Cape Peninsula University of Technology

THE IMPACT OF QUALITY MANAGEMENT SYSTEMS DURING A PEBBLE BED MODULAR REACTOR PROJECT. A CASE STUDY

A Dissertation

by

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Lwandiso Lindani Zamxaka

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ABSTRACT

In the nuclear industry, Quality Management Systems are extremely important, especially if one wishes to improve public acceptance of radioactive solutions. There is normally minimum communication between the public and scientists, especially in nuclear science. People are not comfortable with nuclear technology, based on the past history of the Chernobyl catastrophe. Consequently, it is difficult to discuss important and sensitive issues like disposing of nuclear waste. Quality Management Systems can improve public confidence and communication.

Integrated Management Systems in the project planning stage of the project can be a proactive step towards preventing unnecessary delays and costs. There is a perception that quality is implemented or executed at the implementation stage of the Project Life cycle.

Most people believe that a Quality Management System is quality control only and forget the aspect of Quality assurance. The project managers are more concerned with finishing the project and saving costs. Quality holds together the three pillars of project management, which are schedule, costs and scope.

There are a plethora of things that can go wrong if the Quality Management System is not implemented on time, like scope changes that are not captured, monitored and controlled. This can lead to scope creep, unnecessary costs and schedule overruns. If there is no cost control, the project can also overrun its budget and consequently be stopped. PBMR is the only company that is active in new nuclear projects in South Africa, except Koeberg, which was commissioned about thirty years ago.

GLOSSARY OF TERMS

IAEA	The IAEA is the world's nuclear inspectorate, with more than four decades of verification experience. Inspectors work to verify that safeguarded nuclear material and activities are not used for military purposes.
NNR	The NNR is the national institution established by the National Nuclear Regulator Act, Act No 47 of 1999, for the protection of the public, property and environment against nuclear damage.
PBMR	Pebble Bed Modular Reactor is a commissioned nuclear research project based in South Africa.
RD0034	Requirements Document which is developed by the NNR to address Nuclear Safety and Quality management.
QA	Quality assurance, or QA for short, refers to planned and systematic production processes that provide confidence in a product's suitability for its intended purpose.
NPT	The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) was concluded in 1968 and entered into force on March 5, 1970. It is the founding document of multilateral nonproliferation endeavors.
IMS	An Integrated Management System is a single integrated system used by an organisation to manage the totality of its processes, in order to meet the organisation's objectives and equitably satisfy the stakeholders.
QMS	Collective policies, plans, practices, and the supporting infrastructure by which an organization aims to reduce and eventually eliminate non-conformance to specifications, standards, and customer expectations in the most cost effective and efficient manner.

ISO — Popular name for the International Organization for Standardization (IOS), a voluntary, non-treaty federation of standards setting bodies of 130 countries. Founded in 1946-47 in Geneva as a UN agency, it promotes development of standardization and related activities to facilitate international trade in goods and services, and cooperation on economic, intellectual, scientific, and technological aspects. ISO covers standardization in all fields including computers and data communications, but excluding electrical and electronic engineering (governed by the International Electrotechnical Commission or IEC) and telecommunications (governed by the International Telecommunications Union's Telecommunications Standards Sector or ITU-TSS). See also ISO 9000 Series and ISO 14000 Series

AECL — Atomic Energy of Canada Limited (AECL) is a leading-edge nuclear technology and services company providing services to utilities worldwide. It delivers a range of nuclear services: from R&D support, construction management, design and engineering to specialized technology, waste management and decommissioning in support of CANDU reactor products.

TABLE OF CONTENTS

THE RESEARCH REPORT

TABLE OF FIGURES

CHAPTER 1: SCOPE OF THE RESEARCH

1.1 INTRODUCTION AND MOTIVATION

Energy is very essential for national development, like reducing poverty and raising living standards, improving health care, industrial and agricultural productivity. Many countries are considering nuclear energy to achieve their national energy needs. The increases in oil and natural gas prices force people to change their life style to save energy (Wyatt, 1978:13). This is due to lack of indigenous energy resources, the need to increase the diversity of energy resources and mitigation of carbon emission increases.

South Africa has been experiencing power shortages in the past three years, which resulted in many blackouts or power interruptions. Eskom has embarked on returning to service mothballed power stations and building new ones to increase electricity capacity. Nuclear power stations are part of this plan, which, by implication, calls for national and international regulations that must be adhered to.

Pebble Bed Modular Reactor (Pty) Limited (PBMR) was established in 1999 with the intention to develop and market small scale high temperature reactors, both locally and internationally. This research will address the benefits of applying a Quality Management System (QMS), in such a nuclear project. The Eskom Nuclear Programme can learn much from the PBMR project experience, so that they can be more proactive in dealing with their projects. The benefits include shortening the period for nuclear license application, preventing unnecessary project delays, defined processes, high staff morale, reduction of project costs and confidence from stakeholders.

An Integrated Management System is normally adopted in the nuclear industry. The requirement document (RD0034) which is about 60% ISO9001:2008 and 40% nuclear safety respectively, is used by the National Nuclear Regulator (NNR) as a guide to meet nuclear requirements such safety, health, environmental, security, quality and other considerations. Heising (1994:2), predicts that controversies around nuclear projects can drastically go down if the safety records of the United Sates are maintained through Total Quality Control (TQC).

