.

3 Research Methodology

The objective of the industry review was to gather information on the practitioners' individual behaviour, opinions, knowledge and circumstances during the requirements engineering process. The industry review is used to produce a quantitative description of how the requirements process is executed in practice across the communities in which the requirements discipline is used.

The data gathered provided firstly an understanding of what activities are generally performed during the requirements process and how many of the tools and methodologies available in literature are in use or known by practitioners. This highlights the differences, if any, between practice and theory. Secondly, the data provided insight into the level of collaboration during the process and the impact of the collaboration on the quality of delivered requirements.

Information is required on the behaviour of the practitioners to describe how the requirements process is executed in practice. An observation approach favours collection of information about behaviours (Cooper and Schindler, 2008). In addition, the research also required the collection of information about the motivation for communicating and collaborating, which required communication-based research methods. To ensure that the most appropriate method was used, a comparison of research methods was completed as detailed in the next section.

3.1 Research Method Comparison

Yin (2009) provides a comparison of three factors to consider when selecting a research method. The three factors are as follows:

- The type of research questions which the researcher is investigating
- The control the researcher has to manipulate the actual behavioural events investigated

- The degree of focus on contemporary versus historical events.

A summary is provided in Table 22 to evaluate when a research method is best suited for a situation.

Table 22: Relevant situations for different research methods (Yin, 2009)

METHOD	(1) Form of Research Question	(2) Requires Control of Behavioural Events?	(3) Focuses on Contemporary Events?
Experiment	how, why?	yes	yes
Survey	who, what, where, how many, how much?	no	yes
Archival analysis	who, what, where, how many, how much?	no	yes/no
History	how, why?	no	no
Case study	how, why?	no	yes

If research questions are focused on "what" questions, there could be two research method possibilities, i.e. exploratory research or a survey. For exploratory research, any of the research methods from the summary provided in Table 22 can be applied (Yin, 2009). If the research questions are more in line with inquiry and if the secondary questions are in a form of "who" and "where", survey or archival analysis is favoured above other research methods.

History methods are used when dealing with the past, people are not available to report on what happened and investigations must rely on documents as a main source of evidence. The history method was not considered in this study as the research objective was to obtain current perspectives from practitioners of the requirements process. The researcher is not part of the requirements process in practice and therefore had no control over and could not manipulate the actual behaviour of the events investigated. It was therefore concluded that the survey research method would be best suited to generate data to verify the research hypotheses.

The characteristics of the survey research method as well as the strengths and weaknesses are explored in the following section to validate that it was in fact the most appropriate method.

3.2 Survey Research Method

Survey research involves the systematic collection of information about the behaviour, knowledge, opinions, or attitudes of a defined population of participants (Rasinski, 2005). The type of information available using surveys is classified by Rea and Parker (2005) as either descriptive, behavioural or attitudinal.

Fowler (2009) identifies three characteristics of survey research:

- Survey research is used to produce quantitative descriptions of some aspects of the study population. These aspects involve examining the relationships among different variables.
- The information is collected by asking the population questions and the answers constitute the data that will be used for analysis.
- Information is collected only from a fraction of the population.

The purpose of the industry review was to derive a quantitative description of how the requirements process is executed in practice. In addition, it also attempted to collect behavioural information that would provide insight information into the level of collaboration during the requirements process and the impact of the collaboration on the quality of requirements.

It could be concluded that a survey research method was appropriate based on factors provided by Rea and Parker (2005):

- There is no adequate data available on requirements practice within Africa.
- The objective of the industry review was to study a small population and generalise findings to the larger requirements population.
- The target population of requirements practitioners was accessible.
- A portion of the data was personal and self-reported.

However, different types of surveys are available for consideration (Rasinski, 2005):

- Cross-sectional surveys produce a representation of a population at a given point.
- Longitudinal surveys compare results of the same respondents repeatedly over time.
- Panel interviews are also a type of longitudinal survey where sample respondents are interviewed at fixed intervals to track effects.

Information about the behaviour, knowledge, opinions and attitudes of the requirements practitioners was required and therefore it was felt that a cross-sectional survey would produce data that would describe the required population. To ensure that the survey research method was applied as best as possible, its strengths and weaknesses are considered including the different collection methods.

3.2.1 Strengths and Weaknesses of Survey Research

The strengths and weaknesses of survey research are summarised as follows from literature:

Strengths

- Surveys produce data based on real-world observations which offer the opportunity to reveal the characteristics of a population in an unbiased rigorous manner (Kelly et al., 2003; Rea and Parker, 2005).
- Surveys enable researchers to generalise about an entire population based on data collected from a portion of the population (Rea and Parker, 2005; Wagenaar, 2005).
- Surveys allow the researcher to collect information about the opinions, attitudes and motivations of participants. Other methods such as observation techniques do not allow the collection of information about these elements (Cooper and Schindler, 2008).
- A survey can produce large amounts of data at a relatively low cost in a short time (Rea and Parker, 2005; Kelly et al., 2003).
- Well-structured surveys generate standardised data for statistical analysis. They also allow for the replication to populations in different locations (Rea and Parker, 2005).

Weaknesses

- A high response rate generally cannot be assured by the researcher (Kelly et al., 2003).
- The data could lack details of a topic being investigated (Kelly et al., 2003).
- The data's significance could be compromised if too much focus is on the range of coverage in the survey (Kelly et al., 2003).

Real-world data was required from as many respondents as possible within requirements practice in a short time. To ensure a solid research design and to ensure that these weaknesses did not influence the results of this research, a rigid systematic approach was followed. This process followed by the researcher is described next.

3.2.2 Survey Process

A systematic process was required to ensure that the survey would be conducted rigorously and in an unbiased manner. Steps taken during a survey are available in literature although no order is necessarily enforced (Rea and Parker, 2005; Rasinski, 2005). A systematic process was derived based on the steps provided by Czaja and Blair (2005) and is illustrated in Figure 25.

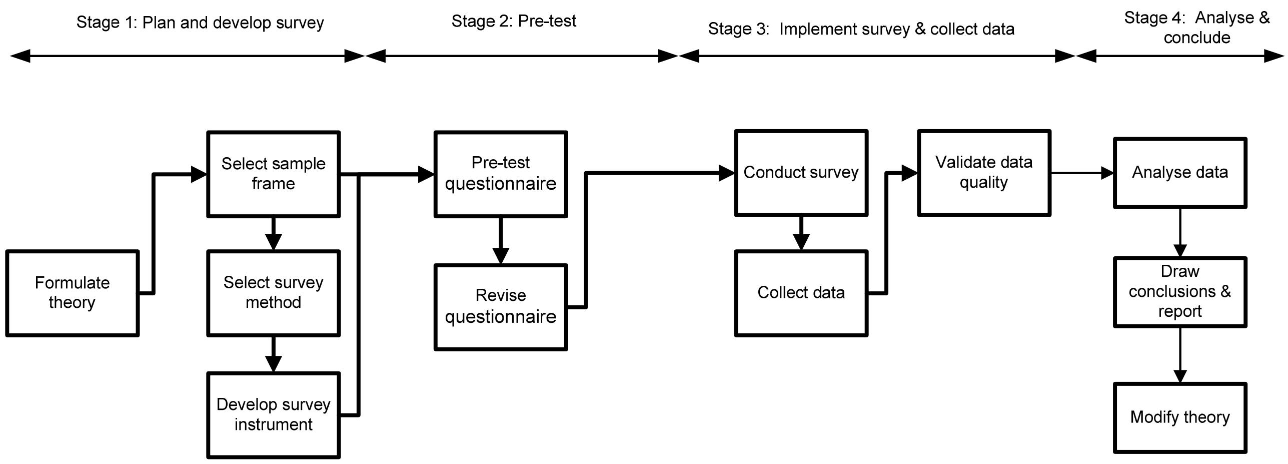

Figure 25: Survey process

Stage 1: Plan and develop the survey

The research objectives, which are based on existing theory, are the input for the survey. This defines the focus of the topic of interest under investigation. After planning the survey, the researcher should have a sample frame for the survey. The sample frame will define the population that will be studied and a list of population elements that will be collected to create the basis for analysis (Rasinski, 2005). The most appropriate survey method should be selected in order to collect the required elements from the population (Rasinski, 2005). Once the appropriate methods have been selected, the survey instrument can be designed.

Stage 2: Pre-test

After the draft questionnaire has been developed, it should be tested under actual survey conditions. Based on the pre-test results, the questionnaire should be refined to ensure that the necessary information will be collected to achieve the research objectives (Rea and Parker, 2005). Depending on the survey method, the selected interviewers should be trained on the questionnaire. If self-administered instruments are used, this is not required (Rasinski, 2005).

Stage 3: Implement survey and collect data

The survey is ready to be conducted. During the survey the researcher should focus on the respondents' privacy and on minimising inconvenience (Rea and Parker, 2005).

Stage 4: Analyse and conclude

The collected data must be entered electronically if the collection was done manually. At this point the collected data is evaluated and analysed. Conclusions from the data will be reported on (Rea and Parker, 2005).

The survey for the industry review is based on the derived systematic process. The following section provides the details on how the process was executed.

3.3 Planning and Development of the Survey

The objectives of the industry review were as follows:

- To produce a quantitative description of how the requirements process is executed by practitioners.
- To identify whether the tools and methodologies available in literature are used or known by practitioners to highlight the gaps between practice and theory.
- To collect data that describes the level of communication during the requirements process and the impact the communication has on the quality of requirements.

The literature review was done on published work that provided the theory as background. Secondly, knowledge was required about how practitioners execute the requirements process to obtain a description. The process to acquire the required knowledge is described in the following sections.

3.3.1 Survey Sample Frame

The sample frame refers to how the researched population has been constituted (Fowler, 2009). The purpose of the industry review was to derive a quantitative description of how the requirements process is executed, including a description of behaviours. During the design, the following factors are taken into consideration to ensure a complete design:

- Who will be included and who will be excluded from the population (Fowler, 2009)
- Variables required for descriptive purposes (Sapsford, 2007)
- Variables required for hypotheses testing (Sapsford, 2007)
- Additional variables required to validate conclusions (Sapsford, 2007)

The sample of the population should be selected in such a way that it represents the population as best as possible (Fowler, 2009). The target population for this study was only those practitioners that were responsible for any activities during the requirements process. The selected method and process to best access the identified population are described below. This defines who was included in the survey target population.

3.3.1.1 Sampling Method

A complete list of requirements practitioners is not available within the South Africa industry. Random sampling could therefore not be used to select the target population. The characteristics of hard-to-reach populations are summarised by Marpsat and Razafindratsima (2010):

- The population has relatively low numbers leading to high costs if the investigation is done throughout the general population.
- Members of the population of interest are hard to identify. Common properties within the population are neither easily detected nor recorded.
- There is no sample frame or only a very incomplete one that yields biased results.
- The population of interest does not wish to disclose their behaviour.
- The behaviour of the population of interest is not known.

From the above characteristics it can be concluded that the requirements practitioners could be classified as a hard-to-reach population as they had not been previously identified. No sample frames could be located in any academic or public publications.

In the case of hard-to-reach populations, snowball, targeted, time space and respondent-driven sampling are suggested to access these hidden populations (Baltar and Brunet, 2012). Snowball sampling makes contact with a small group of relevant people and then uses these contacts to establish new contacts with others (Bryman and Bell, 2011). Targeted sampling includes an initial assessment to identify existing networks within the population. Subgroups are treated as a cluster sample to increase the representativeness to address traditional snowball sampling (Baltar and Brunet, 2012). Time space sampling assists in the research of location-based populations, while respondent-driven sampling combines snowball sampling with a mathematical model that allows for the calculation of probabilities (Baltar and Brunet, 2012).

Snowball sampling is a well-suited method when the focus of the research is a sensitive issue and requires knowledge of insiders to locate people for the research (Biernacki and Waldorf, 1981). Baltar and Brunet (2012) suggest that snowball sampling is a very useful methodology to derive exploratory, qualitative and descriptive research, especially where a high degree of trust is required for initial contact. Based on the strengths of snowball sampling, it was selected as the preferred sampling method for this study, as the population was hard to research and a description of the population was the main objective of the industry review.

During the selection of the target population, the snowball sampling deficiencies were taken into consideration to minimise the impact on data quality. The specific problems as listed by Biernacki and Waldorf (1981) are:

- finding respondents and starting the referral chain
- verifying the eligibility of potential respondents
- engaging respondents as research assistants
- controlling the types of chains and number of cases in any chain
- pacing and monitoring referral chains and data quality.

Snowball sampling does not produce a random sample, and cannot therefore produce a perfectly unbiased sample. During the selection of the population a structured process was followed to ensure as far as possible that an unbiased sample of respondents was contacted during the referral chain. This structured process followed is described next.

3.3.1.2 Sampling Process

The target population was identified as hard to reach and individuals needed to be identified to start the referral chain. Three different approaches were followed to find respondents within the requirements practitioners' social network and to start the referral chain. This was done to ensure that the sample frame included a non-homogeneous set of requirements practitioners across the industry. It also provided coverage of the requirements practitioner population and minimised potential bias which could emerge due to a sample frame that did not fully represent the population (Rasinski, 2005). The three approaches used to identify the variety of requirements practitioners used were:

- engaging trusted individuals within organisations responsible for requirements practice as informal research assistants
- engaging requirements practitioners known to researchers
- engaging with professional bodies relating to requirements to provide access to members.

The referral chain initiation approach is illustrated in Figure 26.

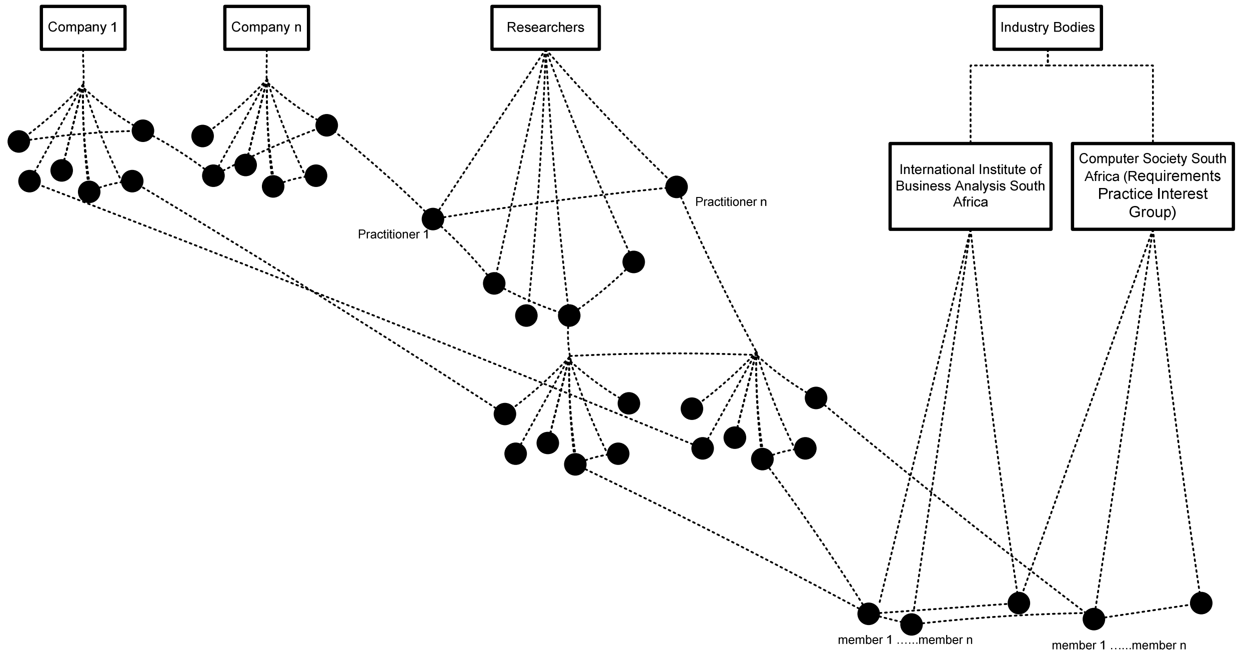

Figure 26: Social network of requirements practitioners

To eliminate suspicion from targeted requirements practitioners, cooperation was obtained from trusted individuals within organisations who were informal research assistants (Atkinson and Flint, 2001). The researcher used multiple individuals with established relationships to start a referral chain within as many organisations as possible. These individuals were either chief information officers to whom requirements practitioners typically reported, or individuals responsible for requirements practice within companies. They were contacted prior to the survey to obtain their cooperation. Once cooperation was obtained, the survey link was distributed to the individuals, who in turn distributed it to their staff members.

A list of individuals practising as requirements practitioners within the industry was known to the researcher. These known practitioners were contacted directly and requested to complete the survey. They were also requested to distribute the survey link to their network of requirements practitioners.

Finally, two professional organisations were contacted and requested to send the survey to their members. The first professional organisation was the Computer Society South Africa, which confirmed that they distributed the survey request to all members that had an interest in requirements practice. The second professional organisation was the International Institute of Business Analysis South Africa. They were requested to send the survey to all members, as their focus is on analysis within the requirements engineering space.

In all three approaches, the referral chains were initiated with the focus on requirements and requirements practitioners to ensure that potential respondents contacted dealt with requirements. Next, the most appropriate survey collection method had to be selected to support the data collection and to minimise non-responses (Rasinski, 2005).

3.3.2 Selection of Survey Collection Method

Different survey collection methods were considered to ensure that valid data was collected during the survey. Table 23 briefly describes the various methods.

Table 23: Survey collection methods

Survey Collection	**Description**	**Advantages**	**Disadvantages**
Postal surveys	Questionnaire is sent through postal services to large sample of people. No previous interaction between respondent and researcher. Respondent's responsibility to return it via post to researcher (Rea and Parker, 2005; Kelly et al., 2003).	• Cost saving: Could be less expensive than telephone or personal interviews. • Convenience: Respondent can complete at own convenience. • Visual aids: Questionnaire can make use of visual aids, which is not possible in telephone interviews.	• Response rate: Very low (Rea and Parker, 2005). • Incomplete data: Questions can be ignored and not be completed by respondents (Rea and Parker, 2005).
Face-to-face interviews	The researcher interviews respondents personally by asking them questions and noting their responses (Kelly et al., 2003).	• Assurances are in place as interview is guided by researcher (Rea and Parker, 2005). • Greater complexity in questions can be handled during these interviews when facilitated by interviewer, which in other survey types could be intimidating to respondents (Rea and Parker, 2005).	• Expensive in terms of cost and time (Rea and Parker, 2005). • Respondents could be reluctant to cooperate (Rea and Parker, 2005; Fowler, 2009). • Respondents' confidentiality less protected (Rea and Parker, 2005). • The interviewer could introduce some source of bias (Rea and Parker, 2005). • Stress could be introduced during an interview that could impact quality of data collection (Rea and

			Parker, 2005).
Internet surveys	Online questionnaire via the internet used to gather data from respondents.	• Cost saving: Lowest cost per respondent of all survey methods (Nathan, 2008). • Real-time interaction between questionnaire and respondent allowing for complex skip patterns (Nathan, 2008). • Data collected can be processed directly as it is in electronic format (Nathan, 2008). • Respondents' confidentiality is protected (Nathan, 2008). • Specialised populations are easily accessible if email address is known (Rea and Parker, 2005).	• Coverage: Users with access to internet are limited, which could have an impact on coverage of the population (Nathan, 2008). • Lack of interviewer involvement could lead to respondents not following instructions (Rea and Parker, 2005). • Respondents elect for themselves to complete survey, which could lead to low response rates (Rea and Parker, 2005).
Telephone interviews	Researcher interviews respondents by telephone by asking them questions (Kelly et al., 2003).	• Cheaper than face-to-face interviews (Kelly et al., 2003). • Rapid data collection possible (Rea and Parker, 2005). • Respondents' confidentiality protected (Rea and Parker, 2005).	• Tend to have a higher response rate than postal surveys but much easier to refuse participation (Kelly et al., 2003). • No visual aid available in telephone communication (Rea and Parker, 2005). • Very difficult for interviewer to establish credibility of respondents (Rea and Parker, 2005).

Requirements practitioners are typically assigned to projects and have limited time for research engagement. Personal interviews were not an option as the data collection period would be very long and access to the practitioners would be difficult. Postal surveys were not considered as the target population was geared towards electronic means rather than the post.

After careful consideration of the advantages and disadvantage of each survey type, the Internet survey was selected as the collection tool. It provided the ability to collect data electronically which would be ready for analysis at a low cost within very short time. The respondents' confidentiality was also protected. The population coverage would not be impacted by Internet access as requirements practitioners normally have this access within their work environment.

The questionnaire had to be designed to ensure that all data required for descriptive purposes, hypotheses testing and to validate conclusions was collected (Sapsford, 2007).

3.3.3 Survey Questionnaire

The sample frame identified who would be measured. This was followed by what would be measured (Rasinski, 2005). The design of the questionnaire has an impact on the quality of data. Elements for good questionnaire design as provided by Rasinski (2005) were considered in order to minimise the impact on data quality:

- Each question should be limited to one topic. A question should never ask about more than one topic (Rasinski, 2005).
- A combination of open-ended and closed questions was used. The closed questions limited the responses to a predefined list and did not require coding of responses. Open-ended questions are particularly useful to assess behaviours (Rasinski, 2005).
- Placement of questions should be considered as topics should be grouped together (Rasinski, 2005).
- Literature should be searched to identify existing, tested questionnaires (Kelly et al., 2003).

The questionnaire for this study was split into four main sections to ensure that relevant questions were grouped together. Firstly, biographical information of the actual practitioner was collected and secondly, information on how requirements activities were executed during the requirements process. The data collected from section 2 was used to explore and document how the practitioners execute the requirements engineering process. Also, it was used to determine if there are any differences between how the literature suggests the requirements engineering process should be executed and how it is executed in practice. The third section collected information to derive a description of the social factors that impact on the requirements process outputs. This data was used to understand the communication patterns and trust relationships between the responsible person generating requirements and the stakeholders. Finally, an optional section collected personal information for follow-up research.

The questions for each section in the questionnaire are described below.

3.3.3.1 Section A – Biographical Information

To analyse collected data as correctly as possible, knowledge about the participants is required. Factors to be taken into account are the participants' current role and past experience (Paech et al., 2005). To establish the role or title assigned to practitioners, the questions used in a study done in Australia were integrated into the questionnaire (Wever and Maiden, 2011). The participants were requested to specify their qualification and/or any industry certifications to provide a linkage to formal education. To establish the practical experience of respondents, questions from Wever and Maiden (2011) were adapted. For a profile of the projects the participants were assigned to, information about people involved, elapsed time, cost and effort was collected as suggested by Neill and Laplante (2003) and Chatzoglou and Macaulay (1996). Table 24 provides information on questions used to produce a description of the practitioners.

Table 24: Section A – biographical information

Objective	Questionnaire Measure	Questionnaire Questions
Profile the requirements practitioners.	To profile who the practitioners were in the requirements discipline within local industry, the participants had to be analysed.	1 – 10: Refer to APPENDIX B for question detail.

3.3.3.2 Section B – Requirements Activities

For a quantitative description of how the requirements process is executed, the project context within which the requirements engineering process is executed was required. As proposed by Houdek and Pohl (2000), when trying to understand the context of the requirements engineering process used in practice information must be collected on (i) all parties involved, (ii) information produced and consumed, (iii) information media, structure and delivery intensity. To derive a description for the requirements engineering process, the focus was on the input to the requirements process, requirements activities and quality of output of the requirements process.

Table 25: Section B – requirements activities

Objective	Questionnaire Measure	Questionnaire questions
Firstly, as input to the requirements engineering process data was required to understand how many stakeholders are involved and what the sources of requirements are.	To identify the research pattern of a typical resource in understanding the problem to be solved, sources of information consulted were established (Tenopir and King, 2004).	11 – 13: Refer to APPENDIX B for question detail.
Confirm literature field study findings indicating that the requirements engineering process in practice is not defined in a structured methodological way.	Determine if the requirements process is an unstructured problem-solving activity.	14 & 15: Refer to APPENDIX B for question detail.
Requirements process activity: planning. Determine if activity is executed or not.	Determine practitioners' involvement in requirements activities. A recent study in Australia done by Wever and Maiden (2011) was used as a basis.	16, 17, 19: Refer to APPENDIX B for question detail.
Requirements process activity: elicitation.	Determine practitioners' involvement in requirements activities. A recent study in	18, 20, 23: Refer to APPENDIX B for question detail.

Determine if activity is executed or not.	Australia done by Wever and Maiden (2011) was used as a basis.	
Identify elicitation tools and techniques in use, known or not known by practitioners.	Tools and techniques were identified based on available literature referred to in section 2.6.2.	21: Refer to APPENDIX B Survey Questionnaire for question detail.
Requirements process activity: analysis and modelling. Determine if activity is executed or not.	Determine practitioners' involvement in requirements activities. A recent study in Australia done by Wever and Maiden (2011) was used as a basis.	22, 24 and 27: Refer to APPENDIX B for question detail.
Identify analysis and modelling tools and techniques in use, known or not known by practitioners.	Tools and techniques were identified based on available literature referred to in section 2.6.3.	25: Refer to APPENDIX B for question detail.
Requirements process activity: specification. Determine if activity is executed or not.	Determine practitioners' involvement in requirements activities. A recent study in Australia done by Wever and Maiden (2011) was used as a basis.	26, 28, 29, 30 and 36: Refer to APPENDIX B for question detail.
Identify specification tools in use, known or not known by practitioners.	Vendor tools were identified based on available literature referred to in section 2.7.	31 and 32: Refer to APPENDIX B for question detail.
Determine the quality of the output of the requirements process.	Quality elements of a specification were identified based on available literature referred to in section 2.6.4.	33, 34, 35: Refer to APPENDIX B for question detail.
Requirements process activity: validation. Determine if activity is executed or not.	Determine the practitioners' involvement in requirements activities. A recent study in Australia done by Wever and Maiden (2011) was used as a basis.	37, 38, 39, 40: Refer to APPENDIX B for question detail.
Determine the level of customer satisfaction with the output of the requirements process.	The goal of the requirements engineering process is delivering a solution fit for purpose. This is to validate if the customers are satisfied with the solution.	41 – 45: Refer to APPENDIX B for question detail.

3.3.3.3 Section C - Social Factors in Requirements Engineering

The context in which the requirements engineering process is performed is a human activity system (Nuseibeh and Easterbrook, 2000). The requirements engineering studies consistently raise human interaction, in the form of either communication, collaboration or relationships, as a challenge (Paech et al., 2005; Marnewick et al., 2011; Curtis et al., 1988; Sutcliff et al., 1999; Hofmann and Lehner, 2001; Damian and Chisan, 2006; Karlsson et al., 2007; Kamata et al., 2007).

With similar results from literature about the challenges in requirements engineering, the focus of the information collected was on communication patterns and trust relationships between stakeholders and the requirements engineer. This data would assist in describing the level of collaboration during the requirements process and the impact of the collaboration on the quality of requirements delivered by the process.

An instrument is available in literature to measure trust in the workplace. To determine the trust relationships of the requirements practitioner, the behavioural trust inventory developed by Gillespie (2012) was used.

During a project, requirements engineering bridges the communication between the stakeholders and the technical delivery team (Wiegers, 2003a). Information regarding the following communication patterns was collected:

- Communication with project manager on project impacts
- Communication with sponsor to elicit business requirements
- Communication with a subject matter expert to acquire domain knowledge
- Communication with users to elicit functional requirements

Table 26: Section C – social factors in requirements engineering

Objective	**Questionnaire Measure**	**Questionnaire Questions**
Establish if regular communication takes place between practitioner and project manager, project sponsor, subject matter expert and end-user.	Measure communication interaction between stakeholders where communication should exist.	46-49; 53-56; 60-63; 67-70
Collect data for communication breakdowns.	Derive factors contributing to gaps in communication (Bjarnason et al., 2011; Debasish and Das, 2009).	51, 58, 65, 72: Refer to APPENDIX B for question detail.
Collect data about the level of trust in the workplace between practitioner and project manager, project sponsor, subject matter expert, end-user and within the team.	The behavioural trust inventory as developed by Gillespie (2012).	50 & 52; 57 & 59; 64 & 66; 71 & 73; 74: Refer to APPENDIX B for question detail.

The questionnaire design consisted of two components, i.e. deciding what to measure and designing and testing the questions that would be good measures (Fowler, 2009). The questions were generated to gather data in order to achieve the survey objectives. The second step in the questionnaire design was to test the questions to ensure that they would gather the best possible data in order to achieve the research objectives.

3.4 Pre-testing of Survey

When the questionnaire was completed, it was tested to ensure that it would work under real-life conditions (Fowler, 2009). As it was a self-administered instrument, it was first configured on the online survey platform that would be used to collect the data. This platform had the ability to build in skip logic. This function allows only relevant questions to be displayed to the respondents based on the previously answered questions. The respondents had no need to read skip instructions as this was taken care of by the platform.

The first pre-test done was to test every scenario of provided answers to ensure that the skip logic worked correctly. The researcher tested the questionnaire's logical flow. These tests were also done by independent testers to test the logic.

The second test performed was to test the duration of the survey as suggested by Fowler (2009) as a good pre-test. The survey took between 20 and 30 minutes to complete. Web-based surveys should aim at completion within 15 minutes (Rea and Parker, 2005). The survey completion time was therefore a bit longer than the suggested time. Two alternatives were considered: remove questions or separate the questionnaire into subsets (Fowler, 2009). The latter choice was elected. The first subsets of questions dealt with the requirements process to derive an industry description. The second subset was more explorative on the social interaction patterns.

The final pre-test was done as a pilot on a sample set of the targeted respondents. This allowed the researcher to identify whether the respondents understood the questions (Kelly et al., 2003). This pilot test was done on the actual platform that would be used during the survey. Once all pre-tests were completed and questions revised, the survey was ready for implementation.

3.5 Implementation of Survey and Data Collection

The following section details the actual steps taken in conducting the survey and collecting the survey data.

3.5.1 Conduct Survey

All the individuals identified as possible main points that could start a referral chain as discussed in 3.3.1.2 were contacted prior to the implementation of the survey. This was done to confirm and agree on individuals' or their employees' participation. Once the survey was ready for implementation, the researcher sent an email to all participants who agreed to participate. As prescribed by Wagenaar (2005), it is important to send a covering letter to explain the importance of participation, and to provide instructions and a deadline. A covering letter was sent as an email to explain the importance of referring the survey to requirements practitioners only, and also committing to share the summary results.

Additionally, the email provided the following information:

- Purpose of research
- Who the researcher was
- What was expected of the respondents
- How results would be used
- How the respondents' confidentiality would be maintained
- The Internet link where the survey was to be completed

- The date that the survey would be closed
- Contact details of the researcher in case of any questions

3.5.2 Data Collection

The survey was opened on the Internet via the platform used. The platform service provider was Survey Monkey. The data collection was facilitated by the platform on which the survey was configured. Data was automatically collected in various electronic formats by the platform. No work was required to manually capture the data in any format, which enabled the researcher to download the collected data once the survey deadline was reached.

The collected data was available in SPSS, Excel and comma delimited files from the platform on which the survey was configured. SPSS is a software package offering a very broad range of statistical methods (Huizingh, 2007).

Once the survey closing date was reached, the survey was closed on the platform to ensure that no more participants could complete it. The data was downloaded in SPSS format and backed up. The data had to be prepared for analysis to ensure that the data quality was understood.

3.5.3 Data Quality

During the design of the questionnaire elements for good questionnaire design were taken into consideration to address data quality. Additional reliability and validation tests were done to evaluate the survey instrument before implementation. Reliability is concerned with how well the survey data can be reproduced, and validity is a measure of how well the survey measures what it is supposed to measure (Kitchenham and Pfleeger, 2002; Kirk and Miller, 1986; Litwin, 1995).

3.5.3.1 Reliability

Litwin (1995) presents some reliability checks that can be done on surveys. Test-retest is relevant when a survey is sampled with the same set of respondents at two different points in time (Kitchenham and Pfleeger, 2002). In this research this was the first time the survey had been sampled, so a test-retest is only possible in future. The interobserver reliability test was not relevant either, as this survey was a self-administered survey intending to measure respondents' behaviours (Litwin, 1995).

As scales were used in the questionnaire, internal consistency was very important to check (Litwin, 1995). Cronbach's alpha is a measure of internal consistency in a survey or questionnaire that forms a scale and the reliability of the scale needs to be determined (Kitchenham and Pfleeger, 2002; Litwin, 1995). Cronbach's alpha coefficient is a reflection of how well the different items complement one another to measure the same variable (Litwin, 1995; Cronbach, 1951). Cronbach's alpha coefficient was calculated for all scales used prior to data analysis.

3.5.3.2 Validity

The goal is for the survey questionnaire to measure what it is intended to measure. Validity checks are available to verify that the questionnaire is suitable (Kitchenham and Pfleeger, 2002). The types of validity checks that can be used to assess survey questionnaires are face, content, criterion and construct validity (Litwin, 1995).

Face validity is when someone looks at a survey and sees if it could be perceived as acceptable. Although this is a very subjective method, the survey was reviewed by another academic colleague. The content validity of the survey questionnaire was measured by two separate focus groups. Firstly, the survey was reviewed by a survey expert. The focus of this review was to check the scales used for validity as well as establishing that a good design process was followed during the survey design.

The second focused review was done by two subject matter experts. This review focused on the instrument's logical layout, and all relevant questions required to collect data to answer the research questions were included. Feedback was received about questions that were not relevant as well as questions that did not measure what they should have. This feedback was incorporated and changes were made to the questionnaire.

Concurrent validity requires that the survey instrument used be compared with a method acknowledged as the "gold standard" of assessing the same variables. There is no "gold standard" available, therefore concurrent validity was not relevant. A portion of the questionnaire was developed by another researcher to measure trust. The behavioural trust inventory used was tested for validity as described in Gillespie (2012).

As this is the first time this survey had been done, construct validity was not relevant. There was no previous data to compare and this will only be relevant if the survey is done again (Kitchenham and Pfleeger, 2002).

3.6 Analyse and Conclude

Once the data has been collected and checked for reliability and validity, the next step is to analyse it to make statistical estimations and reach conclusions (Fowler, 2009). SPSS was selected as the data analysis tool, as the collected data was already in an SPSS data file.

3.6.1 Data Analysis

The basic activity of the data analysis process is to prepare, explore and model the data and finally to do hypothesis testing (Siegel, 2012). The following activities were carried out during the data analysis process:

3.6.1.1 Data Preparation

Data preparation involves the capturing and checking of the data from the survey answers and transforming the data into computer data files (Fowler, 2009). Five separate steps are prescribed during data preparation by Fowler (2009):

1. Decide on a format for organising the data into a file.
2. Define the rules by which a respondent's answers will be assigned values so that they can be processed by a computer.
3. Carry out coding where the responses are mapped to standard categories.
4. Enter the data into the defined computer file format.
5. Clean the data – this is a final check on the data files for accuracy, completeness and consistency prior to the data analysis.

The data was collected from the respondents on the Internet via a service platform. The platform service provider was Survey Monkey. The platform automatically generated a computer file in various formats (SPSS, Excel and CSV) based on the questionnaire design. Steps 1 to 4 were therefore automatically done by the service platform at the point when the survey was closed.

As described by Fowler (2009), computer platforms like Survey Monkey can provide data quality controls such as permitting the entry of only a valid selection of values in a particular field. Complex question patterns can be followed as well. Once the data has been collected, the data file is ready for immediate analysis.

Missing data is one of the most problematic areas in survey research (Litwin, 1995). Special care was therefore taken during the design to decrease the missing values as far as possible. This was done using functionality such as mandatory field requirements as well as skip logic. Structured questions were used as far as possible to improve the data quality.

To address the data cleaning step, the following actions were taken:

- Pre-tests were done. The data collected during the pre-test was removed from the platform. At this point, the data file on the platform was clean. The survey was opened and data collection started on the platform. The responses were monitored during the collection process. The survey was then closed a week after the date communicated to participants. At this point, the data was exported from the platform in all the available formats. The generated data file was ready for immediate analysis.
- Manual validation was done by generating a code book in SPSS and checking the data entries.

During the validation process the responses have to be checked for consistency and completeness (Kitchenham and Pfleeger, 2003). During this process, a decision needs to be made on how to handle incomplete questionnaires. Incomplete questionnaires can be rejected, some questions can be removed and the remainder can be used, or all questionnaires can be used even with some incomplete (Kitchenham and Pfleeger, 2003).

From the initial stages the risk was that the survey was a bit longer that what is usually suggested. The questionnaire was therefore divided into two subsets to gather the relevant data. As previously mentioned, the first subset of questions was on the requirements process to derive an industry description. The second subset was more explorative on social behaviour patterns. This was done to ensure that at least one subset of data would be collected even if the respondents did not complete all the questions. Although there were some questionnaires that were not completed, a decision was made to use all questionnaires as suggested by

Kitchenham and Pfleeger (2003). In this instance each question was reported on the actual size of each sample statistic during the analysis (Kitchenham and Pfleeger, 2003).

The reason for this decision was the skip logic introduced into the questionnaire design. Not all questions would be answered by all respondents, as some might be skipped due to certain answers.

3.6.1.2 Analysis

During the analysis, the data is summarised so that it is easily understood and provides answers to the original research questions (Kelly et al., 2003). The survey was statistically analysed to do the following:

- Describe the respondents.
- Describe the responses to each of the questions.
- Describe how each requirement activity is executed by the practitioners.
- Determine the quality of the output of the requirements engineering process.
- Determine if there is a connection between the quality of requirements and the way the practitioners execute the requirements engineering process.
- Describe the practitioners' communication behaviour.
- Describe the trust relationships between the practitioners and various stakeholders.
- Determine if there is a connection between the quality of requirements and the way the practitioners behave.

To achieve this, the collected data had to be summarised and placed in tabular or graphical format in order to prepare for statistical analysis (Rea and Parker, 2005). The first step was the calculation of descriptive statistics from the raw data. Descriptive statistics utilise techniques to present the collected data in numerical, graphical or tabular format (Argyrous, 2011). Descriptive statistics have the ability to reduce a large set of collected data into a few graphs or tables in order to present the results (Argyrous, 2011). **Table 27** summarises the types of descriptive statistics available to derive a description of how practitioners execute the requirements engineering process.

Table 27: Types of descriptive statistics (Argyrous, 2011)

Type	Function	Examples
Graphs	Provide a visual presentation of data	Pie, bar, histogram, polygon (univariate) Clustered pie, clustered/stacked bar (bivariate, nominal/ordinal scales) Scatter plot (bivariate, interval/ratio scales)
Tables	Provide a frequency distribution of data	Frequency table (univariate) Cross-tabulations (bivariate/multivariate)
Numerical measures	Mathematical operations used to quantify particular features of distributions	Measures of central tendency (univariate) Measures of dispersion (univariate) Measures of association and correlation, regression (bivariate/multivariate)

As shown in Table 27, various methods are available but the most appropriate method should be selected to achieve the original objectives of the survey. The responses to each of the questions in the survey were presented using either graphs or tables.

To enable conclusions to be drawn in order to state relationships in answer to the research questions, a systematic approach is required to make sense of data. A relevant measure is therefore needed. The relevant analysis method to describe the data was selected during analysis based on a checklist provided by Fink (1995):

- Determine the number of independent variables.
- Determine whether the data on the independent variable is nominal, ordinal or numerical.
- Determine the number of dependent variables.
- Determine whether the data on the dependent variables is nominal, ordinal or numerical.
- Select a potential data analysis method.
- Compare the objectives of the survey against the assumptions and outcomes of the data analysis method.

Table 28 shows the decision of the data analysis method used in each case.

Table 28: Selection of data analysis method

Survey Objective	**Data Type**	**Data Analysis Method**
Describe respondents – in this case requirements practitioners – and determine if practitioners have similar background	• Job description (nominal) • Experience (nominal) • Qualifications (nominal) • Industry certifications (nominal)	Lambda is used as a measure of the association for nominal variables (Argyrous, 2011).
Describe how each activity is executed by the practitioners during the requirements engineering process	• Requirements activity involvement (Y/N - ordinal) • Tools (nominal) • Specification format (nominal)	Lambda is used as a measure of the association for nominal variables (Argyrous, 2011).
Determine the quality of the output of the requirements engineering process	• Quality scale (ordinal)	Exploratory factor analysis used as a data reduction technique (Floyd and Widaman, 1995). Measures of central tendency are the mean (numerical values), median (ordinal data) and mode (prevailing view, characteristic or quality) (Fink, 1995).
Determine if there is a relationship between the quality of requirements and the way the practitioners execute the	• Requirements activity involvement (Y/N - ordinal) • Quality scale (ordinal)	Cross-tabulations are used to investigate the relationship between variables (Argyrous, 2011).

requirements engineering process		
Describe the practitioners' communication behaviour	• Communication involvement (Y/N - ordinal)	Measures of central tendency are the mean (numerical values), median (ordinal data) and mode (prevailing view, characteristic or quality) (Fink, 1995).
Describe the trust relationships between the practitioners and various stakeholders	• The behavioural trust inventory (ordinal)	Exploratory factor analysis is used as a data reduction technique (Floyd and Widaman, 1995). Measures of central tendency are the mean (numerical values), median (ordinal data) and mode (prevailing view, characteristic or quality) (Fink, 1995).
Determine if there is a connection between the quality of requirements and the way the practitioners behave	• The behavioural trust inventory (ordinal) • Quality scale (ordinal) • Communication involvement (Y/N - ordinal)	Cross-tabulations are used to investigate the relationship between variables (Argyrous, 2011).

The results of the data analysis will be presented and discussed later. To enable conclusions about the population from which data was collected, more testing had to be done. These techniques are discussed next.

3.6.1.3 Testing Hypotheses and Models (Inferential Statistics)

Numerical tests called inferential statistics are used to draw conclusions about a population based on the sample information collected (Argyrous, 2011). These allow generalisation from the sample to the population.

The main components of the study are:

- the quality of the requirements delivered as a result of the requirements process
- the communication behaviour of the practitioners
- the trust relationship between practitioners and various stakeholders.

To quantify the means of different groups (communication behaviours and requirements activities), a Mann-Whitney test was used. This test can determine if two groups have the same median (Huizingh, 2007).

To quantify the type of trust relationships the practitioners had, these were compared with another sample using t-tests. A one-sample t-test is typically used to compare a sample mean to a known population mean (Argyrous, 2011).

3.6.2 Conclusions and Reporting

The final step in the research is to compile a research report. The data analysis results have been documented in order to communicate the conclusions and recommendations derived from the survey (Rea and Parker, 2005). The results documentation includes interpretation of findings as well as comparisons relative to previous studies (Ott and Longnecker, 2001).

3.7 Conclusion

The objective of this chapter was to select the most appropriate research method to complete the industry and behaviour review. The research method selection establishes a methodological framework containing the detail on how the research should be carried out in order to do an industry and behaviour review.

The objectives of the industry review and various research methods were considered. The most appropriate research method was selected. The selection was driven by which method would best accomplish the objectives of the industry review.

A survey was selected as the most appropriate research method to collect information about behaviours, knowledge, opinions, or attitudes of the requirements participants in order to derive a description of the requirements engineering process. The methodological framework described how the survey research process was executed, detailing how the survey was developed and tested, and the data collected and analysed.

The next chapter contains a description of the data analysis and an industry review description is derived. The industry review describes how practitioners execute the requirements engineering process.

Chapter 4 Industry Review

The industry review describes how practitioners in South African industries execute the requirements engineering process. This generated knowledge on how the requirements engineering process is executed in practice. This knowledge can be used to determine whether the existing requirements engineering knowledge base is actually migrated into practice by comparing the knowledge from literature with the practical execution of the requirements engineering process. Available research methods were evaluated, and a survey was selected, based on its ability to collect information about behaviour, knowledge, opinions, or attitudes. The survey was used to derive a description of the requirements engineering process.

The description of how the requirements engineering process is executed by practitioners will identify whether existing tools, techniques and available modelling methods are actually used by practitioners. The data collected during the survey is presented in the next section, followed by the analysis of the results.

4 Survey Results

A total of 127 responses were received from requirements practitioners. The requirements discipline exists within multiple communities, namely systems engineering, software engineering and business analysis (Gonzales, 2005). A requirements practitioner could potentially also belong to multiple communities. Different professional bodies represent these communities. The South Africa IIBA represents the business analyst community, the South Africa Computer Society represents the software engineering community and the INCOSE South African chapter represents the systems engineering community. The IIBA is the only community that focuses exclusively on requirements, whereas the other communities include requirements within a wider audience. As requirements practitioners are included within a wider audience in the systems engineering and software engineering communities, no estimation of the number of requirements practitioners can be made based on membership figures of these communities. The number was therefore calculated as a percentage of the member base of the IIBA South African chapter, which had 529 members at the end of May 2012 as confirmed by the IIBA South Africa. A potential 24% of the practitioners therefore responded to the survey.