1.2 BACKGROUND TO THE RESEARCH PROBLEM

Vermaercke, Verrezen and Boden (2000:1), found that in the nuclear industry, quality systems are extremely important, especially if one wishes to improve public acceptance of radioactive solutions. There is normally minimum communication between the public and scientists, especially in nuclear science. People are not comfortable with nuclear technology, based on past history such as the Chernobyl catastrophe. Consequently, it is difficult to discuss important and sensitive issues like disposing of nuclear waste. Quality Management Systems can improve public confidence and communication.

Hawkins and Pieroni (1991:1) found that a review executed in the 1980s showed that there were challenges in implementing quality assurance requirements depending on a particular International Atomic Energy Agency (IAEA) member state. Some of the challenges identified included the following:

- Interpreting quality assurance requirements as solely regulatory, as if they had no beneficial effect on work performance.
- Viewing a good quality assurance programme as only demanding many written documents and procedures, i.e. it is only concerned with ‘paper work’.
- Assigning responsibility for quality only to the quality assurance unit.
- Auditing for compliance with formal requirements without analyzing the final results.
- Not recognizing that management and workers have the main responsibilities in the achievement of quality assurance results.
- Being unaware of the importance of adequate qualification and motivation of personnel.
- Not assessing the effectiveness of the quality assurance programme.
- Not providing clear management support and commitment to the implementation of the quality assurance programme.

IAEA (2007:14), states that the advantages of a management system in a nuclear project can be identified as follows:

- Assuring a common understanding of key aspects of the safety culture within the organisation.
- Providing the means by which the organization supports individuals and teams to carry out their tasks safely and successfully, taking into account the interaction between individuals, technology and the organisation.
- Reinforcing learning and questioning attitudes at all levels of the organization.
- Providing the means by which the organization continually seeks to develop and improve its safety culture.

The term Quality Management System means collective policies, plans, practices, and the supporting infrastructure by which an organization aims to reduce and eventually eliminate non-conformance to specifications, standards, and customer expectations in the most cost effective and efficient manner. In a nuclear environment, an Integrated Management System is normally employed. The Integrated Management System is a single integrated system used by an organisation to manage the totality of its processes in order to meet the organisation's objectives, and equitably satisfy the stakeholders. IMS covers both Quality and safety management aspects.

Integrated Management Systems in the project planning stage of the project can be a proactive step towards preventing unnecessary delays and costs. There is a perception that quality is implemented at the implementation stage of the Project Life cycle. See Figure 1.1

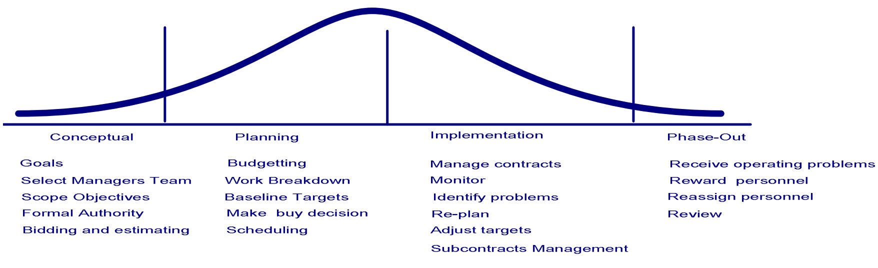

Figure 1.1: Project Life Cycle, (**Source:** Widerman 2004:6)

Most people believe that a Quality Management System is quality control only and forget the aspect of Quality assurance. The project managers are more concerned with finishing the project and saving costs. Quality holds together the three pillars of project management, which are schedule, costs and scope.

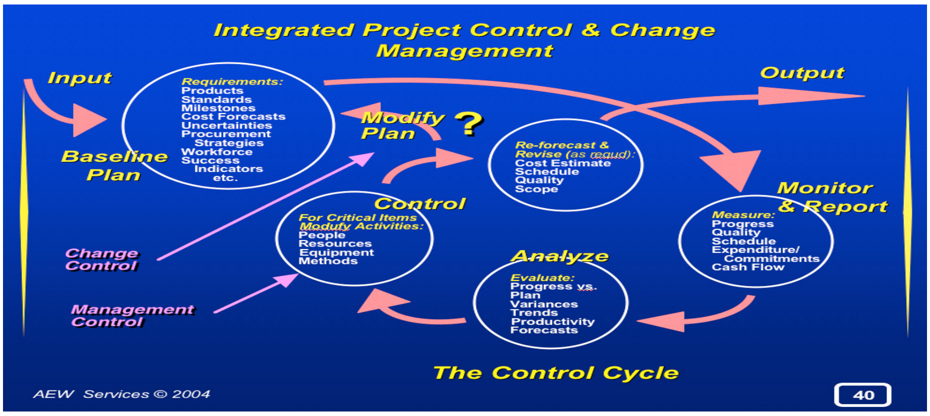

Figure 1.2: Cost control Concept**,** (**Source:** Widerman, 2005:1)

There are a plethora of things that can go wrong if the Quality Management System is not implemented on time, such as scope changes that are not captured, monitored and controlled. See Figure 1.2. This can lead to scope creep, unnecessary costs and schedule overruns. If there is no cost control, the project can also overrun its budget and consequently be stopped. PBMR is the only company that is active in new nuclear projects in South Africa, except Koeberg, which was commissioned about thirty years ago.