One of the research objectives was to obtain a description of how practitioners execute the requirements engineering process, and secondly to identify the differences between how the literature suggests the requirements engineering process should be executed and how it is executed in practice. The data collected during the survey was analysed to achieve these objectives and is presented in two separate sections:

- Section 1 presents the data describing a typical requirements practitioner.
- Section 2 presents the data describing how the requirements process is executed.

4.1 The Respondents

The requirements practitioners in the requirements discipline were profiled according to job description, industry, years of experience, qualifications, as well as the projects worked on.

4.1.1 Job Description and Industry

The respondents were asked to select their current job description. This was a semi-structured question, which had a number of options to select from, as well as an option to use if the options provided were not relevant to them. The purpose of this question was to establish the main job description of a typical practitioner.

The data collected was summarised during analysis by using the variable *job description* in order to identify what the main job description of a typical practitioner is. When creating a statistical summary from one variable, the basic properties of the single piece of information answers questions such as (Siegel, 2012):

- What is the typical value for the job descriptions?
- How diverse are the job descriptions?
- Are there groups that require special attention?

Of the 127 respondents, 47.2% carried the title of business or senior business analyst. Consultant, systems analyst, business architect, academic, enterprise architect, systems engineer and requirements engineer made up 32.3% of the respondents. Other job descriptions ranged from developer, project manager, specialist to programme managers. Figure 27 illustrates the job descriptions of the respondents.

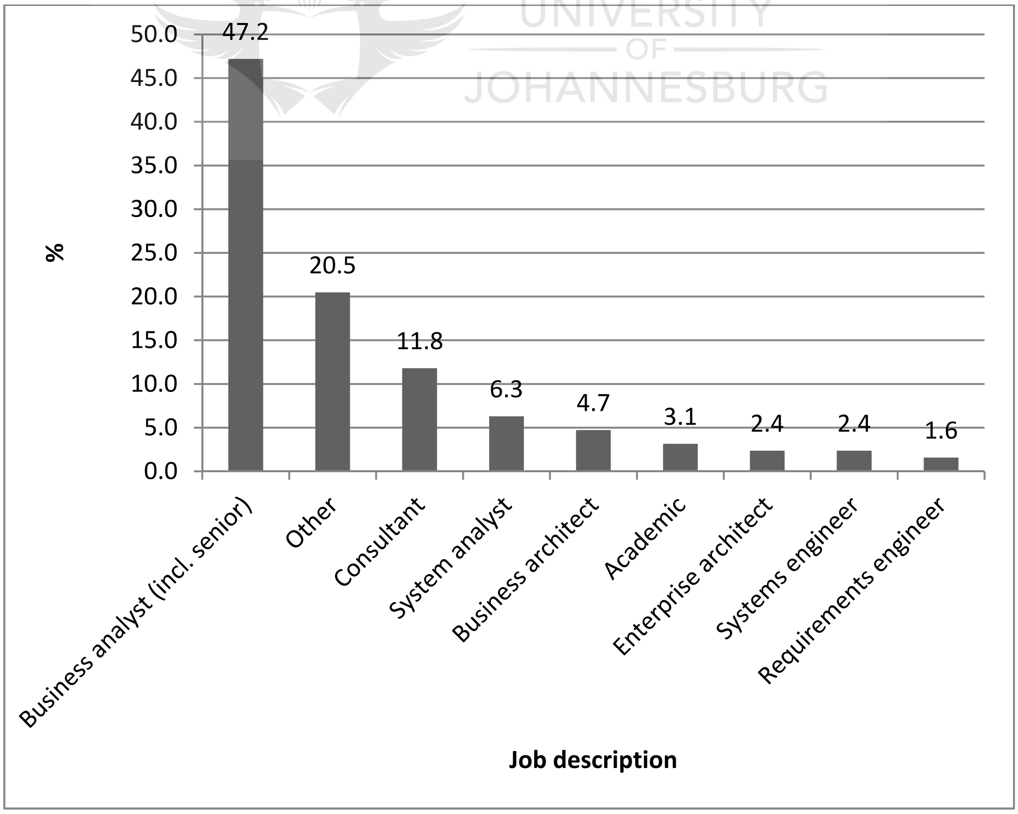

Figure 27: Practitioners' job description

The graph in Figure 27 indicates that the requirements practitioners surveyed had very diverse job descriptions. There was, however, one specific job description that was commonly used, which is the business analyst, used 47.2% of the time. As the practitioners operated within multiple communities, it was expected that the job descriptions would be very diverse.

Due to the high percentage of responses from business analysts, a second summary was generated to understand whether this job description was community specific. An additional variable, *industry*, was compared with the business analyst job description group to identify whether there was any relationship between the two variables. When creating a statistical summary from two-variable datasets the basic properties of information answers questions such as (Siegel, 2012):

- Is there a simple relationship between the two?
- How strong is the relation?
- Can any predictions be made from one another and with what degree of reliability?
- Are there any groups that should be focused on individually?

The data was first summarised by using the single variable, *industry*, in order to identify what the main industry was in which a typical practitioner worked. Secondly, a comparison between the business analyst group and industry was used to identify whether there was any relationship between the two.

Firstly, the data from the respondents' specific industry background was summarised. Of the 127 respondents, only 93 captured the industry. This was a semi-structured question, which had a number of options to select from, as well as an option to use if the options provided were not relevant to them. The industry backgrounds of the practitioners are displayed in Table 29.

Table 29: Practitioners' industry background

	Category	**Responses**	**%**
Industry background	Information and communication technology (ICT)	30	23
	Finance and banking	42	33
	Government public sector and defence	12	9
	Mining and commodities	1	1
	Retail and wholesale	1	1
	Consulting or professional services	5	4
	TME (technology, media and entertainment)	1	1
	Health	1	1
	Not answered	34	27

From the frequency in Table 29, it can be seen that the respondents were mainly from the finance and banking, ICT or government public sector and defence industries. Although the majority of respondents were from these industries, the summary shows a presence of requirements practitioners across all industries.
The second level of analysis was to compare the business analyst job description with the industry variable. The industry of only the business analyst job description group was analysed as this was identified as a special group from the job description analysis. This relationship between the business analyst job description group and the industry is shown in Figure 28.

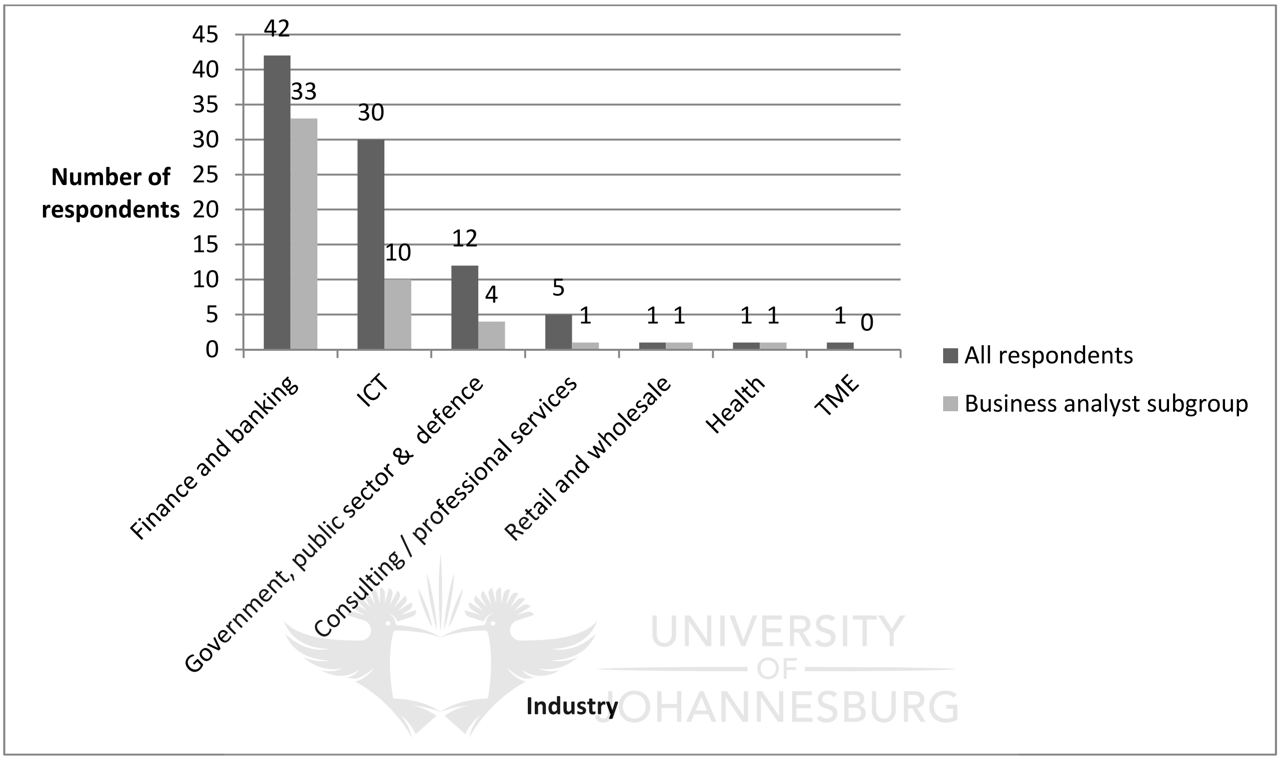

Figure 28: Business analyst industry comparison

The frequency in Figure 28 indicates that business analyst is used as a typical job description for a requirements practitioner in the finance and banking industry. Of the 42 responses from this industry, 33 reported to hold a job description of business analyst or senior business analyst.

The requirements practitioners' presence across all industries was confirmed, all with very diverse job descriptions. This was not unexpected as requirements practitioners belong to three different communities (Gonzales, 2005), as previously mentioned. Although there is an indication that the finance industry typically uses the job description of business analyst or senior business analyst, no relationship was found between the job description and industry. To measure the association and validate that no relationship existed between the job description and industry, Lambda was used. Lambda is a measure for nominal variables (Argyrous, 2011). Nominal data is scales classified into categories that have no quantitative ordering, such as business analyst, requirements engineer, etc. (Argyrous, 2011).

The detailed results from SPSS to measure the association are available in APPENDIX D, section D.1, Table 69. Lambda calculated the symmetric value as 0.218 which falls between 0.327 and 0.134. The value of

Lambda indicates a weak low association if compared to the scales provided in Argyrous (2011). This confirms that there is no relationship between the practitioners' job description and related industry.

4.1.2 Experience

The respondents were asked how many years' experience they had as a requirements practitioner. The responses have been summarised in Table 30.

Table 30: Practitioners' years of experience

	Category	**Responses**	**%**
Years' experience	Less than 1 year	3	3
	1 to 3 years	18	19
	4 to 5 years	20	22
	6 to 10 years	32	34
	More than 10 years	20	22

The majority of the respondents who completed this survey had between 6 and 10 years of experience. This is followed by equal responses of between 4 and 5 years and more than 10 years. It can be concluded that the majority of respondents were experienced practitioners with 56% having experience of 6 years or more.

4.1.3 Qualifications

The respondents were asked to indicate their highest level of tertiary education to establish whether they had similar tertiary backgrounds. The question was semi-structured, which had a number of options to select from, as well as an option to use if the options provided were not relevant. The options provided focused on qualifications relevant to ICT qualifications. Figure 29 provides a summary of the tertiary education levels.

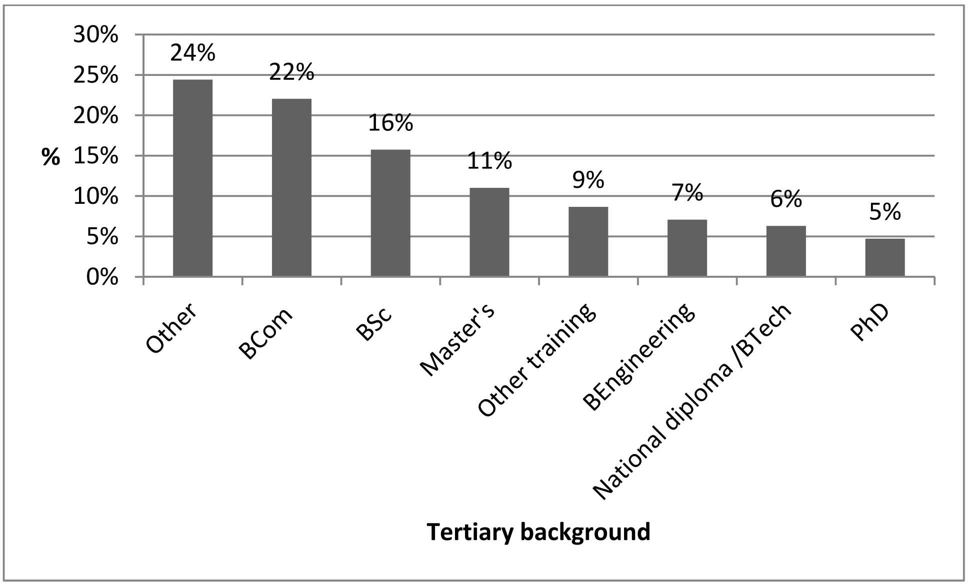

Figure 29: Respondents' tertiary background

From Figure 29 it can be concluded that 85% of the respondents held a tertiary degree. Only 15% did not have a degree, but of these, 6% held a national diploma or BTech diploma. The rest had attended training courses. Although the typical practitioner holds a tertiary degree, the degrees held by the practitioners surveyed were very diverse.

The tertiary backgrounds were then compared against the job description to determine whether respondents with similar job descriptions had similar tertiary backgrounds. Lambda was used as a measure for nominal data to determine if an association existed (Argyrous, 2011). The calculations of association SPSS results are available in APPENDIX D, section D.1, Table 70.

Lambda calculated a symmetric value of 0.111 which falls between 0.083 and 0.14. This indicates a very weak, negligible relationship (Argyrous, 2011). The respondents' tertiary backgrounds were therefore very diverse and no conclusion could be made about any relationship between the practitioners' qualification and job description.

4.1.4 Industry Certifications

Some 34% of the respondents held an industry certification. One respondent was a certified systems engineer. Six respondents were certified business analysis professionals. At the survey closure at the end of May 2012, there were only 19 certified business analysis professionals according to the IIBA certification register in South Africa (IIBA, 2012). Additionally, five respondents held SAP certifications, one held a PRINCE certification and three respondents held Microsoft Certified Systems Engineer or Development certifications.

The industry certifications confirmed the practitioners' qualifications as very diverse. It seems that there is no typical certification held by practitioners.

4.1.5 Project Profiles

To determine the typical project a requirement practitioner works on, they were asked how many people were involved in projects, as well as the duration and cost of the project. Of the 127 respondents, 93 provided answers to these questions.

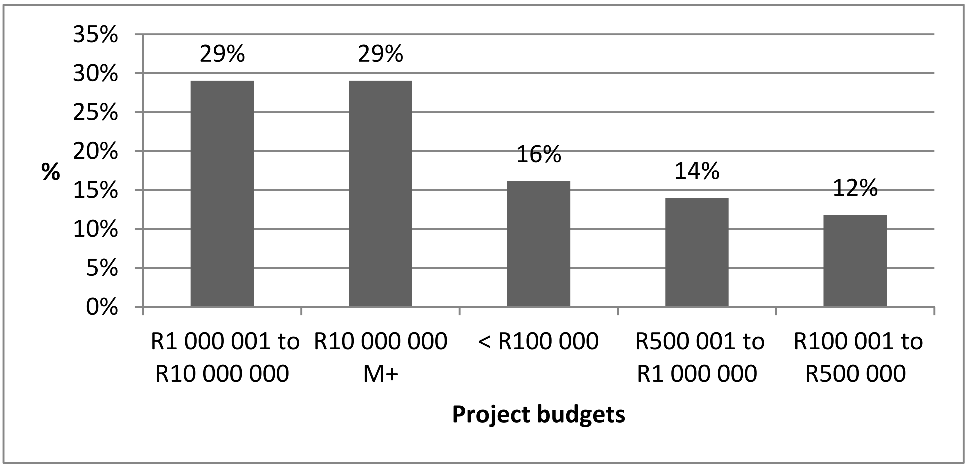

Figure 30: Project budgets

The data presented in Figure 30 shows that the project budgets on which the requirements practitioners worked varied across the board. The majority of projects had a budget of more than R1 million.

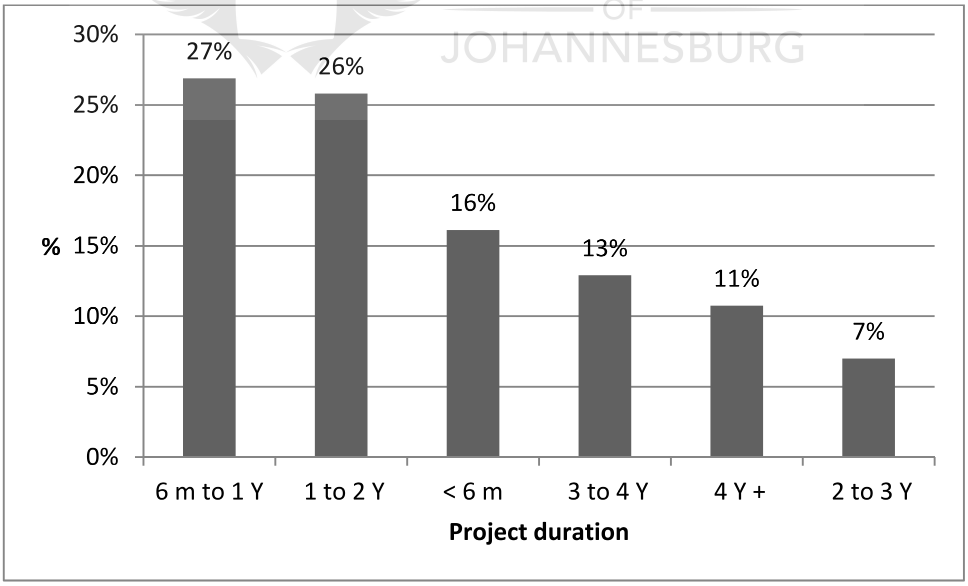

Figure 31: Project duration

The data presented in Figure 31 indicates that 53% of the project duration varied between 6 months and 2 years.

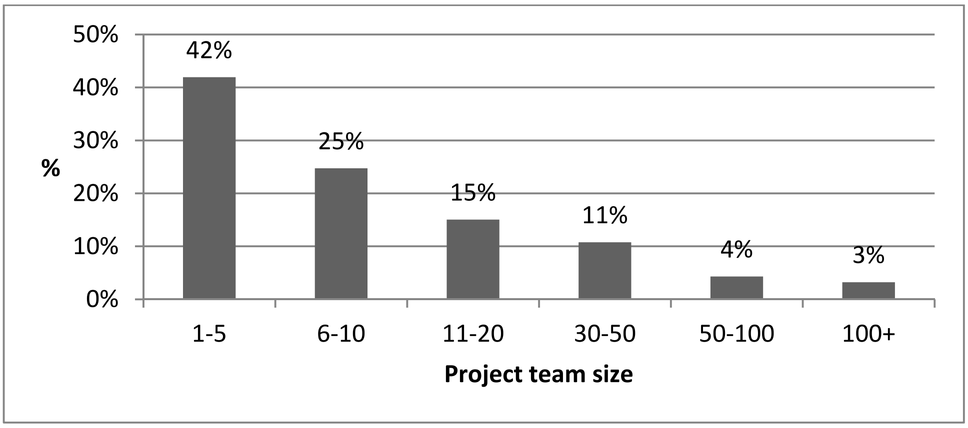

Figure 32: Project team size

The data in Figure 32 shows that 67% of the projects had an optimal team size of fewer than 10 people, with 67% reporting a team size of fewer than 10. The optimal size of a project team is normally fewer than 10 members (Rising, 2010).

Further analyses were done to identify whether there was any correlation between the project budget, duration and team size. Pearson's r was used to determine any relationship between project budget and duration. This is typically used when variables are intervals/ratios with many points on the scale (Argyrous, 2011). The correlation coefficient calculated was 0.55 (significant at the 0.01 level). As the correlation coefficient is close to 1, it shows a strong positive relationship (Siegel, 2012). The conclusion from the relationship is the longer the duration of a project, the larger the project budget, which is to be expected. Refer to Table 71 in APPENDIX D for correlation calculations.

A second measure was calculated to determine whether there was any relationship between the years' experience and the project budget as well as the years' experience and project duration. The correlation coefficients calculated were 0.404 and 0.372 (significant at the 0.01 level), respectively. In both cases there was a relationship, although not a strong positive one. The conclusion from this relationship is that experienced practitioners are generally involved in larger and more expensive projects. Refer to Table 72 in APPENDIX D.

This concludes the analysis of the respondents. The following section focuses on how the practitioners in the requirements discipline execute the requirements process, including the usage of best practice tools and techniques.

4.2 The Requirements Process

The data was explored as follows to describe how practitioners execute the requirements engineering process:

- Requirements engineering process models adopted in practice
- The activities executed during the requirements engineering process by practitioners
- The quality delivered as an output of the requirements engineering process

4.2.1 Requirements Engineering Process Models

The respondents were asked whether a formal approach was followed during the project implementation life cycle. If respondents indicated that a formal approach was used, a semi-structured question collected information about the project approach followed. This information provided some insight into how the overall project was implemented. Of the 127 respondents, 83 provided answers to this question.

Table 31: Project implementation followed

	Category	Responses	%
Project implementation approach followed	Yes	73	88
	No	10	12

From Table 31, it can be seen that in 88% of cases, a formal approach was used as guidance during the project implementation, and 12% indicated that no approach was followed.

A question then followed to collect information about the approaches used. The responses are summarised in Figure 33.

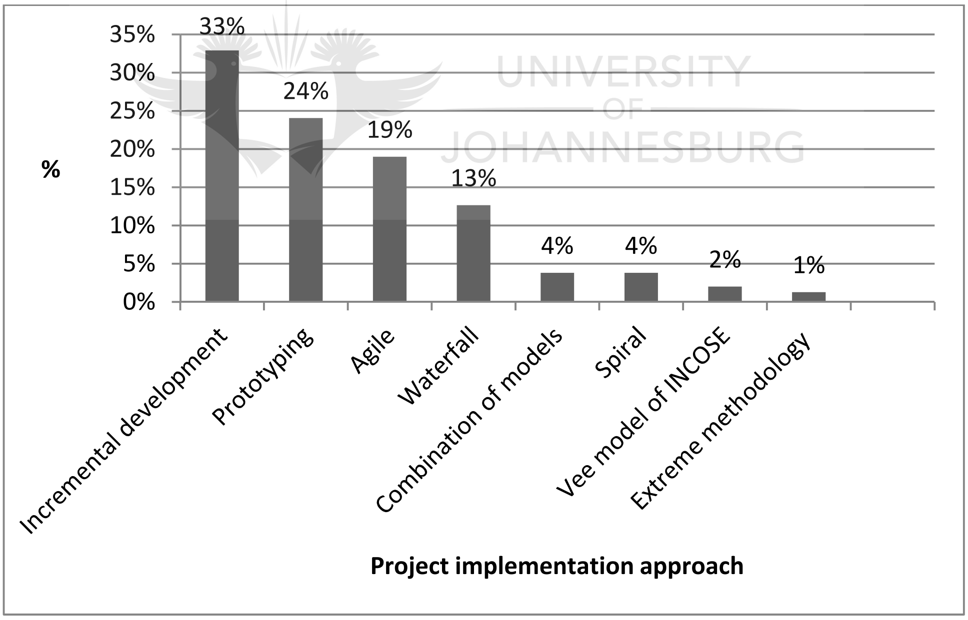

Figure 33: Project implementation approach

It can be seen from the responses that incremental development was the most popular, with 33% of the respondents using it, followed by prototyping (24%), agile (19%) and waterfall (13%).
Two questions in the survey collected information about the overall project implementation approaches. The survey did not include questions on how practitioners dealt with the actual requirements engineering process. A future improvement should be to determine whether practitioners deal with the requirements engineering process as a process or as an unstructured problem-solving activity as suggested by literature in section 2.5.

The practitioners' involvement across the requirements engineering process activities is described below.

4.2.2 Requirements Engineering Process Activities

To derive a description for the requirements engineering process, the practitioners were questioned about (i) how the input to the requirements process was obtained and (ii) in which requirements activities of the requirements process they were involved. Additionally the survey focused on the techniques used during these activities.

4.2.2.1 Involvement across Requirements Process

A study in Australia investigated the barriers experienced by business analysts that prevent them from effective requirements analysis (Wever and Maiden, 2011). The original survey questions and data used by Wever and Maiden (2011) were shared with the researcher. These were integrated into the questionnaire as a basis to determine the practitioners' involvement in the requirements activities. The results are illustrated in Figure 34.

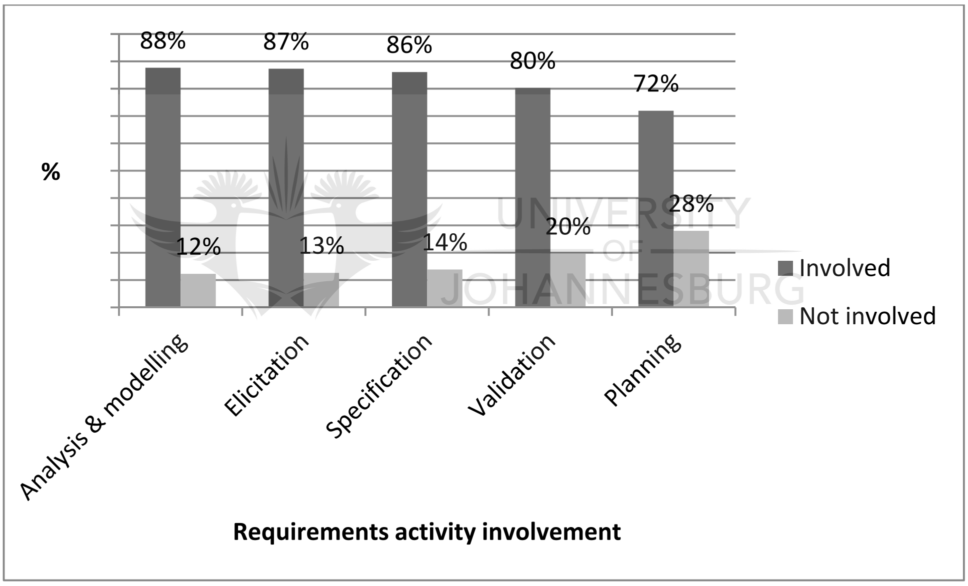

Figure 34: Practitioners' involvement in requirements activities

The practitioners appeared to be very consistently involved in the requirements activities. Most were involved in the analysis and modelling activity, but were the least involved in the planning activity. If this is compared with the results of the Australian study by Wever and Maiden (2011), no similarities can be identified. The business analysts in Australia reported to be engaged inconsistently across the requirements activities. This ranged from being the most involved in requirements elicitation (above 80%) to being the least involved in requirements validation (below 60%) (Wever and Maiden, 2011).

The potential reason for a more consistent involvement across requirements activities in this study compared with the Australian study could be attributed to the fact that the respondents were all experienced practitioners with 6 years or more experience as discussed in 4.1.2. The Australian study reported the majority of respondents' experience to be between one and three years (Wever and Maiden, 2011).

In the cases where the respondents indicated that they were not involved in the specific requirements activity, an additional question captured the reasons for this non-involvement. A summary of the factors preventing respondents' involvement is provided in Table 32.

Table 32: Factors preventing involvement in requirements activities

	Planning	**Elicitation**	**Analysis & Modelling**	**Specification**	**Validation**
This particular activity is not relevant to my project.	1	6	1	1	4
This particular activity is not relevant to my role.	11	1	4	6	5
My time is taken up with tasks unrelated to my role so I do not get time to do this activity.	-	-	-	1	2
Lack of project resources (time, budget, people) is preventing the project manager to engage me effectively in this activity.	2	1	2	2	-
This activity is considered less important than other project related tasks.	-	1	-	-	1
Within my organisation, there is no formal process in place to engage in this activity.	2	-	-	-	1
This activity is performed without consistency and continuity.	2	1	-	-	-
The work was performed by external vendor.	1	-	1	-	-
I was not given an opportunity to implement my acquired skills in this area and now I have forgotten how to do this.	2	-	-	-	-
Joined the project after activity was completed.	2	-	-	-	-
No reason provided	-	-	1	-	
Total N respondents not involved	**23**	**10**	**9**	**10**	**13**
Total N respondents involved	**59**	**69**	**64**	**62**	**53**
Total N not answered	**45**	**48**	**54**	**55**	**61**

Planning is indicated by literature as well as industry communities as a vital step in structuring the requirements activities (Aurum and Wohlin, 2005; IIBA, 2009; van Lamsweerde, 2009). Of the 127 respondents, 11 reported that planning was not part of their role. Two respondents mentioned a lack of resources and therefore planning was simply not done. A respondent mentioned that planning was not relevant to the project he was involved in. A further two respondents gave the reason: w*ithin my organisation, there is no formal process in place to engage in this activity,* suggesting that planning was not done at all during project implementations. It was also mentioned that in some instances planning was done, but in an inconsistent manner and without any continuity. This indicates that planning did not guide the implementation of the requirements during the project at all and was done on an ad hoc basis. In one instance, the planning of the project was done by external vendors. A few respondents also mentioned that they were not given the opportunity to take part in the planning or were not asked to do so.

The reasons for the respondents' non-involvement in requirements activities other than planning could be either that the activities were not part of the respondents' role or were not relevant to the project.

In addition to the respondents' involvement, the respondents were questioned about the deliverables of each activity and the tools or techniques used to produce the specific deliverables.

4.2.2.2 Requirements Planning

The respondents were asked an open-ended question to determine their view of what should be done during requirements planning. The data are classified in categories based on the responses. The responses have been summarised in Figure 35.

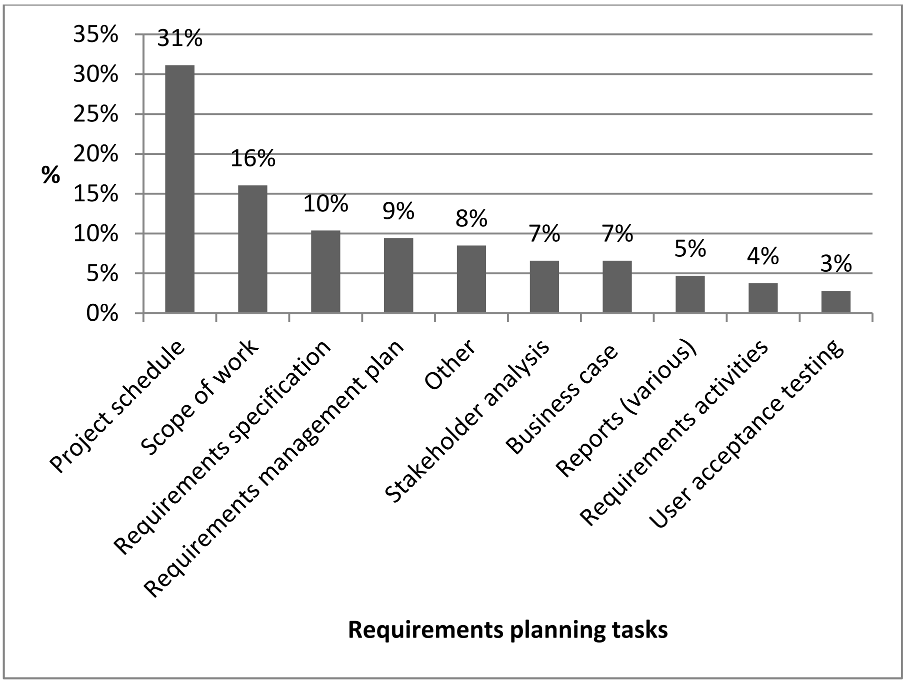

Figure 35: Summary of requirements planning task deliverables

Many different outputs were listed by the respondents as the planning activity deliverables as shown in Figure 35. There was a strong opinion that the project schedule is a deliverable of the requirements planning activity. The second important deliverable is a scope of work or problem definition. Thirdly, the actual requirements specifications (10%) were mentioned as a deliverable, followed by a requirements management plan (9%).

According to the literature as discussed in section 2.6.1, the requirements management plan is a key input to the overall project schedule and should be generated during requirements planning. From the data the practitioners appeared to deliver the actual project schedule during the requirements planning process. Requirements planning was done by only a very few respondents (9%).

The reasons given in section 4.2.2.1 for why planning is not done indicate that planning either does not get done or is very inconsistent and without any continuity.

From the reasons for why planning is not done and the result that if planning is done, it is seen as overall project planning and not the planning of the requirements activities, it is concluded that the requirements activities are carried out in an unstructured fashion without the necessary planning.

4.2.2.3 Requirements Elicitation

During elicitation the relevant knowledge about the problem that needs to be solved is distributed among many stakeholders, standards, regulations, the business domain, information and existing systems which should all be considered as having input into the requirements process. Elicitation is the activity of gathering all the relevant information about the problem as an input to the requirements engineering process. To understand the approach followed by practitioners to gather the input, the respondents were asked about:

- sources they consult to elicit information about the problem
- the typical stakeholders they consult with
- techniques used to elicit information.

To identify the research pattern of the respondents during the problem-solving activity, sources of information consulted were investigated (Tenopir and King, 2004). A semi-structured question was posed to the respondents. The summary of the sources consulted is presented in Figure 36.

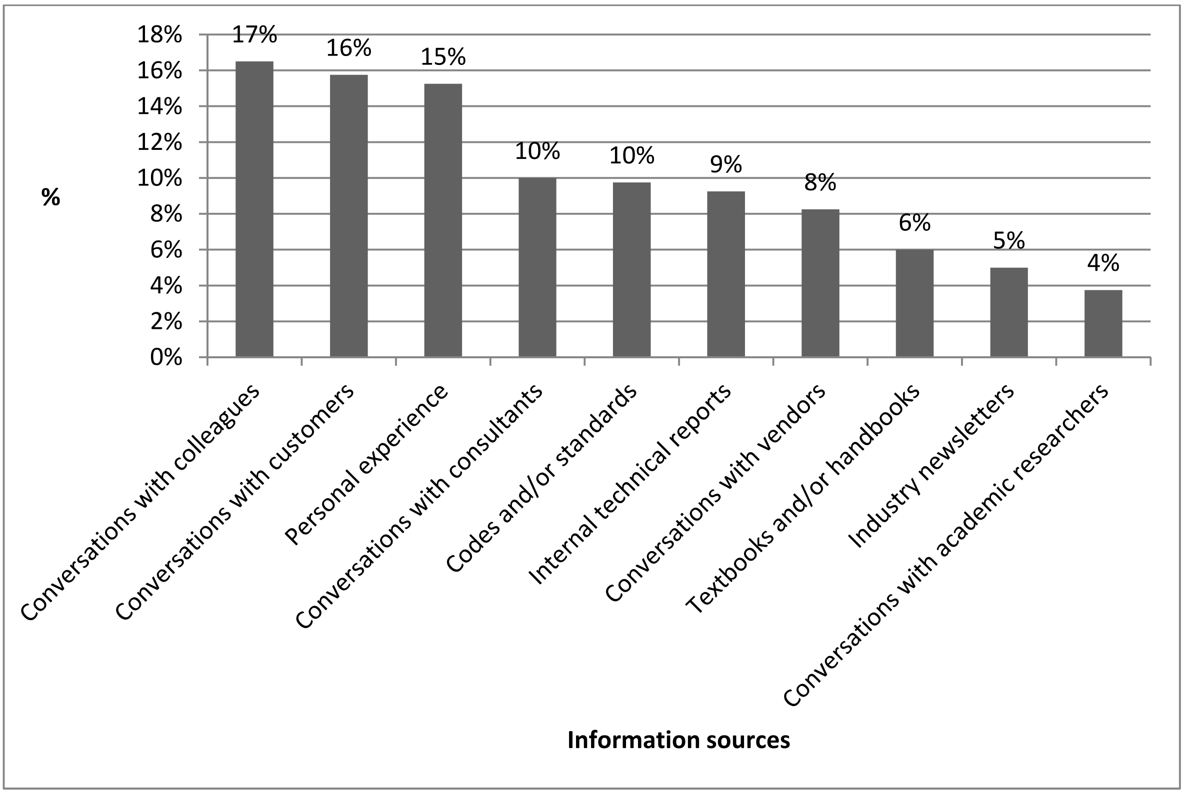

Figure 36: Practitioners' research patterns during elicitation

The summary presented in Figure 36 provides insight into what sources were consulted during requirements elicitation. The respondents preferred sources of information such as personal experience or conversations with customers and colleagues. Academic, industry and textbook sources were utilised by only a very small portion of the respondents.

The elicitation activity is the discovery of knowledge of the problem that should be solved. According to literature, as time passes during the problem-solving process, the sources change (Tenopir and King, 2004). During the early stages conversations with colleagues and personal experience are used. During the later stages of the process textbooks, codes and standards, industry newsletters and conversations with academics are used (Veshosky, 1998). The typical information-seeking behaviour during a problem-solving process is illustrated in Figure 37.

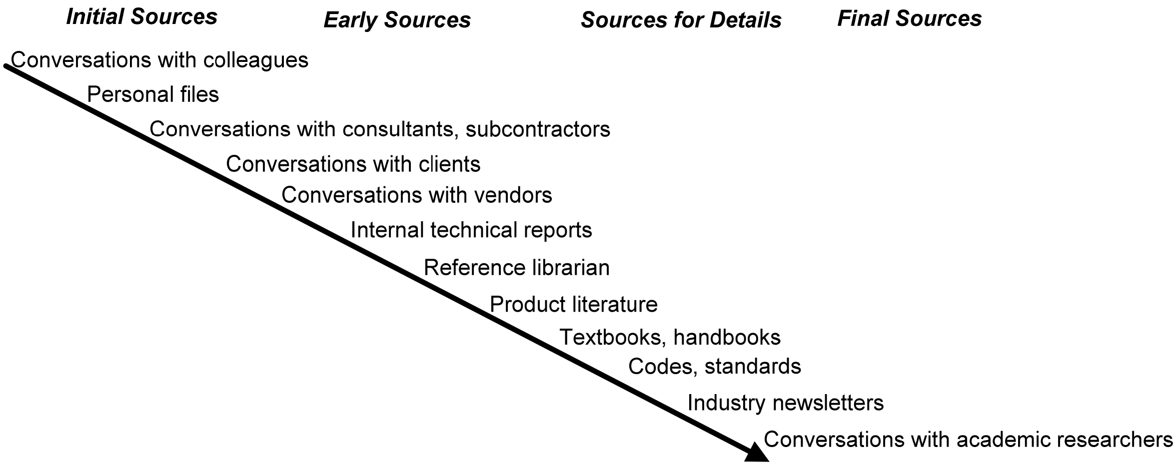

Figure 37: Information-seeking behaviour during the problem-solving process (Veshosky, 1998)

From the data collected as illustrated in Figure 36, academic, industry and textbook sources were used in a few cases (4%, 5%, and 7%, respectively). The preferred sources which were used by the practitioners were either personal experience or conversations with customers and colleagues, which are classified as initial sources as illustrated in Figure 37. The sources used by the practitioners indicate that the information-seeking behaviour did not follow a typical problem-solving process where the sources changed over time.

Knowledge about the problem is distributed among many stakeholders. To establish who the respondents typically interacted with and if they interacted with multiple stakeholders, two questions were posed. They were asked to select the roles of stakeholders they interacted with as well as the number of stakeholders. Figure 38 provides a summary of stakeholders with whom the respondents typically interacted.

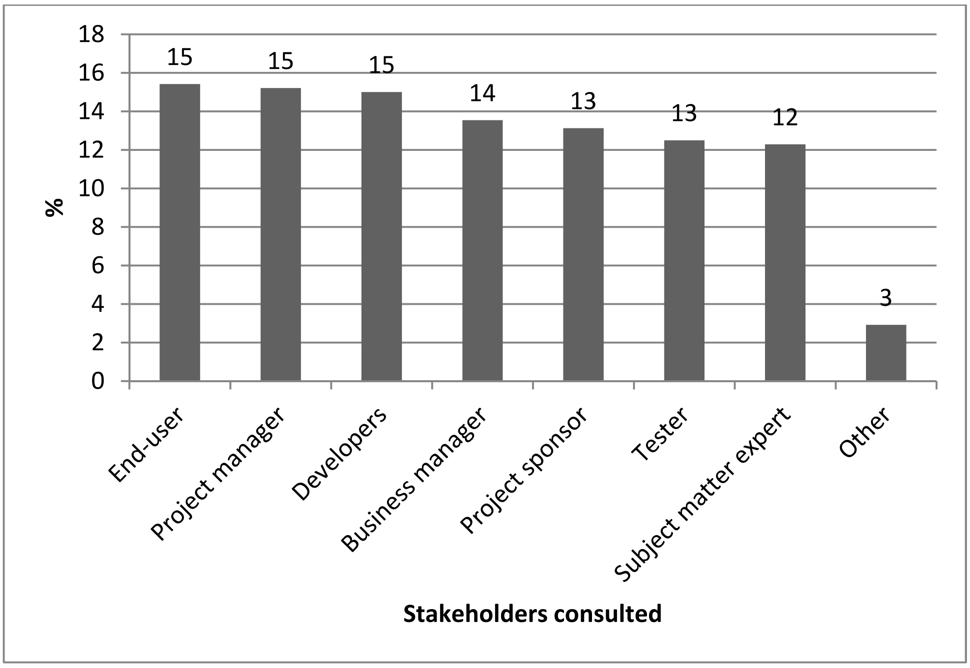

Figure 38: Roles of people consulted during elicitation

From the graph the respondents indicated that they consistently interacted with multiple stakeholders.

The final question for the elicitation activity was to identify which of the techniques were used by the practitioners. The question used a scale to capture the frequency of use. The elicitation techniques usage scale was tested for reliability using Cronbach's alpha prior to data analysis. Levels of 0.7 or more are generally accepted as representing good reliability (Litwin, 1995). Cronbach's alpha calculated for the elicitation techniques scale was 0.748, which is still an acceptable reliability. Refer to APPENDIX C, section C.1 for reliability calculations.

A list of techniques was derived from literature as discussed in section 2.6.2. The practitioners were requested to rate the usages of each technique on a scale of use, never use and never heard of. A stacked bar graph (Figure 39) was used to present the usage of each technique from the data collected.

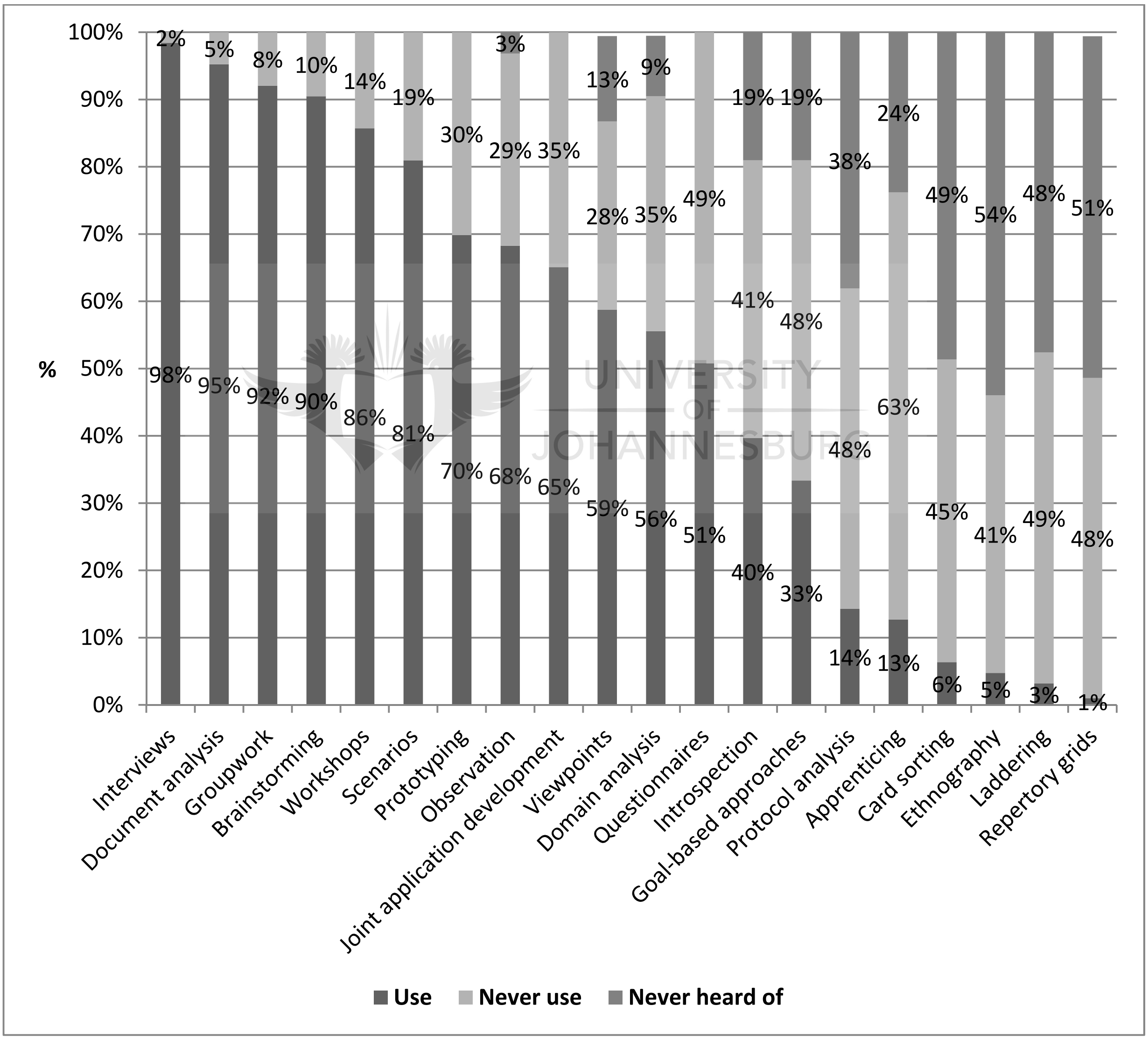

Figure 39: Summary of elicitation techniques usage

The practitioners surveyed utilised interviews, document analysis, groupwork and brainstorming extensively at 98%, 95%, 92% and 90%, respectively. Workshops (86%) and scenarios (81%) were also techniques used.

Prototyping and observation were utilised by 70% and 68%, respectively. Card sorting, ethnography, laddering and repertory grids were used by only a few practitioners.

The respondents preferred traditional techniques such as interviews and brainstorming during requirements elicitation when gathering information about the domain. Literature suggests that the most appropriate combination of techniques must be considered to ensure that all types of knowledge are acquired (Upchurch et al., 2001; Maiden and Rugg, 1996). Alexander (1992) defines domain knowledge as the knowledge individuals have about a particular field or subject. Her opinion is that it encompasses declarative knowledge (knowing that), procedural knowledge (knowing how) and conditional knowledge (knowing when and where). This knowledge operates on both the tacit and explicit level (Alexander, 1992). A significant proportion of knowledge is semi-tacit and can be accessed only through particular techniques (Upchurch et al., 2001).

A framework for selecting the most effective techniques to access non-tacit, semi-tacit and tacit knowledge has been developed by Maiden and Rugg (1996). Maiden and Rugg (1996) also mention that not all requirements can be acquired only from stakeholders; certain knowledge will only be acquired through observation.

Table 33: Effectiveness of techniques for acquiring knowledge (Maiden and Rugg, 1996)

	Observation	Unstructured Interviews	Structured Interviews	Protocols	Card Sorting	Laddering	Repertory Grids	Brainstorming	Prototyping	Scenario Analysis	Rapid Application Development	Ethnography
Future systems knowledge	x	√	√	x	-	√	-	√	√√	√√	√√	x
Non-tacit knowledge	-	√√	√√	√√	√√	√√	√√	√	-	√√	√√	-
Recognised knowledge	x	x	x	-	√	-	-	√	√√	√√	√√	x
Taken for granted knowledge	√√	-	-	√	-	-	-	-	√	√	√	√√
Working memory knowledge	x	x	x	√√	x	x	x	x	x	x	x	x
Compiled knowledge	√√	-	-	√√	-	-	-	-	√	√	√	√√
Implicit knowledge	√√	-	-	√√	-	-	-	-	√	√	√	√√
Method output	NL CD SA	NL	NL	NL	OV	OV	SM	OV SA	NL	NL	NL SA	NL CD SA

√√ = very good fit; √ = good fit; - = weak fit; x = poor fit; NL = natural language; CD = coded data; OV = object attribute value triplets; SM = set/hierarchy maps; SA = structured analysis notations

The highlighted cells of Table 33 indicate the techniques used more than 80% by practitioners as illustrated in Figure 39. Interviews and brainstorming have only a weak ability to acquire taken for granted, compiled and implicit knowledge, and a poor fit to acquire working memory knowledge. Scenarios have a broader coverage when acquiring knowledge although they also have a poor fit to acquire working memory knowledge.

During the survey respondents questioned why the list of elicitation techniques was not the recommended list provided by the IIBA (IIBA, 2009). The list provided by IIBA (2009) consists of brainstorming, document analysis, focus groups, interface analysis, interviews, observation, prototyping, requirements workshops and questionnaires. From the results and comments by respondents it is evident that practitioners have a set of preferred techniques that are used. Practitioners select techniques to be used during elicitation based on what technique is known, and not what the most appropriate combination of techniques is to ensure that all types of knowledge are acquired.

4.2.2.4 Requirements Analysis and Modelling

Once the information is elicited, a list of potential requirements must be derived. Various techniques, analysis and modelling assist in the derivation of the requirements. The respondents were asked about the techniques they used during the analysis and modelling of requirements.

The practitioners were requested to rate the usages of each technique on a scale of use, never use and never heard of. There was also an option to add a technique if the technique used was not listed.

The analysis and modelling techniques usage scale was tested for reliability using Cronbach's alpha prior to data analysis. Levels of 0.7 or more are generally accepted as representing good reliability (Litwin, 1995). The reliability of the analysis and modelling scale of the data collected indicates that there could be a problem with only a reliability of 0.648 which is below acceptable range. Data collected from the question was therefore used with caution. Refer to APPENDIX C, section C.2 for reliability calculations.

The list of techniques was derived from literature as discussed in section 2.6.3. A stacked bar graph was used to present the usage of each technique from the data collected.

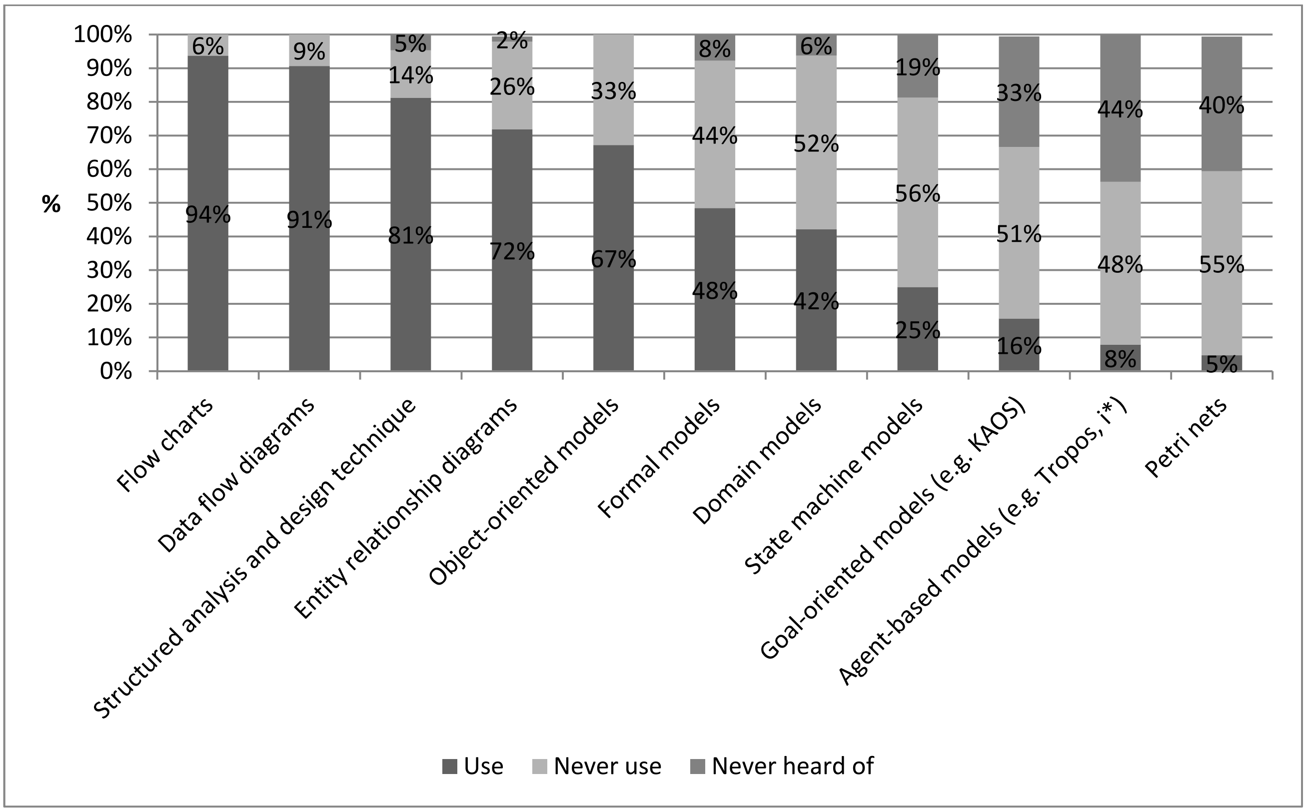

Figure 40: Analysis and modelling techniques

The techniques preferred were flow charts (94%), data flow diagrams (91%), structured analysis (81%) and entity relationship diagrams (72%). Petri nets, agent-based models, goal-oriented models and state machine models were either not in use or not known by most of the respondents.

As with elicitation techniques, the data suggests that practitioners had a set of preferred techniques. Practitioners selected techniques based on what technique was known to them.

The reliability testing on the data collected identifies some reliability issues. For future research consideration should be given to definitions of each technique. During the survey respondents questioned the list of techniques and indicated that they did know what was meant, which is an indication that the techniques were not familiar. Refer to section 3.5.3.1 for reliability results.

4.2.2.5 Requirements Specification

The specification is used to facilitate communication and should be complete to ensure that a working solution fit for purpose can be produced from the requirements (NATURE, 1996). To obtain an understanding of how the specification activity was performed by practitioners, the respondents were questioned on the following aspects of the specification:

- How are the requirements presented in the specification?
- Was the specification agreed on by all stakeholders? This forms the baseline requirements that will be used to build the solution. Do changes in requirements revise the baseline?
- Were requirements management tools used by practitioners?

First, two questions were asked to obtain an understanding of how the specifications were generated. The first structured question established whether there were any templates to provide practitioners with guidelines. Secondly, they were questioned to provide the format of their specification document in a semi-structured question.

Of the 127 respondents, 61 provided answers indicating how the specifications were generated. In response to question 1, 79% of the respondents reported that there were template guidelines available to help the practitioners to generate the specifications. This is illustrated in Figure 41.

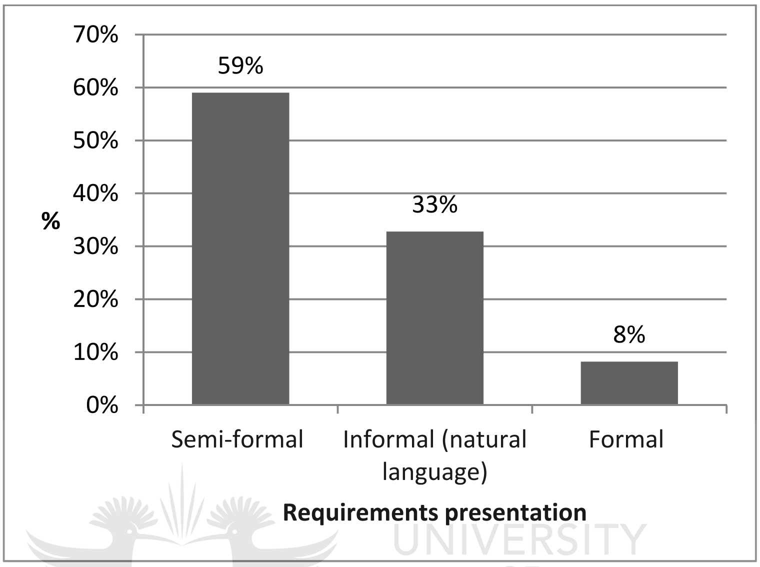

Figure 41: Requirements representation

Figure 41 shows that 8% of the practitioners used formal notation to present the requirements and 59% used semi-formal notation. The balance (33%) used informal presentation such as natural language.

These results were compared with the preferred elicitation techniques of practitioners as discussed in section 4.2.2.3, Table 33. The comparison indicates a potential mismatch. The preferred techniques of respondents all deliver outputs in natural language except brainstorming, which will deliver a semi-formal format. However, 59% of the respondents indicated they produced a specification with a semi-formal presentation. The natural language percentage should therefore be higher than the elicitation techniques used by practitioners to deliver output in natural language.

A measure of association calculation was done to verify the mismatch between the requirements presentation and preferred elicitation techniques. Lambda was used as a measure for nominal data to determine if an association existed (Argyrous, 2011). The calculations of association SPSS results are available in APPENDIX D, section D.2, Table 73.

For each elicitation technique compared with the specification Lambda resulted in a value of between 0 and 0.2, which indicates a very weak, negligible relationship. This confirms that the practitioners stated that they presented their specifications in semi-formal format, but the elicitation techniques that they used did not produce semi-formal notation. It could be that the practitioners generated models from elicited information during the analysis and modelling activity in order to generate a semi-formal notation specification.

A measure of association calculation was done to verify if a relationship could be identified between the requirements presentation and analysis and modelling techniques. Lambda was used as a measure for nominal data to determine if an association existed (Argyrous, 2011). The calculations of association SPSS results are available in APPENDIX D, section D.2 and Table 74.

For each analysis and modelling technique compared with the specification, Lambda resulted in a value of between 0 and 0.2, which indicates a very weak, negligible relationship. This confirms that the practitioners stated that they presented their specifications in semi-formal format, but the analysis and modelling techniques used did not generate semi-formal outputs.

The second set of questions determined whether the respondents obtained agreement between all stakeholders once specifications had been produced. They were also asked whether requirements changes were formally managed and the specification revised. Of the 127 respondents, 55 provided answers to indicate how the specifications management was done.

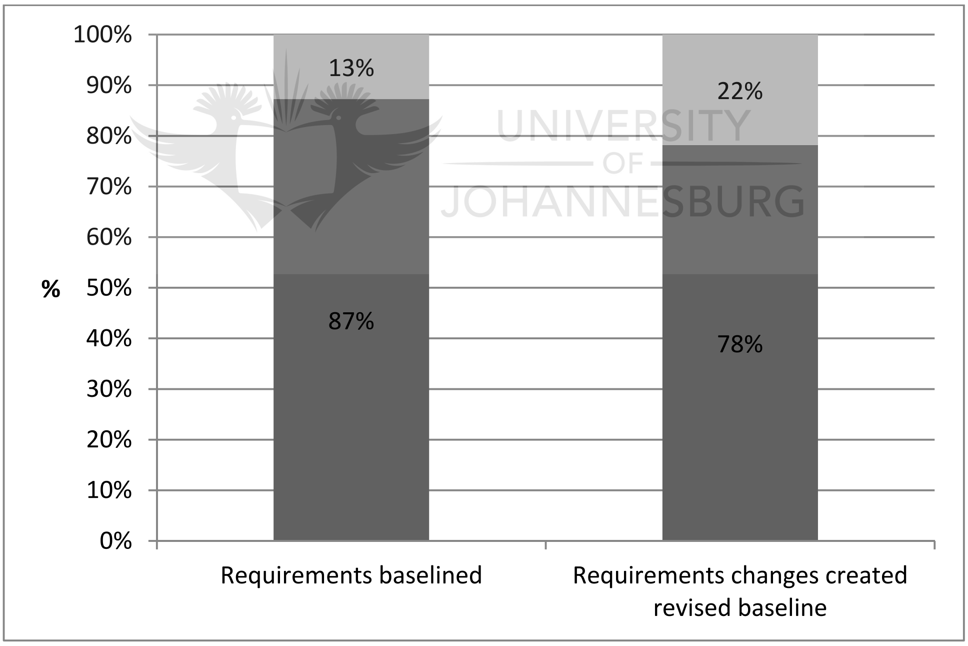

Figure 42: Requirements baseline

Figure 42 shows that 87% of respondents baselined the requirements and 13% did not. If requirements changes occurred after the specification was baselined, only 78% revised the baseline and managed the change via a formal process. In addition, the respondents were asked about the number of iterations the specification underwent before a baseline was produced.

Table 34: Specification iterations

Number of Responses	Minimum	Maximum	Mean	Standard Deviation
55	2.00	15.00	4.0000	2.53129

The summary in Table 34 shows that the number of iterations a specification went through before stakeholders agreed to baseline the requirements was on average four. Note there is a large variance in each case with a standard deviation of 2.53.

Finally, the respondents were asked if a software tool was used to manage the specifications delivered. In total only 12.8% of the respondents indicated that a software tool was used to develop or manage requirements. The usage per tool is illustrated in Figure 43.

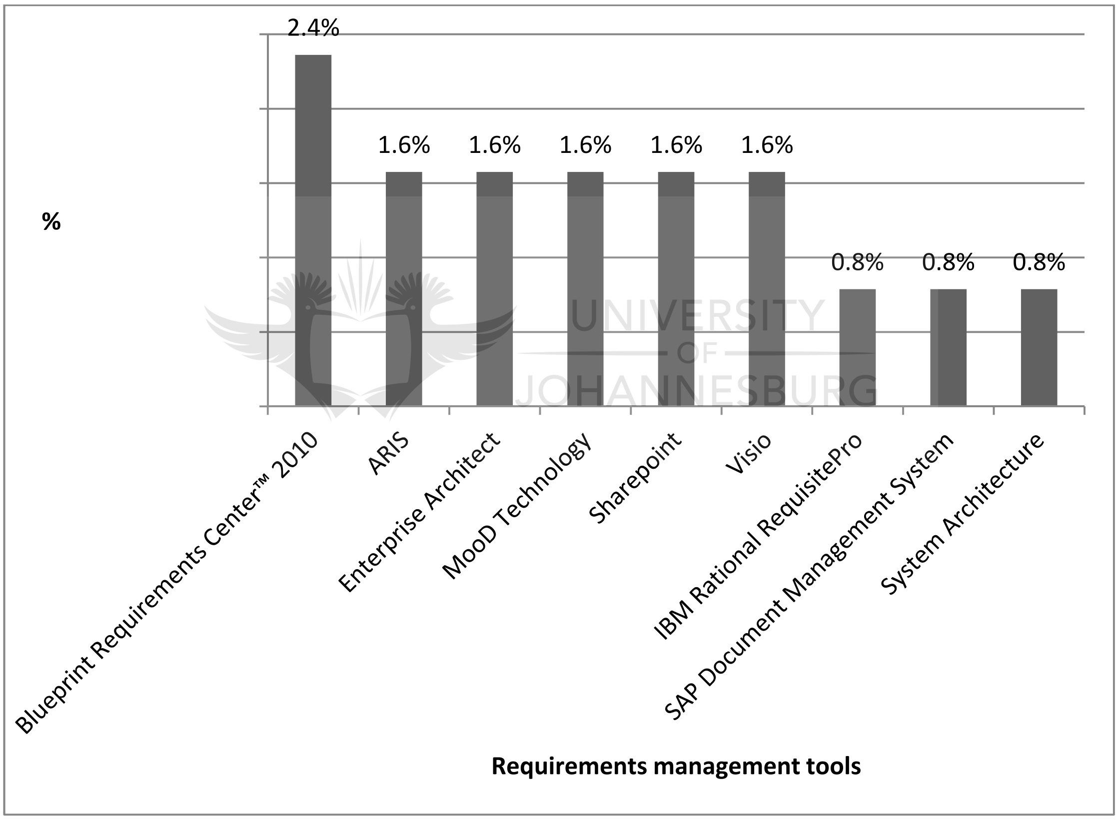

Figure 43: Requirements tools

Three of the tools mentioned by the respondents that they used as requirements management tools can be classified as requirements management tools as per section 2.7, i.e. Blueprint Requirements Center™ 2010, Enterprise Architect and IBM Rational RequisitePro. The other tools mentioned vary from Visio – a modelling tool, SharePoint - a document management tool, System Architecture - a tool used to model business operations and systems. From these results it can be concluded that requirements management tools were not generally used by practitioners to present or manage requirements.

This concludes the discussion of how the practitioners surveyed executed the requirements engineering activities. The next section focuses on the quality delivered as an output of the requirements engineering process.

4.2.3 Quality of Requirements Engineering Process Output

The desired output of the requirements engineering process is commonly agreed upon requirements by all stakeholders as presented in a specification document (Pohl, 1994). To obtain an understanding of the quality delivered as an output of the requirements process, the perceived quality of requirements from the requirements practitioners' point of view was determined.

4.2.3.1 Requirements Specification Quality

The literature prescribes that a requirement should consist of eight characteristics to ensure high quality (IEEE, 1998b; Denger and Olsson, 2005). Although checklists do exist to validate the quality of requirements, a measurement scale to determine the quality of requirements is not available (Firesmith, 2005; Wiegers, 1999; Heck and Parviainen, 2008). As these characteristics are subjective, an ordinal scale was used to measure the quality of the requirements.

The quality scale was tested for reliability using Cronbach's alpha prior to data analysis. Levels of 0.7 or more are generally accepted as representing good reliability (Litwin, 1995). Cronbach's alpha calculated for the quality scale was 0.817, which is within acceptable reliability. Refer to APPENDIX C, sections C.1 to C.3 for reliability calculations.

The scale elements used to determine the quality of the requirements are based on the eight characteristics of a quality specification. These characteristics are traceable, modifiable, verifiable, ranked, consistent, complete, unambiguous and correct as described in section 2.6.4. To estimate if the requirements contained each quality characteristic, a 7-point frequency Likert-type scale was integrated into the scale with the eight characteristics.

The respondents had to rate how frequently the requirements contained the eight quality characteristics. The scale used was 1 – Never; 2 - Rarely, in less than 10%; 3 - Occasionally, in about 30%; 4 - Sometimes, in about 50%; 5 - Frequently, in about 70%; 6 - Usually, in about 90%; 7 - Every time.

In a perfect world each characteristic would be expected to have a result as close as possible to 7, with the exception of the "consistent" characteristic which should be as close as possible to 1 (never) to ensure no conflicts. Each characteristic is presented in Figure 44 with the percentage allocated to each from the seven options of the Likert scale used.

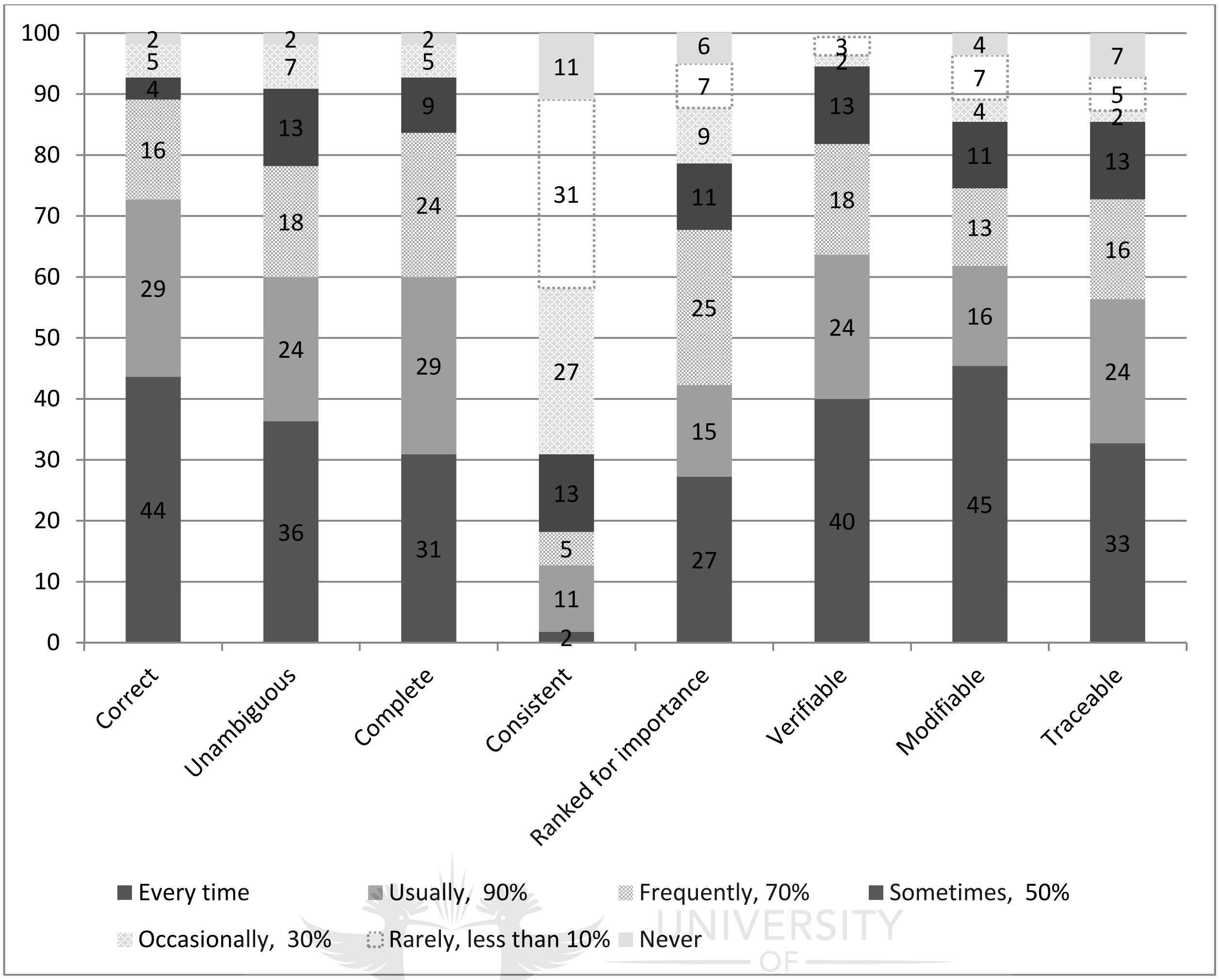

Figure 44: Requirements quality characteristics

Each characteristic was analysed individually to determine whether the requirements had the required characteristic *"Every time"* or in the "consistent" characteristic case *"Never"*. In the case of the characteristics of traceable, modifiable, verifiable, ranked, complete, unambiguous and correct the *"Every time"* rating was selected in less than 45% of the cases. The consistent characteristic "Never" was only selected in 11% of cases. These results indicated that the quality of requirements was low as the characteristics were not present as frequently as expected.

To validate these results, additional data analysis was done to calculate the average values for each characteristic.

Table 35: Descriptions of requirements quality characteristics

	Correct	Unambiguous	Complete	Consistent	Ranked	Verifiable	Modifiable	Traceable
N	55	55	55	55	55	55	55	55
Mean	5.946	5.618	5.636	3.109	4.964	5.764	5.527	5.273

Median	6	6	6	3	5	6	6	6
Std deviation	1.311	1.434	1.324	1.548	1.815	1.347	1.804	1.84
Skewness	-1.635	-.971	-1.125	.775	-.638	-1.014	-1.097	-1.066
Std error of skewness	.322	.322	.322	.322	.322	.322	.322	.322

As quality is an ordinal scale, the median is used for averages. The median value for each quality characteristic is presented in Table 35. For perfect quality requirements, each characteristic would be expected to have a result as close as possible to 7, with the exception of the "consistent" characteristic which should be as close as possible to 1 (never) to ensure no conflicts.

In the case of all the characteristics, except for the case of consistent, the average varies between 5 (frequently, in about 70%) and 6 (usually, in about 90%). For the consistent characteristic, which was expected to be as close as possible to 1 (never), an average value of 3 (30%) is reflected. This indicates that the quality of the requirements could be seen as acceptable but no definite conclusion could be made as there is no existing measure to compare these results.

The standard deviations reflect the deviation around the mean. These variances have been illustrated for each characteristic and all the cases in APPENDIX D, section D.3, Figures 55 to 62. From these figures it is clear that there are large variances around the mean. In each characteristic the mean is smaller than the median and therefore a negative or left-skewness is present in each characteristic due to the extremely low values in the data that reduce the mean (Berenson and Levine, 1989).

Poor requirements are one of the main contributors to failed projects (Ellis, 2008; El Emam and Koru, 2008; Glass, 2003; Rodrigues, 2001; Schwaber, 2006; Hofmann and Lehner, 2001). Further analysis was done to investigate the impact of the execution of activities during the requirements engineering process on the quality of requirements.

To simplify the analysis, exploratory factor analysis was used as a data reduction technique to validate if the eight quality elements could be summarised. Calculations are provided in APPENDIX D, section D.4. Initial factor analysis confirmed that it would not be ideal to summarise the eight elements. However, confirmatory factor analysis was done to validate the underlying structure of the quality scale which suggested that the elements *"consistent"* and *"traceable"* should be excluded. By adjusting the quality scale the factor analysis confirmed that the six other elements could be summarised into one factor. A summary value for quality could therefore be calculated by using the median for each of the six elements.

The quality of the requirements was summarised and displayed separately for practitioners involved in the requirements activity versus practitioners who were not involved in the activity to see whether this impacted the output of the requirements engineering process.

Table 36: Activity involvement by quality of requirements

Requirements Activities	Quality				
	Rating 1	Rating 3	Rating 3 to 5	Rating 5 to 7	Total
Planning *Involve* (N = 43)	0%	0%	23%	77%	100%
Planning *Not involve* (N = 12)	8%	8%	42%	42%	100%
Elicitation *Involve* (N = 50)	0%	2%	24%	74%	100%
Elicitation *Not involve* (N = 5)	20%	0%	60%	20%	100%
Analysis & modelling *Involve* (N = 54)	2%	2%	26%	70%	100%
Analysis & modelling *Not involve* (N = 1)	0%	0%	100%	0%	100%
Specification *Involve* (N = 55)	2%	2%	27%	69%	100%
Specification *Not involve* (N = 0)	n/a	n/a	n/a	n/a	n/a
Validation *Involve* (N = 49)	2%	2%	18%	78%	100%
Validation *Not involve* (N = 6)	0%	0%	100%	0%	100%

1 (Never); 2 (Rarely less than 10%); 3 (Occasionally, in about 30%); 4 (Sometimes, in about 50%); 5 (Frequently, in about 70%); (Usually, in about 90%); 7 (Every time)

In an ideal world a rating of 7 (every time) is expected for the quality of requirements. The cross-tab in Table 36 indicates a higher percentage quality of requirements when the practitioners were involved. This is the case for each of the activities.

The opposite also holds in the case of no n-involvement of the practitioners. The quality of requirements delivered where there was no involvement of the practitioners varies between very poor quality and acceptable.

As explained by Argyrous (2011), to identify a relationship from the data once presented in a cross-tab the identification of any patterns and the strength is required. The results show a clear pattern of dependency between the quality of requirements and the way the requirements engineering process is executed. A positive relationship is clear where the activity is executed and a higher quality of requirements is delivered. The pattern is consistent in the case of every activity.

As the cross-table shows a clear pattern, a Mann-Whitney test was done in each case of the two groups (involved and not involved), to validate that these two groups did not have the same median.
A Mann-Whitney test was performed to test the hypothesis that the means of each activity where practitioners were involved were the same as the group where the practitioners were not involved.
Note that this test could not be done for the specification activity as there was no data available.

Table 37: Mann-Whitney test for quality and requirements activity

Mann-Whitney	**Quality**							
	Planning		Elicitation		Analysis & Modelling		Validation	
	Involved	Not involved	Involved	Not involved	Involved	Not involved	Involved	Not involved
N	43	12	50	5	54	1	49	6
Mean rank	31.12	16.83	29.73	10.70	28.46	3	29.96	12
Mann-Whitney U	124		38.5		2		51	
Sig. (2-tailed)	0.005		0.009		0.105		0.008	

Table 37 indicates that in each result set where there was involvement in the relevant activity, a higher quality of requirements was delivered as it resulted in the highest mean rank. The original hypothesis could be rejected as in each case the group where there was involvement resulted in a higher ranked mean than the group where there was no involvement.

It could only be concluded in the case of planning, elicitation and validation that there were statistically significant differences between the groups where there was involvement in the activity: for the planning activity (U = 124, p = 0.005), for the elicitation activity (U = 38.5, p = 0.009) and for the validation activity (U = 51, p = 0.008). In the analysis and modelling case the sample available for the not involved group was very small and could be the reason why there was no statistically significant difference between the groups.

These tests confirm that the more the practitioner is involved during the requirements activities, the higher the quality of requirements.

For future research, it is suggested that not only the practitioners should rate the quality of requirements, as this is a one-sided measure from their perspective. The stakeholders should also be contacted to rate the quality of requirements and then a holistic view could be obtained on the quality of requirements.

The customer satisfaction levels were also validated to understand whether the delivered solution was used by the customers and perceived fit for purpose.

4.2.3.2 Customer Satisfaction

The respondents were asked to indicate from their personal perspective whether the business stakeholders and end-users were satisfied with the implemented solution. Two questions were asked to capture the satisfaction levels of the end-users separately from the business stakeholders. The questions were separated to estimate the satisfaction level of the stakeholders on different operating levels.

Table 38: Stakeholders' satisfaction levels

	Customer Satisfaction of Business Stakeholders	Customer Satisfaction of End-users
N	63	63
Mean	82.46	81.16
Median	85	90
Std deviation	19.08	21.61
Skewness	-2.73	-2.09
Std error of skewness	0.301	0.302

The satisfaction levels of the business stakeholders are listed in Table 38. For the business stakeholders the mean is 82.46%, which indicates an average of the business stakeholders' satisfaction. The end-users have an average of 81.16% of satisfaction. In both cases the mean is less than the median; therefore a negative or left-skewness is present in each case due to the low values in the data that reduce the mean (Berenson and Levine, 1989). This variance is seen in the standard deviation, which implies that there are cases that had a low customer satisfaction rate.

These satisfaction levels are high and it could simply be the perception of the practitioners. A future improvement would be to measure this directly with the actual users and not obtain the perception of the practitioners. A final question was asked to determine whether the users actually used the system.

Table 39: Customer usage of solution

	Category	Responses	%
Is the solution delivered by the project, currently in use by the end-users?	Yes	52	82.5
	No	11	17.5

Table 39 shows that 82% of the solutions delivered were used and about 18% of the solutions were not. A high correlation was expected between the customer satisfaction levels of the end-users and the usage of the solution. The business stakeholders would not necessarily use the solution. However, end-users are typical users of the solution. Correlations were calculated to determine whether there was a relationship between customer satisfaction and the usage of the solution.

A negative relationship was identified between end-user satisfaction and the usage of the solution with a correlation of -0.288* significant at the 0.05 level. Additionally, a negative relationship was identified between the business stakeholders and the usage of the solution with a correlation -0.391 significant at the 0.01 level. Refer to APPENDIX D, section D.5 for correlation calculation details. This negative relationship contradicts the data presented in Table 38.

From this it is clear that there could be a perception that stakeholders are satisfied with the solution. However, the solution could potentially not be in use. In future research, this relationship needs to be explored directly with the stakeholders as previously suggested.

The following reasons were provided for why customers do not use the solution:

- The users do not understand how the technology supports their business processes.
- The users are still using the old solution.
- The users do not use training and user manuals.
- Users are waiting for more requirements to be implemented.
- Development is still in progress.
- Users are forced to use the solution but it is imposed on the industry.

The perception of the practitioners is that customer satisfaction levels are high; however, the relationship with the usage of the solution by stakeholders suggests that there is more information that must be explored.

This concludes the analysis of the data on how the practitioners execute the requirements engineering process in practice. The next section summarises themes that were identified during the data analysis and a comparison is made with the results from the literature review.

4.3 Literature and Industry Comparison

The industry review highlighted a few themes, which are compared with what literature suggests.

Table 40: Literature and industry review comparison

	Literature Review	Industry Review
Requirements practitioners – education	There are tertiary programmes and industry-specific certification for requirements engineering (Holm et al., 2010; IIBA, 2009; IREB, 2006).	The typical practitioner holds a degree; however, the degrees held by the practitioners surveyed were very diverse. There is no typical certification held by the practitioners. Refer to sections 4.1.3 and 4.1.4.
Planning activity	The requirements practitioner is responsible for creating a requirements management plan which is the key input into the overall project plan (Carkenord et al., 2010; Weese and Wagner, 2011). Refer to section 2.6.1.	The project schedule was listed by practitioners as the most important deliverable of the requirements planning activity. Refer to section 4.2.2.2.
Elicitation	Information-seeking behaviour during	The practitioners preferred sources of

activity – information sources	problem-solving shows preference for conversations with colleagues and consultants during initial stages, but this changes during later stages of the problem-solving process (Tenopir and King, 2004).	information which were either personal experience or conversations with customers and colleagues. Refer to section 4.2.2.3.
Elicitation activity – techniques	A range of techniques are available to assist during elicitation of knowledge. Consider the most appropriate combination of techniques to ensure that all types of knowledge are acquired (Upchurch et al., 2001; Maiden and Rugg, 1996).	Traditional techniques such as interviews and brainstorming as preferred by practitioners during the elicitation activity could be a weak fit to acquire all types of knowledge. Refer to section 4.2.2.3.
Requirements management	At least 92 requirements management tools are found in the market that can be used to manage requirements. Refer to section 2.7.	Requirements management tools were not used by practitioners surveyed – only three of the tools mentioned were requirements management tools. Refer to section 4.2.2.5.
Requirements quality	Quality of requirements is complex to measure (Denger and Olsson, 2005). There are various guidelines and checklists to validate the quality of requirements (Firesmith, 2005; Wiegers, 1999; Sommerville and Sawyer, 1997; Heck and Parviainen, 2008; Denger and Olsson, 2005).	Although quality is subjective to measure, an attempt was made to measure the requirements quality delivered by practitioners.
Efficient requirements engineering process	Literature suggests that the more effective the requirements process, the better the quality of the requirements delivered. A study by Damian and Chisan (2006) showed that improvements in the requirements engineering process led to improvements in productivity, quality and risk management.	The data collected from the practitioners confirms that where the practitioners were involved in the requirements activities, the requirements engineering process was more efficient. The quality delivered was higher than the quality delivered by practitioners not involved in the requirements activities during the requirements engineering process. Refer to section 4.2.3.1.

The main findings from the above comparison are as follows:

1. Requirements practitioners operate within different communities, i.e. software engineering, systems engineering or business analysis. Focused tertiary degrees as well as industry certifications are established for each of these communities. Practitioners hold very diverse tertiary degrees with no consistent education between the practitioners.

2. The requirements planning activity is seen by literature as a separate activity delivering a requirements management plan which is an input to the overall project plan. From an industry perspective there is a planning activity delivering the overall project plan. It seems as if the practitioners do a single planning task for the project and it is not clear if the requirements planning forms part of the overall plan. The actual focus of the requirements planning activity should be to generate a requirements management plan that identifies the required work.
3. The information-seeking behaviour during a problem-solving process changes over time according to the literature (Veshosky, 1998). The majority of practitioners depend on sources of information such as either personal experience or conversations with customers and colleagues. Less than 10% of practitioners consult standards, technical reports and even less utilise academic, industry and textbook sources. The information-seeking behaviour suggests that no changes take place over time during the problem-solving process. This could indicate that practitioners do not utilise all sources available to define problems and detail could be missing during the problem-solving process.
4. During the elicitation activity literature suggests that a combination of techniques should be used to ensure that all types of knowledge are acquired (Maiden and Rugg, 1996). The preferred techniques of practitioners, such as interviews, brainstorming, workshops and scenarios, vary between poor fit to weak fit when certain knowledge should be acquired, for example working memory knowledge.
5. Many requirements management tools are available but these tools are not generally used by practitioners to present or manage requirements.
6. For good quality requirements the characteristics of traceable, modifiable, verifiable, ranked, complete, unambiguous and correct would be expected to result in a rating of compliance as close as possible to 7 (every time). The practitioners rated these characteristics for the requirements consistently between 5 (frequently) in about 70% and 6 (usually) in about 90% of the time. The exception "consistent" should be as close as possible to 1 (never) to ensure no conflicts. This was rated with an average of 3 (occasionally) in about 30% of the time. This data suggests that the quality of requirements is below the high quality norm and that quality can definitely be improved. This is in line with the studies found in literature that constantly report that the requirements engineering process delivers poor quality projects (El Emam and Koru, 2008; Ellis, 2008; Glass, 2003; Rodrigues, 2001; Ferrari and Madhavji, 2008).
7. The results confirmed that in the cases where practitioners are involved in the activities, high quality requirements are delivered. This implies a more efficient requirements engineering process.

4.4 Conclusion

The industry review described how the requirements engineering process is executed by practitioners. It identified their involvement during the process and the existing tools, techniques and modelling methods which are actually used by practitioners. It highlighted existing differences between what is in literature and what is used in practice.

Practitioners utilise only a subset of tools, techniques and modelling methods available. Determining the reason for this is a future research possibility. This could have affect the types of knowledge acquired during the requirements process. The knowledge leads to a complete understanding of the problem to be solved and ultimately impacts the quality of requirements delivered as an output of the requirements process. The quality delivered in practice is influenced by the involvement of the practitioners in each of the activities of the requirements process. Quality requirements have an impact on project success. There is a definite need to focus on improvement on quality of requirements. This was identified from the literature as well as the industry review.

This knowledge of how practitioners do things will contribute to the existing body of knowledge. This can be used to identify future research focuses. It highlights the importance of understanding the underlying factors that contribute to quality requirements. If the input, which is the requirements, into the product development, software or system engineering processes is improved, everyone involved would benefit. The rate of project success could improve.

Communication is a challenge faced across communities in which the requirements discipline is executed; it is also identified as one of the main impacts on the quality of requirements as discussed in the literature review. Social studies show that if trust is not present in a relationship, effective communication will not take place (Zeffane et al., 2011). It was therefore decided to explore the existence and level of trust relationships between a requirements practitioner and relevant stakeholders. This could provide insight regarding the potential to deliver quality requirements. The next chapter will deal with these behaviours of practitioners.

Chapter 5 Review of Practitioners' Behaviour

The behaviour review describes the typical communication behaviour and relationships that practitioners establish with stakeholders during the requirements engineering process. This generated knowledge on how the practitioner behaves when the requirements engineering process is executed in practice. The knowledge was generated using a survey to collect information about behaviour, knowledge, opinions, or attitudes of requirements practitioners.

This knowledge can be utilised to overcome the social challenges that are experienced during the requirements engineering process. These results could potentially indicate areas of improvement to address the quality of requirements as the output of the process.

The description of how the practitioner behaves during the requirements engineering process will identify whether communication takes place between the practitioner and the various stakeholders and it will describe the trust levels.

5 Socio-technical Factors

The context in which the requirements engineering process is performed is a human activity system as described by Nuseibeh and Easterbrook (2000): *"The context in which Requirements Engineering takes place is usually a human activity system, and the problem owners are people. Engagement in a requirements engineering process presupposes that some new computer-based system could be useful, but such a system will change the activities that it supports. Therefore, requirements engineering needs to be sensitive to how people perceive and understand the world around them, how they interact, and how the sociology of the workplace affects their actions."*

In requirements engineering, the domain of the problem is defined by Leffingwell and Widrig (2000) as the home (problems, culture, language) of the users and stakeholders whose needs/problems must be addressed to develop a solution. It is therefore all about acquiring domain knowledge that forms part of the world in which the system will be a solution. Requirements emerge from the social interaction and communication between the users and the requirements engineer (Siddiqi, 1996). As described by De Oliveira et al. (2004), to generate quality requirements the following knowledge is also required:

- Knowledge about the domain in which the application/solution will operate
- Knowledge about the activities performed in this domain

Many of the challenges experienced during the requirements engineering process relate to social interaction challenges and not technical challenges, specifically communication breakdowns. Communication has been reported as a challenge during the requirements engineering process in multiple studies (Paech et al., 2005; Karlsson et al., 2007; Curtis et al., 1988; Sutcliff et al., 1999).

Available social studies show that when trust is not present in a relationship, effective communication will not take place (Zeffane et al., 2011). It was therefore decided to explore the communication behaviour and trust relationships between the various stakeholders and the requirements engineer and to describe the behaviours to determine the social behaviour view required during the requirements engineering process.

5.1 Social Factors

The fundamental objective of communication is to reproduce a message at a certain point to be exactly the same as the initial message at the origination (Shannon, 1948). This general model of the communication process is applicable across diverse disciplines such as engineering, speech and human sciences. The information source where the message originated from, called the sender, may be of various types, for example the writer of a document or an email message, a person making telephone call, a verbal message or the internet (Ellis, 1997; Shannon, 1948). A general communication system as adapted and simplified by Ellis (1997) from the Shannon model (1948) is illustrated in Figure 45.