1.2.1 Statement of the research problem

Against the above background, the research problem to be researched in this dissertation reads as follows: "The non implementation of a Quality Management System has an adverse effect on the pebble bed modular reactor project licensing process."

1.3 THE RESEARCH QUESTION STATEMENT

The research question forming the crux of this dissertation reads as follow: 'Is the implementation of a Quality Management System necessary when implementing a nuclear project and what impact would the absence thereof have on overall project execution'

1.3.1 Investigative (sub-) questions

The investigative sub-questions to be researched in support of the research question read as follows:

- Is the implementation of a Quality Management System necessary when implementing the Nuclear Project, and are there any lessons learnt by not implementing a Quality Management System at the planning stage of the Project Life Cycle?
- Was there any commitment of the PBMR senior management in implementing the Quality Management System at the planning stage of the project life cycle?
- Did the PBMR project management department experience problems as a result of a Quality Management System not being implemented at the planning stage of the project life cycle?
- Did the PBMR quality department experience any compliance problems as a result of a Quality Management System not being implemented at the planning stage of the life cycle project?

1.4 PRIMARY RESEARCH OBJECTIVES

The research objectives to be considered in this research project are the following:

- To investigate the impact of a Quality Management System on a nuclear project.
- To determine the effect of quality in the project triangle, cost, scope and schedule.
- To determine the influence of project managers in implementing a Quality Management System in a project.

- To investigate if implementing a Quality Management System can help the company meet the minimum regulatory requirements, when applying for a nuclear license.

1.5 THE RESEARCH PROCESS

The research process provides insight into the process of 'how' the research will be conducted, from formulating the research proposal to final submission of the dissertation. The fundamental stages in the research process common to all scientific based investigations are listed below:

- Remenyi, Williams, Money and Swartz *(*2002:64-65), explain the research process as consisting of eight specific phases, namely:
  - Reviewing the literature.
  - Formalizing a research question.
  - Establishing the methodology.
  - Collecting evidence.
  - Analyzing the evidence.
  - Developing conclusions
  - Understanding the limitations of the research.
  - Producing management guidelines or recommendations.

- According to Collis and Hussey (2003:16), there are six fundamental stages in the research process, namely:
  - The identification of the research topic.
  - Definition of the research problem.
  - Determine how the research is going to be conducted.
  - Collection of the research data.
  - Analysis and interpretation of the research data.
  - Writing up of the dissertation or thesis.

After detailed consideration of these diverse types of processes, the researcher will adopt the Collis and Hussey method. Although the Remenyi *et al* method is good; Collis and Hussey's method will suite this research, as it is direct and simple to follow.

1.6 THE RESEARCH DESIGN AND METHODOLOGY

Falling within the phenomenological (qualitative) paradigm, action research will be used in this research study, which a type of applied research designed to find an effective way of bringing about conscious change in a partly controlled environment; for example, a study aimed at improving communications between management and staff in a particular company. The main aim of action research is to enter into a situation, attempt to bring about change and monitor the results. There are clear tangent planes between action research and case study research.

Action research is described by Gummesson (2000:116) as, "…a method of doing case study research". According to Collis and Hussey (2003:66-67), "…action research is a type of applied research designed to find an effective way of bringing about a conscious change in a partly controlled environment". Coghlan & Brannick (2002:6-7), list the following most salient features of 'action research':

- Action researchers take action.
- Action science always involves two goals: 'Solve a problem for the client' and 'contribute to science'. This means being 'a management consultant' and an 'academic researcher' at the same time.
- Action research is interactive. It requires cooperation between the researcher and the client personnel, and continuous adjustments to new information and new events.
- Action science is applicable to the understanding, planning and implementation of change in business firms and other organizations.
- It is essential to understand the ethical framework, the values norms within which action research is used in a particular context.
- Action research can include all types of data gathering methods, but requires the total involvement of the researcher.
- Constructively applied pre-understanding of the corporate environment and of the conditions of business is essential.

- ‘Management action research’ should be conducted in real time, though retrospective research is also acceptable.
- The ‘management action research’ paradigm requires its own quality criteria.

Coghlan and Brannick (2002:17-18), describe the action research cycle as follows:

- **Diagnosing:** Diagnosing involves naming what the issues are, however provisionally, as a working theme on the basis of which action will be planned and taken.
- **Planned action:** Planning action follows from the analysis of the context and purpose of the project, the framing of the issue and the diagnosis, and is consistent with them.
- **Taking action:** Plans are implemented and interventions are made.
- **Evaluating action:** The outcomes of the action, both intended and unintended, are examined with a view to seeing:
  - If the original diagnosis was correct.
  - If the action taken was correct.
  - If the action was taken in an appropriate manner.
  - The above, which feeds into the next cycle of diagnosis, planning and action.