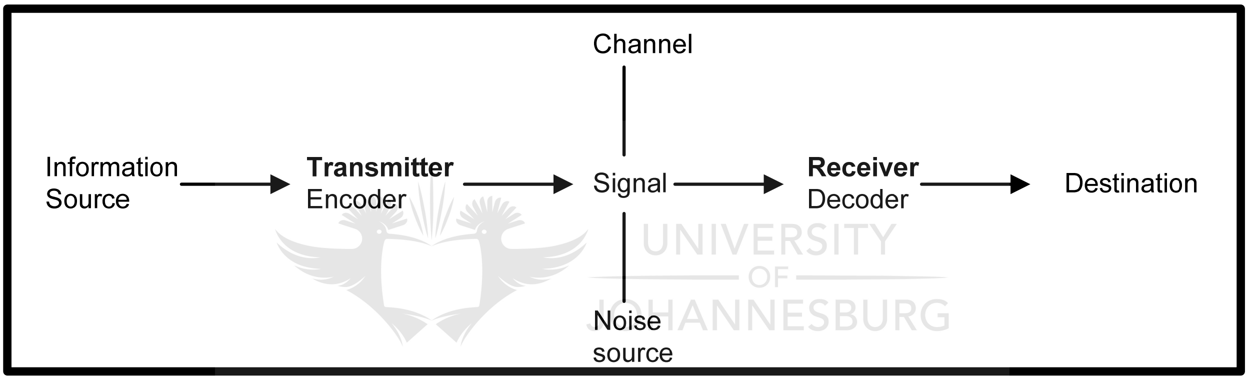

Figure 45: A general communication system (Ellis, 1997)

There is interaction between the sender and receiver through several communication networks and feedback loops (Narula, 2006). Linear as well as dynamic communication models are discussed by Narula (2006).

During communication, the message exchange contains both content and relational characteristics (Debasish and Das, 2009; Johnson and Long, 2002; Bateson, 1958). The content characteristic refers to the message and the relational characteristics are the rules that bind the parties within the communication system (Johnson and Long, 2002; Millar and Rogers, 1976). The rules that bind the parties within the communication system define the type of relationship that exists between the parties (Millar and Rogers, 1976).

To describe the communication process during the requirements process and the impact that communication has on the quality of requirements, data was collected about the communication behaviour of requirements practitioners. Data was also collected regarding the trust relationships between the requirements practitioners and the various stakeholders. The communication behaviour and trust relationships are now discussed.

5.1.1 Practitioners' Communication Behaviour

Five questions were posed to establish whether regular communication takes place between the requirements practitioner and the relevant stakeholders, such as the project manager, the project sponsor, the subject matter expert and the end-user.

The first structured question determined whether the practitioners established communication with the relevant stakeholders. The results are illustrated in Figure 46.

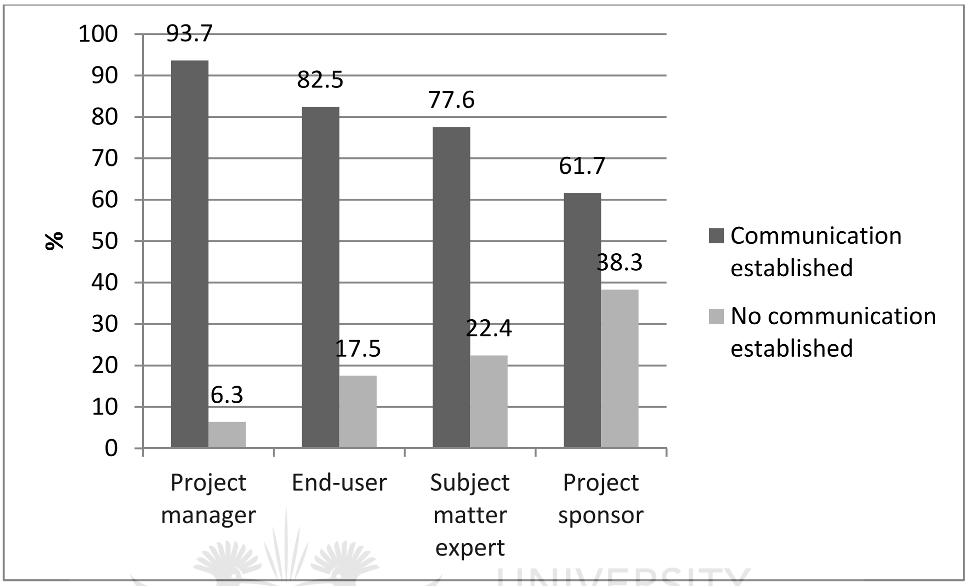

Figure 46: Communication established

The practitioners appeared to have established communication with the different stakeholders. In 93.7% of the instances the practitioners established communication with the project manager, and in 82.5% of the cases with the end-users. Communication was established with the subject matter expert in 77.6% of the cases. Communication with the project sponsor was established in only 61.7% of the cases.

The project sponsor is responsible for initiating the effort to define the business problem and to develop a solution that solves the problem. The project sponsor provides the authorisation and controls the budget of the project (Gottesdiener, 2002; IIBA, 2009; Robertson and Robertson, 2010a). It is therefore concerning that the practitioners only established communication with the project sponsor in 61.7% of the cases. An active project sponsor engagement is always suggested as a contributing factor to effective project implementation (Robertson and Robertson, 2010a; Maiden et al., 2004; Carkenord et al., 2010).

Further analysis was done to determine whether the communication behaviour had any impact on the quality of the requirements delivered by the practitioners.

Table 41: Communication established by quality of requirements

Communication Established	Quality				
	Rating 1	Rating 3	Rating 3 to 5	Rating 5 to 7	Total
PM communication established (N = 49)	0%	2%	24%	74%	100%
PM no communication established (N = 4)	25%	0%	25%	50%	100%
PS communication established (N = 31)	0%	0%	16%	84%	100%
PS no communication established (N = 20)	5%	5%	35%	55%	100%
SME communication established (N = 40)	0%	3%	20%	77%	100%
SME no communication established (N = 10)	10%	0%	30%	60%	100%
EU communication established (N = 41)	2%	2%	10%	86%	100%
EU no communication established (N = 8)	0%	0%	63%	37%	100%

PM (Project manager), PS (Project sponsor), SME (Subject matter expert), EU (End-user)

Rating: 1 (Never); 2 (Rarely less than 10%); 3 (Occasionally, in about 30%); 4 (Sometimes, in about 50%); 5 (Frequently, in about 70%); (Usually, in about 90%); 7 (Every time)

The cross-tab in Table 41 indicates a higher percentage quality of requirements when the practitioners established communication with the relevant stakeholder. The results show a clear pattern of dependency between the quality of the requirements and the communication established by the practitioners. A positive relationship is evident where established communication leads to the delivery of higher quality requirements. The pattern is consistent in each stakeholder's case.

Where communication was established between the practitioner and the project manager, 74% of the cases delivered high quality requirements with a rating above 5 to 7. Similarly, high quality requirements were produced 84% of the time where communication was established with the project sponsor, 77% of the time where communication was established with the subject matter expert and 86% of the time with the end-user.

The quality of delivered requirements where there was no involvement of the practitioners varied between very poor and good quality. There was no pattern here.

As the cross-table shows a clear pattern, a Mann-Whitney test was done in each case of the two groups, where communication was established and in the case of no communication established, to validate if these two groups had the same median.

A Mann-Whitney test was performed to test the hypothesis that the means of the group where communication was established is the same as the mean as the group where no communication was established.

Table 42: Mann-Whitney test for quality and communication

Mann-Whitney	Quality							
	Project Manager		Project Sponsor		Subject Matter Expert		End-user	
	1	2	1	2	1	2	1	2
N	49	4	31	20	40	10	41	8
Mean rank	27.47	21.25	29.84	20.05	26.55	21.30	26.89	15.31
Mann-Whitney U	75		191		158		86.5	
Sig. (2-tailed)	0.424		0.017		0.292		0.030	

[1] Communication established

[2] No communication established

Table 42 indicates that in each result set where communication had been established, higher quality requirements were delivered, as it resulted in the highest mean rank. The original hypothesis could be rejected because in each case the group where communication was established resulted in a higher ranked mean than the group where no communication was established.

In the cases of the project sponsor and end-user there is a statistically significant difference in the means of the groups where communication was established and where no communication was established. This supports the rejection of the hypothesis and shows that where communication was established, higher quality requirements were delivered. The significance can be derived from Table 42 for the project sponsor data (U = 191, p = 0.017) and for the end-user (U = 86.5, p = 0.03).

This statistical significance did not hold up in the case of the project manager. The sample available for the *no communication established* group was very small and could be the reason why no statistically significant difference between the project manager groups could be found. These tests confirm that the more communication there was, the higher the quality of requirements was.

In the cases where communications were not established, a second structured question requested that the practitioners select the main reason for this. This was done to identify the reasons for communication breakdowns. A summary of the factors preventing respondents from establishing communication is provided in Table 43.

Table 43: Communication preventative factors

	Project Manager	Project Sponsor	Subject Matter Expert	End-user
The complexity of the project prohibited communication to this person	-	5	2	-
The size of the organisation prohibited communication to this person	-	6	1	3
The person in this role does not respect my viewpoint	-	-	1	-
The person in this role does not understand the purpose of the project	1	-	1	-
In my organisation I am not allowed to communicate with the person in this role and should follow a proper communication channel	-	5	1	4
The person in this role is to busy (lack of time) to be involved in any communication	-	2	2	-
The respondent played the role of the project manager as well	3		-	-
The project manager communicated to this person	-	3	-	-
No need to communicate to this person	-	1	1	1
I already had the knowledge no need for communication	-	-	2	-
No resources assigned to project	-	-	1	-
Total N respondents with *no* communication established	4	22	12	8
Total N respondents with communication established	59	37	45	47
Total N not answered	64	68	70	72

Table 43 confirms that the respondents had the most difficulty in establishing communication with the project sponsor and subject matter experts. The three communication barriers that were selected the most by the respondents are:

- the size of the organisation which prohibited communication
- the fact that they were not allowed to communicate with the person in this role and had to follow a proper communication channel
- the complexity of the project prohibited communication to this person.

Two of the communication barriers mentioned relate to organisational barriers and the third to the project structure. The respondents were classified as experienced practitioners based on the data they provided and as discussed in section 4.1.2. It is therefore surprising that the complexity of a project and organisation barriers were listed as barriers. An experienced practitioner would be expected to overcome communication barriers. More analysis was done to gain insight into this phenomenon.

The question on this issue was a semi-structured one which allowed the respondents to capture other reasons why communication was not established. In one case the respondent indicated that the responsibility was delegated from the sponsor to another business owner. In all the other cases the respondents indicated that they did not need to communicate with the project sponsor as this was the responsibility of the project manager. Although the project manager is accountable for communication management, the requirements practitioner is responsible for the communication management plan (Carkenord et al., 2010). The requirements practitioner still has a direct responsibility to communicate with all relevant stakeholders on the impact of the solution (Carkenord et al., 2010).

Based on this responsibility of the practitioners, it can be concluded that the communication established between the practitioner and project sponsor is a focus area of improvement.

In the cases where practitioners established communication with the relevant stakeholders, three additional questions were posed to them. The following information was collected from these questions:

- The frequency of communication interactions per week between the practitioner and relevant stakeholder
- The initiator of the communication interaction
- The main reason for the communication interaction

5.1.1.1 Communication Frequency

To determine the frequency of interactions between the practitioner and each stakeholder, a structured question was posed to the respondents. This question used a frequency scale to estimate the interactions on a weekly basis.

The respondents were requested to indicate the frequency as well as the main initiator of communication with the following stakeholders:

- The project manager with regard to project impacts
- The sponsor to elicit business requirements
- A subject matter expert to acquire domain knowledge
- Users to elicit functional requirements

The data has been summarised and is presented in Table 44.

Table 44: Communication interaction frequency

	Number of Responses	Mean	Median	Std Deviation	Skewness
Project manager	56	2.839	3	1.005	-0.334
Project sponsor	36	2	2	0.894	0.507
Subject matter expert	45	2.82	3	0.96	-0.271

End-user	46	2.608	2.5	1.084	-0.019

The data was summarised by using the variable of communication frequency in order to identify the communication frequency between stakeholders and practitioners. When creating a statistical summary from one variable the basic properties of the single piece of information answers questions such as (Siegel, 2012):

- What is the typical value for the communication frequency by the stakeholder?
- Is the communication frequency across stakeholders different?
- Are there groups that require special attention?

The statistics of the frequency of communication per week between the requirements practitioner and the relevant stakeholders suggest that communication activity definitely takes place between the practitioners and the stakeholders. On average the practitioners communicated at least twice or more a week with all stakeholders.

This data suggests that the communication frequency between the practitioner and all stakeholders has a typical value of between two and three times a week. This communication behaviour needs to be validated with each relevant stakeholder as a future research improvement.

The next section presents the results on what type of communication model is used by the practitioner when communicating with the stakeholders.

5.1.1.2 Communication Models

The next question requested the practitioners to indicate who initiated the communication interaction. This question identified the communication models used by practitioners when communicating to various stakeholders. A summary of the communication by interaction direction is presented in Table 45.

Table 45: Communication interaction direction

Communication Direction with Stakeholder	Initiated by Stakeholder	Initiated by Practitioner
Project manager	41.1%	58.9%
Project sponsor	25%	75%
Subject matter expert	4.4%	95.6%
End-user	6.5%	93.5%

The communication direction between the practitioners and project manager indicates that both parties initiated communication interaction, with the project manager initiating communication 41.1% of the times and the practitioner 58.9%. In 75% of the cases the communication interactions between the practitioner and the project sponsor were initiated by the practitioner. In 95.6% of the cases the communication interactions between the practitioner and the subject matter expert were initiated by the practitioner and in 93.5% of the cases between the practitioner and the end-user it was initiated by the practitioner.

A linear communication model is a unidirectional model that sends a message from the sender to receiver with or without effect. In non-linear models, the message flow is multi-directional (Narula, 2006).

In the majority of the cases the practitioners established one-way communication with the project sponsor, subject matter expert and the end-user. The communication models used between the practitioners and the project sponsor, subject matter expert and the end-user are linear models, as there is only a one-directional message flow.

In the case of the practitioner and project manager, the message flow was multi-directional. It is therefore concluded that the typical communication model between the practitioners and project manager is a non-linear model.

The fundamental driver for a practitioner to communicate with the various stakeholders is to elicit information about the domain in which the problem should be solved. From the communication behaviour of the practitioners, it is evident that they established communication to acquire knowledge. Additionally, the value for stakeholders is to acquire knowledge about how the solution to the problem will affect their business activities. As emphasised by Sommerville et al. (2012), when solving complex problems a socio-technical perspective is required. A socio-technical solution includes technical systems, but also includes knowledge of how the system should be used by stakeholders to achieve the ultimate objective (Sommerville, 2004).

The one-way linear communication model is not good enough to assist the practitioner in acquiring knowledge about the domain of the problem and in facilitating all stakeholders developing a mutual understanding of the solution.

To master the requirements engineering process, a good requirements engineer needs to manage the incompleteness of communication (Rupp, 2002). The practitioner as the owner of the requirements engineering process is responsible for facilitating this knowledge transfer to the various stakeholders. From the behaviour review it is evident that there is no drive from the practitioners' side to facilitate the knowledge acquisition for the stakeholders about how the solution to the problem will affect business activities. If a more collaborative environment is created by the practitioners, this knowledge acquisition could be facilitated instead of just the knowledge they require.

To solve complex problems, companies and people are required to work together to create high quality solutions which they would not be able to produce individually (Stohl and Walker, 2002). Collaborations have become common where communication brings groups of people from diverse backgrounds and organisation roles together to work on a common problem (Stohl and Walker, 2002). Stohl and Walker (2002) define collaboration as follows:

"Collaboration is the process of creating and sustaining a negotiated temporary system which spans organisational boundaries involving autonomous stakeholders with varying capabilities including resources,

knowledge and expertise and which is directed toward individual goals and mutually accountable and innovative ends."

A collaboration process, with the group of people working together as the collaborating group, is explained by using a bona fide group collaboration model as presented in Figure 47.

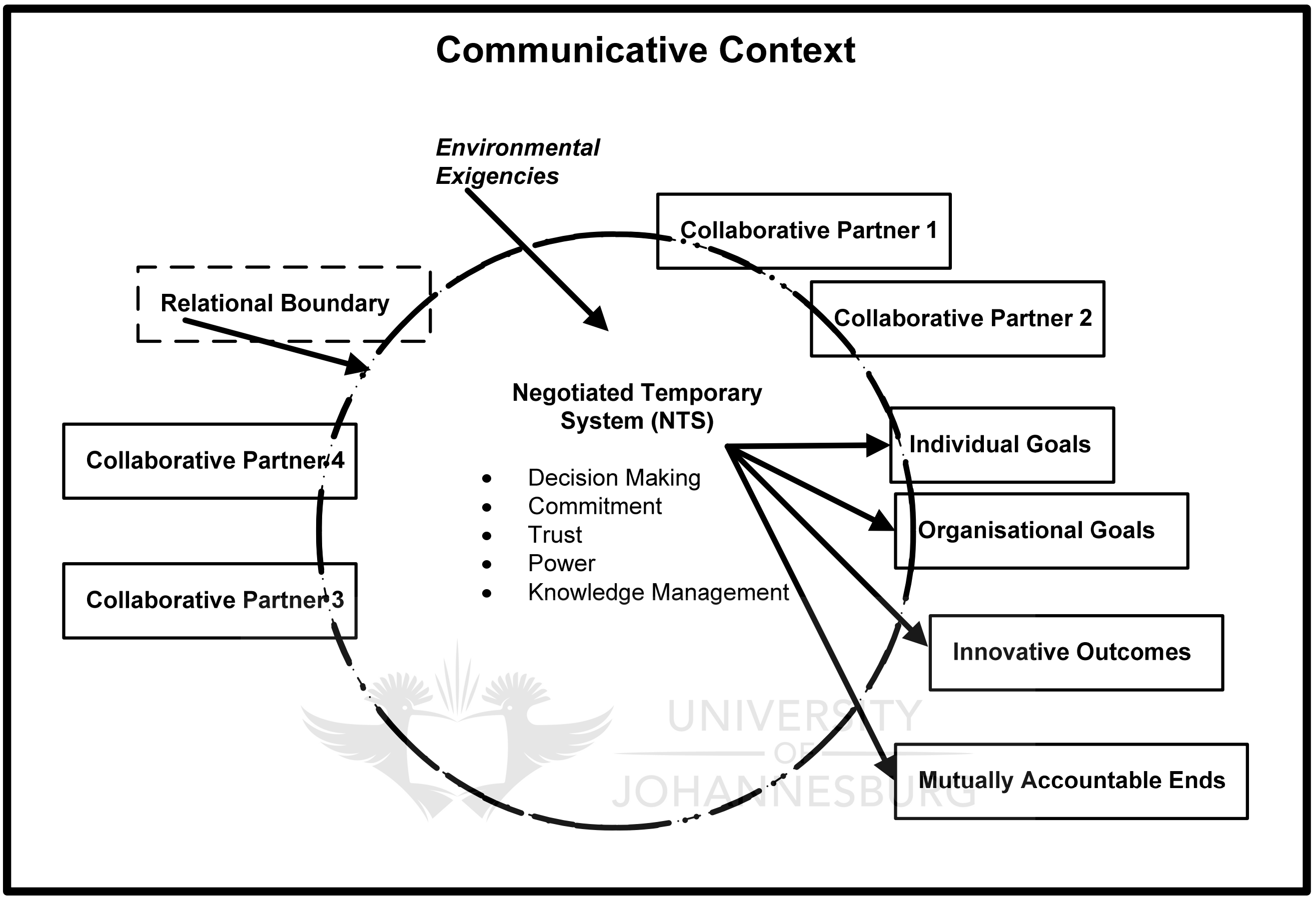

Figure 47: Bona fide group collaboration model (Stohl and Walker, 2002)

The primary element of this collaboration model is the communicative context. The outcome of the collaboration effort covers individual goals, organisational goals, innovative outcomes and mutually accountable ends (Stohl and Walker, 2002). As explained by Stohl and Walker (2002), different collaborative partners join the collaboration based on their level of involvement and commitment to the collaboration required. This type of model allows for information acquisition and knowledge management required in order to complete tasks.

A case study was used by Damian and Chisan (2006) to prove empirically that requirements engineering, if done effectively, can lead to benefits such as improved productivity, quality and risk management. Six principles, one of which was the use of cross-functional teams, were introduced to improve requirements and the benefits were observed. One of the main contributions to the benefits was collaboration instead of working in isolation where there was a united effort with no communication barriers.

If practitioners implement a more collaborative communication model instead of a linear communication model they can facilitate the knowledge acquisition cycle for themselves (about the problem) as well as for the stakeholders (about the solution). In this way both parties would derive value from the engagement and a more complete understanding would be reached between practitioners and stakeholders as shown in Figure 48.

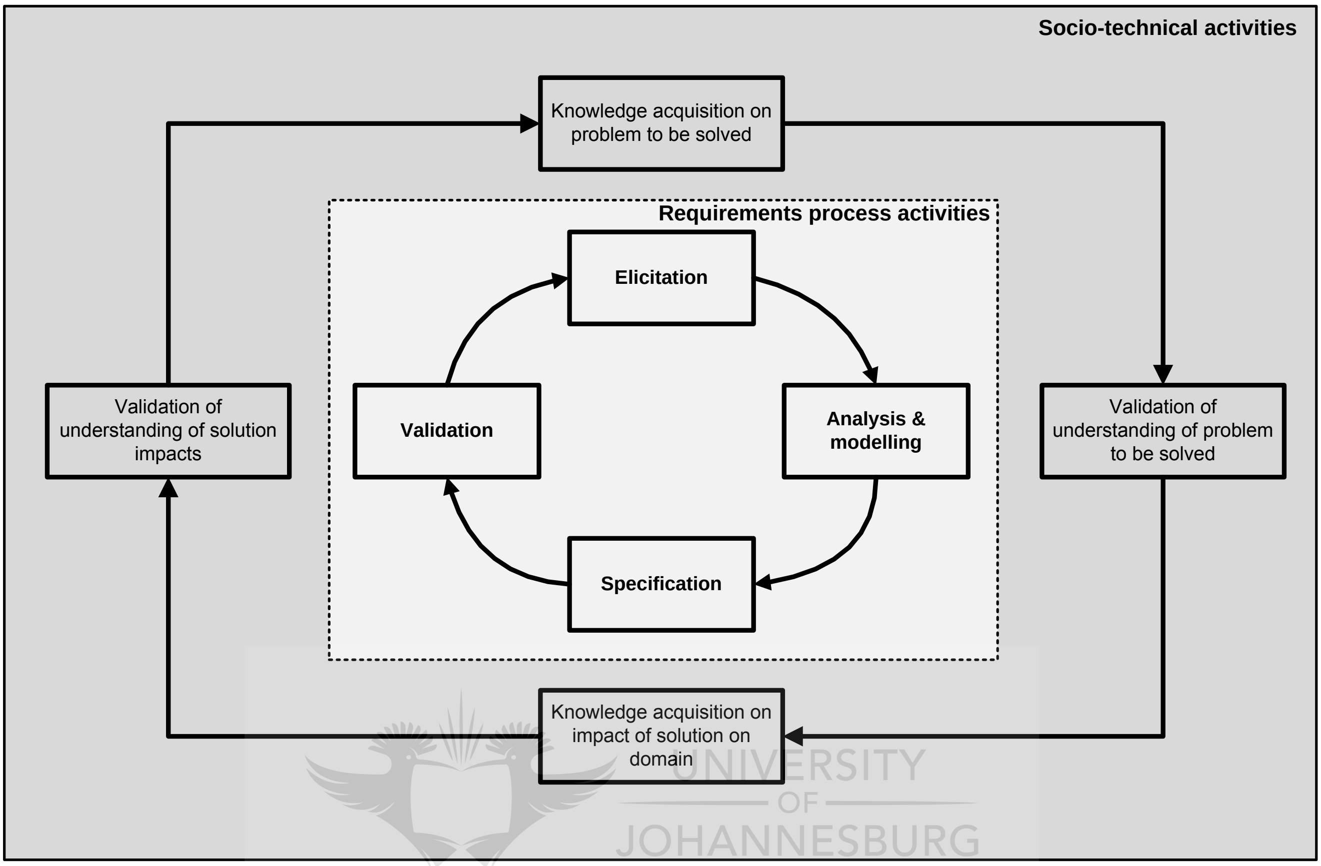

Figure 48: Socio-technical activities

The requirements engineering process activities once planning has been done are shown in Figure 48. This provides a socio-technical view of the requirements process.

1. As part of elicitation, the requirements practitioner must acquire all possible information to gain knowledge about the problem to be solved.
2. As part of analysis and modelling, the requirements practitioner should validate the understanding accumulated from the information from stakeholders and generate a single understanding of the problem.
3. As part of specification, the requirements practitioner should facilitate the knowledge acquisition of all relevant stakeholders to acquire knowledge about how the solution will impact business activities.
4. As part of validation, the requirements practitioner should validate the understanding the stakeholders have of the solution and generate a single understanding of the solution and how it will impact the business activities.

By facilitating the communication process to ensure a knowledge acquisition cycle, the practitioner will deliver value to the stakeholders. This process will ensure that the stakeholders acquire knowledge of how they should use the system to achieve the ultimate objective as suggested by Sommerville (2004). If practitioners want to deliver socio-technical solutions, their communication behaviour needs adaptation.

To validate the communication model used by the practitioners, they were also requested to indicate the main reason why they interacted with the relevant stakeholder.

5.1.1.3 Communication Driver

The respondents were requested to indicate the main reason for communication with the following stakeholders:

- The project manager
- The project sponsor
- A subject matter expert
- End-users

The communication drivers for each stakeholder are discussed separately.

Communication driver with project manager

The practitioners reported that the main reason for interaction with the *project manager* was to report on the progress of the analysis effort. Of the 127 respondents, 56 provided answers indicating the reason for communication. The results are presented in Table 46.

Table 46: Reasons for communication with project manager

Reasons for Communication	%
Raising or identifying risks	14
Input for project costs, resource requirements and delivery	5
Agree analysis approach for project	7
Reporting on progress of analysis effort	64
Requirement changes	7
Project status reports	2

Table 46 indicates that the practitioners communicated with the project manager to report on the progress of the analysis (64%). According to the literature, the requirements practitioner is responsible for the creation of a requirements management plan, which is a key input to the overall project schedule (Carkenord et al., 2010; Weese and Wagner, 2011). Agreement on the requirements planning activity was done in only 7% of the cases. This low percentage confirms the lack of focus on the requirements planning activity. During requirements planning a requirements management plan is generated that identifies the required work. The plan forms the basis for the project cost and resource estimation. Only 5% of the practitioners communicated with the project manager regarding input into these estimations.

Guidelines on how to do requirements planning are available in literature (IIBA, 2009; Sommerville, 2004; Carkenord, 2009). Very practical advice has also been provided by Ellis (2011), highlighting that requirements planning should consider the following:

- Requirements planning should not only be done for eliciting the information but should cover the end-to-end requirements engineering process.
- It should consider the value added during planning and ensure that this value is delivered to various stakeholders.
- End-to-end requirements planning helps the practitioner to set expectations with stakeholders directly. It enables the practitioner to inform stakeholders of what is required of them, by when, where, type of engagement and why this is needed.
- Requirements planning allows confirming resource estimates.
- It allows for communicating the progress of the process.
- It allows for coordinating the requirements process
- Requirements planning allows for considering previous lessons learnt and adapting.

The requirements planning activity is the activity that receives the least attention from practitioners as per section 4.2.2.1. This is also confirmed by the reasons given for communicating with the project manager. The planning activity has the potential to impact the value added during the requirements engineering process.

Communication driver with project sponsor

The main reason provided for interaction with the project sponsor was to communicate the expectations and feedback from other senior managers and stakeholders. Of the 127 respondents, 36 provided answers indicating the reason for communication. Refer to Table 47 for a summary.

Table 47: Reasons for communication with project sponsor

Reasons for Communication	%
Help manage conflicts and political issues	19.4
Communicate expectations and feedback from other senior managers and stakeholders	52.8
Take the time to understand the solution	19.4
Status and progress reporting	3.1
Raise stakeholder concerns	0.8
No reason provided	4.4

Practitioners appeared to spend time with the project sponsor to ensure that the solution was understood (19.4%) as well as to resolve conflicts and political issues (19.4%). A high percentage (52.8%) communicated expectations and feedback from various stakeholders back to the sponsors. The communication between the practitioner and project sponsor covered a diverse spectrum.

Communication driver with subject matter expert

The main reason for interacting with the subject matter expert is to gather knowledge about the domain in which the application/solution will operate. The subject matter expert is typically the stakeholder which has domain knowledge. Kaiya and Saeki (2006) define domain knowledge as the knowledge of an expert in the domain. The knowledge of an expert is summarised (Alexander, 2003; Alexander and Murphy, 1998; Bransford et al., 2000) as follows:

- Experts possess extensive bodies of domain knowledge.
- They have the ability to recognise the underlying structure of domain problems.
- They have the ability to select and apply appropriate problem-solving techniques in the environment.
- They retrieve relevant domain knowledge with minimum cognitive effort.

Of the 127 respondents, 45 provided answers indicating the reason for communication. Refer to Table 48 for a summary.

Table 48: Reasons for communication with subject matter expert

Reasons for Communication	**%**
Gather an understanding of the underlying structure of domain problems	20.0
Gather knowledge about the domain in which the application/solution will operate	44.4
Gather knowledge about the activities performed in this domain	28.9
Resolve conflicting issues	3.1
No reason provided	3.6

Typically a requirements practitioner will not have the domain knowledge and must usually acquire this knowledge from users in the domain (Zong-yong et al., 2007). The main reason for interacting with the subject matter expert is aligned with this (44.4%).

A few respondents mentioned that there was no need to communicate with the subject matter expert since they themselves were the subject matter expert or already had all the knowledge. If this is compared to section 4.2.2.3, it corresponds with the practitioners' information-seeking behaviour.

The information-seeking behaviour during a problem-solving process changes over time according to literature (Veshosky, 1998). From the industry review, the majority of practitioners depend on sources of information which are either personal experience or conversations with customers and colleagues. The information-seeking behaviour of the practitioners suggests that no change takes place over time during the problem-solving process.

This is quite concerning that some practitioners only collect information based on personal experience and there is a risk that the requirements will be incomplete as a result of this. Incomplete requirements impact the quality of requirements, which will then not be within acceptable norms.

Communication driver with end-user

The two main reasons given for the interaction were (i) to interview the end-user about the functional requirements or (ii) to observe the user while executing the daily activities to understand the domain. Of the 127 respondents, 46 provided answers indicating the reason for communication. Refer to Table 49 for a summary.

Table 49: Reasons for communication with end-user

Reasons for Communication	**%**
Observe user while executing daily activities to understand domain	30.4
Interview user about functional requirements	58.7
Validate understanding	0.8
Discuss issues experiencing	0.8
Progress reporting	1.6
No reason provided	7.7

Only a very small percentage of the respondents (0.8%) spent time with the end-users to validate their understanding and discuss issues that were experienced (0.8%). When this is compared with the communication model in the previous section, it aligns with the findings that the practitioners communicate with the end-users to elicit information or to obtain knowledge about the domain in which the problem should be solved. There is no drive from the practitioners' side to facilitate the knowledge acquisition for the stakeholders regarding how the solution to the problem will affect business activities.

The communication model behaviour of the practitioner indicated that in the majority of the cases, the practitioners established only one-way communication with the project sponsor, subject matter expert as well as the end-user. The main reasons provided further indicated that there is potentially no value for the stakeholders in the communication, and the focus of the practitioners is collecting the information that they need. This reveals that potentially there is no common understanding between the practitioners and the various stakeholders about the problem to be solved, as well as the solution's impact on current business activities.

The rules that bind the parties within the communication system define the type of relationship that exists between the parties (Millar and Rogers, 1976). Bateson's view (1958) is that a message exchange during communication contains both content and relational characteristics. The content characteristic refers to the message and the relational characteristics are the rules that bind the parties within the communication system (Millar and Rogers, 1976). The relationship that is established between two parties drives the communication. *Relationship* is defined by Roloff (1976) as follows:

"A relationship, regardless of type, represents mutual agreement, implicit or explicit, between people to interact in order to maximize rewards."

The following implications are derived from this definition by Millar and Rogers (1976):

- It involves a certain level of mutual agreement between both persons. The rules of the relationship are mutually agreed upon to some extent.
- Relationships are formed to serve a function, and attempt to gain some kind of reward.
- There is an implicit or explicit agreement or knowledge that the relationship exists.
- The types of communication patterns between the parties in the relationship affect the parties' ability to attain rewards.

From these definitions and implications it is clear that there is a relationship between parties within a communication system for the reward of each party. The relationship between practitioners and various stakeholders was further explored to understand the behaviour and explore what value each party receives. Social studies show that when trust is not present in a relationship, effective communication will not take place (Zeffane et al., 2011). The focus of investigation was therefore on the trust relationship between practitioners and the various stakeholders.

5.1.2 Practitioners' Trust Relationships

Trust has been identified as one of seven success factors influencing the delivery of requirements (Hoffmann and Lescher, 2009). The success of an organisation, team or project depends on the knowledge in the organisation and is represented by the relationships amongst the people (Dawson, 2000). It was decided to explore the trust relationships between the requirements practitioners and determine whether these relationships have any impact on the quality of the requirements. In a previous study, it was identified that the root cause of quality-related problems in requirements is that communication and interaction have not been established effectively. Without trust there is no communication and without communication there is no knowledge transfer (Marnewick et al., 2011; Zeffane et al., 2011; Hoffmann and Lescher, 2009).

The focus of the trust relationships is intra- organisational among co-workers (Dietz and Den Hartog, 2006). It was decided to use the behavioural trust inventory as developed by Gillespie (2012). Refer to Gillespie (2003) for a description and validation of this method. This trust measurement was selected based on the fact that it has been validated by other researchers and was classified as a best fit instrument to capture trusting behaviours (McEvily and Tortoriello, 2011). The behavioural trust inventory measures the work relationships between employees and immediate managers as well as between employees and immediate work colleagues (Dietz and Den Hartog, 2006). This allows for a single instrument that measures the typical relationships a requirements practitioner has. Refer to APPENDIX E for a detailed description of the behavioural trust inventory used.

The behavioural trust inventory was tested for reliability as described in Gillespie (2003). Additional reliability checks were done on this survey data for each dataset where the behavioural trust inventory was used by calculating Cronbach's alpha. Levels of 0.7 or more are generally accepted as representing good reliability (Litwin, 1995).

The results for Cronbach's alpha calculated for the trust scales were as follows:

- Project manager with communication established (0.868); no communication established (0.934)
- Project sponsor with communication established (0.87); no communication established (0.937)

- Subject matter expert with communication established (0.883); no communication established (0.934)
- End-user with communication established (0.856); no communication established (0.919)
- The project team (0.917)

Refer to APPENDIX C, sections C.4 to C.12 for details on the reliability calculations. In each instance where the behavioural trust inventory was used, Cronbach's alpha was above 0.8, indicating a high level of reliability.

The behavioural trust inventory measuring trust relationships between the requirements practitioner and the various stakeholders calculations are available in APPENDIX E from sections E.2 to E.6. The inventory suggests that there are two dimensions of trust, i.e. reliance and disclosure (Gillespie, 2003). Exploratory factor analysis was used as a data reduction technique to confirm that the ten trust elements can be summarised into two elements, i.e. reliance and disclosure (Floyd and Widaman, 1995). The factor analysis is presented in section E.7 of APPENDIX E.

From the factor analysis results, it can be concluded that the ten elements in the trust scale can be summarised into two factors, one factor summarising five reliance elements and the other summarising five disclosure elements. A summary of the trust behaviour of the respondents within interpersonal work relationships is given based on their willingness to be vulnerable. This willingness is described by the engagement in reliance and disclosure and presented in Table 50. This summary separates the trust relationships where communication was established between the practitioner and relevant stakeholder versus where no communication was established.

Table 50: Trust relationships summary

Trust Relationships	**Project Manager**		**Project Sponsor**		**Subject Matter Expert**		**End-user**		**Team**
	1	2	1	2	1	2	1	2	
Reliance-based elements mean	4.5	3.95	4.74	3.36	4.56	3.73	4.12	1.77	5.2
Disclosure-based elements mean	3.9	4.6	2.91	1.99	3.08	2.7	2.79	1.2	3.9

[1] Communication established

[2] No communication established

A relationship that is characterised by a willingness to both rely and disclose represents a higher level of trust than a relationship that is characterised by a willingness to trust in only one dimension (Gillespie, 2003). The reliance and disclosure dimensions that characterise the trust relationship between the practitioner and the relevant stakeholder where *communication* was established were evaluated from Table 50. The mean of each dimension was presented on the original scale used to measure the trust, i.e. a scale from 1 (not at all willing) to 7 (completely willing), with 7 indicating high disclosure or reliance and 1 low disclosure or reliance. The data is presented for each relationship the practitioner had with various stakeholders. This data is presented in Figure 49.

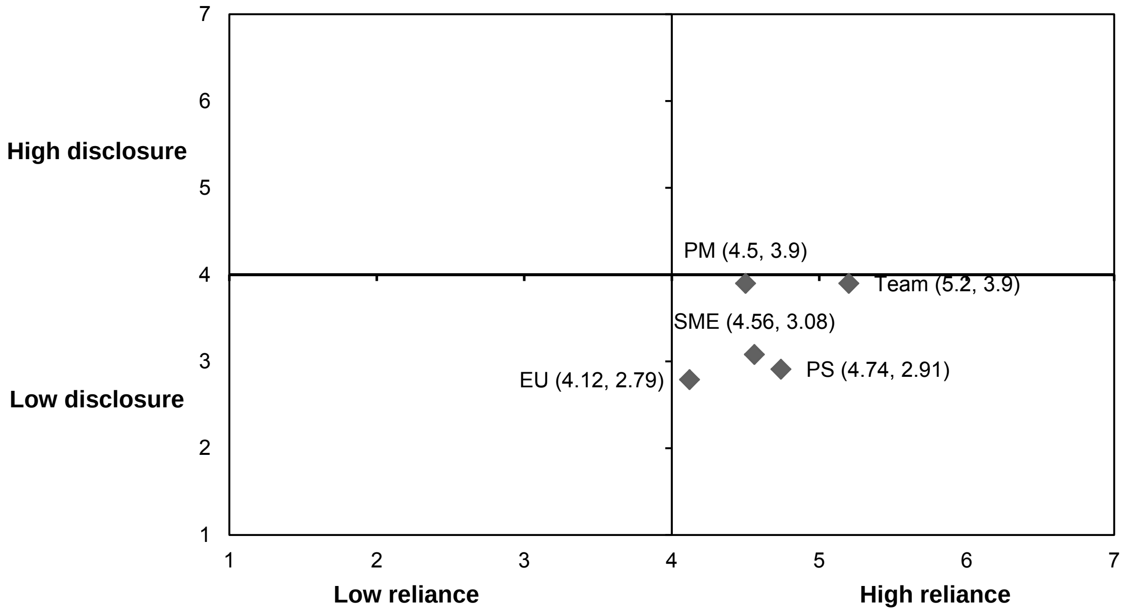

Figure 49: Characteristics of trust relationships (communication established)

It can be deduced from Figure 49 that practitioners have only a one-dimensional trust relationship with all stakeholders which is based on willingness to rely. The willingness to disclose in all the relationships between the practitioner and the relevant stakeholder was low. To determine whether the reliance trust element was high or low, a comparison with a known population mean was done using a one-sample t-test.

A one-sample t-test is typically used to compare a sample mean to a known population mean (Argyrous, 2011). The means calculated from the collected data was compared with the means calculated by Gillespie (2003), where it was reported that high levels of trust existed within sampled relationships. Gillespie (2003) reported high levels of trust between a direct report and their leader as willingness to rely (M = 5.93, SD = 0.96) and disclose (M = 5.4, SD = 1.27). These means were used to compare the mean of the trust relationship between the practitioner and project manager, as a practitioner is always directly reporting to a project manager within a project environment.

The assumption that was tested by the one-sample t-test was as follows:
A one-sample t-test was performed to test the hypothesis that the means of the trust elements reliance and disclosure reflect a high level of trust between the practitioner and project manager (direct report and their leader).

Table 51: One-sample statistics

	Number of Responses	**Mean**	**Std Deviation**	**Std Error Mean**
Reliance trust element	56	4.5286	1.51906	.20299
Disclosure trust element	56	3.9036	1.44825	0.19353

Table 52: One-sample test

	Test values Reliance trust element M = 5.93; Disclosure trust element M = 5.4					
	t	df	Significance (2-tailed)	Mean difference	**95% confidence interval of the difference**	
					Lower	**Upper**
Reliance trust element	-6.904	55	.000	-1.40143	-1.8082	-.9946
Disclosure trust element	-7.732	55	.000	-1.49643	-1.8843	-1.1086

From Table 52, it can be seen that the reliance trust element (mean = 4.5286, SD = 1.51906, N = 56) was significantly different from the hypothesis value of 5.93, t (55) = -6.904, ρ = 0.000. The disclosure trust element (mean = 3.9036, SD = 1.44825, N = 56) was significantly different from the hypothesis value of 5.4, t (55) = -7.732, ρ = 0.000.

Although the reliance trust element falls in the high reliance area, it can be confirmed that the trust relationship between the project manager and practitioner reflects low levels of trust. This is the only trust relationship that could be estimated as low or high compared with a known population mean, as no other population data exists for a relationship with the other stakeholders.

It can therefore be concluded that the trust relationship between the practitioners is only one-dimensional with all stakeholders. It is based on willingness to rely, but is low as displayed in Figure 49.

If this one-dimensional *reliance* trust behaviour is compared with the practitioners' communication behaviour as discussed in section 5.1.1.2, there is alignment. The practitioners' objective is to acquire knowledge from stakeholders during communication. They are therefore prepared to rely on the knowledge or skills of various stakeholders to acquire knowledge of the problem.

Literature indicates the relationship between communication and trust during the solution of problems (Sarker et al., 2003; Sarker et al., 2011; Chiocchio et al., 2011; Zeffane et al., 2011; Ellen and Steve, 2011). The practitioners' behaviour was explored to determine if the trust relationship between practitioners and various stakeholders was similar or different when communication was established compared with when no communication was established.

The reliance and disclosure dimensions that characterise the trust relationship between the practitioner and the relevant stakeholder where *no communication* was established was evaluated using data from Table 50. The two trust elements for each relationship between the practitioners are shown in Figure 50.

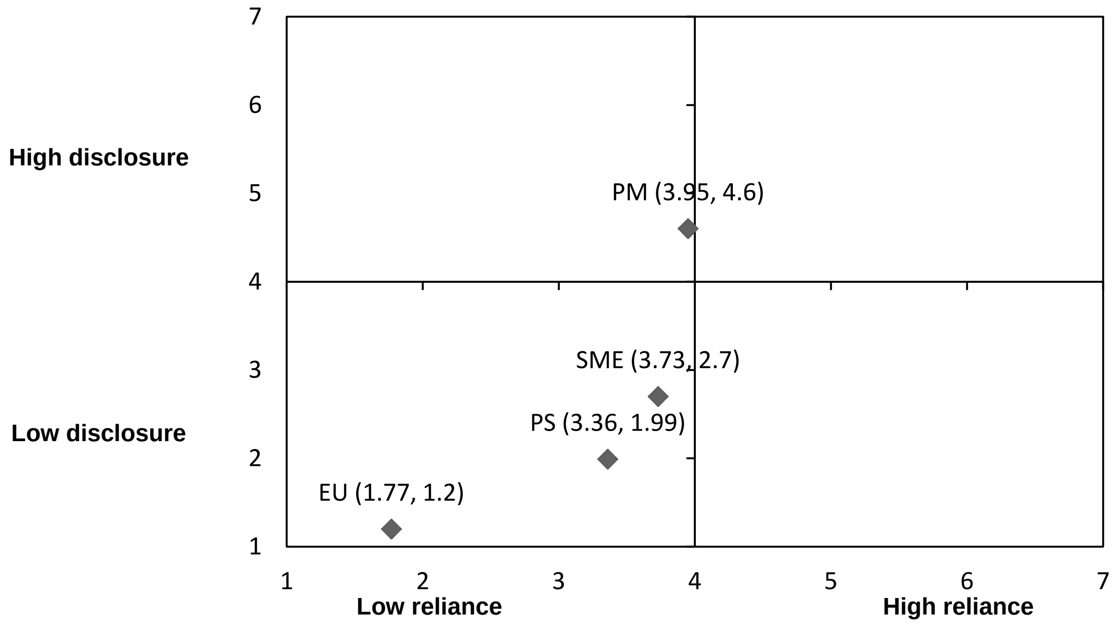

Figure 50: Characteristics of trust relationships (no communication established)

In all the relationships between the practitioner and stakeholder, except in the case of the project manager, both dimensions of trust were low as illustrated in Figure 50. There was no willingness to rely or disclose. This suggests a relationship with low trust.

The trust elements in Figure 49, where communication was established, were compared with those in Figure 50, where no communication was established, in the case of the end-user, project sponsor and subject matter expert.

Where communication was established, there was a higher level of trust in the relationship. The project manager trust relationship calculation is presented in section E.2 of APPENDIX E. There were only four responses, and this is a very small sample to derive any conclusion.

This data confirms that where communication is not established, trust is low as suggested by the literature. Available social studies show that when trust is not present in a relationship, effective communication will not take place (Zeffane et al., 2011).

If the level of trust between the respondents and the various stakeholders is that low, it can be expected that the communication levels and interaction have not been established effectively. As summarised, communication was established but it is suspected that there was no two-way communication of information exchange. This is confirmed by the level of trust as indicated.

5.2 Literature, Industry and Behaviour Comparison

The behaviour review highlighted a few themes. These are compared with what literature suggests as well as the findings from the industry review.

Table 53: Industry and behaviour review comparison

	Literature and Industry Review	Behavioural Review
Communication established with project sponsor	The literature indicates that project sponsor engagement contributes to effective project implementation (Robertson and Robertson, 2010a; Maiden et al., 2004; Carkenord et al., 2010).	Although the practitioners established communication with various stakeholders, they only established communication with the project sponsor in 61.7% of the cases. The practitioners indicated that they did not need to communicate with the project sponsor as this was the responsibility of the project manager. Refer to section 5.1.1.
Practitioners' communication behaviour and the impact on the quality of requirements	Communication and its impact has been reported as a challenge during the requirements engineering process in literature (Paech et al., 2005; Karlsson et al., 2007; Curtis et al., 1988; Sutcliff et al., 1999).	The results identified a pattern of dependency between the quality of requirements and the communication established by the practitioners. A positive relationship was present in that where the communication was established, a higher quality of requirements was delivered. This pattern was consistent in the communication established in each stakeholder's case. Refer to section 5.1.1.
Communication models	To master the requirements engineering process, a good requirements engineer needs to manage the incompleteness of communication (Rupp, 2002).	The communication behaviour explored indicates only one-way communication interaction between the practitioner and the project sponsor, subject matter expert as well as the end-user. Refer to section 5.1.1.2. The practitioners only focused on retrieving information they needed and did not facilitate the communication process to ensure mutual understanding.
Requirements planning	The actual focus of the requirements planning activity should be to generate a requirements management plan that identifies the required work. The industry review highlighted that the practitioners focus on an overall project plan and that the requirements planning during the project was done on an ad hoc basis. Refer to sections 4.2.2.1 and 4.2.2.2.	The communication behaviour of the practitioner indicates a low percentage of communication with the project manager to agree on the analysis approach. This behaviour confirms the lack of focus on the requirements planning activity to generate a requirements management plan that identifies the required work. Refer to section 5.1.1.3.
Communication behaviour with subject matter expert	From the industry review the majority of practitioners depend on sources of information which are either personal experience or conversations with customers and colleagues. The information-seeking behaviour of the practitioners surveyed suggests no change over time during the problem-solving process. Refer to section	The communication behaviour of the practitioner with the subject matter expert confirmed that practitioners established communication to gather knowledge about the domain. However, a few respondents mentioned that there was no need to communicate with the subject matter expert since they themselves were the subject matter expert or already had all the knowledge. Refer to section

	4.2.2.3.	5.1.1.3.
Communication behaviour with end-user	Stakeholders should obtain knowledge of how the system should be used by stakeholders to achieve the ultimate objective (Sommerville, 2004).	The practitioners communicated with the end-users to elicit information or to obtain knowledge about the domain. There was no focus on spending time with the end-users to validate their understanding. Refer to section 5.1.1.3.
Trust relationship behaviour	Social studies show that if trust is not present in a relationship, effective communication will not take place (Zeffane et al., 2011).	Where a trust relationship does not exist, effective communication is not established. Refer to section 5.1.2.

1. The behaviour review highlighted that practitioners did not feel obliged to communicate with the project sponsor. They indicated that this was the project manager's responsibility. Although the project manager is accountable for the communication management, the requirements practitioner is responsible for the communication management plan (Carkenord et al., 2010). The requirements practitioner still has a direct responsibility to communicate with all relevant stakeholders within the business domain regarding the impact of the solution (Carkenord et al., 2010).
2. The behaviour review confirmed the relationship between quality of requirements and communication. Where communication has been established, the quality of requirements is higher.
3. The linear communication model used by the practitioners confirms that they communicated with the various stakeholders to obtain knowledge about the domain. The value for stakeholders should be to acquire knowledge about how the solution to the problem will affect their business activities. As emphasised by Sommerville et al. (2012), when solving complex problems a socio-technical perspective is required, which includes technical systems, as well as the knowledge of how the system should be used by stakeholders to achieve the ultimate objective (Sommerville, 2004). A collaborative communication model will assist the practitioners in acquiring knowledge about the domain of the problem and will facilitate all stakeholders developing a mutual understanding of the solution.
4. The industry review highlighted that practitioners focus on delivering the overall project plan during the planning activity. The actual focus of the requirements planning activity should be to generate a requirements management plan that identifies the required work. According to the literature, the requirements practitioner is responsible for creating a requirements management plan, which is the key input to the overall project plan (Carkenord et al., 2010; Weese and Wagner, 2011). The communication behaviour between the practitioner and the project manager indicates that communication was established to agree on the analysis approach for the project. Only a few practitioners mentioned that communication was established to focus on the requirements planning activity to generate a requirements management plan that identified the required work. Requirements planning can enable a practitioner to facilitate the value added for stakeholders during the process as discussed in section 5.1.1.3.
5. The information-seeking behaviour during a problem-solving process changes over time according to the literature (Veshosky, 1998). However, the industry review indicated that this behaviour of the practitioners did not change over time during the problem-solving process. Some practitioners felt that there was no need to establish communication with the subject matter expert since they themselves were the subject matter expert or had already acquired all the knowledge.
6. There is no drive from the practitioners' side to facilitate the knowledge acquisition for the end-users about how the solution to the problem will affect business activities. This indicates that potentially there is a

common understanding between the practitioners and the end-users about the problem to be solved, as well as the solution's impact on current business activities. This behaviour confirms the communication model used, which is linear as discussed in point 3.

7. The behaviour review confirmed that trust is low where communication has not been established. If trust is present, people collaborate, communication channels open and sharing of knowledge is the norm (Reina and Reina, 2006). The trust relationship is very low between practitioners and stakeholders, which confirms the one-way communication model used by practitioners and the knowledge sharing that only entails knowledge that practitioners need and not what stakeholders require.

5.3 Conclusion

The behaviour review provided a description about the practitioners' communication behaviour and the trust relationships they established during the requirements engineering process with various stakeholders. It identified the communication model used by practitioners during the execution of the requirements activities. This provided the social context during the requirements process within which the practitioners operated.

The fundamental driver for a practitioner to communicate with the various stakeholders was to elicit information about the domain in which the problem should be solved. From the communication behaviour of the practitioners, it is evident that they established communication to acquire knowledge. The value of this process for stakeholders would be to acquire knowledge about how the solution to the problem would affect their business activities.

The practitioner as the owner of the requirements engineering process is responsible for facilitating this knowledge transfer to the various stakeholders. From the behaviour review, it is evident that there was no drive from the practitioners' side to do this so that the stakeholders would know how the solution to the problem would affect business activities.

The behaviour review confirmed that communication is problematic during the requirements engineering process as suggested by many studies in literature (Bjarnason et al., 2011; Karlsson et al., 2007; Kamata et al., 2007; Paech et al., 2005). It identified that there is a relationship between the trust relationship behaviour of the practitioner and the communication behaviour. It also confirmed the relationship between the communication established and the quality of requirements. These relationships confirm that quality requirements impact on how the requirements activities are executed as well as the behaviour of the practitioner. This adds to the body of knowledge on challenges during the requirements engineering process. It highlights the impact of the social context within which the requirements engineering process is executed.

This study confirms the importance of the social context of the requirements engineering process. To achieve better quality requirements, the requirements activities should be executed effectively and the knowledge acquisition about the problem and solution should be facilitated by the practitioner. Future research should focus on integrating the social context into the requirements engineering process and determining the impact on the quality of requirements. In the next chapter the results are integrated from the industry and behaviour reviews and a holistic description is provided of the requirements engineering process.

Chapter 6 A Socio-technical View

The industry review provided a description of how the requirements engineering process is executed in practice. It highlighted the differences between what knowledge is available in literature and what is actually used by practitioners. The behaviour review, on the other hand, described the social behaviour during the execution of the process itself. The communication patterns of practitioners that lead to communication breakdowns were identified. In both reviews, the impact on the quality of the requirements was noted.

In this chapter the results are compared to validate the original study hypotheses. These results are used to describe how the social factors should be taken into consideration as part of the requirements process. These factors should improve the quality of the delivered requirements.

6 Summary of Research Results

The goal of this study was to determine the social behaviour of practitioners during the requirements engineering process. The aim was to identify the social behaviour that causes communication breakdowns, as communication is one of the challenges impacting on the quality of requirements. The social behaviour was not researched in isolation, but within the context of how the requirements engineering process is executed by practitioners. The execution of this process was included to provide the social context of each requirements activity.

The research started with the following hypothesis:
When the requirements practitioner establishes trust relationships with stakeholders, in addition to executing the requirements engineering process activities effectively, communication improves and this leads to the increased quality of requirements.

The main research hypothesis was broken down into three subhypotheses to determine why the requirements engineering process often produces poor quality requirements. The research results from the literature, industry and behaviour reviews provided some insights into the research hypotheses as presented in Table 54.

Table 54: Research hypotheses

Research Hypotheses	Research Results
H1: Established trust relationships between the requirements practitioner and relevant stakeholders enable communication.	Literature indicates that trust in a relationship is the foundation for effective communication during the requirements engineering process (Coughlan et al., 2003; Holtzblatt and Beyer, 1995; Hoffmann and Lescher, 2009; Marnewick et al., 2011; Zeffane et al., 2011). The results of the behaviour review confirmed that where practitioners did not establish

	communication with the various stakeholders, there was *a low* trust relationship between the practitioner and the relevant stakeholder. The results also indicated that in the cases where practitioners established communication, the trust relationship between the practitioner and the relevant stakeholder was *higher*. For detail results refer to section 5.1.2. It can be confirmed from the results that there is a relationship between the trust relationship and the established communication between the practitioner and the stakeholders. It can be concluded that hypothesis (H1) can be accepted.
H2: The impact on the output of the requirements engineering process quality is positive if all activities during the process are executed effectively.	Literature confirms that the more effective the requirement process, the better the quality of the requirements (Damian and Chisan, 2006). The data of the industry review confirmed that where the practitioners were involved in the requirements activity, the requirements engineering process was more efficient. A positive relationship was identified between the execution of the activities during the requirements engineering process and the quality of requirements: the better the activities were executed, the higher the quality of requirements. A clear negative relationship could not be identified in the case where the activities were not executed. Refer to section 4.2.3.1. From these results it can be concluded that hypothesis (H2) can be accepted.
H3: The output of the requirements engineering process quality is dependent on the communication established between the requirements practitioner and relevant stakeholders.	Literature constantly identifies communication and its impact as a challenge during the requirements engineering process (Paech et al., 2005; Karlsson et al., 2007; Curtis et al., 1988; Sutcliff et al., 1999). The results of the behaviour review confirmed the impact of communication on the quality of requirements. A positive relationship was identified in that where communication has been established, a higher quality of requirements is delivered. Refer to section 5.1.1 for a detailed discussion. From these results it can be concluded that hypothesis (H3) can be accepted.

From the results as discussed in Table 54, the requirements quality is positively impacted if all activities during the process are executed effectively. It is also dependent on the communication established between the requirements practitioner and relevant stakeholders. The communication is enabled through the trust relationships between requirements practitioner and relevant stakeholders. The impact of the social elements and the technical process as confirmed by the results is illustrated in Figure 51.

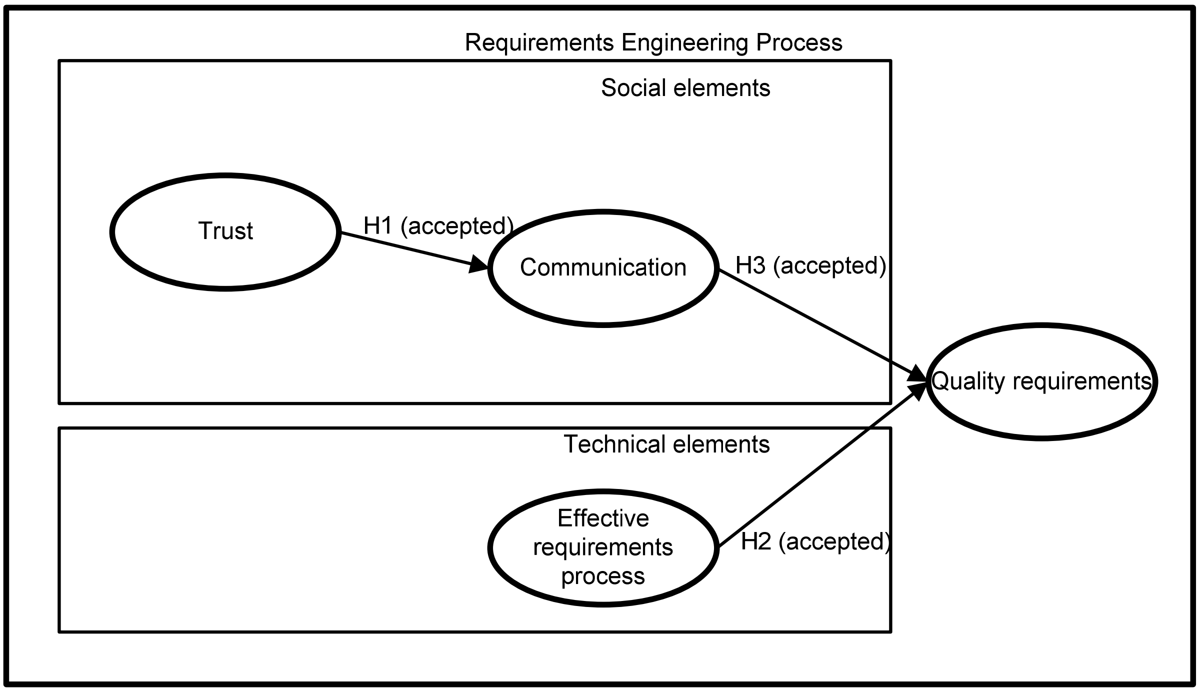

Figure 51: Research model

These results confirmed that the effectiveness of communication and of the execution of the requirements activities and their impact on the quality of requirements. In addition, the trust relationships between the practitioners and the stakeholders affect communication effectiveness. The conclusion from these results is that the success of the requirements process is dependent on how well the process is executed, the creation of communication channels between the practitioner and various stakeholders as well as the development of human relationships based on trust. Therefore to improve the quality of the requirements, the process that produces the requirements should be adjusted to include the social elements as well. By improving the quality, the overall success of the solution delivery will be affected. Requirements are the input to the solution process; if the requirements are wrong, the solution is a failure even if all other work has been done perfectly (Berenbach et al., 2009; Brooks, 1987; Viller et al., 1999).

As the environment within which the requirements process is executed consists of a social and technical system, for optimisation the social and technical elements should be brought together (Patnayakuni and Ruppel, 2010). The result when considering social and technical elements is the effective utilisation of people and technology (Mumford, 2006). As confirmed by Sommerville (2011), when solving problems the success of the solution is dependent on how well the human, social and organisational elements have been considered. A framework is therefore needed for the requirements engineering process that includes technical, human and social elements. The following section deals with how the principles of a socio-technical system in conjunction with the research results have been applied to derive a framework for the requirements engineering process to include the social elements.

6.1 Socio-technical Systems

A socio-technical system includes the technical system as well as the people that understand the purpose of the system (Sommerville, 2011). When a socio-technical approach is adopted during system development, the result is a system that is more acceptable to the end-users and it delivers better value to the stakeholders (Baxter and Sommerville, 2011). If the focus is only on the impact of a solution on the tasks and technology during the solution development, the impact of the change on the people and the structure in the environment is ignored (Bostrom and Heinen, 1977). The changes in the work relationships and people are also very important and should be taken into account to ensure that the task, technology, people and structure complement one another in the solution as illustrated in Figure 52.

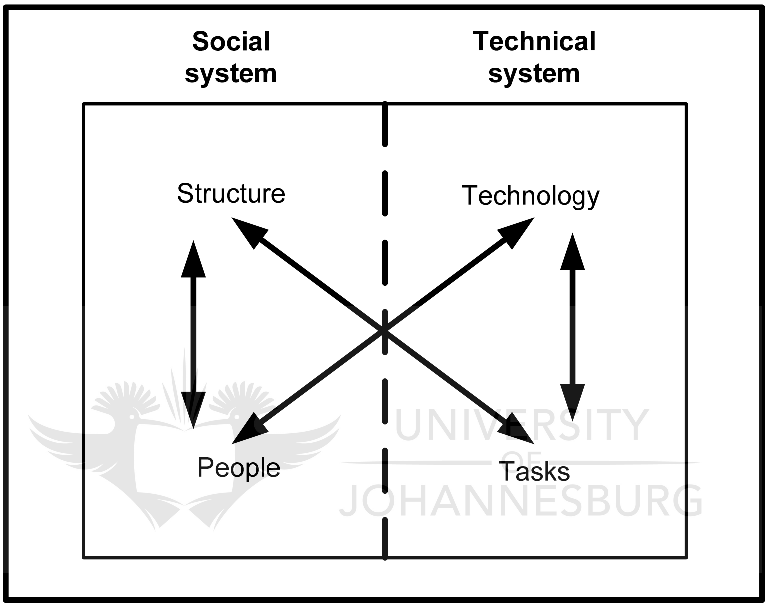

Figure 52: The interacting variable classes within a work system (Bostrom and Heinen, 1977)

The communication channels in an organisation are one of the primary structures (Patnayakuni and Ruppel, 2010). These channels have a direct impact on realising the effective outcomes of the process (Patnayakuni and Ruppel, 2010; Fidler and Johnson, 1984). The research model in Figure 51 shows the influence of communication on requirements quality. From the research results and literature, it is evident that the informal communication support in the organisation increases the distribution of the knowledge base and facilitates collaboration. The social system that contributes to the effective outcome of the process is therefore built on the informal communication channels which also encompass relationships within and between groups. Secondly, the results as summarised in Figure 51 show that the communication structures are affected by the trust relationships developed between people. To optimise the requirements engineering process and positively impact the quality, which is the output, the focus should be on adding the social system that provides guidelines on what the goals of these communication channels should be.

A socio-technical approach does not consider only the technical solution to the problem. It considers all variables within the environment (Bostrom and Heinen, 1977).

A socio-technical system has five key characteristics as presented by Baxter and Sommerville (2011):

- The system should consist of interdependent parts.
- The system should adapt to pursue the goals of the external environment.
- The system has an internal environment comprising separate but interdependent technical and social subsystems.
- The system goals can be achieved through more than one means.
- The system performance relies on the joint optimisation of the technical and social subsystems.

The characteristics and the results from the literature, industry and behaviour review were combined to derive a socio-technical framework for the requirements engineering process.

Figure 53 provides this social-technical framework. The framework consists of interdependent technical and social parts. The focus of the framework is to achieve the goals of the external environment. It does not prescribe how to achieve the goals, as this can be done in various ways. If the technical and social activities are executed effectively, the quality of requirements will improve.

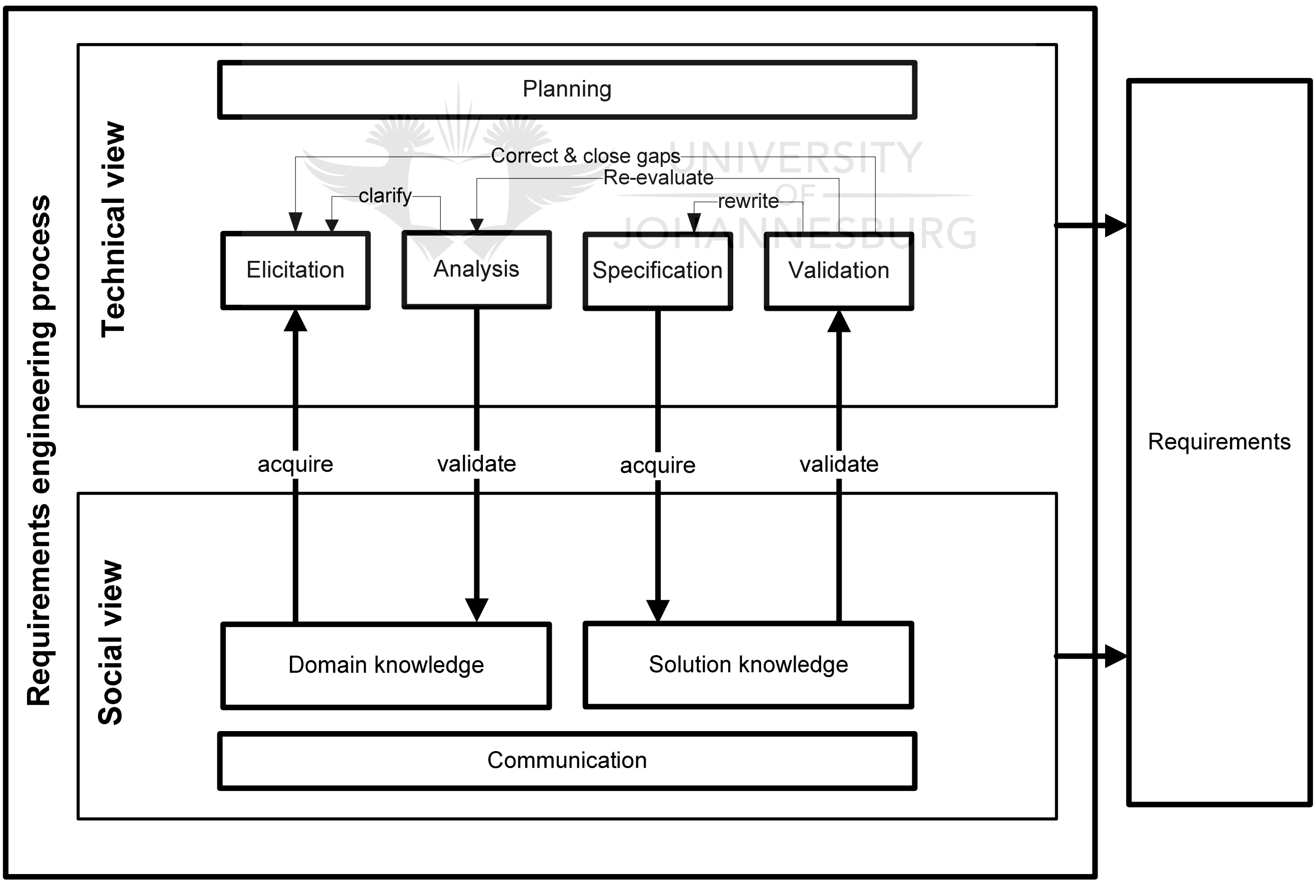

Figure 53: A socio-technical framework for the requirements engineering process

The technical activities for the requirements engineering process are elicitation, analysis, specification and validation. A detailed description of these activities was given in section 2.6. However, from the results of both the industry and behaviour reviews, it became clear that these activities are executed without any detailed planning by the practitioners in the population sample considered. Refer to sections 4.2.2.2 and 5.1.1.3 for these results. Adding planning as a technical activity will assist in adapting the process to pursue the goals of the external environment. If the practitioner considers what value should be added to each stakeholder during the planning activity, the delivery of the value for the stakeholder has a chance of being achieved.

The aim of this framework is to overcome the social behaviour that causes communication breakdowns, as communication is one of the challenges that affects the quality of requirements. The literature highlights a number of challenges that are experienced in delivering quality requirements (Curtis et al., 1988; Damian and Chisan, 2006; Hofmann and Lehner, 2001; Kamata et al., 2007; Karlsson et al., 2007; Sutcliff et al., 1999). The two main factors that are repeatedly identified by literature are:

- communication between the stakeholders and the implementation team that provides the solution
- acquiring domain knowledge, i.e. understanding the problem.

The results from the industry review confirm that the problem-solving process of the practitioners depends on sources of information which are either personal experience or conversations. Their information-seeking behaviour also does not change over time. This affects the completeness of the domain knowledge that is acquired. Additionally, the tools and techniques selected by practitioners to be used during the activities are based on what is known, and not on the most appropriate combination of techniques. A combination of techniques must be considered to ensure that all types of knowledge are acquired. The detailed results are discussed in section 4.2.2.3. To address these shortcomings, the first social activity added to the framework is domain knowledge. This activity has a dependency on the technical activity of elicitation, as this activity's purpose is to acquire domain knowledge when understanding the problem. However, this activity takes place through communication, as discussed by Marnewick et al. (2011). The communication channels are the underlying structure as illustrated in Figure 52 for people to execute tasks. This domain knowledge is the value the practitioners receive. The contribution which a socio-technical approach has is the value it adds during the system implementation (Mumford, 2000).

Finally, as emphasised by Sommerville et al. (2012), when solving complex problems a socio-technical perspective is required, which includes knowledge of technical systems, as well as of how the system should be used by stakeholders to achieve the ultimate objective (Sommerville, 2004). This knowledge acquisition about the problem and solution should be facilitated by communication between the practitioners and stakeholders. The practitioners, as the owner of the requirements process, should enable this communication throughout the entire process and not just the portion which collects information about the problem.

The industry review results confirm that the practitioners elicit information from the various stakeholders to acquire knowledge about the problem. The behaviour review confirmed that the practitioners use a linear communication model when they collect the information about the problem. However, it was clear from the results that the practitioners do not facilitate knowledge acquisition for the stakeholders. The detailed results are discussed in section 5.1.1.2. A final social activity is therefore added called solution knowledge. This activity focuses on ensuring that the stakeholders obtain knowledge during the requirements engineering process, as well as of how the system should be used by stakeholders to achieve the ultimate objective. This solution knowledge is the value the stakeholders receive.

This framework provides an integrated view of the requirements engineering process. During the requirements process, information is elicited and processed to be understood and analysed. After this, the derived requirements are documented into a specification which all the stakeholders will validate. The requirements are then the output of this process. The activities are executed as an iterative process continuously throughout the life cycle of the process. Due to its nature, multiple iterations are possible through the requirements activities until agreement on the requirements is obtained.

Knowledge acquisition continues throughout the requirements process. The first step is knowledge acquisition by the practitioners to obtain information about the problem. This is followed by knowledge acquisition by the stakeholders to obtain information about the solution. This is facilitated by communication. The relationships between the practitioners and stakeholders will be established based on the knowledge exchange during the communication. If the stakeholders receive value from these relationships, which is the knowledge about how the solution will impact business, more trust will be developed between the stakeholders and practitioners. The successes of an organisation, team or project depend on the knowledge in the organisation and are represented by the relationships between the people and the organisation (Dawson, 2000).

This framework integrates the communicative activities required with the requirements activities. It also ensures that there is emphasis on facilitating the knowledge acquisition of all stakeholders about how the solution will operate and impact the business environment. Some practical considerations that can be considered during project implementation are discussed next when implementing the framework.

6.2 Approach to implement and validate framework

The communication efforts required to elicit information about the domain in which the problem should be solved, noted as “Domain knowledge” in the provided socio-technical framework for requirements engineering should be planned for during the creation of the a requirements plan. Similar planning is required for the communication efforts required for stakeholders to acquire knowledge about how the solution to the problem will affect their business activities noted as “Solution knowledge”.

The practical approach that is suggested to implement the social elements into any formal project effort is that it should be planned for. Successful projects need a requirements plan (Anton, 2003). A requirements management plan is a key input to the overall project schedule (Carkenord et al., 2010; Weese and Wagner, 2011). If the social elements are planned for, it should form part of the formal project effort.

During planning, the communication efforts required to achieve the goals “Domain knowledge” and “Solution knowledge” activities should consider the following:

- What is the goal or value add of each activity i.e. during elicitation the requirements practitioner must acquire all possible information about the problem to be solved.

- Identifying and assess the people that should be involved to achieve the goal of each activity (Carkenord, 2009).
- How will the progress for each activity be communicated, to whom it should be communicated and what artefact should be delivered to facilitate communication (Ellis, 2011).
- What is the best suited processes or techniques that will be used to conduct the tasks required during each activity (Carkenord, 2009).
- Generate an estimation of the task based on people required to be involved availability and work required to generate artefact required to facilitate communication efforts.
- Plan for rework based on feedback received from communication efforts.
- Consider previous lessons learnt and adapt tasks based on that (Ellis, 2011).

Once the social elements are planned for and incorporated into the overall project schedule, monitoring should be done to ensure that the social element are completed and the goals and value add of each is achieve.

Requirements engineering is about understanding the problem, and then creating and describing solutions for the problem (Maiden, 2013). To measure whether the problem was solved successfully, multiple dimensions should be measured to determine and validate the success of the delivered solution (Petter et al., 2008)

The approach suggested to validate the social approach impacts are as follow:

- Key variables that contribute to the success of a project should be measured prior to the implementation of the social approach.
- The requirement engineering process should then be adapted to include the social approach.
- Review and observe the implementation to ensure the application of the social approach.
- A final measurement of the key variables that contribute to the success of a project should be measured to determine the impact of the social approach implementation.
- Perform analysis to compare the results of both measurements to determine and validate the social approach impact.
- The measurements should be done from different views i.e. practitioners, end users, sponsor, project manager and the subject matter expert and not only a single perspective.

The minimum key variables that should be measured are:

- Requirements quality. By improving the quality, the overall success of the solution delivery will be affected. The requirements quality before social approach implementation and after should be measured.
- User satisfaction with the solution – from different stakeholders' perspectives.
- The usage of the solution by the users.
- The requirements' quality is dependent on the communication established between the requirements practitioner and relevant stakeholders. It is therefore important to understand the communication patterns before the implementation and after of the social approach.
- Measure trust relationships prior to the implementation of the social approach implementation and after the implementation of the social approach.

The results from the industry and behaviour review are subject to a number of threats to their validity. These are discussed in the next section and improvements for future research to address them are suggested.

6.3 Threats to Validity and Improvements

There are several possible threats to the validity of the results.

6.3.1 Industry Review Threats to Validity

The closed set of questions used in the industry review could have led respondents to select only the available responses rather than to take more time to provide open-ended answers that required more time and cognitive effort. However, the respondents did provide complete answers in cases where they could provide comments. For example, the planning output received 83, 90 and 102 responses out of 127.

The list of elicitation as well as analysis and modelling techniques was generated based on what is available in the literature across the requirements discipline. A usage rating scale was used to determine whether practitioners surveyed used the technique, did not use it or had never heard of it. During the survey, respondents questioned the list of techniques and indicated they did not know what was meant, which is an indication that the techniques were not familiar. It seems as if certain techniques are not known by certain communities of practitioners. In future, more definitions should be included as descriptions for respondents from communities where only a subset of techniques are used or known.

6.3.2 Requirements Quality Measurement

The scale used to measure the requirements quality was a 7-point frequency Likert-type scale. The scale elements used to determine the quality of the requirements were based on the eight characteristics of a quality requirement. Confirmatory factor analysis was done to validate the structure of the scale used and the detailed calculations are discussed in APPENDIX D, section D.4. During the analysis, elements 4 (consistent), and 8 (traceable) were excluded. For future measurement of the requirements quality, these two elements should be reconsidered and modified. The wording of element 4 should be changed for future use. Element 8 could be seen as measuring the same as element 7 and needs to be revisited.

The quality of the delivered requirements was measured from the point of view of the practitioners who were responsible for delivering the requirements. This has the potential to introduce some bias. For future measurement, it is suggested that the quality of the requirements be rated by the practitioners as well as the various stakeholders.

Finally, the user satisfaction and usage of system were measured from the practitioners' point of view. This also has potential for bias. In future, this section of questions should also be measured from actual stakeholders' point of view and not just that of practitioners.

6.3.3 Behaviour Review Threats to Validity

The closed set of questions used in the behaviour review to establish whether the communication model used was linear or more dynamic could possibly have introduced bias. In future, it is suggested that semi-structured questions as well as multiple-answer options be introduced. Communication model questions should be expanded to validate one- or two-way communication.

The frequency of communication for all stakeholders provided the same results. This question should be restructured for future use of the survey as it had the potential of participants just selecting similar answers.

6.4 Conclusion

Chapter 6 validated whether the original study hypotheses could be accepted or should be rejected. It confirmed that the social elements as well as the activities during the requirements engineering process impact on the quality of requirements. A socio-technical framework was derived to include the social elements in the requirements process to ensure that all socio-technical elements that affect the quality of requirements are considered during the requirements engineering process.

By following a socio-technical approach during the requirements engineering process, the practitioner should be able to deliver a higher quality of requirements. Both the practitioner and the stakeholders involved should receive value from the process. The stakeholders should acquire knowledge of the solution, which will also facilitate the change process on how the solution will impact business activities.

The combination of the industry and behaviour reviews provided a clear indication of how both affect the quality of requirements. The framework presented an integrated view of the elements of the requirements process and behaviour of practitioners during the process into a single socio-technical view that can be used during the execution of the requirements process and improve the quality of requirements. Practitioners that use the framework would benefit as their quality of their work should be higher, and the value they provide to their stakeholders should improve.

The description of how the requirements engineering process is executed by practitioners and how they behave identified areas for practitioners to focus on and improve their engineering process without having to adopt any new tools or methodologies. The next chapter provides a summary of these focus areas identified and proposes future research themes.

CHAPTER 7 Conclusion

The conclusion provides a summary of the knowledge discovery process that was followed during the research. The knowledge generated is summarised and the conclusions made during the research process are given. Finally, the future research suggestions based on this new knowledge will also be discussed.

7 Introduction

The requirements discipline is at the heart of systems engineering, software engineering and business analysis (Gonzales, 2005). Requirements are about understanding the problem before developing a solution to the problem (Gonzales, 2005). To understand the problem, communication is required. Requirements emerge from the social interaction and communication between the users and the requirements engineer (Siddiqi, 1996). Human interaction is therefore an integral part of understanding the problem. These social interactions are continuously highlighted as a contributing factor for poor requirements (Piri, 2008; Bjarnason et al., 2011). Research in requirements engineering constantly highlights the same challenges. Paech et al. (2005) have summarised studies reported on in the literature. This summary confirms that communication and coordination breakdowns, the lack of domain knowledge and changing and conflicting requirements are known problems during the requirements process.

Based on these challenges, the goal of this study was to discover the social behaviour of practitioners during the requirements engineering process which contributes to communication breakdowns. The social behaviour was not researched in isolation, but within the context of how the requirements engineering process is executed by practitioners. The execution of this process was included in this study to provide the social context of each requirements activity.

The focus of this research was only on the requirements engineering process. It was approached from three different perspectives to gain a complete understanding of the process as illustrated in Figure 54.

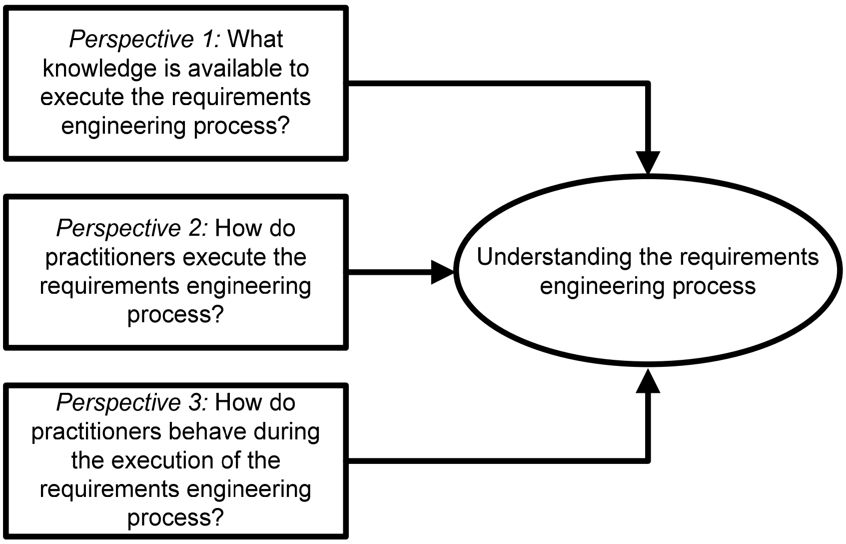

Figure 54: Three perspectives of the requirements engineering process

The first perspective was to acquire and confirm the body of knowledge in requirements engineering that is available in literature. This knowledge was used as a basis to develop a survey to understand how the requirements engineering process is executed in practice. A survey was used to determine the second and third perspectives of the requirements engineering process. This was to understand how the requirements engineering process is executed by practitioners and how they behave during the process.

This complete understanding about the requirements engineering process provides insight into the available knowledge about the industry as well as the social context that causes the communication breakdowns. With this knowledge, it could be confirmed that the quality of the requirements is influenced by the effective execution of the technical activities during the requirements process as well as the social behaviour of the practitioners as stated in the original research hypothesis:

When the requirements practitioner establishes trust relationships with stakeholders, in addition to executing the requirements engineering process activities effectively, communication improves and this leads to the increased quality of requirements.

The next section provides a summary of how knowledge of each of the three perspectives of the requirements engineering process were discovered.

7.1 Requirements Engineering Field Covered

The first stage of the knowledge discovery was to do a literature review to determine and confirm the body of knowledge within the requirements engineering discipline. This provided a history of the requirements discipline, the current challenges within the discipline and how the requirements engineering process should be executed including the existing tools, techniques and modelling methods. Importantly, the literature suggests that research efforts should focus on the integration between software, hardware and people.

The second stage of the knowledge discovery was to determine whether the existing knowledge from literature is used in practice. The first purpose of the survey was to describe how the requirements engineering process is executed by practitioners and to establish what is used and what is not used in practice. The hypothesis driving this perspective was:

- *The impact on the output of the requirements engineering process quality is positive if all activities during the process are executed effectively.*

The final stage of the knowledge discovery was to understand the social context within which the practitioners executed the requirements engineering process. Guided by the literature findings, the second purpose of the survey was to determine if the following two following hypotheses could be accepted:

- *Established trust relationships between the requirements practitioner and relevant stakeholders enable communication.*
- *The output of the requirements engineering process quality is dependent on the communication established between the requirements practitioner and relevant stakeholders.*

The results from this knowledge discovery from the literature, namely how practitioners execute the requirements process and how they behave during the execution of the requirements process, were integrated and the key findings across these different perspectives are summarised in Table 55.

Theme	**Finding**
Social and technical elements impact the quality of requirements	The effectiveness of communication and of the execution of the requirements activities impacted the quality of requirements.
Quality impacted by effectiveness of requirements process	The more involved practitioners are during the activities of the requirements process, the higher the quality of requirements delivered.
Quality impacted by the effectiveness of communication	The more practitioners established communication with various stakeholders, the higher the quality of requirements delivered.
Requirements planning	Practitioners do not follow a formal planning activity to consider how the requirements activities should be approached prior to executing them.
Practitioners' information-seeking behaviour	The problem-solving process of the practitioners depends on sources of information which are either personal experience or conversations; their information-seeking behaviour does not change over time.
Tools and techniques used during activities	The tools and techniques selected by practitioners to be used during activities are based on what is known, and not on the most appropriate combination of techniques.
Knowledge acquisition	There is no drive from the practitioners' side to facilitate knowledge acquisition for the stakeholders about how the solution to the problem will affect business activities.
Trust	Trust between practitioner and relevant stakeholder is low if communication has not been established.

Table 55: Summary of research findings

The findings of the research were evaluated and based on this evaluation the conclusions were derived. The research conclusions are discussed in the next section.

7.2 Conclusions

Based on the acceptance of the three research hypotheses, it was confirmed that the requirements quality is positively impacted if all activities during the process are executed effectively. Quality is also dependent on the communication established between the requirements practitioner and relevant stakeholders. The communication is enabled through the trust relationships between the requirements practitioner and relevant stakeholders.

From these results the *main conclusion* of this research confirms that the success of the requirements process is dependent on how well the process is executed, the creation of communication channels between the practitioner and various stakeholders as well as the development of human relationships based on trust. Therefore to improve the quality of the requirements, the process that produces the requirements should be adapted to include the social elements as well. The characteristics and the results from the literature, industry and behaviour reviews were combined to derive a socio-technical framework for the requirements engineering process.

The aim of this framework is to overcome the social behaviour that causes communication breakdowns, as communication is one of the challenges that has an impact on the quality of requirements. To optimise the requirements engineering process and positively impact the quality, which is the output, the socio-technical framework for the requirements engineering process provides a guideline of what activities a practitioner should execute and facilitate.

A secondary *conclusion* is that the effectiveness of the requirements process as well as the establishment of communication channels could be improved. This will impact the requirements quality positively if practitioners are more involved in the planning activity. Planning the activities during the requirements engineering process allows a practitioner to confirm resource estimates, communicate the progress of the process, coordinate the requirements process as well as consider previous lessons learnt so that the approach can be adapted. If practitioners spend time on planning as a formal activity, they would be able to inform stakeholders what is required of them, by when, where, type of engagement and why this is needed prior to the start of the process. This will initiate a more collaborative communication effort, which has the potential to lead to fewer communication breakdowns.

A third *conclusion* confirms that the sources used by the practitioners reveal that the information-seeking behaviour does not follow a typical problem-solving process where the sources change over time. The preferred sources which were used by the practitioners were either personal experience or conversations. If practitioners aligned their information-seeking behaviour with a typical problem-solving process where the sources change over time, the quality of the requirements would be affected as more knowledge will be acquired during the problem-solving process. This would enable practitioners to gather a comprehensive set of information about the problem.

A fourth *conclusion* was made that the tools and techniques used during the requirements activities are selected by practitioners based on personal preference and no consideration is given to the most appropriate tools and techniques. If the selection behaviour of practitioners could change to select a combination of techniques which will be most appropriate to acquire all types of knowledge during elicitation, the domain knowledge obtained would be more complete. This would enable practitioners to gather a comprehensive set of information about the problem.

If practitioners implemented a more collaborative communication model instead of a linear communication model, they would be able to facilitate the knowledge acquisition cycle for themselves (about the problem) as well as for the stakeholders (about the solution). In this way, both parties would derive value from the engagement and a more complete understanding would be reached between practitioners. If stakeholders received value from the engagement, a more collaborative environment would be established and fewer communication breakdowns would follow. More efficient communication has a direct impact on the quality of requirements.

Finally, if trust is present people collaborate, communication channels are established and sharing of knowledge is the norm (Reina and Reina, 2006). The trust relationship, which is very low between practitioners and stakeholders, confirms the one-way communication model used by practitioners and the fact that knowledge acquisition refers to the knowledge that practitioners need and not what stakeholders require. If a more collaborative communication model were implemented by practitioners, it would impact on the trust between practitioners and stakeholders. This would enable the facilitation of the knowledge acquisition cycle for themselves (about the problem) as well as for the stakeholders (about the solution).

The main contribution of the socio-technical view of the requirements engineering process includes how both the social and technical elements should be integrated to optimise the positive impact on the quality of requirements. The planning activity is included to ensure a solid start of the process. To facilitate knowledge acquisition during the process, both domain knowledge and solution knowledge activities have been included to ensure that both practitioners and the stakeholders derive value from the process. In the literature the focus is on obtaining domain knowledge, but the acquisition of solution knowledge for the stakeholders is less emphasised. The socio-technical view adds equal importance to both elements of knowledge acquisition that must be facilitated by the practitioner. This will enable both practitioners and stakeholders to derive value from the interactions; through value comes trust.

By integrating the social and technical elements, the result will be increased effectiveness of communication as well as of the execution of the requirements activities which will influence the quality of requirements.

7.3 Contributions

The contributions of the study involve four areas of the requirements engineering discipline:

- The requirements engineering knowledge base
- The requirements industry data
- The requirements practitioner behaviour knowledge base
- The research methodology

The research contributes to the existing requirements knowledge base. This novel contribution relates to the socio-technical framework derived for the requirements process. A view is provided of social and technical activities that should be facilitated by the requirements engineering process. This framework integrates the communicative activities required along with the traditional requirements activities. It also ensures that there is a new focus on facilitating the acquisition of knowledge by all stakeholders about how the solution will operate and impact the business environment. This framework addresses the communication breakdowns continuously highlighted as a contributing factor to poor requirements.

Secondly, the research creates a local industry description of how practitioners execute the requirements engineering process. It confirms what is known by practitioners and how they use the knowledge of requirements practice. This novel knowledge provides adequate data on requirements practice within Africa for future research. It also includes very specific focus areas for practitioners and managers on how to improve the requirements engineering process without adopting any new tools or methodologies. The focus areas identified from the results are practical with minor changes in practitioners' behaviour that could have a major impact on the results of the requirements engineering process.

The third contribution is a description of how practitioners behave during the requirements process. This entails a description of how they gather information about the problem during the requirements process, use the information and share their resulting information. By discovering these interaction patterns, communication can be improved and made more effective. Additionally, the relationships between the practitioners and their stakeholders were described. These trust patterns provide insight into the levels of collaboration, communication and sharing of knowledge between the practitioners and their stakeholders. By identifying these relationship patterns, the value from the relationships can be improved, and the communication breakdowns could be minimised.

Finally the quality scale and survey questionnaire can be adapted based on suggestions and future research can reuse these tools. Based on the lessons learnt during the research process, certain recommendations can be made.