1.7 COLLECTING PRIMARY DATA USING ‘QUESTIONNAIRES’

Questionnaires, fall within the ambit of a broader definition of ‘survey research or ‘descriptive survey’. The concept of ‘survey’ is defined by Remey et al. (2002:290) as: “……the collection of a large quantity of evidence usually numeric, or evidence that will be converted to numbers, normally by means of a questionnaire”. A questionnaire is a list of carefully structured questions, chosen after considerable testing with a view to eliciting reliable responses from a chosen sample. The aim is to establish what a selected group of participants do, think or feel. A positivistic approach suggests structured ‘closed’ questions, while a phenomenological approach suggests unstructured ‘open-ended’ questions.

For the purpose of this research 'questionnaires' will be used to collect data. For this survey, 8 employees systematically selected from the Quality management department and Project management department. 100% participation from both the project management and quality management departments was achieved, from 3 quality management department participants and 5 project management department participants. Six (6) managers randomly selected from PBMR (Pty) Ltd, representing 60 managers, also participated in the survey.

1.8 DATA VALIDITY AND RELIABILITY

According to Collis and Hussey (2003: 186), 'validity' is concerned with the extent to which the research findings accurately represent what is happening. More specifically, whether the data is a true picture of what is being studied. According to Cooper and Schindler (2006: 318-320), three major forms of validity can be identified, namely 'content validity', 'criterion-related validity' and 'construct validity', which is expanded upon below to provide a holistic perspective of each of the concepts:

- **Content validity:** Content of the measuring instrument is the extent to which it provides adequate coverage of the investigative (sub-) questions guiding the study. If the instrument contains a representative sample of the universe of subject matter of interest, then content validity is good.
- **Criterion-related validity:** Reflects the success of measures used for prediction or estimation. Any criterion measure must be judged in terms of the following four qualities:
    - Criterion is relevant: If the criterion is defined and scored in the terms we judge the proper measures of success.
    - Freedom from bias: when the criterion gives each respondent the opportunity to score well.
    - Reliability: A reliable criterion is stable and responsible.
    - Availability: The information specified by the criterion must be available.
- **Construct validity:** In attempting to evaluate construct validity, both the theory and the measuring instrument being used should be considered.

> According to Collis and Hussey (1979:59), construct validity relates to the problem that there are a number of phenomena, which are not directly observable, such as motivation, satisfaction, ambition and anxiety. These are known as hypothetical constructs, which are assumed to exist as factors which explain observable phenomena. For example, you may observe someone shaking or sweating before an interview. However, you are not actually observing anxiety, but the manifestation of anxiety.

Reliability (also referred to as 'trustworthiness'), is concerned with the findings of the research (Collis & Hussey, 2003: 186). The findings can be said to be reliable if you or anyone else repeated the research and obtained the same results. There are three common ways of estimating the reliability of the responses to questions in questionnaires or interviews, namely the 'test re-test method', 'split-halves method' and the 'split-halves method' and 'internal consistency method':

- **Test re-test method:** The questions are asked of the same people, but on two separate occasions. Responses of the two occasions are correlated and the correlation coefficient of the two sets of data computed, thus providing an index of reliability.
- **Split-halves method:** The questionnaires or interview record sheets are divided into two equal halves. The two piles are then correlated and the correlation coefficient of the two sets of data computed, thus providing an index of reliability.
- **Internal consistency method:** Every item is correlated with every other item across the entire sample and the average inter-item correlation is taken as the index of reliability.

1.9 ETHICS

In the context of research, according to Suanders et al. (200: 130), "…ethics refers to the appropriateness of your behaviour in relation to the rights of those who become the subject of your work, or are affected by it". The following will be this researcher's conduct and behaviour guide when conducting the research:

- **Informed consent**: Participants will be informed of the nature of the study and will be given a choice to participate or withdraw when they feel uncomfortable about the research.

- **Right to Privacy:** The right to privacy of the participant will be respected and the performance of the participant will be strictly confidential.

- **Honesty with Professional Colleagues:** The findings will be reported in a complete and honest fashion, without misrepresenting what the participants have done. The data will not be fabricated to support the research conclusion.

1.10 RESEARCH ASSUMPTIONS

It is assumed that in most nuclear build projects, a Quality Management System is implemented at the execution stage of the project, without considering it at the planning stage. The lack of implementing a Quality Management System will lead to project delays; affect the nuclear license application and lead to unnecessary costs, as a result of re-work and other consequences of not implementing the Quality Management System correctly.

1.11 RESEARCH CONSTRAINTS

Research constraints (limitations or de-limitations); pertain to any inhibiting factor which would in any way constrain the research student's ability to conduct the research in a normal way. According to Colliss and Hussey (2003: 128-129), 'limitations' identify weaknesses in the research, while 'de-limitations' explain how the scope of the study was focused on only one particular area or entity, as opposed to say a wider or holistic approach. The research constraints are as follows:

- **Limitations:** Upon investigation it was realised that most nuclear research focusses on nuclear safety and protective engineering designs. It should be noted that the focus of this research is on 'quality'.
- **De-limitations:** The research will be confined in the nuclear industry and the questionnaires will be specific to PBMR (Pty) Ltd.

1.12 CHAPTER AND CONTENT ANALYSIS

The chapter and content analysis as it applies to this dissertation reads as follows:

- **Chapter 1 – Scope of the research:** Includes the background for the research, the research process, the research problem and question, the research design and methodology, research assumptions and constraints, and key research objectives.
- **Chapter 2 – Pebble bed modular reactor Project: Introduction:** Background and holistic view of pebble bed modular reactor projects.
- **Chapter 3 – Nuclear power plant project dynamics: A literature review:** The international experience, guidelines and views on nuclear project power plants.
- **Chapter 4 – Research and data acquisition:** Research and interviewing participants at PBMR (Pty) Ltd.
- **Chapter 5 – Data Analysis and evaluation:** Analysis of the results of the tests conducted within the ambit of chapter 4.
- **Chapter 6 – Recommendations and conclusion**

1.13 SIGNIFICANCE OF THE PROPOSED RESEARCH

This research will address the benefits of applying a Quality Management System, in a nuclear project. Eskom Nuclear Programme can learn from PBMR's experiences, so that they can be more proactive in dealing with their projects. Eskom will benefit as follows:

- Shortened period for the nuclear license application.
- Preventing unnecessary project delays.
- Defined processes.
- High staff morale.
- Reduction of project costs.
- Confidence from the stakeholders.

The International Atomic Energy Agency showed interest in this research. They indicated that no one has done research on this issue before and would welcome reviewing the outcomes.

CHAPTER 2: PEBBLE BED MODULAR REACTOR

2.1 INTRODUCTION

Pebble Bed Modular Reactor (PBMR) is a South African Company established in 1999 with Eskom Limited as the major shareholder, Other shareholding in the company was held by the Industrial Development Corporation (IDC), British Nuclear Fuels plc (BNFL), and Exelon. In later years Exelon pulled out of the project and BNFL sold its stake in the project to Westinghouse Toshiba. The intention of the PBMR project was to develop and market small-scale, high-temperature reactors both locally and internationally. The company employed 800 people, which most of whom were engineers and scientists, and is based in Centurion near Pretoria, South Africa. Due to financial constraints the project was reduced to about 250 people, with the intention of later closing the entire project in due course.

The PBMR is a helium-cooled High Temperature Reactor (HTR) with a pebble bed reactor core. It is a Generation IV reactor design with applications ranging from electricity generation and process heat applications. Unlike conversional nuclear power plants, the PBMR promised very high efficiencies and attractive economics, without compromising the high levels of passive safety expected of advanced nuclear designs.
Gas-cooled reactor technology started in 1947 at the Oak Ridge National Laboratory in the United States of America. Other countries involved in the development of gas-cooled reactors include the United Kingdom (Dragon Project), Germany (AVR and THTR300), China (HTR-10), and Japan (HTTR).

2.2. MANAGEMENT

2.2.1 Assurance

The Pebble Bed Modular Reactor's legal governance and compliance is fundamental to providing assurance in terms of Safety Health Environment

Quality (SHEQ), risk management and internal audit. In their quest to provide the necessary assurances, Pebble Bed Modular Reactor's executive management, and employees are continuously assessing, managing, reporting and improving the process. Facilitated workshops, training and support are provided for the process and responsibilities are included in and reviewed through performance compacts and service level agreements.

2.2.2 Risk Management

The Pebble Bed Modular Reactor (Pty) Ltd board is accountable for the process of risk management and the system of internal control. These are reviewed regularly for effectiveness. Relevant policies are established and communicated by management across the company. The Pebble Bed Modular Reactor board retains ultimate control through the final review and adoption of key risk factors affecting the company. Risk management is an ongoing process and is focused on identifying, assessing, managing and monitoring all known forms of risk across the company.

2.2.3 Safety, Health, Environment and quality

Safety, Health, Environment and Quality Management Systems are implemented throughout the company in accordance with the requirements of international and national regulatory requirements. These systems not only address requirements but also provide values for employee behaviour in creating a culture of "safety first".

The commitment of the company's executives ensures that a Quality Management System meets all requirements to maintain certification under the ISO 9001:2000 standard. Pebble Bed Modular Reactor implements the environmental management requirements of IS0 14001:2004 and safety and health management requirements of OHSAS 18001:2007.

2.3. TECHNOLOGY

2.3.1 Background

Technology development is required to enhance the passive and safety attributes of the pebble bed modular reactor; to make it environmentally more attractive; to provide means to measure the hottest fuel temperature; and to improve the performance characteristics of the fuel.

2.3.2 Test facilities

Pebble Bed Modular Reactor's test facilities are critical to effective licence approval and design maturity of the reactor and fuel plant. The progress of facilities is tangible and practical evidence of pebble bed modular reactor's engineering, design and operational maturity.

2.3.3 Helium Test Facility (HELIUM TEST FACILITY)

The helium test facility was designed and constructed to provide a high-temperature, high-pressure helium environment. The helium test facility will enable the first full-scale operating tests of the critical components of the reactivity control system, reserve shutdown system and fuel-handling system. Active components such as valves and measuring equipment will be tested at high temperatures in a high-pressure helium environment, simulating reactor operating conditions.