7.4 Recommendations

As a practitioner, the researcher's desire is to contribute usable knowledge to practitioners to improve their performance. Literature also emphasises the importance of establishing collaborative partnerships between researchers and practitioners to increase industry relevance of research outcomes as well as to share industry data to understand practitioners' real problems (Cheng and Atlee, 2009; Zowghi and Coulin, 2005; Hansen et al., 2009). It is therefore vital from the researcher's perspective that the knowledge generated on requirements practice be documented as a public report which is accessible to all practitioners. The practitioners gave input into the research process and to receive value back, the knowledge generated should be published.

This knowledge presented to the practitioners could lead to the establishment of collaborative partnerships between researchers and practitioners to increase industry relevance of research outcomes as well to share industry data to understand practitioners' real problems.
The knowledge of practitioners and how they use the knowledge of requirements practice can be applied to focus future research efforts. The knowledge on the behaviour of practitioner could form the basis of cross-disciplinary research.

The socio-technical framework of the requirements engineering should be implemented and tested in a practical environment. In parallel, future research could be done on tools and techniques available that could be used to execute the knowledge acquisition activities.

7.5 Research Limitations

The first limitation was the measurement of the quality of requirements delivered by the practitioners. The quality scale was only completed by practitioners and not the end-users as well. Only a single perspective is therefore measured. A more complete measurement of the quality of requirements would include various stakeholders.

The socio-technical framework presented was validated using the results derived from the survey. However, to validate that this framework is relevant to the industry, it warrants future research where it is tested in practice.

The socio-technical framework only includes the activities that should be executed and does not provide guidance on how to execute these activities. This extension of the framework should be included in future research.

7.6 Conclusion

The research approached the requirements engineering discipline from different perspectives to derive an understanding of all influences. By considering past research of the requirements engineering process, real-world practice as well as people's behaviour in the real world, a complete understanding of the influence on the requirements process was gained. This integration of the information collected and knowledge generated formed a complete understanding of the causes of the communication breakdowns and therefore the lack of acquisition of domain knowledge, which is continuously mentioned as a challenge in requirements engineering that affects quality.

In response to this understanding a socio-technical framework for the requirements engineering process was developed. The aim of this framework is to change the social behaviour that causes communication breakdowns and affects the quality of the requirements. The framework provides an integrated view of the technical activities of the requirements process as well as the social activities.

References

Al-Rawas, A. & Easterbrook, S. (1996). *Communication Problems In Requirements Engineering A Field Study* Proceedings of the First Westminster Conference on Professional Awareness in Software Engineering 1-2 February 1996. London. Royal Society.
Alexander, P.A. (1992). Domain Knowledge: Evolving Themes and Emerging Concerns. *Educational Psychologist,* 27 (1):33-51.
Alexander, P.A. (2003). Can We Get There From Here? *Educational Researcher,* 32 (8):3-4.
Alexander, P.A. & Murphy, P.K. (1998). The Research Base for APA's Learner-Centered Psychological Principles In *How Students Learn: Reforming Schools Through Learner-Centered Education*. Edited by Lambert, N. M. & McCombs, B. L. Washington, DC: American Psychological Association.
Anton, A.I. (2003). Successful software projects need requirements planning. *IEEE Software*, 20 (3):44, 46.
Argyrous, G. (2011). *Statistics For Research With A Guide To SPSS* London: Sage.
Arthur, J.D. & Gröner, M.K. (2005). An operational model for structuring the requirements generation process. *Requirements Engineering,* 10 (1):45-62.
Atkinson, R. & Flint, F. (2001). Accessing Hidden and Hard-to-Reach Populations: Snowball Research Strategies. *Social Research Update.* Guildford Department of Sociology, University of Surrey.
Aurum, A. & Wohlin, C. (2003). The fundamental nature of requirements engineering activities as a decision-making process. *Information and Software Technology,* 45 (14):945-954.
Aurum, A. & Wohlin, C. (2005). Requirements Engineering: Setting the Context In *Engineering and Managing Software Requirements*. Edited by Aurum, A. & Wohlin, C. Berlin Heidelberg: Springer.
Baltar, F. & Brunet, I. (2012). Social research 2.0: virtual snowball sampling method using Facebook. *Internet Research,* 22 (1):57-74.
Bateson, G. (1958). *Naven.* California: Stanford University Press.
Baxter, G. & Sommerville, I. (2011). Socio-technical systems: From design methods to systems engineering. *Interacting with Computers,* 23 (1):4-17.
Bell, T.E. & Thayer, T.A. (1976). Software requirements: Are they really a problem? *Proceedings of the 2nd International Conference on Software Engineering.* San Francisco, California: IEEE Computer Society Press.
Berander, P. & Andrews, A. (2005). Requirements Prioritization. In *Engineering and Managing Software Requirements*. Edited by Aurum, A. & Wohlin, C. Berlin Heidelberg: Springer.
Berenbach, B., Paulish, D.J., Kazmeier, J. & Rudorfer, A. (2009). *Software & Systems Requirements Engineering: In Practice.* New York: McGraw Hill.
Berenson, M.L. & Levine, D.M. (1989). *Basic Business Statistics Concepts and Applications.* New Jersey: Prentice-Hall International.
Biernacki, P. & Waldorf, D. (1981). Snowball Sampling: Problems and Techniques of Chain Referral Sampling. *Sociological Methods & Research,* 10 (2):141-163.
Bjarnason, E., Wnuk, K. & Regnell, B. (2011). *Requirements are slipping through the gaps - A case study on causes & effects of communication gaps in large-scale software development*. Requirements Engineering Conference (RE), 2011 19th IEEE International, 29 August - 2 September. Trento, Italy. IEEE
Boehm, B. (2002). Get ready for agile methods, with care. *Computer,* 35 (1):64-69.
Boehm, B. (2006). *A view of 20th and 21st century software engineering*. Proceedings of the 28th International Conference on Software Engineering, 20-28 May. New York. ACM.
Boehm, B.W. (1976). Software Engineering. *IEEE Transactions on Computers,* C-25 (12):1226-1241.
Boehm, B.W. (1984). Verifying and Validating Software Requirements and Design Specifications. *Software, IEEE,* 1 (1):75-88.
Boehm, B.W. (1986). A spiral model of software development and enhancement. *International Workshop on the Software Process and Software Environments,* 11:22-42.
Boehm, B.W. & Papaccio, P.N. (1988). Understanding and controlling software costs. *IEEE Transactions on Software Engineering,* 14 (10):1462-1477
Bostrom, R.P. (1989). Successful application of communication techniques to improve the systems development process. *Information & Management,* 16 (5):279-295.
Bostrom, R.P. & Heinen, J.S. (1977). MIS Problems and Failures: A Socio-Technical Perspective. Part I: The Causes. *MIS Quarterly,* 1 (3):17-32.
Brand, D. & Zafiropulo, P. (1983). On Communicating Finite-State Machines. *Journal of the Association for Computing Machinery,* 30 (2):323-342.

Bransford, J.D., Brown, A.L. & Cocking, R.R. (2000). *How People Learn Brain, Mind, Experience, and School.* Washington, D.C.: National Academy Press
Bresciani, P., Perini, A., Giorgini, P., Giunchiglia, F. & Mylopoulos, J. (2004). Tropos: An Agent-Oriented Software Development Methodology. *Autonomous Agents and Multi-Agent Systems,* 8 (3):203-236.
Brill, J.H. (1998). Systems engineering— A retrospective view. *Systems Engineering,* 1 (4):258-266.
Brooks, F.P., Jr. (1987). No silver bullet; essence and accidents of software engineering. *Computer,* 20 (Copyright 1987, IEE):10-19.
Brown, T.A. (2006). *Confirmatory Factor Analysis for Applied Research.* New York: The Guilford Press.
Browne, G.J. & Rogich, M.B. (2001). An Empirical Investigation of User Requirements Elicitation: Comparing the Effectiveness of Prompting Techniques. *Journal of Management Information Systems,* 17 (4):223-249.
Bryman, A. & Bell, E. (2011). *Business Research Methods.* Oxford: Oxford University Press.
Byrne, B.M. (2010). *Structural Equation Modeling with AMOS Basic Concepts, Applications and Programming.* New York: Routledge Taylor Francis.
Campbell-Kelly, M. (2003). *From Airline Reservations to Sonic the Hedgehog A History of the Software Industry.* Massachusetts: MIT Press.
Cares, C., Franch, X., Mayol, E. & Quer, C. (2011). A Reference Model for i*. In *Social Modeling for Requirements Engineering*. Edited by Yu, E., Giorgini, P., Maiden, N. & Mylopoulos, J. Cambridge, Massachusetts: MIT Press.
Carkenord, B. (2009). *Seven Steps to Mastering Business Analysis.* Florida: J.Ross.
Carkenord, B., Cartwright, C., Grace, R., Goldsmith, L., Larson, E., Skrabak, J. & Vonk, C. (2010). *Partnering for Project Success Project Manager and Business Analyst Collaboration*. Proceedings of the PMI Global Congress Washington, DC. Project Management Institute.
Carrillo de Gea, J.M., Nicolas, J., Aleman, J.L.F., Toval, A., Ebert, C. & Vizcaino, A. (2011). Requirements Engineering Tools. *Software, IEEE,* 28 (4):86-91.
Chatzoglou, P.D. & Macaulay, L.A. (1996). Requirements capture and analysis: A survey of current practice. *Requirements Engineering,* 1 (2):75-87.
Cheng, B.H.C. & Atlee, J.M. (2007). *Research Directions in Requirements Engineering*. 2007 Future of Software Engineering, 23-25 May Minneapolis. IEEE Computer Society.
Cheng, B.H.C. & Atlee, J.M. (2009). Current and Future Research Directions in Requirements Engineering. In *Design Requirements Engineering: A Ten-Year Perspective*. Edited by Lyytinen, K., Loucopoulos, P., Mylopoulos, J. & Robinson, B. Heidelberg: Springer-Verlag.
Chiocchio, F., Forgues, D., Paradis, D. & Iordanova, I. (2011). Teamwork in integrated design projects: Understanding the effects of trust, conflict, and collaboration on performance. *Project Management Journal,* 42 (6):78-91.
Computer History Museum. (2006). Timeline of Computer History. Available: http://www.computerhistory.org/timeline/?category=cmptr [Accessed 12 June 2012].
Cooling, J.E. (1991). *Software Design for Real-time Systems.* London: Chapman and Hall.
Cooper, D.R. & Schindler, P.S. (2008). *Business Research Methods.* Boston: Mc Graw Hill.
Coughlan, J., Lycett, M. & Macredie, R.D. (2003). Communication issues in requirements elicitation: A content analysis of stakeholder experiences. *Information and Software Technology,* 45 (8):525-537.
Cronbach, L. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika,* 16 (3):297-334.
Curtis, B., Krasner, H. & Iscoe, N. (1988). A field study of the software design process for large systems. *Communications of the ACM,* 31 (11):1268-1287.
Czaja, R. & Blair, J. (2005). Designing Surveys. Second ed.: Pine Forge Press.
Damian, D. & Chisan, J. (2006). An Empirical Study of the Complex Relationships between Requirements Engineering Processes and Other Processes that Lead to Payoffs in Productivity, Quality, and Risk Management. *IEEE Transactions on Software Engineering,* 32 (7):433-453.
Damian, D. & Zowghi, D. (2003). RE challenges in multi-site software development organisations. *Requirements Engineering,* 8 (3):149-160.
Dardenne, A., Van Lamsweerde, A. & Fickas, S. (1993). Goal-directed requirements acquisition. *Science of Computer Programming,* 20:3-50.
Davis, A.M. & Hickey, A.M. (2002). Requirements Researchers: Do We Practice What We Preach? *Requirements Engineering,* 7 (2):107-111.
Dawson, R. (2000). *Developing Knowledge-Based Client Relationships The Future of Professional Services.* Boston: Butterworth-Heinemann.
de Oliveira, K.M., Zlot, F., Rocha, A.R., Travassos, G.H., Galotta, C. & de Menezes, C.S. (2004). Domain-oriented software development environment. *Journal of Systems and Software,* 72 (2):145-161.
Debasish, S.S. & Das, B. (2009). *Business Communication.* New Delhi: Prentice-Hall.
DeCoster, J. (1998). Overview of Factor Analysis. Available: http://www.stat-help.com/notes.html [Accessed 11 January 2013].
DeMarco, T. (1979). *Structured Analysis and System Specification.* New Jersey: Prentice-Hall.

Denger, C. & Olsson, T. (2005). Quality Assurance in Requirements Engineering. In *Engineering and Managing Software Requirements*. Edited by Aurum, A. & Wohlin, C. Berlin Heidelberg: Springer.
Dietz, G. & Den Hartog, D., N. (2006). Measuring trust inside organisations. *Personnel Review,* 35 (5):557-588.
Dittrich, Y., Floyd, C. & Klischewski, R. (2002). *Social Thinking Software Practice.* Massachusetts: MIT Press.
Dorfman, M. (2000). Requirements Engineering. In *Software Requirements Engineering*. Edited by Dorfman, M. & Thayer, R. H. Los Alamitos, California: IEEE Computer Society Press.
Dorfman, M. & Thayer, R.H. (2000). *Software Requirements Engineering.* Los Alamitos, California: IEEE Computer Society Press.
Easterbrook, S. (1993). *Domain modelling with hierarchies of alternative viewpoints*. Proceedings of IEEE International Symposium on Requirements Engineering, 4-6 Jan 1993. IEEE.
Ebert, C. (2008). A Brief History of Software Technology. *Software, IEEE,* 25 (6):22-25.
El Emam, K. & Koru, A.G. (2008). A Replicated Survey of IT Software Project Failures. *IEEE Software,* 25 (5):84-90.
El Emam, K. & Madhavji, N.H. (1995). *A field study of requirements engineering practices in information systems development*. Requirements Engineering, 1995., Proceedings of the Second IEEE International Symposium on, 27-29 Mar 1995. IEEE.
Ellen, L. & Steve, R. (2011). The implications of trust in relationships in managing construction projects. *International Journal of Managing Projects in Business,* 4 (4):633-659.
Ellis, K. (2008). Business Analysis Benchmark The Impact of Business Requirements on the Success of Technology Projects. Delaware: IAG Consulting
Ellis, K. (2011). Five Things You Must Know About Requirements Planning. Available: http://www.modernanalyst.com/Webinars/tabid/207/articleType/ArticleView/articleId/1674/5-Things-You-Must-Know-About-Requirements-Planning.aspx [Accessed 5 November 2012].
Ellis, R. (1997). *Communication for engineers: bridge that gap.* New York: John Wiley & Sons.
Feeny, D.F. & Willcocks, L.P. (1998). Core IS capabilities for exploiting information technology. *Sloan Management Review,* 39 (3).
Ferrari, R.N. & Madhavji, N.H. (2008). Architecting-problems rooted in requirements. *Information and Software Technology,* 50 (1-2):53-66.
Fidler, L.A. & Johnson, J.D. (1984). Communication and Innovation Implementation. *Academy of Management Review,* 9 (4):704-711.
Fink, A. (1995). *How to analyze survey data.* Thousand Oaks: Sage.
Firesmith, D. (2005). Quality Requirements Checklist. *Journal of Object Technology,* 4 (9).
Fisher, J. (1999). The value of the technical communicator's role in the development of information systems. *IEEE Transactions on Professional Communication,* 42 (3):145-155.
Floyd, F.J. & Widaman, K.F. (1995). Factor analysis in the development and refinement of clinical assessment instruments. *Psychological Assessment,* 7 (3).
Fowler, F.J. (2009). *Survey Research Methods.* Thousand Oaks: Sage.
Fuentes-Fernández, R., Gómez-Sanz, J. & Pavón, J. (2010). Understanding the human context in requirements elicitation. *Requirements Engineering,* 15 (3):267-283.
Gane, C.S., T. (1979). *Structured Systems Analysis: Tools and Techniques.* New Jersey: Prentice-Hall.
Gause, D.C. & Weinberg, G.M. (1990). *Are Your Lights On? How to Figure Out What the Problem REALLY Is.* New York: Dorset House.
Gillespie, N. (2003). Measuring trust in work relationships: The Behavioural Trust Inventory. *Academy of Management* Seattle.
Gillespie, N., A. (2012). Measuring trust in organizational contexts: An overview of survey-based measures. In *Handbook of Research Methods on Trust*. Edited by Lyon, F., Möllering, G. & Saunders, M. N. K. Surrey: Edward Elgar.
Glass, R.L. (1998). *In The Beginning Recollections of Software Pioneers.* Los Alamitos: IEEE Computer Society Press.
Glass, R.L. (2003). Facts and fallacies of software engineering Boston: Addison-Welsey.
Goguen, J.A. & Linde, C. (1993). *Techniques for requirements elicitation*. Proceedings of IEEE International Symposium on Requirements Engineering, 4-6 Jan 1993.
Gonzales, R. (2005). Developing the requirements discipline: Software vs. systems. *IEEE Software,* 22 (2):59-61.
Gottesdiener, E. (2002). *Requirements By Collaboration Workshops for Defining Needs.* Boston: Addison-Wesley.
Greenspan, S., Mylopoulos, J. & Borgida, A. (1994). *On formal requirements modeling languages: RML revisited*. Proceedings of 16th International Conference on Software Engineering 16-21 May. Los Alamitos. IEEE Computer Society Press.
Hansen, S., Berente, N. & Lyytinen, K. (2009). Requirements in the 21st Century: Current Practice and Emerging Trends. In *Design Requirements Engineering: A Ten-Year Perspective*. Edited by Lyytinen, K., Loucopoulos, P., Mylopoulos, J. & Robinson, B. Heidelberg: Springer-Verlag.

Hartwick, J. & Barki, H. (2001). Communication as a dimension of user participation. *IEEE Transactions on Professional Communication,* 44 (1):21-36.
Heck, P. & Parviainen, P. (2008). *Experiences on Analysis of Requirements Quality*. The Third International Conference on Software Engineering Advances, 26-31 Oct. 2008. IEEE Computer Society Press.
Herbsleb, J.D. & Mockus, A. (2003). An empirical study of speed and communication in globally distributed software development. *IEEE Transactions on Software Engineering,* 29 (6):481-494.
Hickey, A.M. & Davis, A.M. (2004). A Unified Model of Requirements Elicitation. *Journal of Management Information Systems,* 20 (4):65-84.
Hoffmann, A. & Lescher, C. (2009). *Collaboration and Intercultural Issues on Requirements:Communication, Understanding and Softskills (CIRCUS)*. Collaboration and Intercultural Issues on Requirements: Communication, Understanding and Softskills, 31 Augustus. IEEE.
Hofmann, H.F. & Lehner, F. (2001). Requirements engineering as a success factor in software projects. *Software, IEEE,* 18 (4):58-66.
Holm, J.E.W., van der Walt, M. & Stoker, P.W. (2010). *Systems Engineering Training in Engineering Education*. Transforming Engineering Education: Creating Interdisciplinary Skills for Complex Global Environments, IEEE Conference, 6-9 April. IEEE.
Holtzblatt, K. & Beyer, H.R. (1995). Requirements gathering: The human factor. *Communications of the ACM,* 38 (5):31-32.
Hooks, I.F. & Farry, K.A. (2001). *Customer-Centered Products Creating Successful Products Through Smart Requirements Management.* New York: AMACOM/American Management Association.
Houdek, F. & Pohl, K. (2000). *Analyzing requirements engineering processes: A case study*. Proceedings of the 11th International Workshop on Database and Expert Systems Applications.
Hsia, P., Davis, A.M. & Kung, D.C. (1993). Status report: Requirements engineering. *IEEE Software,* 10:75-9.
Huizingh, E. (2007). *Applied Statistics with SPSS.* Thousand Oaks: SAGE.
IEEE (1990). IEEE Standard Glossary of Software Engineering Terminology. *IEEE Std 610.12-1990*:1.
IEEE (1998a). IEEE Guide for Developing System Requirements Specifications. *IEEE Std 1233, 1998 Edition*:i.
IEEE (1998b). IEEE Recommended Practice for Software Requirements Specifications. *IEEE Std 830-1998*:i.
IEEE Computer Society, I. (2004). *Guide to the Software Engineering Body of Knowledge (SWEBOK).* Los Alamitos: IEEE Computer Society.
IIBA, I.I.o.B.A. (2012). *Certification Registry* [Online]. IIBA. Available: http://www.iiba.org/imis15/IIBA/Certification/Certification_Registry/IIBA_Website/Certification/Certification_Registry.aspx?hkey=ef6f2bc3-b6d6-40a4-a38d-36c681b5daea [Accessed 19 May 2012].
International Institute of Business Analysis (2009). *A Guide to the Business Analysis Body of Knowledge® (BABOK® Guide).* Toronto: International Institute of Business Analysis.
IREB. (2006). *International Requirements Engineering Board* [Online]. Available: http://www.certified-re.de/en/ [Accessed 9 June 2012].
Jackson, M. (1983). *System Development.* New Jersey: Prentice Hall International.
Jackson, M. (1995). The world and the machine. *Proceedings of the 17th International Conference on Software Engineering.* Seattle, Washington: ACM.
Johnson, S.D. & Long, L.M. (2002). Being a Part and Being Apart. In *New Directions In Group Communication*. Edited by Frey, L. R. Thousand Oaks: Sage.
Jones, C. (1996). Software change management. *Computer,* 29 (2):80-82.
Kaiya, H. & Saeki, M. (2006). *Using Domain Ontology as Domain Knowledge for Requirements Elicitation*. 14th IEEE International Requirements Engineering Conference, 11-15 September. IEEE Computer Society Press.
Kamata, M.I. & Tamai, T. (2007). *How Does Requirements Quality Relate to Project Success or Failure?* 15th IEEE International Requirements Engineering Conference, 15-19 October. IEEE Computer Society Press.
Kamata, M.I., Yoshida, A.Y., Yoshida, H. & Aoki, N. (2007). *Figure Out the Current Software Requirements Engineering - What Practitioners Expect to Requirements Engineering?* 14th Asia-Pacific Software Engineering Conference, 4-7 December. IEEE Computer Society Press.
Karlsson, L., Dahlstedt, A.G., Regnell, B., Natt och Dag, J. & Persson, A. (2007). Requirements engineering challenges in market-driven software development - An interview study with practitioners. *Information and Software Technology,* 49 (6):588-604.
Kelly, K., Clark, B., Brown, V. & Sitzia, J. (2003). Good practice in the conduct and reporting of survey research. *International Journal for Quality in Health Care,* 15 (3):261-266.
Kim, J.-N. & Grunig, J.E. (2011). Problem Solving and Communicative Action: A Situational Theory of Problem Solving. *Journal of Communication,* 61 (1):120-149.
Kirk, J. & Miller, M.L. (1986). *Reliability and Validity in Qualitative Research.* Thousand Oaks: Sage.
Kitchenham, B. & Pfleeger, S.L. (2002). Principles of survey research part 4: Questionnaire evaluation. *SIGSOFT Software Engineering Notes,* 27 (3):20-23.
Kitchenham, B. & Pfleeger, S.L. (2003). Principles of survey research part 6: Data analysis. *SIGSOFT Software Engineering Notes,* 28 (2):24-27.

Kotonya, G. & Sommerville, I. (1998). *Requirements Engineering Processes and Techniques.* Chichester: John Wiley & Sons.
Lederer, A.L. & Prasad, J. (1992). Nine management guidelines for better cost estimating. *Communications of the ACM,* 35 (2):51-59.
Leffingwell, D. (1997). Calculating your Return on Investment from More Effective Requirements Management. Available: http://www-128.ibm.com/developerworks/rational/library/347.html. [Accessed 12 May 2011].
Leffingwell, D. (2011). *Agile Software Requirements Lean Requirements Practices for Teams, Programs, and the Enterprise.* Boston: Addison-Wesley
Leffingwell, D. & Widrig, D. (2000). *Managing Software Requirements: A Unified Approach.* Boston: Addison-Wesley.
Litwin, M.S. (1995). *How to Measure Survey Reliability and Validity.* Thousand Oaks: Sage.
Loucopoulos, P. (2005). Requirements engineering. In *Design process improvement: A review of current practice*. Edited by Clarkson, J. & Eckert, C. London: Springer.
Loucopoulos, P. & Karakostas, V. (1995). *System requirements engineering.* New York: McGraw-Hill.
Macaulay, L. (1996). *Requirements for requirements engineering techniques*. Proceedings of the Second International Conference on Requirements Engineering, 15-18 April. Los Alamitos. IEEE Computer Society Press.
Machado, R.J., Ramos, I. & Fernandes, J.M. (2005). Specification of Requirements Models. In *Engineering and Managing Software Requirements*. Edited by Aurum, A. & Wohlin, C. Berlin Heidelberg: Springer.
Maiden, N. (2013). So, What Is Requirements Work? *IEEE Software*, 30 (2):14-15.
Maiden, N. (2008). Requirements 25 years on. *IEEE Software,* 25 (Compendex):26-28.
Maiden, N., Gizikis, A. & Robertson, S. (2004). Provoking creativity: Imagine what your requirements could be like. *IEEE Software,* 21 (5):68-75.
Maiden, N.A.M. & Rugg, G. (1996). ACRE: Selecting methods for requirements acquisition. *Software Engineering Journal,* 11 (3):183-192.
Marnewick, A. 2011. *The Effect of Requirements Engineering on the Success of System Implementation: A Comparative Case Study* Magister Ingeneriae University of Johannesburg.
Marnewick, A., Pretorius, J.-H. & Pretorius, L. (2011). *A perspective on human factors contributing to quality requirements: A cross-case analysis*. IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), 6-9 December. IEEE.
Marpsat, M. & Razafindratsima, N. (2010). Survey methods for hard-to-reach populations: Introduction to the special issue. *Methodological Innovations Online,* 5 (2).
Martin, S., Aurum, A., Jeffery, R. & Paech, B. (2002). *Requirements Engineering Process Models in Practise*. 7th Australian Workshop on Requirements Engineering, Melbourne.
McEvily, B. & Tortoriello, M. (2011). Measuring trust in organisational research: Review and recommendations. *Journal of Trust Research,* 1 (1):23-63.
McManus, J. & Wood-Harper, T. (2007). Understanding the Sources of Information Systems Project Failure. *Management Services,* 51 (3):38-43.
Millar, F.E. & Rogers, E.L. (1976). A Relational Approach to Interpersonal Communication. In *Explorations in Interpersonal Communication*. Edited by Miller, G. R. Thousand Oaks: Sage.
Moreau, R. (1986). *The Computer Comes of Age The People the Hardware and the Software.* Cambridge: MIT Press (MA).
Mumford, E. (2000). A Socio-Technical Approach to Systems Design. *Requirements Engineering,* 5 (2):125-133.
Mumford, E. (2006). The story of socio-technical design: Reflections on its successes, failures and potential. *Information Systems Journal,* 16 (4):317-342.
Mylopoulos, J., Chung, L. & Nixon, B. (1992). Representing and using nonfunctional requirements: A process-oriented approach. *IEEE Transactions on Software Engineering,* 18 (6):483-497.
Mylopoulos, J., Chung, L. & Yu, E. (1999). From object-oriented to goal-oriented requirements analysis. *Communications of the ACM,* 42 (1):31-37.
Narula, U. (2006). *Communication Models.* New Delhi: Atlantic Publishers & Distributors (P) Ltd.
Nathan, G. (2008). Internet Surveys. In *Encyclopedia of Survey Research Methods* (Vol. 1). Thousand Oaks: Sage.
NATURE, T. (1996). Defining visions in context: Models, processes and tools for requirements engineering. *Information Systems,* 21 (6):515-547.
Neill, C.J. & Laplante, P.A. (2003). Requirements engineering: The state of the practice. *IEEE Software,* 20 (6):40-45.
Nguyen, L. & Swatman, P.A. (2003). Managing the requirements engineering process. *Requirements Engineering,* 8 (1):55-68.
Nuseibeh, B. & Easterbrook, S. (2000). Requirements engineering: A roadmap. *Proceedings of the Conference on The Future of Software Engineering.* Limerick: ACM.
O'Leary, T. & O'Leary, L. (2000). *Computing Essentials 2000-2001.* Irwin: McGraw-Hill.

O'Leary, T. & O'Leary, L. (2010). *Computing Essentials 2010 Introductory Edition.* Irwin: McGraw-Hill Higher Education.
Ott, R.L. & Longnecker, M. (2001). *An Introduction to Statistical Methods and Data Analysis.* Pacific Grove: Duxbury Thomson Learning.
Paech, B., Koenig, T., Borner, L. & Aurum, A. (2005). An Analysis of Empirical Requirements Engineering Survey data. In *Engineering and Managing Software Requirements*. Edited by Aurum, A. & Wohlin, C. Berlin Heidelberg: Springer.
Parnas, D.L. (2009). Document based rational software development. *Knowledge-Based Systems,* 22 (3):132-141.
Pastor, O., Estrada, H. & Martinez, A. (2011). Strengths and Weaknesses of the i* Framework: An Empirical Evaluation. In *Social Modeling for Requirements Engineering*. Edited by Yu, E., Giorgini, P., Maiden, N. & Mylopoulos, J. Cambridge, Massachusetts: MIT Press.
Patnayakuni, R. & Ruppel, C. (2010). A socio-technical approach to improving the systems development process. *Information Systems Frontiers,* 12 (2):219-234.
Paul, D., Eva, M., Yeates, D., Hindle, K., Cadle, J. & Rollaston, C. (2010). *Business Analysis.* Swindon: British Informatics Society
Penzenstadler, B., Haller, G., Schlosser, T. & Frenzel, G. (2009). *Soft Skills Required: A Practical Approach for Empowering Soft Skills in the Engineering World*. Collaboration and Intercultural Issues on Requirements: Communication, Understanding and Softskills, 31 August. IEEE.
Petter, S., DeLone, W. & McLean, E. (2008). Measuring information systems success: models, dimensions, measures, and interrelationships. *European Journal of Information Systems*, 17 (3):236-263.
Piho, G., Tepandi, J., Roost, M., Parman, M. & Puusep, V. (2011). *From archetypes based domain model via requirements to software: Exemplified by LIMS Software Factory*. MIPRO, 2011 Proceedings of the 34th International Convention, 23-27 May IEEE.
Pinheiro, F.A.C. (2003). Requirements honesty. *Requirements Engineering,* 8 (3):183-192.
Piri, A. (2008). *Challenges of Globally Distributed Software Development - Analysis of Problems Related to Social Processes and Group Relations*. IEEE International Conference on Global Software Engineering, 17-20 August. IEEE.
Pohl, K. (1994). The three dimensions of requirements engineering: A framework and its applications. *Information Systems,* 19 (3):243-258.
Pohl, K. (1997). Requirement engineering: An overview. In *Encyclopedia of Computer Science and Technology* (Vol. 36). New York: Taylor and Francis (CRC Press).
Quinlan, C. (2011). *Business Research Methods.* Hampshire: South-Western Cengage Learning.
Ramachandran, S., Dodda, S. & Santapoor, L. (2011). Overcoming Social Issues in Requirements Engineering
Advanced Computing. In Edited by Meghanathan, N., Kaushik, B. K. & Nagamalai, D.: Springer Berlin Heidelberg.
Randell, B. & Naur, P. (1968). Software Engineering Report on a conference sponsored by the NATO Science Committee Garmisch, Germany.
Rasinski, K.A. (2005). Surveys. In *Encyclopedia of Social Measurement* (Vol. 3 P-Y). Oxford: Elsevier Academic Press.
Rea, L.M. & Parker, R.A. (2005). *Designing and Conducting Survey Research - A Comprehensive Guide.* San Francisco: Jossey-Bass.
Reifer, D.J. (2007). Profiles of Level 5 CMMI Organizations. *Crosstalk: The Journal of Defense Software Engineering.* The USAF Software Technology Support Center (STSC)
Reina, D.S. & Reina, M.L. (2006). *Trust & Betrayal in the Workplace Building Effective Relationships in Your Organization.* San Francisco: Berrett-Koehler.
Reinhartz-Berger, I. & Sturm, A. (2009). Utilizing domain models for application design and validation. *Information and Software Technology,* 51 (8):1275-1289.
Rising, L. (2010). The Benefit of Patterns. *Software, IEEE,* 27 (5):15-17.
Robertson, S. (2001). Requirements trawling: Techniques for discovering requirements. *International Journal of Human-Computer Studies,* 55 (4):405-421.
Robertson, S. (2007). Requirements for Managing Requirements *In:* Swain, C. (ed.) *Agile Product & Project Management Advisory Executive Report.* Arlington: Cutter Consortium.
Robertson, S. & Robertson, J. (2010a). *Mastering the Requirements Process.* Boston: Addison-Wesley.
Robertson, S. & Robertson, J. (2010b). Volere Requirements Specification Template. 15 ed.: Atlantic Systems Guild Limited.
Rodrigues, A. (2001). Project Goals, Business Performance, and Risk. *e-Project Management Advisory Service's Executive Report.* Arlington: Cutter Consortium.
Roloff, M.E. (1976). Communication Strategies, Relationships, and Relational Change. In *Explorations in Interpersonal Communication*. Edited by Miller, G. R. Beverly Hills: Sage.
Ross, D.T. (1977). Structured Analysis (SA): A Language for Communicating Ideas. *IEEE Transactions on Software Engineering,* SE-3 (1):16-34.

Ross, D.T. & Schoman, K.E., Jr. (1977). Structured analysis for requirements definition. *IEEE Transactions on Software Engineering,* SE-3 (Copyright 1977, IEE):6-15.
Royce, W.W. (1970). *Managing the development of large software systems: concepts and techniques*. 1970 WESCON technical papers volume 14, Western electronic show and convention, 25-28 August. Los Angeles. WESCON.
Rumbaugh, J., Blaha, M., Premerlani, W., Eddy, F. & Lorensen, W. (1991). *Object-Oriented Modeling and Design.* New Jersey Prentice-Hall International Inc.
Rupp, C. (2002). Requirements and psychology. *IEEE Software,* 19 (May/June):16-18.
Rupp, C. (2006). Are Systems Engineers Complete Losers When It Comes to Communication? . *Cutter IT Journal*.
Sammet, J.E. (1991). Some Approaches to, and Illustrations of, Programming Language History. *Annals of the History of Computing,* 13 (1):33-50.
Sapsford, R. (2007). *Survey Research.* Thousand Oaks: Sage.
Sarker, S., Ajuja, M., Sarker, S. & Kirkeby, S. (2011). The Role of Communication and Trust in Global Virtual Teams: A Social Network Perspective. *Journal of Management Information Systems,* 28 (1):273-309.
Sarker, S., Sarker, S. & Valacich, J.S. (2003). Virtual team trust: Instrument development and validation in an IS educational environment. *Information Resources Management Journal,* 16 (2):35.
Schwaber, C. (2006). The Root of the Problem: Poor Requirements. *Trends.* Cambridge: Forrester Research.
Senge, P.M. (2006). *The Fifth Discipline: The Art and Practice of the Learning Organization* New York: Doubleday.
Shannon, C.E. (1948). A Mathematical Theory of Communication. *The Bell System Technical Journal,* 27 (July and October):379-423 and 623-656.
Siau, K. & Tan, X. (2005). Technical communication in information systems development: The use of cognitive mapping. *IEEE Transactions on Professional Communication,* 48 (3):269-284.
Siddiqi, J. (1996). Requirement Engineering: The Emerging Wisdom. *Software, IEEE,* 13 (2):15.
Siegel, A.F. (2012). *Practical Business Statistics.* Amsterdam: Elsevier.
Sillitti, A. & Succi, G. (2005). Requirements Engineering for Agile Methods. In *Engineering and Managing Software Requirements*. Edited by Aurum, A. & Wohlin, C. Berlin Heidelberg: Springer.
Sommerville, I. (2001). *Software Engineering.* Harlow: Addison-Wesley.
Sommerville, I. (2004). *Software Engineering* Harlow: Pearson Education.
Sommerville, I. (2011). *Software Engineering.* Harlow: Addison-Wesley.
Sommerville, I., Cliff, D., Calinescu, R., Keen, J., Kelly, T., Kwiatkowska, M., Mcdermid, J. & Paige, R. (2012). Large-scale complex IT systems. *Communications of the ACM,* 55 (7):71-77.
Sommerville, I., Rodden, T., Sawyer, P., Bentley, R. & Twidale, M. (1992). *Integrating ethnography into the requirements engineering process*. Proceedings of IEEE International Symposium on Requirements Engineering, 4-6 January. Los Alamitos. IEEE Computer Society Press.
Sommerville, I. & Sawyer, P. (1997). *Requirements Engineering A good practice guide.* Chichester: John Wiley & Sons.
Stohl, C. & Walker, K. (2002). A Bona Fide Perspective for the Future of Groups Understanding Collaborating Groups. In *New Directions In Group Communication*. Edited by Frey, L. R. Thousand Oaks: Sage.
Sutcliff, A.G., Economou, A. & Markis, P. (1999). Tracing requirements errors to problems in the requirements engineering process. *Requirements Engineering,* 4:134-51.
Sutcliffe, A., G. (1991). Object-oriented systems development: Survey of structured methods. *Information and Software Technology,* 33 (6):433-442.
Tenopir, C. & King, D.W. (2004). *Communication Patterns of Engineers.* Hoboken: Wiley.
The International Council on Systems Engineering (2007). *System Engineering Handbook.* San Diego: The International Council on Systems Engineering.
Union, I.T. (2011). *The World in 2011: ICT Facts and Figures* [Online]. International Telecommunication Union. Available: http://www.itu.int/ITU-D/ict/facts/2011/index.html [Accessed August 2012].
Upchurch, L., Rugg, G. & Kitchenham, B. (2001). Using card sorts to elicit web page quality attributes. *Software, IEEE,* 18 (4):84-89.
van Lamsweerde, A. (2000). *Requirements engineering in the year 00: A research perspective*. Proceedings of International Conference on Software Engineering, 4-11 June. New York. ACM.
van Lamsweerde, A. (2009). *Requirements Engineering From Systems Goals to UML Models to Software Specification.* Chichester: John Wiley & Sons.
Van Vliet, H. (2008). *Software Engineering Principles and Practice.* John Wiley & Sons.
Veshosky, D. (1998). Managing Innovation Information in Engineering and Construction Firms. *Journal of Management in Engineering,* 14 (1):58-66.
Viller, S., Bowers, J. & Rodden, T. (1999). Human factors in requirements engineering:: A survey of human sciences literature relevant to the improvement of dependable systems development processes. *Interacting with Computers,* 11 (6):665-698.
Vitalari, N.P. & Dickson, G.W. (1983). Problem solving for effective systems analysis: an experimental exploration. *Communications of the ACM,* 26 (11):948-956.

Wagenaar, T.C. (2005). Survey Design. In *Encyclopedia of Social Measurement* (Vol. 3 P-Y). Oxford: Elsevier Academic Press.
Weese, S. & Wagner, T. (2011). *CBAP/CCBA Certified Business Analysis Study Guide.* Wiley.
Wever, A. & Maiden, N. (2011). *What are the day-to-day factors that are preventing business analysts from effective business analysis?* 19th IEEE International Requirements Engineering Conference, 29 August - 2 September. IEEE.
Wiegers, K. (1999). Writing Quality Requirements. *Software Development* [Online], 7. Available: http://www.processimpact.com/pubs.shtml#requirements [Accessed 4 April 2012].
Wiegers, K. (2003a). So You Want to Be a Requirements Analyst. *Software Development* [Online], 11. Available: http://www.processimpact.com/pubs.shtml#requirements [Accessed 23 February 2012].
Wiegers, K.E. (2003b). *Software requirements: practical techniques for gathering and managing requirements throughout the product development cycle.* Microsoft Press.
Wing, J.M. (1990). A specifier's introduction to formal methods. *Computer,* 23 (9):8-22.
Wirth, N. (2008). A Brief History of Software Engineering. *Annals of the History of Computing, IEEE,* 30 (3):32-39.
Wu, Q., Ying, M., Wang, J., Xie, M., Chen, Z. & Chen, J. (2009). *A discussion on three critical issues for assuring quality of the users' requirements specification*. 16th International Conference on Industrial Engineering and Engineering Management. IEEE.
Yin, R.K. (2009). *Case Study Research Design and Methods.* Los Angeles: Sage.
Yu, E., Giorgini, P., Maiden, N. & Mylopoulos, J. (2011). Social Modeling for Requirements Engineering: An Introduction. In *Social Modeling for Requirements Engineering*. Edited by Yu, E., Giorgini, P., Maiden, N. & Mylopoulos, J. Cambridge, Massachusetts: MIT Press.
Yu, Y., Niu, N., González-Baixauli, B., Mylopoulos, J., Easterbrook, S. & Prado Leite, J.C.S. (2009). Requirements Engineering and Aspects. In *Design Requirements Engineering: A Ten-Year Perspective*. Edited by Lyytinen, K., Loucopoulos, P., Mylopoulos, J. & Robinson, B. Heidelberg: Springer-Verlag.
Zeffane, R., Tipu, S.A. & Ryan, J.C. (2011). Communication, Commitment & Trust: Exploring the Triad. *International Journal of Business & Management,* 6 (6):77-87.
Zong-yong, L., Zhi-xue, W., Ying-ying, Y., Yue, W. & Ying, L. (2007). *Towards a Multiple Ontology Framework for Requirements Elicitation and Reuse*. 31st Annual International Computer Software and Applications Conference. IEEE Computer Society Press.
Zowghi, D. & Coulin , C. (2005). Requirements Elicitation: A Survey of Techniques, Approaches and Tools. In *Engineering and Managing Software Requirements*. Edited by Aurum, A. & Wohlin, C. Berlin Heidelberg: Springer.
Zurawski, R. & MengChu, Z. (1994). Petri nets and industrial applications: A tutorial. *IEEE Transactions on Industrial Electronics,* 41 (6):567-583.
Zwiers, V. (2011). *The Business Analyst Information Technology's Paradigm Shift.* Kenwyn: Juta.