2.3.4 Heat Transfer Test Facility (HTTF)

The Heat Transfer Test Facility consists of a High Pressure Test Unit and a High-Temperature Test Unit (HTTU). These units will perform high-pressure and high-temperature core heat transfer tests. These heat transfer tests will validate heat transfer correlations used in the analyses done to determine the heat transfer in and from the core during normal conditions as well as following upset events.

These thermo-hydraulic core calculations have laid the platform for the design optimisation and component design specifications of the Pebble Bed Modular Reactor's Brayton thermodynamic cycle.

2.3.5 Fuel Development Laboratories

The Fuel Development Laboratories are situated on the Necsa site and are being operated under the Necsa nuclear licence. They consist of four laboratories, kernel, casting fuel-coating sphere manufacturing and quality control laboratories.

2.4. SAFETY AND ENVIRONMENT

2.4.1 Safety culture

Organisational culture is the shared basic assumptions that are developed in an organisation as it learns and copes with problems. These are the basic assumptions that are taught to new members of the organisation as the correct way to perceive, think, act and feel. Culture is the sum total of a group's learning and is demonstrated by its members' values and behaviour.

In addition to a healthy organisational culture, each nuclear facility needs a strong safety culture. This is because of the special characteristics and unique hazards of the technology, eg radioactive by-products, concentration of energy in the reactor core, and decay heat.

Implied in the safety culture definition is the notion that:

- Nuclear power plants are designed, built and operated to produce power in a safe, reliable and efficient manner;
- The concept of safety culture applies to every employee in the nuclear organisation, from the Board of Directors to the individual contributor;
- The focus is on nuclear safety, although the same principles apply to radiological safety, industrial safety and environmental safety; and
- Nuclear safety is the first value adopted at a nuclear station and is never abandoned.

Safety is espoused and enshrined in all actions of each and every Pebble Bed Modular Reactor employee. No one in Pebble Bed Modular Reactor is exempt from the obligation to ensure safety first. By embedding safety in all Pebble Bed Modular Reactor project activities, a safe workplace and environment is established.

2.4.3 Training and development

Safety culture and training form an integral part of Pebble Bed Modular Reactor's training and development initiatives. Induction and orientation training is conducted on a regular basis. As part of the overall induction course, Safety, Health, Environment and Quality (SHEQ) management awareness training is presented to new employees.

2.5. QUALITY

Pebble Bed Modular Reactor successfully retained its ISO 9001 compliance certificate after an interim audit was performed by the accredited ISO 9001 certification body TÜV Quality Services South Africa in November and December 2007. The scope of this activity was extended to include the Pebble Bed Modular Reactor Helium Test Facility at Pelindaba. The successful outcome of the certification audit resulted in the scope of the Pebble Bed Modular Reactor ISO 9001 compliance certificate being extended to include the operation of the Helium Test Facility.

An Enterprise Improvement process was introduced in September 2007. This is a process of identifying, reporting and resolving non-conformances, events and opportunities for improvement. Various internal audits were conducted to verify the ability of Pebble Bed Modular Reactor to meet customer and regulatory requirements and to determine the effectiveness of the Quality Management System. The internal audit programme was fully implemented ensuring that every Pebble Bed Modular Reactor department was audited at least once during the year. A number of significant management and technical processes were also audited. The results of internal audits indicate that the Quality Management System is generally effective.

As a vehicle for continual improvement, Pebble Bed Modular Reactor is embarking on a programme of self-assessments. This is a process whereby a business unit analyses its performance, identifies its strengths and weaknesses and implements measures for improvement. A procedure has been established to document the self-assessment process.

2.6. HEALTH AND ENVIRONMENT

Pebble Bed Modular Reactor is committed to:

- Ensuring compliance of health and safety in all working environments;
- Ensuring compliance of nuclear material safeguards;
- Documenting environmental management strategy;
- Implementing environmental management policy;
- Ensuring resource awareness; and establishing operational performance management using best practice criteria.

The Pebble Bed Modular Reactor is an environmental-friendly way of electricity generation. It does not emit any carbon dioxide or other gases contributing to the effect of global warming like a fossil fuel power plant. The high net efficiency permits the reactor to eject 10% less waste heat to the surroundings compared to current operating nuclear power plants. Pebble Bed Modular Reactor is a proliferation-resistant reactor system with downstream opportunities to close the fuel cycle. Pebble Bed Modular Reactor offers a unique solution to government relating to its objective of managing energy-related environmental and health impacts. Direct occupational health risks and global greenhouse issues can be mitigated through the appropriate use of nuclear energy. Energy policy in South Africa is closely linked to environmental issues. In the Pebble Bed Modular Reactor context, the Clean Development Mechanism (CDM) and the Framework for considering market based Instruments to support environmental fiscal reform in South Africa (National Treasury) is of interest, and, in the Clean Development Mechanism case, of potential benefit to Pebble Bed Modular Reactor:

The Clean Development Mechanism is a strategy based on the Kyoto Protocol to reduce greenhouse gas emissions by allowing industrialised countries to invest in projects that reduce emissions in developing countries. Clean Development

Mechanism could result in additional investment being available for activities in South Africa, which result in a less carbon-intensive economy.
The national treasury framework is focused on introducing environmental taxes and charges to support sustainable development. Nuclear activities are specifically mentioned under ‘rehabilitation funds and guarantees’ in the context of nuclear power station decommissioning and treatment of spent nuclear fuel.