APPENDIX A. Requirements Tools

Table 56: Requirements tools in market

Tool Name	Company Name	Website
Accept 360°, version 4.0	Accept Software, Inc.	http://www.acceptsoftware.com
Acclaro DFSS Version 5	Axiomatic Design Solutions	http://www.dfss-software.com
Accompa	Accompa, Inc.	http://www.accompa.com/
Aligned Elements Version 1.5	Aligned AG	http://www.aligned.ch/
ARCWAY Cockpit	ARCWAY AG	http://www.arcway.com
Avenqo PEP	Avenqo GmbH	http://www.avenqo.com/
Balsamiq Mockups	Balsamiq	http://www.balsamiq.com
BambooRM	Bamboo Solutions	http://store.bamboosolutions.com/bamboomainweb/
Blueprint Requirements Center™ 2010	Blueprint Software Systems Inc.	http://www.blueprintsys.com/products/
Bright Green Projects	Bright Green Projects	http://www.brightgreenprojects.com
Business Optix WorkPad	Business Optix	http://www.businessoptix.com
CaliberRM 2005	Borland	http://www.borland.com/us/products/caliber/index.html/
Cameo Requirements+ Version 4.0	No Magic Inc.	http://www.magicdraw.com
CASE Spec Version 9.0	Goda Software, Inc.	http://www.casespec.net/
CaseComplete	Serlio Software	http://www.casecomplete.com/
Cognition Cockpit (Cockpit) Version 5.1	Cognition Corporation	http://www.cognition.us
Contour by Jama Software (Contour) Version 2.9	Jama Software	http://www.jamasoftware.com
CORE Version 7.0	Vitech Corporation	http://www.vitechcorp.com
Cradle Version 6.6	3SL (Structured Software Systems Ltd)	http://www.threesl.com/

Dimensions RM (DimRM) Version 10.1.4	Serena Software	http://www.serena.com/products/rm/index.html
Enterprise Architect	Sparx Systems Pty Ltd	http://www.sparxsystems.com
Envision VIP Version 9	Future Tech Systems, Inc.	http://www.future-tech.com/prod01.htm
FeatureSet	FeatureSet Inc.	http://www.featureset.com
Foresight Version 5.3.1	Foresight Systems Inc.	http://www.foresightsystems-mands.com/
Gatherspace	Gatherspace	http://www.gatherspace.com/
GMARC (Generic Model Approach to Requirements Capture)	Computer System Architects Ltd.	http://www.freenetpages.co.uk/hp/csa/
HP Quality Center 9.2	Hewlett Packard	http://www.hp.com/software
IBM Rational DOORS	IBM	http://www-01.ibm.com/software/awdtools/doors/
IBM Rational Requirements Composer	IBM	http://www.ibm.com/software/awdtools/rrc/
IBM Rational RequisitePro	IBM	http://www.ibm.com/software/awdtools/reqpro/
IdeaShare	OpenCrowd	http://ideashare.opencrowd.com
inteGREAT	eDev Technologies Inc.	http://www.edevtech.com
iRise	iRise	http://www.irise.com/
IRQA	Visure Solutions	http://vimeo.com/36010384
IRQA Web	Visure Solutions	http://www.visuresolutions.com/irqa-web
Jama Contour, version 3	Jama Software, Inc.	http://www.jamasoftware.com
Justinmind Prototyper	Justinmind	http://www.justinmind.com
Kovair Global Lifecycle (Kovair) Version 5.5	Kovair Software, Inc.	http://www.kovair.com
Leap SE	Leap Systems	http://www.leapse.com
LiteRM	ClearSpecs Enterprises	http://www.LiteRM.com
Lotus Notes	Lotus Software from IBM	http://www-01.ibm.com/software/lotus/products/notes/
MacA&D / WinA&D	Excel Software	http://www.excelsoftware.com/uml_topic.html
MagicDraw and SysML Plugin Version 16.5	No Magic Inc.	http://www.magicdraw.com
METIS Version 3.4	Troux Technologies AS / Computas AS	http://www.metis.no/
MKS Integrity	MKS	http://www.mks.com/products/requirements

MockupScreens v1.41	MockupScreens	http://mockupscreens.com
Modelio Requirement Analyst	Modeliosoft	http://www.modeliosoft.com/en/modules/modelio-requirement-analyst.html
MooD Technology	The Salamander Organization Limited	http://www.tsorg.com/
Objectiver	Respect-IT	http://www.objectiver.com/
Optimal Trace	Micro Focus	http://www.powertest.com
PACE Version 3	Viewset Corporation	http://www.viewset.com
Polarion REQUIREMENTS	Polarion Software	www.polarion.com/products/requirements/index.php
Psoda	Psoda	http://www.psoda.com
Poseidon for UML Version 3.2.1	Gentleware	http://www.gentleware.com/index.php
QFDcapture Version 4	International TechneGroup Incorporated (ITI)	http://www.qfdcapture.com/
Qpack	Orcanos	http://www.orcanos.com/Orcanos_QPack.htm
RaQuest	SparxSystems Japan	http://www.raquest.com/
Raven	Ravenflow	http://www.ravenflow.com/product
Rational Focal Point	IBM	http://www-01.ibm.com/software/awdtools/focalpoint/
RAWeb / Requirements Assistant	Sunny Hills Consultancy BV - Emphasysgroup	http://www.requirementsassistant.nl/
RDD.COM Version 1.2	Holagent Corporation	http://www.holagent.com/
RDD-100 Version 4.1.2	Holagent Corporation	http://www.holagent.com/
Reconcile Version 2.0	Compuware Corporation	http://www.compuware.com/
ReMa	Accord Software and Systems Pvt. Ltd	http://www.rema-soft.com
ReqMan	RequirementOne	http://www.requirementone.com/Project-Management-Platform
Repository-Driven Specification Development Suite (RESDES)	Jenz & Partner GmbH	http://www.jenzundpartner.de
Reqline	Pragnalysis	http://pragnalysis.com
Reqtify version 2.1	Geensoft	http://users.reqtify.tni-software.com/?p=home
Requirements Traceability Management (RTM) Version 5.6	Serena Software ,Inc.	http://www.serena.com/Products/rtm/home.asp

rmtoo	flonatel GmbH & Co	http://www.flonatel.de/projekte/rmtoo/
RMTrak	RBC Product Development	http://www.rmtrak.com/
RTIME	QAvantage	http://www.sdlctools.com/New/about.asp
Rommana	Rommana Software	http://www.rommanasoftware.com/requirement-tools.php
Scenario Plus	Scenario Plus	http://www.scenarioplus.org.uk/
SHORE version 2.0	SD&M (Software Design and Management) AG	http://www.openshore.org/
Software through Pictures (StP) Version 8.3.1	Aonix	http://www.aonix.com/stp.html
speeDEV	speeDEV	http://www.speedev.com/
SpiraTeam	Inflectra	http://www.inflectra.com/spirateam/
Statestep	Statestep	http://statestep.com
TestTrack RM	Seapine Software	http://www.seapine.com/ttrm.html
TcSE (Teamcenter Systems Engineering) Version 7.0	UGS	http://www.ugs.com/products/teamcenter/sol_prod/requirements
TopTeam	Technosolutions Corporation	http://www.technosolutions.com/
TraceCloud	TraceCloud	http://www.tracecloud.com
TrackStudio	TrackStudio	http://www.trackstudio.com/
VeroTrace	Verocel	http://www.verocel.com/verotrace.htm
VisibleThread On-demand/On-premise	VisibleThread	http://www.visiblethread.com
Visual Information Portal (VIP) Version	Future Tech Systems, Inc.	http://www.future-tech.com/prod01.htm
workspace.com	workspace.com	http://www.workspace.com/
XTie-RT (Cross Tie Requirements Tracer) Version 3.1.02	Teledyne Brown Engineering	http://www.tbe.com/products/xtie/xtie.asp
Yonix	Yonix Ltd.	http://www.yonix.com

APPENDIX B. Survey Questionnaire

SECTION A - BIOGRAPHICAL INFORMATION

Please answer the following questions based on **a completed project** that you have been involved with during **the past 2 years.**

1. Please select your current job description

1.1	Business Analyst	
1.2	Senior Business Analyst	
1.3	Requirements Engineer	
1.4	System Analyst	
1.5	Product Manager	
1.6	Process Analyst	
1.7	Enterprise Architect	
1.8	Business Architect	
1.9	Consultant	
1.10	Other (Please specify)	

2. Please select your highest qualification

2.1	BCom Informatics	
2.2	BCom Informatics (Honours)	
2.3	MCom (Informatics)	
2.4	BSc Applied Mathematics	
2.5	BSc Computer Science	
2.6	BSc Computer Science (Honours)	
2.7	MSc (Computer Science)	
2.8	B Engineering	
2.9	M Engineering	
2.10	PhD	
2.11	Other (Please specify)	

3. Have you attended any training courses relevant to the requirements context?

3.1	Yes	
3.2	No	

Skip logic: If 3 equal yes go to 4, else go to 5.

4. Please list the training courses that you have attended?

4.1	
4.2	

5. Please select the certification that you have obtained

5.1	None	
5.2	CCBA	
5.3	CBAP	
5.4	Other (Please specify)	

6. How many years' experience do you have as a practitioner in the requirements field?

6.1	Please give a number	

7. In which Industry are you employed?

7.1	Information and Communications Technology (ICT)	
7.2	Finance and Banking	
7.3	Energy and Utilities	
7.4	Government, Public Sector & Defence	
7.5	Mining & Commodities	
7.6	Transport	
7.7	Retail and Wholesale	
7.8	Construction and Civil Engineering	
7.9	Consulting or professional services	
7.10	Fast Moving Consumer Goods (FMCG)	
7.11	TMT (Technology, Media and Entertainment)	
7.12	Other (please specify below)	

8. Please select the duration of the project, from inception to delivery

8.1	Less than 6 months	
8.2	Between 6 months and 1 Year	
8.3	Between 1 and 2 Years	
8.4	Between 2 and 3 years	
8.5	Between 3 and 4 years	
8.6	More than 4 years	

9. How many team members were assigned to the project?

9.1	Please give a number	

10. Please select the overall budget of the project

9.1	Less than R100 000	
9.2	Between R100 001 and R500 000	
9.3	Between R500 001 and R1 000 000	
9.4	Between R1 000 001 and R10 000 000	
9.5	More than R10 000 000	

SECTION B - REQUIREMENT ACTIVITIES

Requirements process involves all activities required to understand the needs of users, customers and other stakeholders; understanding the context in which the to-be solution will be used; elicitation, analysing, modelling, negotiating and documenting stakeholders requirements; validating that the requirements match the users' needs.

11. How many stakeholders (customers, end-users, project sponsor) did you interact with during this project?

11.1	Please give a number	

12. Please select all applicable roles of stakeholders that you interacted with during the project

12.1	Business Manager	
12.2	Developers	
12.3	End-user	
12.4	Project Manager	
12.5	Project Sponsor	
12.6	Subject Matter Expert	
12.7	Tester	

12.8	Other (please specify below)	

13. What sources do you use to collect requirements?

13.1	Personal experience	
13.2	Conversations with colleagues	
13.3	Conversations with consultants	
13.4	Conversations with customers	
13.5	Conversations with vendors	
13.6	Conversation with academic researchers	
13.7	Textbooks and/or handbooks	
13.8	Codes and/or standards	
13.9	Industry newsletters	
13.10	Internal technical reports	
13.11	Other (please specify below)	

14. Was a formal project implementation approach followed during the project lifecycle?

14.1	Yes	
14.2	No	

Skip logic: If 14 equal yes go to 15, else go to 16.

15. Please select the project lifecycle approach that was used during the project

15.1	Waterfall
15.2	Prototyping
15.3	Incremental development
15.4	Spiral
15.5	Agile
15.6	Other (please specify below)

16. Were you involved in planning the requirements process of the project?

16.1	Yes	
16.2	No	

Skip logic: If 16 equal yes go to 17, else go to 19.

17. Specify the outputs of the planning task

17.1	
17.2	

18. Were you involved in requirements elicitation i.e. gathering activities?

18.1	Yes	
18.2	No	

Skip logic: If 18 equal yes go to 21, else go to 23.

19. Please select the main reason why you were not involved in planning of the requirements process, of the project

19.1	This particular activity is not relevant to my project.	
19.2	This particular activity is not relevant to my role.	
19.3	My time is taken up with tasks unrelated to my role so I do not get time to do this activity.	
19.4	Lack of project resources (time, budget, people) is preventing the project manager to engage me effectively in this activity.	
19.5	This activity is considered less important than other project related tasks.	
19.6	Within my organisation, there is no formal process in place to engage in this activity.	
19.7	This activity is performed without consistency and continuity.	
19.8	Although I received training, I am not confident enough in applying myself in this area of work.	
19.9	I was not given an opportunity to implement my acquired skills in this area and now I have forgotten how to do this.	
19.10	Other (please specify below)	

20. Were you involved in requirements elicitation i.e. gathering activities?

18.1	Yes	
18.2	No	

Skip logic: If 20 equal yes go to 21, else go to 23.

21. What techniques did you utilise during eliciting i.e. gathering of requirements?

		Use	Never use	Never heard of
21.1	Interviews			
21.2	Questionnaires			
21.3	Document analysis			
21.4	Brainstorming			
21.5	Group Work			
21.6	Joint Application Development			
21.7	Workshops			
21.8	Prototyping			
21.9	Domain Analysis			
21.10	Introspection			
21.11	Goal Based Approaches			
21.12	Scenarios			
21.13	Viewpoints			
21.14	Repertory Grids			
21.15	Card sorting			
21.16	Laddering			
21.17	Protocol Analysis			
21.18	Ethnography			
21.19	Observation			
21.20	Apprenticing			
21.21	Other (please specify below)			

22. Were you involved in requirements analysing and modelling activities?

22.1	Yes	
22.2	No	

Skip logic: If 22 equal yes go to 25, else go to 27.

23. Please select the main reason why you were not involved in requirements elicitation i.e. gathering activities?

23.1	This particular activity is not relevant to my project.	
23.2	This particular activity is not relevant to my role.	
23.3	My time is taken up with tasks unrelated to my role so I do not get time to do this activity.	
23.4	Lack of project resources (time, budget, people) is preventing the project manager to engage me effectively in this activity.	
23.5	This activity is considered less important than other project related tasks.	
23.6	Within my organisation, there is no formal process in place to engage in this activity.	
23.7	This activity is performed without consistency and continuity.	
23.8	Although I received training, I am not confident enough in applying myself in this area of work.	
23.9	I was not given an opportunity to implement my acquired skills in this area and now I have forgotten how to do this.	
23.10	Other (please specify below)	

24. Were you involved in requirements analysing and modelling activities?

24.1	Yes	
24.2	No	

Skip logic: If 24 equal yes go to 25, else go to 27.

25. What techniques did you utilise during analysing and modelling requirements?

		Use	Never use	Never heard of
25.1	Goal oriented models (e.g. KAOS)			
25.2	Agent based models (e.g. Tropos, i*)			
25.3	State machines models			
25.4	Petri nets			
25.5	Structured analysis and design technique			
25.6	Data flow diagrams			
25.7	Flow charts			
25.8	Object oriented models			
25.9	Formal models			
25.10	Entity relationship diagrams			
25.11	Domain models			
25.12	Other (please specify below)			

26. Were you involved in requirements specification activities?

26.1	Yes	
26.2	No	

Skip logic: If 26 equal yes go to 29, else go to 38.

27. Please select the main reason why you were not involved requirements analysing and modelling activities

27.1	This particular activity is not relevant to my project.	
27.2	This particular activity is not relevant to my role.	

27.3	My time is taken up with tasks unrelated to my role so I do not get time to do this activity.	
27.4	Lack of project resources (time, budget, people) is preventing the project manager to engage me effectively in this activity.	
27.5	This activity is considered less important than other project related tasks.	
27.6	Within my organisation, there is no formal process in place to engage in this activity.	
27.7	This activity is performed without consistency and continuity.	
27.8	Although I received training, I am not confident enough in applying myself in this area of work.	
27.9	I was not given an opportunity to implement my acquired skills in this area and now I have forgotten how to do this.	
27.10	Other (please specify below)	

28. Were you involved in requirements specification activities?

28.1	Yes	
28.2	No	

Skip logic: If 28 equal yes go to 29, else go to 38.

29. Did you use a standardised template as guideline that states what should be included in the specification?

29.1	Yes	
29.2	No	

30. Please select notation used, to produce the specification

30.1	Formal (e.g. Z, VDM)	
30.2	Semi-formal (using modelling techniques e.g. data flow diagrams or state diagrams)	
30.3	Informal (Natural Language)	
30.4	Other (please specify below)	

31. Did you use a software tool to generate, manage or store the specification ?

31.1	Yes	
31.2	No	

Skip logic: If 31 equal yes go to 32, else go to 33.

32. Please select the software tool used

32.1	Avenqo PEP	
32.2	Blueprint Requirements Center™ 2010	
32.3	CASE Spec Version 9.0	
32.4	Cradle Version 6.6	
32.5	IBM Rational DOORS	
32.6	IBM Rational RequisitePro	
32.7	inteGREAT	
32.8	IRQA	
32.9	MKS Integrity	
32.10	Polarion REQUIREMENTS	
32.11	Other (please specify below)	

33. Please rate the characteristics of the documented requirements

For each statement, provide a rating using the following scale:
1: Never
2: Rarely, in less than 10% of the chances when I could have
3: Occasionally, in about 30% of the chances when I could have
4: Sometimes, in about 50% of the chances when I could have
5: Frequently, in about 70% of the chances when I could have
6: Usually, in about 90% of the chances when I could have
7: Every time

		1	2	3	4	5	6	7
33.1	Have all the requirements been validated by the source of the requirement i.e. typically the stakeholder?							
33.2	Was there a single interpretation for each requirement to enable the common understanding by all stakeholders?							
33.3	Were all the required requirements present in the specification ensuring a workable solution fit for purpose by the user?							
33.4	Did some requirements conflict with other requirements or with higher level system or business requirements?							
33.5	Were all the requirements prioritised based on importance or in terms of expected changes associated with the requirement?							
33.6	Was it possible to test each requirement to determine whether it has been properly implemented?							
33.7	Was a history of changes made to each requirement kept?							
33.8	Was each requirement linked back to its source of origination?							

34. Did all the stakeholders agree upon the specification once the specification has been produced?

34.1	Yes	
34.2	No	

35. How many iterations of the specification has been produced before an agreed upon version was produced?

35.1	Please enter a number	

36. Once the specification has been agreed upon, were changes managed via a formal change process?

36.1	Yes	
36.2	No	

37. Were you involved in requirements validation or verification activities?

37.1	Yes	
37.2	No	

Skip logic: If 37 equal yes go to 41, else go to 40.

38. Please select the main reason why you were not involve in requirements specification activities

38.1	This particular activity is not relevant to my project.	
38.2	This particular activity is not relevant to my role.	
38.3	My time is taken up with tasks unrelated to my role so I do not get time to do this activity.	

38.4	Lack of project resources (time, budget, people) is preventing the project manager to engage me effectively in this activity.	
38.5	This activity is considered less important than other project related tasks.	
38.6	Within my organisation, there is no formal process in place to engage in this activity.	
38.7	This activity is performed without consistency and continuity.	
38.8	Although I received training, I am not confident enough in applying myself in this area of work.	
38.9	I was not given an opportunity to implement my acquired skills in this area and now I have forgotten how to do this.	
38.10	Other (please specify below)	

39. Were you involved in requirements validation or verification activities?

39.1	Yes	
39.2	No	

Skip logic: If 37 equal yes go to 41, else go to 40.

40. Please select the main reason why you were not involve in requirements validation activities

40.1	This particular activity is not relevant to my project.	
40.2	This particular activity is not relevant to my role.	
40.3	My time is taken up with tasks unrelated to my role so I do not get time to do this activity.	
40.4	Lack of project resources (time, budget, people) is preventing the project manager to engage me effectively in this activity.	
40.5	This activity is considered less important than other project related tasks.	
40.6	Within my organisation, there is no formal process in place to engage in this activity.	
40.7	This activity is performed without consistency and continuity.	
40.8	Although I received training, I am not confident enough in applying myself in this area of work.	
40.9	I was not given an opportunity to implement my acquired skills in this area and now I have forgotten how to do this.	
40.10	Other (please specify below)	

41. What percentage of your business stakeholders were satisfied with the delivered project?

41.1	Please enter a number between 0 and 100	

42. What percentage, of your end-users was satisfied with the delivered project?

42.1	Please enter a number between 0 and 100	

43. How many business interruptions were there due to the new project?

42.1	Please enter a number	

44. Is the solution currently in use by the end-users?

44.1	Yes	
44.2	No	

45. Indicate why the users are not using the solution

45.1	The users do not understand how technology support their business processes	

45.2	The users still using the old solution	
45.3	The users do not use training and user manuals	
45.4	New solution cause too many business interruptions	
45.5	Users waiting for more requirements to be implemented	
45.6	Other (please specify below)	

SECTION C - REQUIREMENT SOCIAL FACTORS

Please complete questions based on your communication with your project manager.

46. Did you regularly communicate with your project manager?

46.1	Yes	
46.2	No	

Skip logic: If 46 equal yes go to 47-50 then 53, else go to 51.

47. How often did you communicate with your project manager, per week?

47.1	Less than once	
47.2	Once or twice	
47.3	3 to 4 times	
47.4	5 or more times	

48. Who typically initiated the interaction or communication?

48.1	I did	
48.2	Project Manager did	

49. Please select the main reason for the interaction

49.1	Raising or identifying risks	
49.2	Input for project costs, resource requirements and delivery schedules	
49.3	Agree analysis approach for project	
49.4	Reporting on progress of analysis effort	
49.5	Requirement changes	
49.6	Other (please specify below)	

50. Please indicate how willing you are to engage in each of the following behaviours with your project manager

		Not at all willing						Completely willing
		1	2	3	4	5	6	7
50.1	Rely on your project manager's task related skills and abilities.							
50.2	Depend on your project manager to handle an important issue on your behalf.							
50.3	Rely on your project manager to represent your work accurately to others.							
50.4	Depend on your project manager to back you up in difficult situations.							
50.5	Rely on your project manager's work-related judgments.							

50.6	Share your personal feelings with your project manager.							
50.7	Discuss work-related problems or difficulties with your project manager that could potentially be used to disadvantage you.							
50.8	Confide in your project manager about personal issues that are affecting your work.							
50.9	Discuss how you honestly feel about your work, even negative feelings and frustration.							
50.10	Share your personal beliefs with your project manager.							

51. Please select the main reason why you did not communicate with the Project Manager

51.1	The complexity of the project prohibited communication to this person	
51.2	The size of the organisation prohibited communication to this person	
51.3	The person in this role does not respect my viewpoint	
51.4	The person in this role does not understand the purpose of the project	
51.5	I am to scared of the consequences to challenge the person in this role	
51.6	I do not have the confidence to speak to the person in this role as he/she is my superior	
51.7	In my organisation I am not allowed to communicate with the person in this role and should follow a proper communication channel	
51.8	The person in this role is to busy (lack of time) to be involved in any communication	
51.9	Other (please specify below)	

52. Please indicate how willing you are to engage in each of the following behaviours with your project manager

		Not at all willing				Completely willing		
		1	2	3	4	5	6	7
52.1	Rely on your project manager’s task related skills and abilities.							
52.2	Depend on your project manager to handle an important issue on your behalf.							
52.3	Rely on your project manager to represent your work accurately to others.							
52.4	Depend on your project manager to back you up in difficult situations.							
52.5	Rely on your project manager’s work-related judgments.							
52.6	Share your personal feelings with your project manager.							
52.7	Discuss work-related problems or difficulties with your project manager that could potentially be used to disadvantage you.							
52.8	Confide in your project manager about personal issues that are affecting your work.							
52.9	Discuss how you honestly feel about your work, even negative feelings and frustration.							
52.10	Share your personal beliefs with your project manager.							

Please complete questions based on your communication with your project sponsor.

53. Did you regularly communicate with your project sponsor?

53.1	Yes	
53.2	No	

Skip logic: If 53 equal yes go to 54-57 then 60, else go to 58.

54. How often did you communicate with your project sponsor, per week?

54.1	Less than once	
54.2	Once or twice	
54.3	3 to 4 times	
54.4	5 or more times	

55. Who typically initiated the interaction or communication?

55.1	I did	
5.2	Project Sponsor did	

56. Please select the main reason for the interaction

56.1	Help manage conflicts and political issues	
56.2	Communicate expectations and feedback from other senior managers and stakeholders	
56.3	Take the time to understand the solution	
56.4	Identify linkages to other projects that may impact the team	
56.6	Other (please specify below)	

57. Please indicate how willing you are to engage in each of the following behaviours with your project sponsor

		Not at all willing					Completely willing	
		1	2	3	4	5	6	7
57.1	Rely on your project sponsor's task related skills and abilities.							
57.2	Depend on your project sponsor to handle an important issue on your behalf.							
57.3	Rely on your project sponsor to represent your work accurately to others.							
57.4	Depend on your project sponsor to back you up in difficult situations.							
57.5	Rely on your project sponsor's work-related judgments.							
57.6	Share your personal feelings with your project sponsor.							
57.7	Discuss work-related problems or difficulties with your project sponsor that could potentially be used to disadvantage you.							
57.8	Confide in your project sponsor about personal issues that are affecting your work.							
57.9	Discuss how you honestly feel about your work, even negative feelings and frustration.							
57.10	Share your personal beliefs with your project sponsor.							

58. Please select the main reason why you did not communicate with the Project Sponsor

58.1	The complexity of the project prohibited communication to this person	
58.2	The size of the organisation prohibited communication to this person	

58.3	The person in this role does not respect my viewpoint	
58.4	The person in this role does not understand the purpose of the project	
58.5	I am to scared of the consequences to challenge the person in this role	
58.6	I do not have the confidence to speak to the person in this role as he/she is my superior	
58.7	In my organisation I am not allowed to communicate with the person in this role and should follow a proper communication channel	
58.8	The person in this role is to busy (lack of time) to be involved in any communication	
58.9	Other (please specify below)	

59. Please indicate how willing you are to engage in each of the following behaviours with your Project Sponsor

		Not at all willing						Completely willing
		1	2	3	4	5	6	7
59.1	Rely on your project sponsor's task related skills and abilities.							
59.2	Depend on your project sponsor to handle an important issue on your behalf.							
59.3	Rely on your project sponsor to represent your work accurately to others.							
59.4	Depend on your project sponsor to back you up in difficult situations.							
59.5	Rely on your project sponsor's work-related judgments.							
59.6	Share your personal feelings with your project sponsor.							
59.7	Discuss work-related problems or difficulties with your project sponsor that could potentially be used to disadvantage you.							
59.8	Confide in your project sponsor about personal issues that are affecting your work.							
59.9	Discuss how you honestly feel about your work, even negative feelings and frustration.							
59.10	Share your personal beliefs with your project manager.							

Please complete questions based on your communication with your main subject-matter expert.

60. Did you regularly communicate with the main subject-matter expert?

60.1	Yes	
60.2	No	

Skip logic: If 60 equal yes go to 61-64 then 67, else go to 65.

61. How often did you communicate with the main subject-matter expert, per week?

61.1	Less than once	
61.2	Once or twice	
61.3	3 to 4 times	
61.4	5 or more times	

62. Who typically initiated the interaction or communication?

62.1	I did	
62.2	Subject-matter expert did	

63. Please select the main reason for the interaction

63.1	Gather an understanding of the underlying structure of domain problems.	
63.2	Gather knowledge about the domain in which the application/solution will operate	
63.3	Gather knowledge about the activities performed in this domain	
63.4	Other (please specify below)	

64. Please indicate how willing you are to engage in each of the following behaviours with the main subject-matter expert

		Not at all willing					Completely willing	
		1	2	3	4	5	6	7
64.1	Rely on your subject-matter expert's task related skills and abilities.							
64.2	Depend on your subject-matter expert to handle an important issue on your behalf.							
64.3	Rely on your subject-matter expert to represent your work accurately to others.							
64.4	Depend on your subject-matter expert to back you up in difficult situations.							
64.5	Rely on your subject-matter expert work-related judgments.							
64.6	Share your personal feelings with your subject-matter expert.							
64.7	Discuss work-related problems or difficulties with the subject-matter expert that could potentially be used to disadvantage you.							
64.8	Confide in the subject-matter expert about personal issues that are affecting your work.							
64.9	Discuss how you honestly feel about your work, even negative feelings and frustration.							
64.10	Share your personal beliefs with the subject-matter expert.							

65. Please select the main reason why you did not communicate with the main subject-matter expert

65.1	The complexity of the project prohibited communication to this person	
65.2	The size of the organisation prohibited communication to this person	
65.3	The person in this role does not respect my viewpoint	
65.4	The person in this role does not understand the purpose of the project	
65.5	I am to scared of the consequences to challenge the person in this role	
65.6	I do not have the confidence to speak to the person in this role as he/she is my superior	
65.7	In my organisation I am not allowed to communicate with the person in this role and should follow a proper communication channel	
65.8	The person in this role is to busy (lack of time) to be involved in any communication	
65.9	Other (please specify below)	

66. Please indicate how willing you are to engage in each of the following behaviours with the main subject-matter expert

	Not at all willing					Completely willing	
	1	2	3	4	5	6	7

66.1	Rely on your subject-matter expert's task related skills and abilities.							
66.2	Depend on your subject-matter expert to handle an important issue on your behalf.							
66.3	Rely on your subject-matter expert to represent your work accurately to others.							
66.4	Depend on your subject-matter expert to back you up in difficult situations.							
66.5	Rely on your subject-matter expert work-related judgments.							
66.6	Share your personal feelings with your subject-matter expert.							
66.7	Discuss work-related problems or difficulties with the subject-matter expert that could potentially be used to disadvantage you.							
66.8	Confide in the subject-matter expert about personal issues that are affecting your work.							
66.9	Discuss how you honestly feel about your work, even negative feelings and frustration.							
66.10	Share your personal beliefs with the subject-matter expert.							

Please complete questions based on your communication with your main end-user.

67. Did you regularly communicate with your main end-user?

67.1	Yes	
67.2	No	

Skip logic: If 67 equal yes go to 68-71 then 74, else go to 72.

68. How often did you communicate with your main end-user, per week?

68.1	Less than once	
68.2	Once or twice	
68.3	3 to 4 times	
68.4	5 or more times	

69. Who typically initiated the interaction or communication?

69.1	I did	
69.2	End-user did	

70. Please select the main reason for the interaction

70.1	Observe user while executing daily activities to understand domain.	
70.2	Interview user about functional requirements	
70.3	Other (please specify below)	

71. Please indicate how willing you are to engage in each of the following behaviours with the main end-user

		Not at all willing						Completely willing
		1	2	3	4	5	6	7
71.1	Rely on your main end-user's task related skills and abilities.							

71.2	Depend on your main end-user to handle an important issue on your behalf.							
71.3	Rely on your main end-user to represent your work accurately to others.							
71.4	Depend on your main end-user to back you up in difficult situations.							
71.5	Rely on your main end-user work-related judgments.							
71.6	Share your personal feelings with your main end-user.							
71.7	Discuss work-related problems or difficulties with the main end-user that could potentially be used to disadvantage you.							
71.8	Confide in the main end-user about personal issues that are affecting your work.							
71.9	Discuss how you honestly feel about your work, even negative feelings and frustration.							
71.10	Share your personal beliefs with the main end-user.							

72. Please select the main reason why you did not communicate with the main end-user

72.1	The complexity of the project prohibited communication to this person	
72.2	The size of the organisation prohibited communication to this person	
72.3	The person in this role does not respect my viewpoint	
72.4	The person in this role does not understand the purpose of the project	
72.5	I am to scared of the consequences to challenge the person in this role	
72.6	I do not have the confidence to speak to the person in this role as he/she is my superior	
72.7	In my organisation I am not allowed to communicate with the person in this role and should follow a proper communication channel	
72.8	The person in this role is to busy (lack of time) to be involved in any communication	
72.9	Other (please specify below)	

73. Please indicate how willing you are to engage in each of the following behaviours with the main end-user

		Not at all willing					Completely willing	
		1	2	3	4	5	6	7
73.1	Rely on your main end-user's task related skills and abilities.							
73.2	Depend on your main end-user to handle an important issue on your behalf.							
73.3	Rely on your main end-user to represent your work accurately to others.							
73.4	Depend on your main end-user to back you up in difficult situations.							
73.5	Rely on your main end-user work-related judgments.							
73.6	Share your personal feelings with your main end-user.							
73.7	Discuss work-related problems or difficulties with the main end-user that could potentially be used to disadvantage you.							
73.8	Confide in the main end-user about personal issues that are affecting your work.							
73.9	Discuss how you honestly feel about your work, even negative feelings and frustration.							

73.10	Share your personal beliefs with the main end-user.							

Please complete questions based on the relationship within project team

74. Please indicate how willing you are to engage in each of the following behaviours with your team

		Not at all willing					Completely willing	
		1	2	3	4	5	6	7
74.1	Rely on your team's task related skills and abilities.							
74.2	Depend on your team to handle an important issue on your behalf.							
74.3	Rely on your team to represent your work accurately to others.							
74.4	Depend on your team to back you up in difficult situations.							
74.5	Rely on your team work-related judgments.							
74.6	Share your personal feelings with your team.							
74.7	Discuss work-related problems or difficulties with the team that could potentially be used to disadvantage you.							
74.8	Confide in the team about personal issues that are affecting your work.							
74.9	Discuss how you honestly feel about your work, even negative feelings and frustration.							
74.10	Share your personal beliefs with the team.							

Thank you for your valuable time.

SECTION D - OPTIONAL INFORMATION

Your answers to this questionnaire will remain completely confidential (although responses are not encrypted), but if you would like to be informed as to the progress and results of this research, please complete the following information:

75. Would you be prepared to be involve in follow up discussions

75.1	Yes	
75.2	No	

76. Personal Details

Name and Surname	
Company name	
Department / Division	
Email address	
Telephone number	

APPENDIX C. Reliability and Validity Checks

The following section provides detail of calculations done during the data reliability and validity checks.

C.1 Reliability - elicitation techniques usage scale

Cronbach's alpha coefficient was calculated for the 20 elements in the scale used to determine the usage of elicitation techniques. The internal consistency coefficient alpha of 0.748 suggests very good reliability in this scale. Levels of 0.7 or more are generally accepted as representing good reliability (Litwin, 1995). This data was collected through question 21 in the survey.

Table 57: Cronbach's alpha for elicitation techniques

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item - Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Interviews	31.9841	19.532	.058		.749
Questionnaires	31.5079	19.189	.038		.757
Document analysis	31.9524	19.369	.105		.748
Brainstorming	31.9048	18.862	.258		.742
Groupwork	31.9206	19.494	.019		.752
Joint application development	31.6508	19.489	-.025		.760
Workshops	31.8571	18.834	.214		.744
Prototyping	31.6984	18.924	.118		.750
Domain analysis	31.4603	17.091	.376		.732
Introspection	31.2063	16.747	.380		.732
Goal-based approaches	31.1429	16.189	.506		.718
Scenarios	31.8095	18.770	.200		.745
Viewpoints	31.4603	16.769	.399		.730
Repertory grids	30.5079	17.028	.521		.721
Card sorting	30.5714	17.217	.396		.730
Laddering	30.5556	16.638	.580		.715
Protocol analysis	30.7619	15.829	.604		.708
Ethnography	30.5079	16.835	.500		.721
Observation	31.6508	19.070	.052		.757

Apprenticing	30.8889	16.842	.491		.722

Table 57 presents the impact on the internal consistency coefficient if elements are removed. As the coefficient suggests a good reliability in this scale, none of the elements was removed.

C.2 Reliability – analysis and modelling techniques usage scale

Cronbach's alpha coefficient was calculated for the 11 elements in the scale used to determine the usage of analysis and modelling techniques. The internal consistency coefficient alpha of 0.648 suggests an unacceptable reliability in this scale. Levels of 0.7 or more are generally accepted as representing good reliability (Litwin, 1995). This data was collected through question 25 in the survey.

Table 58: Cronbach's alpha for analysis and modelling techniques

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item - Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Goal-oriented models (e.g. KAOS)	15.9063	6.467	.303	.357	.627
Agent-based models (e.g. Tropos, i*)	15.7188	5.983	.523	.586	.575
State machine models	16.1406	6.885	.187	.287	.653
Petri nets	15.7188	6.459	.408	.478	.604
Structured analysis and design technique	16.8438	6.991	.255	.308	.634
Data flow diagrams	16.9844	7.635	.158	.273	.646
Flow charts	17.0156	7.762	.115	.151	.650
Object-oriented models	16.7500	7.302	.177	.303	.646
Formal models	16.4844	6.412	.361	.242	.613
Entity relationship diagrams	16.7813	6.777	.372	.444	.613
Domain models	16.4375	6.409	.397	.440	.605

Table 58 shows the impact on the internal consistency coefficient if elements are removed. The coefficient calculated does not predict good reliability as it is below 0.7; however, removing any element would not improve the coefficient to good reliability either. This scale was left as is and data was used cautiously.

C.3 Reliability - quality of the output of the requirements process

Cronbach's alpha coefficient was calculated for the eight elements in the scale used to determine the quality of the requirements process output. The internal consistency coefficient alpha of 0.817 suggests very good reliability in this scale. Levels of 0.7 or more are generally accepted as representing good reliability (Litwin, 1995). This data was collected through question 33 in the survey.

Table 59: Cronbach's alpha for requirements quality scale

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item - Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Have all the requirements been validated by the source of the requirement i.e. typically the stakeholder?	35.8909	54.951	.636	.656	.785
Was there a single interpretation for each requirement to enable the common understanding by all stakeholders?	36.2182	51.396	.758	.785	.767
Were all the required requirements present in the specification ensuring a workable solution fit for purpose by the user?	36.2000	53.311	.722	.716	.775
Did some requirements conflict with other requirements or with higher level system or business requirements?	38.7273	69.239	-.101	.067	.876
Were all the requirements prioritised based on importance or in terms of expected changes associated with the requirement?	36.8727	52.595	.499	.369	.803
Was it possible to test each requirement to determine whether it has been properly implemented?	36.0727	54.587	.635	.541	.785
Was a history of changes made to each requirement kept?	36.3091	48.625	.682	.742	.773
Was each requirement linked back to its source of origination?	36.5636	49.139	.640	.731	.780

Table 59 shows the impact of the internal consistency coefficient if elements are removed. As the coefficient suggests good reliability in this scale, none of the elements was removed.

C.4 Reliability – trust relationship with project manager (communication established)

Cronbach's alpha coefficient was calculated for the ten elements in the scale used to determine the trust relationship with the project manager where communication was established. The internal consistency coefficient alpha of 0.868 suggests very good reliability in this scale. This data was collected through question 50 in the survey.

Table 60: Cronbach's alpha for trust relationship with project manager (communication established)

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item - Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Rely on your project manager's task related skills and abilities.	37.4821	130.727	.532	.580	.860
Depend on your project manager to handle an important issue on your behalf.	37.7321	122.745	.740	.666	.843
Rely on your project manager to represent your work accurately to others.	38.3036	127.306	.585	.682	.856
Depend on your project manager to back you up in difficult situations.	37.1964	128.379	.610	.632	.854
Rely on your project manager's work-related judgments.	37.4464	129.779	.632	.734	.853
Share your personal feelings with your project manager.	38.3393	127.792	.560	.524	.858
Discuss work-related problems or difficulties with your project manager that could potentially be used to disadvantage you.	37.6607	126.919	.713	.538	.847
Confide in your project manager about personal issues that are affecting your work.	38.7321	127.945	.531	.541	.861
Discuss how you honestly feel about your work, even negative feelings and frustration.	38.0536	132.670	.485	.582	.864
Rely on your project manager's task related skills and abilities.	38.5000	134.582	.488	.562	.863

C.5 Reliability – trust relationship with project manager (no communication established)

Cronbach's alpha coefficient was calculated for the ten elements in the scale used to determine the trust relationship with the project manager where no communication was established. The internal consistency coefficient alpha of 0.934 suggests very good reliability in this scale. This data was collected through question 52 in the survey.

Table 61: Cronbach's alpha for trust relationship with project manager (no communication established)

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item – Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Rely on your project manager's task related skills and abilities.	37.7500	311.583	.656		.931
Depend on your project manager to handle an important issue on your behalf.	40.0000	266.000	.982		.913
Rely on your project manager to represent your work accurately to others.	40.0000	266.000	.982		.913
Depend on your project manager to back you up in difficult situations.	37.5000	315.000	.920		.924
Rely on your project manager's work-related judgments.	38.7500	304.250	.614		.934
Share your personal feelings with your project manager.	37.5000	313.667	.607		.933
Discuss work-related problems or difficulties with your project manager that could potentially be used to disadvantage you.	37.5000	313.667	.607		.933
Confide in your project manager about personal issues that are affecting your work.	38.7500	288.250	.866		.920
Discuss how you honestly feel about your work, even negative feelings and frustration.	39.0000	274.667	.920		.917
Rely on your project manager's task related skills and abilities.	38.0000	335.333	.320		.946

C.6 Reliability – trust relationship with project sponsor (communication established)

Cronbach's alpha coefficient was calculated for the ten elements in the scale used to determine the trust relationship with the project sponsor where communication was established. The internal consistency coefficient alpha of 0.87 suggests very good reliability in this scale. This data was collected through question 57 in the survey.

Table 62: Cronbach's alpha for trust relationship with project sponsor (communication established)

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item - Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Rely on your project sponsor's task related skills and abilities.	33.6111	138.073	.411	.561	.871
Depend on your project sponsor to handle an important issue on your behalf.	33.4167	129.793	.579	.823	.858
Rely on your project sponsor to represent your work accurately to others.	33.9722	125.971	.591	.726	.858
Depend on your project sponsor to back you up in difficult situations.	33.4444	133.854	.496	.556	.865
Rely on your project sponsor's work-related judgments.	33.2222	132.463	.583	.831	.858
Share your personal feelings with your project sponsor.	35.3333	124.571	.677	.733	.850
Discuss work-related problems or difficulties with your project sponsor that could potentially be used to disadvantage you.	34.8333	126.429	.615	.827	.855
Confide in your project sponsor about personal issues that are affecting your work.	35.8333	127.971	.725	.789	.848
Discuss how you honestly feel about your work, even negative feelings and frustration.	35.4167	130.593	.558	.899	.860
Share your personal beliefs with your project sponsor.	35.4167	126.021	.651	.811	.852

C.7 Reliability – trust relationship with project sponsor (no communication established)

Cronbach's alpha coefficient was calculated for the ten elements in the scale used to determine the trust relationship with the project sponsor where no communication was established. The internal consistency coefficient alpha of 0.937 suggests very good reliability in this scale. This data was collected through question 59 in the survey.

Table 63: Cronbach's alpha for trust relationship with project sponsor (no communication established)

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item - Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Rely on your project sponsor's task related skills and abilities.	23.5909	200.444	.658	.682	.935
Depend on your project sponsor to handle an important issue on your behalf.	23.1364	186.314	.887	.969	.923
Rely on your project sponsor to represent your work accurately to others.	23.9091	194.848	.777	.820	.929
Depend on your project sponsor to back you up in difficult situations.	23.3182	188.608	.831	.961	.926
Rely on your project sponsor's work-related judgments.	23.0909	199.420	.587	.783	.940
Share your personal feelings with your project sponsor.	24.9545	208.236	.765	.972	.931
Discuss work-related problems or difficulties with your project sponsor that could potentially be used to disadvantage you.	24.3182	199.275	.761	.873	.930
Confide in your project sponsor about personal issues that are affecting your work.	25.0909	207.991	.758	.972	.931
Discuss how you honestly feel about your work, even negative feelings and frustration.	24.9091	203.896	.774	.974	.930
Share your personal beliefs with your project sponsor.	24.6364	198.052	.780	.943	.929

C.8 Reliability – trust relationship with subject matter expert (communication established)

Cronbach's alpha coefficient was calculated for the ten elements in the scale used to determine the trust relationship with the subject matter expert where communication was established. The internal consistency coefficient alpha of 0.883 suggests very good reliability in this scale. This data was collected through question 64 in the survey.

Table 64: Cronbach's alpha for trust relationship with subject matter expert (communication established)

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item - Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Rely on your subject-matter expert's task related skills and abilities.	33.0222	150.522	.477	.702	.881
Depend on your subject-matter expert to handle an important issue on your behalf.	33.8000	141.073	.590	.651	.873
Rely on your subject-matter expert to represent your work accurately to others.	34.4667	142.800	.563	.557	.875
Depend on your subject-matter expert to back you up in difficult situations.	33.9556	141.453	.667	.593	.868
Rely on your subject-matter expert work-related judgments.	33.2667	148.518	.509	.713	.879
Share your personal feelings with your subject-matter expert.	35.4667	140.164	.738	.754	.863
Discuss work-related problems or difficulties with the subject-matter expert that could potentially be used to disadvantage you.	34.6000	139.018	.639	.687	.869
Confide in the subject-matter expert about personal issues that are affecting your work.	35.4889	139.937	.682	.793	.866
Discuss how you honestly feel about your work, even negative feelings and frustration.	35.1333	139.936	.643	.748	.869
Share your personal beliefs with the subject-matter expert.	35.2000	141.118	.630	.698	.870

C.9 Reliability – trust relationship with subject matter expert (no communication established)

Cronbach's alpha coefficient was calculated for the ten elements in the scale used to determine the trust relationship with the subject matter expert where no communication was established. The internal consistency coefficient alpha of 0.934 suggests very good reliability in this scale. This data was collected through question 66 in the survey.

Table 65: Cronbach's alpha for trust relationship with subject matter expert (no communication)

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item - Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Rely on your subject-matter expert's task related skills and abilities.	27.4167	259.538	.063	.503	.955
Depend on your subject-matter expert to handle an important issue on your behalf.	28.9167	209.356	.850	.994	.921
Rely on your subject-matter expert to represent your work accurately to others.	28.9167	210.992	.840	.994	.922
Depend on your subject-matter expert to back you up in difficult situations.	28.9167	200.629	.877	.939	.920
Rely on your subject-matter expert work-related judgments.	28.0000	223.273	.543	.698	.938
Share your personal feelings with your subject-matter expert.	29.4167	211.538	.830	.988	.923
Discuss work-related problems or difficulties with the subject-matter expert that could potentially be used to disadvantage you.	29.1667	210.152	.903	.981	.919
Confide in the subject-matter expert about personal issues that are affecting your work.	29.7500	217.477	.902	.961	.921
Discuss how you honestly feel about your work, even negative feelings and frustration.	29.5833	216.992	.806	.982	.924
Share your personal beliefs with the subject-matter expert.	29.4167	214.629	.837	.986	.923

C.10 Reliability – trust relationship with end-user (communication established)

Cronbach's alpha coefficient was calculated for the ten elements in the scale used to determine the trust relationship with the end user where communication was established. The internal consistency coefficient alpha of 0.856 suggests very good reliability in this scale. This data was collected through question 71 in the survey.

Table 66: Cronbach's alpha for trust relationship with end-user (communication established)

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item - Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Rely on your main end-user's task related skills and abilities.	29.7391	152.197	.196	.592	.872
Depend on your main end-user to handle an important issue on your behalf.	30.9565	134.887	.566	.783	.842
Rely on your main end-user to represent your work accurately to others.	30.7826	130.041	.673	.809	.832
Depend on your main end-user to back you up in difficult situations.	30.7174	133.318	.621	.565	.837
Rely on your main end-user work-related judgments.	30.2174	141.774	.469	.614	.850
Share your personal feelings with your main end-user.	31.6957	130.705	.683	.890	.831
Discuss work-related problems or difficulties with the main end-user that could potentially be used to disadvantage you.	31.3696	140.994	.422	.488	.854
Confide in the main end-user about personal issues that are affecting your work.	32.2609	133.708	.701	.839	.831
Discuss how you honestly feel about your work, even negative feelings and frustration.	32.0652	133.218	.666	.806	.834
Share your personal beliefs with the main end-user.	31.6739	128.891	.652	.879	.834

C.11 Reliability – trust relationship with end-user (no communication established)

Cronbach's alpha coefficient was calculated for the ten elements in the scale used to determine the trust relationship with the end-user where no communication was established. The internal consistency coefficient alpha of 0.919 suggests very good reliability in this scale. This data was collected through question 73 in the survey.