Eskom, Pebble Bed Modular Reactor and the National Nuclear Regulator have all agreed on a staged licensing process. The stages are:

- Construction and installation,
- Fuel to site/fuel load/initial criticality and power ascension,
- Operation; and decommissioning.

At each licensing stage, a full safety case demonstrating compliance with regulatory requirements must be submitted to the NNR.

2.7. EIA PROCESS

The construction phase of the Pebble Bed Modular Reactor project is subject to obtaining a positive Record of Decision (RoD) on the environmental impact assessment (EIA) study. The subsequent environmental impact assessment processes included extensive public participation, numerous interactions and public meetings and extended periods for comment.

2.8. LICENSING

Pebble Bed Modular Reactor (Pty) Ltd. is engaged on multiple projects that will further the development and deployment of the Pebble Bed Modular Reactor design, both in South Africa and in the international community. Within South Africa, the National Nuclear Regulator (NNR) – an independent statutory body established under the National Nuclear Regulator Act, Act 47 of 1999 – is responsible for issuing licenses related to the siting, design, construction, operation, decontamination, decommissioning and closure of any nuclear installation. Pebble Bed Modular Reactor is actively working with the National Nuclear Reactor and with Eskom, the national electricity provider, in establishing and updating the safety documentation needed to support licensing of the Pebble Bed Modular Reactor Demonstration Power Plant (DPP) project to be sited at Koeberg near Cape Town, South Africa.

Eskom, as applicant and future licence holder, is responsible for submitting all licensing documentation to the National Nuclear Reactor that is needed for it to grant the Nuclear Installation Licence for the Demonstration Power Plant. Pebble Bed Modular Reactor is supporting Eskom in these activities, to include the development of strategies to resolve the set of Key Licensing Issues that have been defined for the project, the completion of a Safety Analysis Report (SAR), and the submission of supporting documents that, together with the Safety Analysis Report, fully describe the Safety Case for the Pebble Bed Modular Reactor Demonstration Power Plant. Additionally, Pebble Bed Modular Reactor and Eskom are reviewing a series of Requirements Documents, License Documents, and License Guides with the National Nuclear Reactor that will form the regulatory requirements set for the design, construction, start-up, and safe operation of the Demonstration Power Plant.

2.9. PEBBLE BED MODULAR REACTOR PROJECT STATUS

From a small nuclear engineering company with barely 100 employees at its inception in 1999, Pebble Bed Modular Reactor (Pty) Ltd has grown into one of the largest nuclear reactor design and engineering companies in the world. In addition to the core team of some 800 people at the Pebble Bed Modular Reactor head-office in Centurion near Pretoria, more than a 1000 people at universities, private companies and research institutes are involved with the project.

Pebble Bed Modular Reactor (Pty) Limited is a public-private partnership comprising the South African government, nuclear industry players and utilities. The Pebble Bed Modular Reactor is a strategic national project due to its significance to South Africa and its potential in international markets, as a prospective provider of safe, clean energy. Pebble Bed Modular Reactor’s goal is to be one of the first organisations that successfully commercialises pebble bed technology for the world’s energy market. Subject to regulatory and other approvals, the first pebble bed reactor plant could be commissioned at Koeberg near Cape Town around 2020.

This will be the first time that South Africa is designing, licensing and building its own nuclear reactor plant. The successful deployment of this leading-edge technology has the potential to make a significant contribution to local and international energy supply. In addition, it will contribute to the transformation of South Africa's current resource-based economy. There is speculation regarding downsizing or closure of the Pebble Bed Modular Reactor project. "Officially, the PBMR Company is still busy with the restructuring – and the downsizing process announced early this year, in terms of which the workforce of 800 was to be cut by 75%, to 200, is still under negotiation with the unions. The board and management are also awaiting directives from the Department of Public Enterprises " (Keith Campbel, 2010).

2.10. GOVERNMENT SUPPORT

The South African Government recognises the importance of energy security and supply and the fact that Pebble Bed Modular Reactor can contribute significantly to local economic growth and development by forming part of a technology-intensive nuclear manufacturing sector which could, in future, export this technology. The Government therefore regards the Pebble Bed Modular Reactor project as one of the most important capital investment and development projects yet undertaken in the country. In July 2009, the then Minister of Public Enterprises, Ms Barbara Hogan, gave the assurance that the government remains committed to the Pebble Bed Modular Reactor programme.

She said Pebble Bed Modular Reactor could provide the South African economy not only with electricity, but also other applications such as clean-process heat. It is therefore and ideal programme to increase the country's exports. "The Pebble Bed Modular Reactor project and company play an extremely important role in skills development in this country, especially since the nuclear industry requires functionalities which far exceed those of other industries," (Hogan, 2009).