Table 67: Cronbach's alpha for trust relationship with end-user (no communication established)

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item - Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Rely on your main end-user's task related skills and abilities.	12.7778	38.444	.987		.902
Depend on your main end-user to handle an important issue on your behalf.	13.2222	50.694	.906		.898
Rely on your main end-user to represent your work accurately to others.	13.3333	54.500	.724		.909
Depend on your main end-user to back you up in difficult situations.	13.3333	53.000	.980		.898
Rely on your main end-user work-related judgments.	12.8889	41.611	.973		.896
Share your personal feelings with your main end-user.	13.7778	62.444	.722		.920
Discuss work-related problems or difficulties with the main end-user that could potentially be used to disadvantage you.	13.4444	54.778	.703		.910
Confide in the main end-user about personal issues that are affecting your work.	13.7778	62.444	.722		.920
Discuss how you honestly feel about your work, even negative feelings and frustration.	13.7778	62.444	.722		.920
Share your personal beliefs with the main end-user.	13.6667	62.000	.600		.920

C.12 Reliability – trust relationship within team

Cronbach's alpha coefficient was calculated for the ten elements in the scale used to determine the trust relationship within the team where communication was established. The internal consistency coefficient alpha of 0.917 suggests very good reliability in this scale. This data was collected through question 74 in the survey.

Table 68: Cronbach's alpha for trust relationship within the team

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item - Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Rely on your team's task related skills and abilities.	40.2364	150.739	.616	.795	.912
Depend on your team to handle an important issue on your behalf.	40.6909	145.143	.654	.851	.910
Rely on your team to represent your work accurately to others.	40.9091	142.677	.722	.874	.906
Depend on your team to back you up in difficult situations.	40.5091	146.995	.726	.772	.907
Rely on your team work-related judgments.	40.2909	150.988	.710	.800	.909
Share your personal feelings with your team.	41.9273	141.995	.707	.790	.907
Discuss work-related problems or difficulties with the team that could potentially be used to disadvantage you.	41.4000	143.170	.691	.773	.908
Confide in the team about personal issues that are affecting your work.	42.1636	136.102	.747	.831	.905
Discuss how you honestly feel about your work, even negative feelings and frustration.	41.6727	140.039	.633	.650	.913
Share your personal beliefs with the team.	41.9091	138.603	.762	.760	.904

APPENDIX D. Industry Review Data Analysis Results

The following section provides details of calculations done during the data analysis process.

D.1 The respondents data analysis

The following table provides the calculation results from SPSS to determine if there was any association between the business analyst group job description and industry using Lambda.

Table 69: Lambda results between job description and industry

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Lambda	Symmetric	0.218	0.061	3.232	0.001
	In which Industry are you employed?	0.327	0.085	3.341	0.001
	Please select your current job description	0.134	0.067	1.913	0.056
Goodman and Kruskal tau	In which Industry are you employed?	0.221	0.049		0.000[c]
	Please select your current job description	0.124	0.026		0.001[c]

[a] Not assuming the null hypothesis.

[b] Using the asymptotic standard error assuming the null hypothesis.

[c] Based on chi-square approximation.

The following table provides the calculation results from SPSS to determine if there was any association between the practitioners' job description and qualification.

Table 70: Lambda results between job description and qualification

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Lambda	Symmetric	0.111	0.038	2.769	0.006
	Please select your highest qualification?	0.083	0.032	2.596	0.009
	Please select your current job description	0.140	0.068	1.924	0.054
Goodman and	In which Industry are you employed?	0.095	0.012		0.012[c]

Kruskal tau	Please select your highest qualification?	0.122	0.020		0.025[c]

[a] Not assuming the null hypothesis.

[b] Using the asymptotic standard error assuming the null hypothesis.

[c] Based on chi-square approximation.

The following table provides the calculation results from SPSS to determine if there was any correlation between the project budget and the duration of a project.

Table 71: Correlation results between project budget and duration

		Please select the overall budget of the project
Please select the overall budget of the project	Pearson correlation	1
	Sig. (2-tailed)	
	N	93
Please select the duration of the project, from inception to delivery	Pearson correlation	0.550** **. Correlation is significant at the 0.01 level (2-tailed)
	Sig. (2-tailed)	0.000
	N	93

The following table provides the calculation results from SPSS to determine if there was any correlation between the project budget, duration of a project and the practitioners' years of experience.

Table 72: Correlation results between project budgets, duration and years' experience

		Please select the overall budget of the project	**Please select the overall budget of the project**
Please select the duration of the project, from inception to delivery	Pearson correlation	1	0.550** **. Correlation is significant at the 0.01 level (2-tailed)
	Sig. (2-tailed)		0.000
	N	93	93
Please select the overall budget of the project	Pearson correlation	0.550** **. Correlation is significant at the 0.01 level (2-tailed)	1

	Sig. (2-tailed)	0.000	
	N	93	93
Practitioners' years of experience	Pearson correlation	0.372** **. Correlation is significant at the 0.01 level (2-tailed)	0.404** **. Correlation is significant at the 0.01 level (2-tailed)
	Sig. (2-tailed)	0.000	0.000
	N	93	93

D.2 The requirements engineering process data analysis

The following table summarises the results from SPSS where Lambda was measured to determine if there was any association between the requirements presentation and election techniques. The summary shows the Lambda symmetric value, which falls between the value of the elicitation technique and the specification notation calculated.

Table 73: Lambda between requirements presentation and elicitation techniques

	Symmetric Lambda	**Specification Notation**	**Elicitation Technique**
Interviews	0.042	0.043	0.000
Questionnaires	0.100	0.000	0.185
Document analysis	0.000	0.000	0.000
Brainstorming	0.074	0.087	0.000
Groupwork	0.000	0.000	0.000
Joint application development	0.026	0.000	0.063
Workshops	0.034	0.043	0.000
Prototyping	0.000	0.000	0.000
Domain analysis	0.000	0.000	0.000
Introspection	0.054	0.000	0.091
Goal-based approaches	0.038	0.000	0.067
Scenarios	0.000	0.000	0.000
Viewpoints	0.000	0.000	0.000
Repertory grids	0.065	0.043	0.087
Card sorting	0.000	0.000	0.000
Laddering	0.000	0.000	0.000

Protocol analysis	0.074	0.000	0.129
Ethnography	0.023	0.043	0.000
Observation	0.100	0.087	0.118
Apprenticing	0.000	0.000	0.000

The following table summarises the results from SPSS where Lambda was measured to determine if there was any association between the requirements presentation and analysis and modelling techniques. The summary shows the Lambda symmetric value, which falls between the value of the analysis and modelling technique and the specification notation calculated.

Table 74: Lambda between requirements presentation and analysis and modelling techniques

	Symmetric Lambda	**Specification Notation**	**Analysis and Modelling Technique**
Goal-oriented models (e.g. KAOS)	0.053	0.000	0.100
Agent-based models (e.g. Tropos, i*)	0.085	0.000	0.156
State machine models	0.038	0.000	0.077
Petri nets	0.018	0.000	0.034
Structured analysis and design technique	0.027	0.037	0.000
Data flow diagrams	0.031	0.037	0.000
Flow charts	0.000	0.000	0.000
Object-oriented models	0.191	0.185	0.200
Formal models	0.123	0.037	0.200
Entity relationship diagrams	0.000	0.000	0.000
Domain models	0.036	0.000	0.071

D.3 Requirements quality characteristics

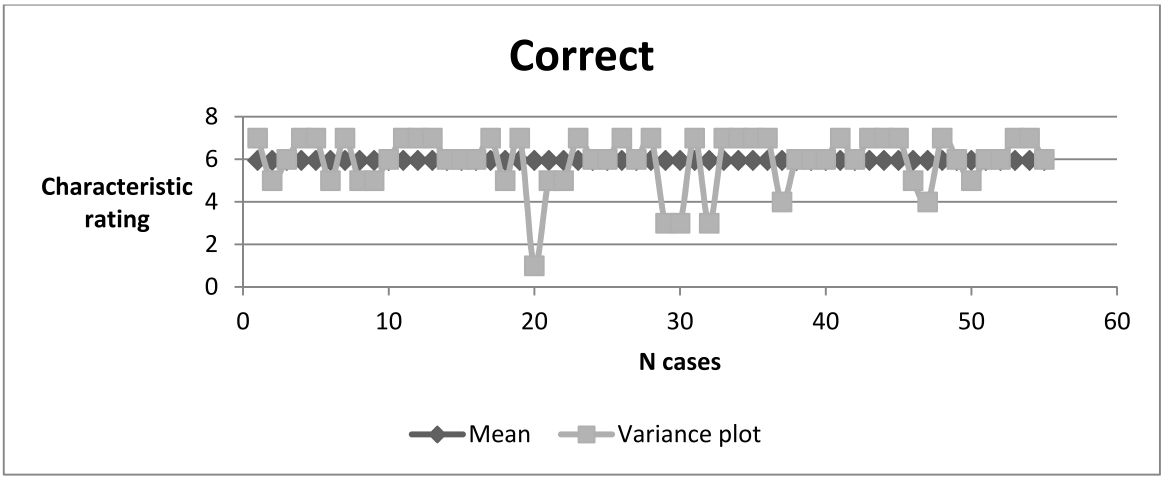

Figure 55: Correctness characteristic deviation around mean

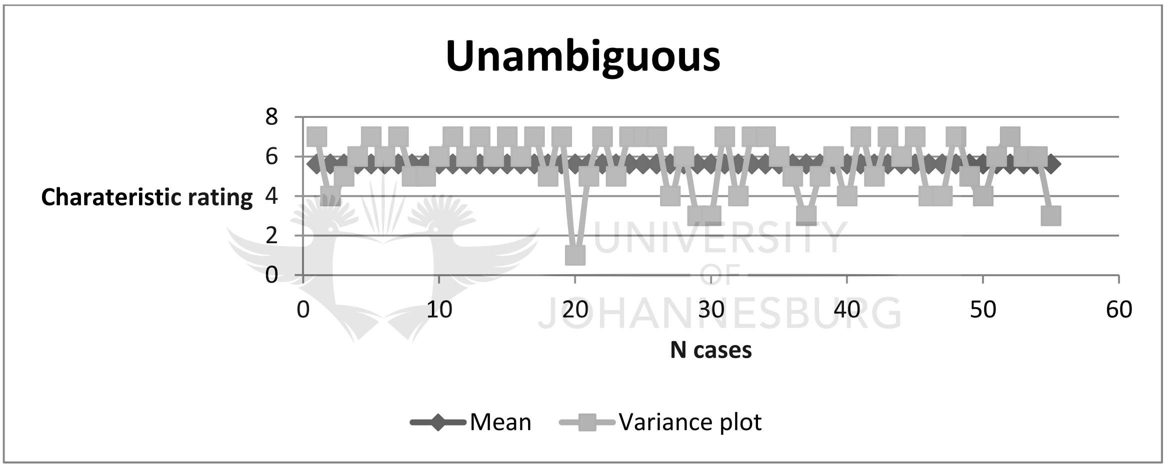

Figure 56: Unambiguous characteristic deviation around mean

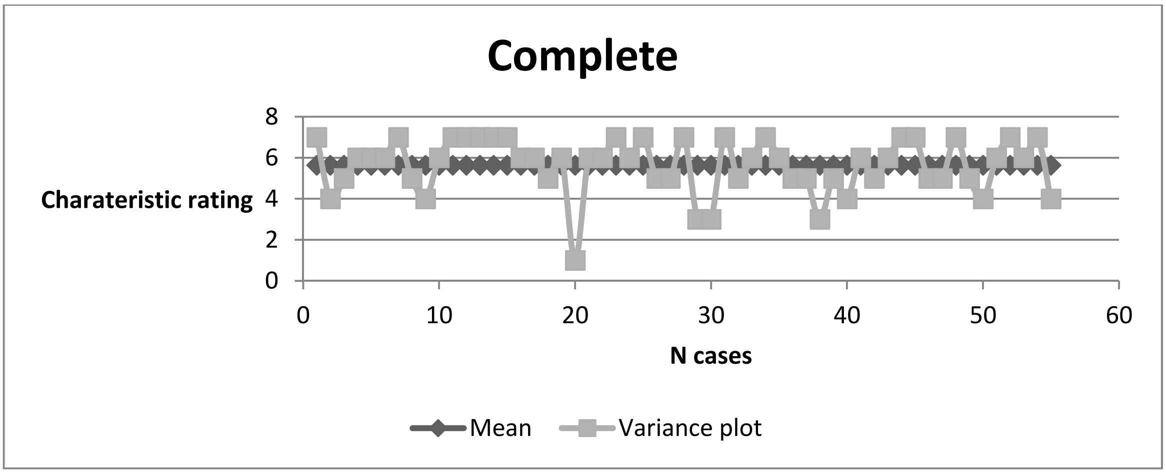

Figure 57: Complete characteristic deviation around mean

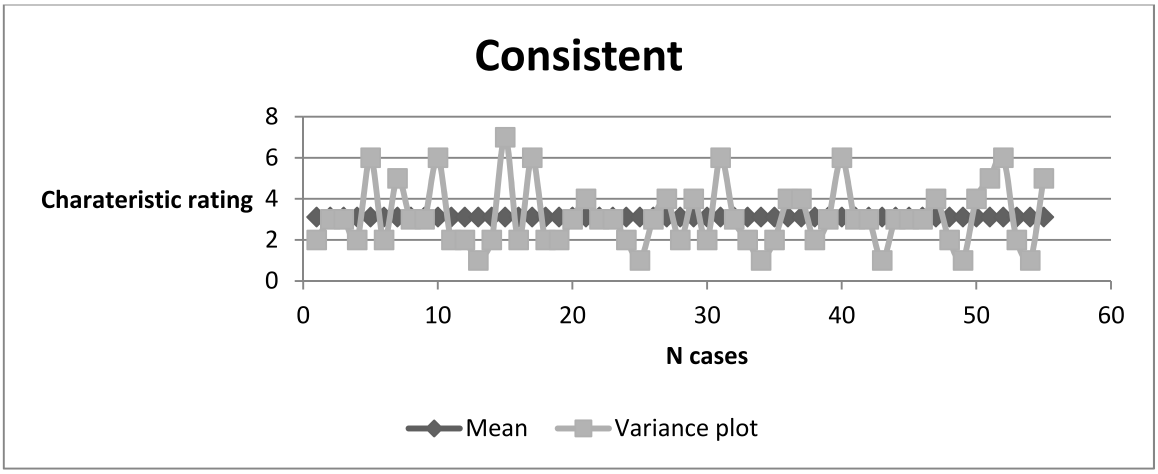

Figure 58: Consistent characteristic deviation around mean

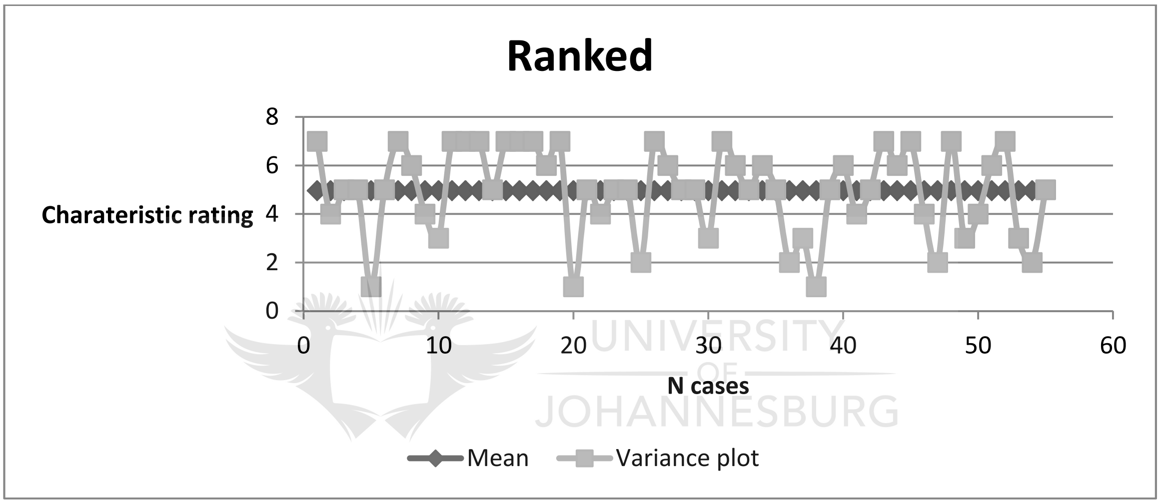

Figure 59: Ranked characteristic deviation around mean

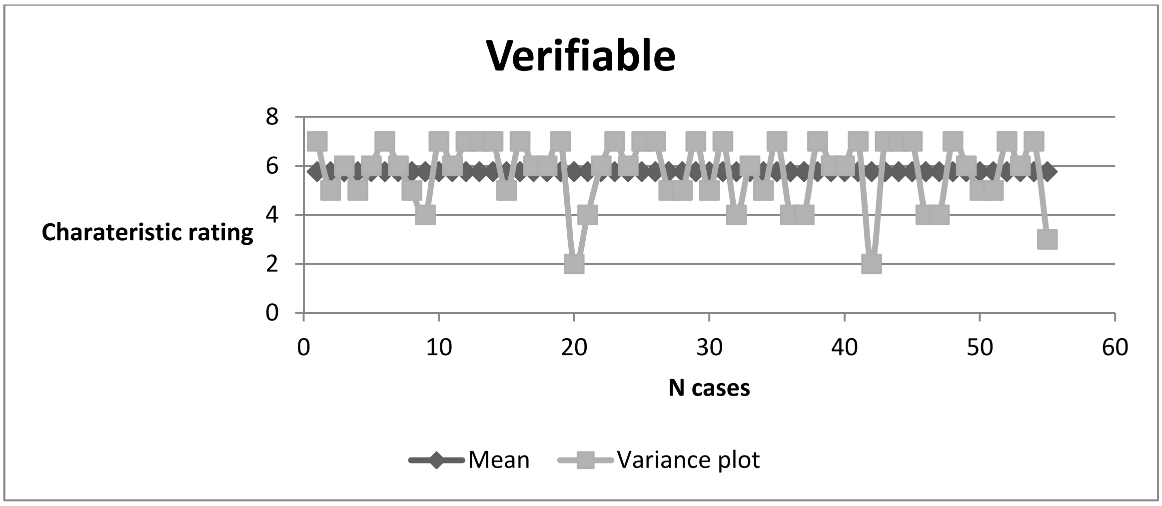

Figure 60: Verifiable characteristic deviation around mean

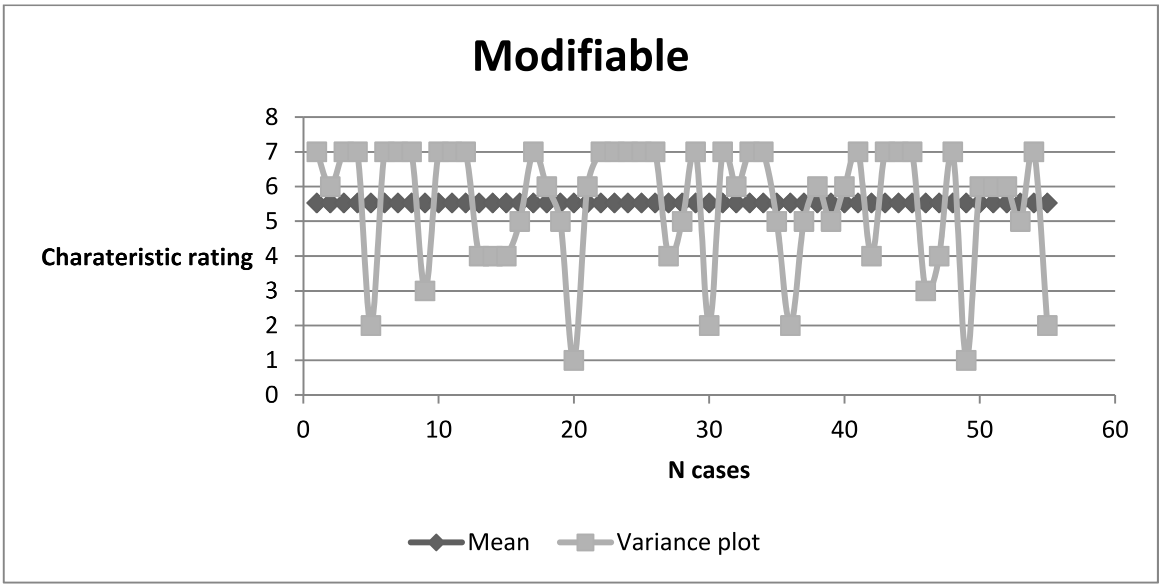

Figure 61: Modifiable characteristic deviation around mean

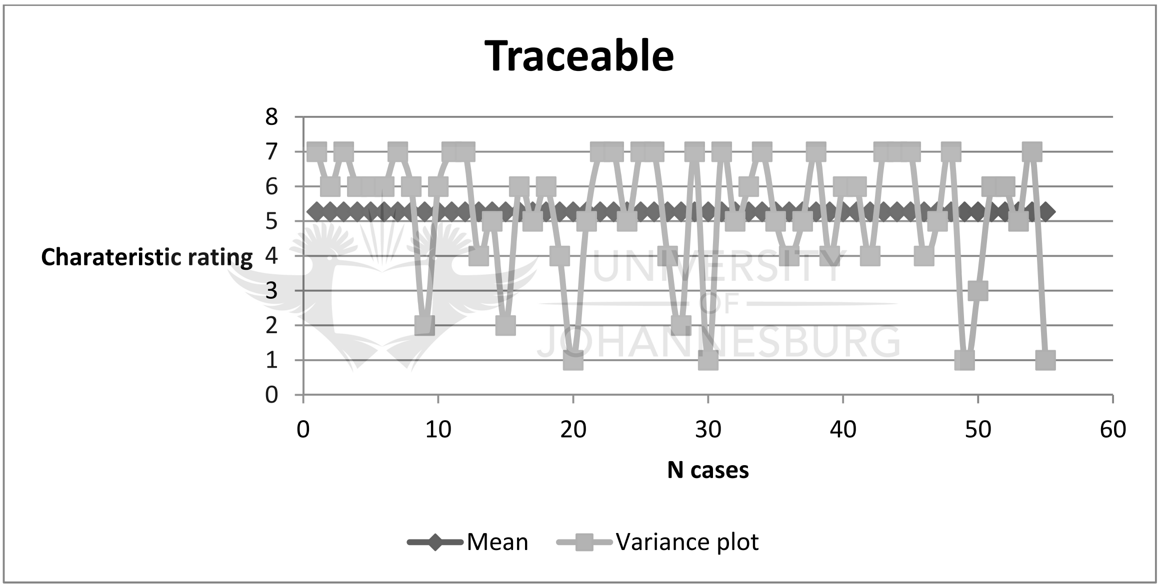

Figure 62: Traceable characteristic deviation around mean

D.4 Factor analysis for the quality scale

Factor analysis was done to determine if the eight quality elements could be reduced to only a few to provide a summary of results. The factor analysis results as determined using SPSS are discussed below. The factor analysis process involves firstly determining if data is suitable for factor analysis, secondly, extracting the factors identified and finally interpretation.

The first step was to determine if factor analysis would be relevant in each case where the quality was measured. The results from SPSS are summarised below.

Table 75: Appropriateness results for quality scale factor analysis

Factor Analysis Results	
Kaiser-Meyer-Olkin measure of sampling adequacy (KMO)	0.797
Significance (p)	0.000
Correlation coefficients	1, 0.787, 0.735, -0.088, 0.380, 0.527, 0.349, 0.389
Factor analysis appropriate (KMO 0.6 or above & significance value 0.05 or less & majority correlation coefficients 0.3 or above)	Yes

From Table 75 factor analysis was appropriate. The second step was to identify how many and which factors should be extracted to summarise the eight quality elements. The eigenvalue had to be 1 or more.

Table 76: Identification of factors for quality scale factor analysis

Factor Determination	
Factors with initial eigenvalues of 1 or more (relevant eigenvalue)	1, 2 & 3 (4.210, 1.104, 1.039)
Total variance of factors identified	Factor 1 - 52.628% Factors 1 and 2 - 66.429% Factors 1, 2 and 3 - 79.415%

After reviewing the scree plot of each, it was decided to use factors 1 and 2. This confirms that components 1 and 2 captured most of the variances. Therefore only these two component s were extracted.

Finally the loading on factors was analysed to identify how the summary elements could be grouped into factors.
The following legends were used:

- Have all the requirements been validated by the source of the requirement, i.e. typically the stakeholder? (Correct)
- Was there a single interpretation for each requirement to enable common understanding by all stakeholders? (Unambiguous)
- Were all the required requirements present in the specification, ensuring a workable solution fit for purpose by the user? (Complete)
- Did some requirements conflict with other requirements or with higher level system or business requirements? (Consistent)

- Were all the requirements prioritised based on importance or in terms of expected changes associated with the requirement? (Ranked for importance)
- Was it possible to test each requirement to determine whether it has been properly implemented? (Verifiable)
- Was a history of changes made to each requirement kept? (Modifiable)
- Was each requirement linked back to its source of origination? (Traceable)

Table 77: Quality scale factor analysis – pattern matrix

Element	**Pattern Coefficient**	
	Component 1	Component 2
Correct	0.957	
Unambiguous	0.885	
Complete	0.893	
Consistent		
Ranked for importance	0.494	
Verifiable	0.362	-0.534
Modifiable		-0.959
Traceable		-0.963

Table 77 shows that the correct, unambiguous, complete, ranked for importance and verifiable elements loaded on one factor. However, the second factor has three elements with negative loading. The two components therefore do not give a perfect loading of how the eight elements in the quality scale can be summarised into two factors. The quality scale had to be evaluated to determine why.

Confirmatory factor analysis is always used during the process of a scale development to examine the structure of the questionnaire (Brown, 2006). To test the quality scale's underlying structure, confirmatory factor analysis was performed using EQS 6.1 software, although the sample size was relatively small (n = 55) for performing this analysis.

If the researcher has a measurement scale and has collected the data to perform confirmatory factor analysis, he or she needs to obtain the correlation matrix, fit the model to the data and evaluate model adequacy (DeCoster, 1998). For this study, there was a quality scale and the data had been collected.

Confirmatory factor analysis was evaluated by using statistics. The model consists of the elements within the scale. The first model defined is based on the quality scale as specified with eight elements: correct, unambiguous, complete, consistent, ranked for importance, verifiable, modifiable and traceable.

To evaluate the goodness-of-fit for the model, the following tests were done:

Chi-square (χ^2) test:

- Lower chi-square values indicate better fit (DeCoster, 1998; Byrne, 2010).

χ^2/df (degrees of freedom) ratio:

- The ratio of chi square to df is used in some instances but there are no firmly established values for good and bad ratios (Brown, 2006).

The normed fit index (NFI), non-normed fit (NNFI) index and corporative fit index (CFI):

- Possible range of values from 0.0 to 1.0.
- Value greater than 0.9 indicating a good fit (Byrne, 2010).

Root mean square error of approximation (RMSEA) range:

- If the RMSEA value is less than 0.08, this suggests an acceptable fit, less than 0.05 suggests a good fit and less than 0.01 suggests an exceptionally good fit (Brown, 2006).
- Models with RMSEA ≥ 0.1 should be rejected (Brown, 2006).

The results for the confirmatory factor analysis from EQS are presented in Table 78.

Table 78: Confirmatory factor analysis results

Model	χ^2	**df**	χ^2**/df**	**Mardias**	**NFI**	**NNFI**	**CFI**	**RMSEA**
Model 1	56.9	20	2.85	2.4	0.635	0.598	0.73	0.182 (0.126-0.238)
Model 2	12.9	9	1.43	1.7	0.859	0.918	0.951	0.087 (0.000-0.187)

From Table 78 it was concluded that model 1 (the quality scale with the eight elements) model fit was not adequate. Chi square was a significant value, and NFI, NNFI, CFI and RMSEA were not within acceptable ranges.

As the model was rejected, the fit of the eight elements was assessed using standardised residuals. If the standardised residual is very low it indicates that the elements do not fit well. If the coefficient between two items is high, it suggests that they might be measuring the same element (Brown, 2006; Byrne, 2010).

Element 4 (consistent) had a low standardised residual (0.014). Element 8 (traceable) seemed to be a similar measurement item to element 7 (largest standardised residual 0.486). A second model was run to assess the effect of removing these two elements with poor fit. The quality scale resulted in a reasonable fit if the items *consistent* and *traceable* were removed as shown in Table 78.

Based on the confirmatory factor analysis of model 2, factor analysis was done to investigate if the six quality elements could be reduced to only a single factor by excluding the elements *consistent* and *traceable* as suggested by the confirmatory factor analysis results.

The first step was to determine if factor analysis would be relevant in each case where quality was measured. The results from SPSS are summarised below.

Table 79: Appropriateness results of adjusted quality scale factor analysis

Factor Analysis Results	
Kaiser-Meyer-Olkin measure of sampling adequacy (KMO)	0.834
Significance (p)	0.000
Correlation coefficients	1, 0.787, 0.735, 0.380, 0.527, 0.349
Factor analysis appropriate (KMO 0.6 or above & significance value 0.05 or less & majority correlation coefficients 0.3 or above)	Yes

Table 79 shows that factor analysis was appropriate. The second step was to identify how many and which factors should be extracted to summarise the eight quality elements. The eigenvalue had to be 1 or more.

Table 80: Identification of factors for adjusted quality scale factor analysis

Factor Determination	
Factors with initial eigenvalues of 1 or more (relevant eigenvalue)	1 (3.712)
Total variance of factors identified	61.87%

After reviewing the scree plot of each, it was decided to use factor 1. This confirms that component 1 captured most of the variances. Therefore only this component was extracted.

Table 81: Adjusted quality scale factor analysis – pattern matrix

Element	Component 1
Correct	0.824
Unambiguous	0.912
Complete	0.875
Ranked for importance	0.624
Verifiable	0.757
Modifiable	0.687

From Table 81 it can be seen that the correct, unambiguous, complete, ranked for importance, verifiable and modifiable elements loaded on one factor. This factor analysis confirmed that by excluding the elements of *consistent* and *traceable,* the other six elements in the quality scale could be summarised into a single factor.

D.5 The customer satisfaction data analysis

The following table provides the calculation results from SPSS to determine if there was any correlation between the customer satisfaction and usage of solution.

Table 82: Correlation results between customer satisfaction and usage of solution

		Percentage of Business Stakeholders satisfied with Delivered Project	**Percentage of End-users satisfied with Delivered Project**
What percentage of your business stakeholders were satisfied with the delivered project	Pearson correlation	1	.842** **. Correlation is significant at the 0.01 level (2-tailed)
	Sig. (2-tailed)		.000
	N	63	63
What percentage, of your end-users was satisfied with the delivered project	Pearson correlation	.842** **. Correlation is significant at the 0.01 level (2-tailed)	1
	Sig. (2-tailed)	.000	
	N	63	63
Is the solution delivered by the project, currently in use by the end-users?	Pearson correlation	-.391** **. Correlation is significant at the 0.01 level (2-tailed)	-.288* *. Correlation is significant at the 0.05 level (2-tailed)
	Sig. (2-tailed)	.002	.022
	N	63	63

APPENDIX E. Data Analysis Results of Practitioners' Behaviour Review

The following section provides details of calculations done during the data analysis process.

E.1 The behavioural trust inventory

This ten-item instrument measures willingness to engage in two types of trust behaviours, i.e. reliance and disclosure within the context of interpersonal work relationships (Gillespie, 2003). Reliance-based trust is based upon (i) relying on another's skill, (ii) knowledge, (iii) judgement, (iv) actions including delegating and (v) giving autonomy. Disclosure-based trust focuses on sharing work-related or personal information that is of a sensitive nature (Gillespie, 2003). Each item within the two types of trust behaviours is measured on a scale from 1 (not at all willing) to 7 (completely willing*)*. The behavioural trust inventory is shown in Table 83.

Table 83: The behavioural trust inventory (Gillespie, 2012)

Rely on your leader's task related skills and abilities	**Reliance-based trust**
Depend on your leader to handle an important issue on your behalf.	Reliance-based trust
Rely on your leader to represent your work accurately to others.	Reliance-based trust
Depend on your leader to back you up in difficult situations.	Reliance-based trust
Rely on your leader's work-related judgments.	Reliance-based trust
Share your personal feelings with your leader.	Disclosure-based trust
Discuss work-related problems or difficulties with your leader that could potentially be used to disadvantage you.	Disclosure-based trust
Confide in your leader about personal issues that are affecting your work.	Disclosure-based trust
Discuss how you honestly feel about your work, even negative feelings and frustration.	Disclosure-based trust
Share your personal beliefs with your leader.	Disclosure-based trust

E.2 Trust relationship with project manager

The respondents were requested to rate how willing they were to engage in certain behaviours with the project manager. The trust in each relationship was measured separately based on whether communication was established or not.

Table 84: Behavioural trust inventory with project manager – communication established

	Communication Established (N = 56)			No Communication Established (N = 4)		
	Mean	Median	Std Deviation	Mean	Median	Std Deviation
Rely on your project manager's task related skills and abilities.	4.6786	5	1.859	5	5.5	2.16
Depend on your project manager to handle an important issue on your behalf.	4.4286	4	1.867	2.75	1.5	2.872
Rely on your project manager to represent your work accurately to others.	3.8571	4	1.948	2.75	1.5	2.872
Depend on your project manager to back you up in difficult situations.	4.9643	5.5	1.818	5.25	5	1.5
Rely on your project manager's work-related judgments.	4.7143	5	1.681	4	4	2.58
Share your personal feelings with your project manager.	3.8214	4	1.982	5.25	6	2.217
Discuss work-related problems or difficulties with your project manager that could potentially be used to disadvantage you.	4.5000	5	1.684	5.25	6	2.217
Confide in your project manager about personal issues that are affecting your work.	3.4286	3	2.052	4	4	2.449
Discuss how you honestly feel about your work, even negative feelings and frustration.	4.1071	4	1.855	3.75	3.5	2.753
Share your personal beliefs with your project manager.	3.6607	4	1.708	4.75	5	2.217

E.3 Trust relationship with project sponsor

The respondents were requested to rate how willing they were to engage in certain behaviours with the project sponsor.

Table 85: Behavioural trust inventory with project sponsor – communication established

	Communication Established (N = 36)			No Communication Established (N =22)		
	Mean	Median	Std Deviation	Mean	Median	Std Deviation
Rely on your project sponsor's task related skills and abilities.	4.6667	5	1.723	3.1818	2.5	2.084
Depend on your project sponsor to handle an important	4.8611	5	1.854	3.6364	4	2.172

issue on your behalf.						
Rely on your project sponsor to represent your work accurately to others.	4.3056	5	2.067	2.8636	2	2.053
Depend on your project sponsor to back you up in difficult situations.	4.8333	5.5	1.796	3.4545	4	2.197
Rely on your project sponsor's work-related judgments.	5.0556	5	1.672	3.6818	3.5	2.337
Share your personal feelings with your project sponsor.	2.9444	2	1.941	1.8182	1	1.500
Discuss work-related problems or difficulties with your project sponsor that could potentially be used to disadvantage you.	3.4444	3.5	1.977	2.4545	2	1.895
Confide in your project sponsor about personal issues that are affecting your work.	2.4444	2	1.646	1.6818	1	1.523
Discuss how you honestly feel about your work, even negative feelings and frustration.	2.8611	2	1.854	1.8636	1	1.670
Share your personal beliefs with your project sponsor.	2.8611	2	1.914	2.1364	1	1.909

E.4 Trust relationship with subject matter expert

The trust that the respondents had in the subject matter expert is reported on in Table 86.

Table 86: Behavioural trust inventory with subject matter expert – communication established

	Communication Established (N = 45)			**No Communication Established (N =12)**		
	Mean	Median	Std Deviation	Mean	Median	Std Deviation
Rely on your subject-matter expert's task related skills and abilities.	5.2444	6	1.720	4.75	5	1.815
Depend on your subject-matter expert to handle an important issue on your behalf.	4.4667	5	2.029	3.25	3	2.137
Rely on your subject-matter expert to represent your work accurately to others.	3.8000	4	1.995	3.25	3	2.094
Depend on your subject-matter expert to back you up in difficult situations.	4.3111	5	1.819	3.25	3	2.416
Rely on your subject-matter expert work-related judgments.	5	6	1.770	4.166	4.5	2.329
Share your personal feelings with your subject-matter expert.	2.8000	2	1.739	2.75	1.5	2.094

Discuss work-related problems or difficulties with the subject-matter expert that could potentially be used to disadvantage you.	3.6667	4	2.022	3	2.5	2
Confide in the subject-matter expert about personal issues that are affecting your work.	2.7778	2	1.869	2.416	2	1.729
Discuss how you honestly feel about your work, even negative feelings and frustration.	3.1333	2	1.960	2.583	1.5	1.928
Share your personal beliefs with the subject-matter expert.	3.0667	3	1.923	2.75	2	1.959

E.5 Trust relationship with end-user

The trust that the respondents had in the end-user is reported on in Table 87.

Table 87: Behavioural trust inventory with end-user – communication established

	Communication Established (N = 46)			**No Communication Established (N =9)**		
	Mean	Median	Std Deviation	Mean	Median	Std Deviation
Rely on your main end-user's task related skills and abilities.	4.8696	5	1.927	2.111	1	1.964
Depend on your main end-user to handle an important issue on your behalf.	3.6522	3.5	2.002	1.666	1	1.118
Rely on your main end-user to represent your work accurately to others.	3.8261	4	2.025	1.555	1	1.013
Depend on your main end-user to back you up in difficult situations.	3.8913	4.5	1.957	1.555	1	0.881
Rely on your main end-user work-related judgments.	4.3913	5	1.807	2	1	1.732
Share your personal feelings with your main end-user.	2.9130	2.5	1.964	1.111	1	0.333
Discuss work-related problems or difficulties with the main end-user that could potentially be used to disadvantage you.	3.2391	3	2.013	1.444	1	1.013
Confide in the main end-user about personal issues that are affecting your work.	2.3478	1	1.753	1.111	1	0.333
Discuss how you honestly feel about your work, even negative feelings and frustration.	2.5435	2	1.858	1.111	1	0.333
Share your personal beliefs with the main end-user.	2.9348	2	2.143	1.222	1	0.440

E.6 Trust relationship within team

The trust that the respondents had in the project team is reported on in Table 88.

Table 88: Behavioural trust inventory within the team

	N = 55		
	Mean	Median	Std Deviation
Rely on your team's task related skills and abilities.	5.5091	6	1.501
Depend on your team to handle an important issue on your behalf.	5.0545	6	1.747
Rely on your team to represent your work accurately to others.	4.8364	5	1.740
Depend on your team to back you up in difficult situations.	5.2364	6	1.502
Rely on your team work-related judgments.	5.4545	6	1.316
Share your personal feelings with your team.	3.8182	4	1.806
Discuss work-related problems or difficulties with the team that could potentially be used to disadvantage you.	4.3455	5	1.776
Confide in the team about personal issues that are affecting your work.	3.5818	4	2.033
Discuss how you honestly feel about your work, even negative feelings and frustration.	4.0727	4	2.089
Share your personal beliefs with the team.	3.8364	4	1.873

E.7 Factor analysis of trust scale

Factor analysis was done to investigate if the ten trust elements could be reduced to only a few to provide a summary of results. The factor analysis results as determined using SPSS are discussed below. The factor analysis process involved firstly determining if data was suitable for factor analysis, secondly extracting the factors identified and finally interpretation.

The first step was to determine if factor analysis would be relevant in each case where trust was measured. The trust scale was used in nine instances and the factor analysis was done in each instance to validate that factor analysis would be appropriate. The results from SPSS are summarised below for all nine instances.

Table 89: Appropriateness results of trust scale factor analysis

	Project Manager		**Project Sponsor**		**Subject Matter Expert**		**End-user**		**Team**
	1	2	1	2	1	2	1	2	
Kaiser-Meyer-Olkin measure of sampling adequacy (KMO)	0.803		0.756	0.801	0.771	0.753	0.680		0.755
Significance (p)	0.000		0.000	0.000	0.000	0.000	0.000		0.000
Correlation coefficients	1.000, 0.585, 0.644, 0.367, 0.703, 0.181, 0.424, 0.189, 0.116, 0.125	1.000, 0.698, 0.698, 0.823, 0.837, 0.139, 0.139, 0.378, 0.728, 0.278	1.000, 0.602, 0.631, 0.175, 0.443, 0.139, 0.078, 0.275, 0.119, 0.133	1.000, 0.667, 0.440, 0.657, 0.687, 0.559, 0.376, 0.514, 0.541, 0.352	1.000, 0.624, 0.418, 0.491, 0.701, 0.184, 0.122, 0.173, 0.138, 0.235	1.000, 0.088, 0.042, 0.161, 0.484, -0.137, -0.05, 0.065, -0.110, -0.147	1.000, 0.529, 0.529, 0.149, 0.487, -0.050, -0.221, -0.065, -0.029, -0.083	1.000, 0.929, 0.781, 0.970, 0.992, 0.742, 0.725, 0.742, 0.742, 0.545	1.000, 0.745, 0.628, 0.652, 0.808, 0.308, 0.322, 0.307, 0.307, 0.392
Factor analysis appropriate (KMO 0.6 or above & significance value 0.05 or less & majority correlation coefficients 0.3 or above)	Yes	n/a	Yes	Yes	Yes	Yes – coefficients is low	Yes	n/a	Yes

[1] Communication established

[2] No communication established

In seven of the nine cases factor analysis was appropriate as deduced in Table 89. In the cases of the trust measure between the practitioner and project manager as well as end-user where no communication existed, the correlation matrix was not positively definite. The sample size for project manager and end-user where no communication existed were four and nine, respectively, which is most probably why the correlation matrix was not positively definite. As factor analysis was definitely appropriate in seven cases, it was further explored.

The second step was to identify how many and which factors should be extracted to summarise the ten trust elements. The eigenvalue had to be 1 or more.

Table 90: Identification of factors for trust scale factor analysis

	Project Manager		**Project Sponsor**		**Subject Matter Expert**		**End-user**		**Team**
	1	2	1	2	1	2	1	2	
Factors with initial eigenvalues of 1 or more (relevant eigenvalue)	1 & 2 (4.678, 2.049)		1 & 2 (4.688, 2.740)	1, 2 & 3 (6.598, 1.395, 1.189)	1 & 2 (4.931, 2.021)	1 & 2 (6.880, 1.651)	1 & 2 (4.591, 2.362)		1 & 2 (5.825, 1.743)
Total variance of factors identified	67.27%		74.28%	91.8 %	69.53%	85.31%	69.53 %		75.67 %

[1] Communication established
[2] No communication established

After reviewing the scree plot of each, it was decided to use factors 1 and 2. In all cases the change in the plot takes place at factor 3 which indicates that it is important to retain factors 1 and 2. This confirms that components 1 and 2 captured most of the variances. Therefore only these two component s were extracted.

Finally the loading on factors was analysed to identify how the summary elements could be grouped into factors.
The following legends were used:
R1: Rely on the stakeholder task related skills and abilities.
R2: Depend on stakeholder to handle an important issue on your behalf.
R3: Rely on stakeholder to represent your work accurately to others.

R4: Depend on stakeholder to back you up in difficult situations.

R5: Rely on stakeholder work-related judgments.

D1: Share your personal feelings with stakeholder.

D2: Discuss work-related problems or difficulties with stakeholder that could potentially be used to disadvantage you.

D3: Confide in stakeholder about personal issues that are affecting your work.

D4: Discuss how you honestly feel about your work, even negative feelings and frustration.

D5: Share your personal beliefs with stakeholder.

Table 91: Trust scale factor analysis – pattern matrix

Element	**Pattern Coefficients**													
	Component 1							Component 2						
	PM[1]	PS[1]	PS[2]	SME[1]	SME[2]	EU[1]	Team	PM[1]	PS[1]	PS[2]	SME[1]	SME[2]	EU[1]	Team
R1	0.764					-0.317			0.573		0.876	0.475	0.735	-0.934
R2	0.753				0.643				0.958		0.752	0.517	0.757	-0.876
R3	0.865				0.629				0.852		0.631	0.527	0.896	-0.75
R4	0.565			0.316	0.569	0.358			0.579		0.531	0.656	0.498	-0.747
R5	0.913								0.899		0.748	0.620	0.586	-0.802
D1		0.835		0.833	0.997	0.864	0.849	0.628						
D2	0.416	0.785		0.758	0.982	0.709	0.766	0.498						
D3		0.869		0.890	0.893	0.833	0.897	0.693						
D4		0.998		0.812	0.989	0.748	0.756	0.793						
D5		0.812		0.807	1.003	0.881	0.81	0.818						

[1] Communication established

[2] No communication established

Table 91 shows that the reliance elements loaded on one factor and the disclosure elements loaded on another. From this it can be concluded that the ten elements in the trust scale could be summarised into two factors, one factor summarising five reliance elements and one factor summarising five disclosure elements.