2.11 LATEST STATUS

On the 14 of August 2010, according to the internal communication in PBMR Company, the Chief Executive pronounced that the Government will no longer support the PBMR project. The current 255 employees will be retrenched at the end of October 2010.

CHAPTER 3: NUCLEAR POWER PLANT PROJECT DYNAMICS: A LITERATURE REVIEW

3.1 INTRODUCTION TO PROJECT MANAGEMENT

Pinkerton (2003:4.5), defines a project as a plan, scheme, an organized undertaking. Schwalbe (2006:4), defines a project as "a temporal endeavour undertaken to create a unique product, service, or result". Projects come in different types, sizes. They may range from thousands of rand to billions of rand. A project is unique, temporary, requires resources, has a sponsor, and involves uncertainty. Pinkerton (2003:7), explains that the project is composed of eight elements as follows:

- Project origination and definition,
- Pre-project planning and organisation,
- Design, procurement, and pre-testing,
- Construction and installation,
- Training,
- Preoperational testing,
- Start-up (commissioning) and initial operations and,
- Closeout and make-good analysis.

According to Schwalbe (2006:7), project management can be defined as "the application of knowledge, skills, tools, and techniques to project activities to meet project requirements". Key elements of the project management framework are as follows:

- Scope management,
- Time management,
- Cost management,
- Quality management,
- Project integration management,
- Human resource management,
- Communications management,
- Risk management, and

➢ Procurement management.

Integration of all the above elements can pose a challenge. See Figure 3.1.

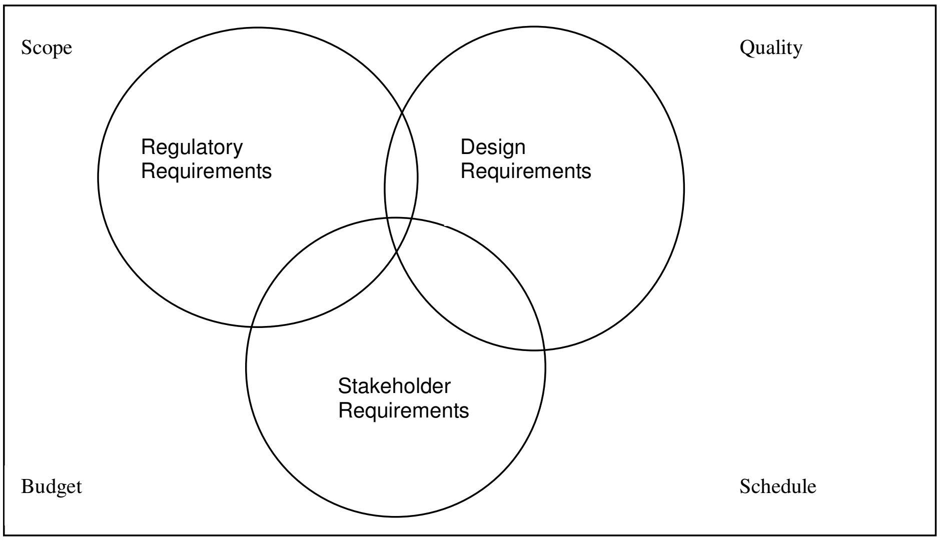

Figure 3.1: Project challenge-integration, (**source:** Campagna, Lenyk and Hess, 2006)

The International Atomic Energy Agency (IAEA) (1988:18), states that project management is the function of defining, steering, controlling and correcting a project or major parts of it. It can also be defined as a technique for the efficient expenditure of resources to achieve a desired result. It defines the work to be done, estimates the resources that will be required to accomplish the work, controls the quality of the work, monitors the expenditure of the resources, monitors the progress towards the final objectives, and makes corrections in all the foregoing as may be required to achieve the ultimate goal.

The IAEA (2007: iii), requires that the start of a nuclear power plant project involves several complex and interrelated activities with long duration. They estimate that the time between the initial policy decisions by a State to consider nuclear power up to the start of operation of its first nuclear power plant is about 10 to 15 years and that, before specific project management can proceed, several key infrastructure issues have to be in place.

3.1.1 Project origination and definition

Whelton (2004:3), (citing Winch *et al.* 1998), explains that project definition is known in construction as a strategic facility planning, needs assessment, requirements processing, and project programming normally practised by architects. It is a briefing session with a client to turn the client's desire for a built product into a clear brief for the project development team. It is also seen as a process prior to final investment decision. Project definition formalises the purpose of the organisation and the purpose of the physical project. In large multi-faced organisations, it is sometimes difficult to realise and distinguish real needs from wants or desires from different stakeholders. It is the imperative at this stage that all the stakeholders are clear regarding their needs.

Pinterton (2003:27-50), concurs with Whelton (2004:3) that capital projects can originate from several places or perceived needs. Most of the investors can get carried away by the rhetoric of a good salesperson and those projects end up being white elephants. The need for a capital project normally arises from market demand, governmental or company mandate, and cost reduction exercises. Defining the project need can be relatively easy if the government or company mandate and market demand are met. The project definition must be linked to the long term strategy of the company, as the short term strategy can be met by the project definition, but long term strategy may not look good in terms of return on investment. Managers in the organisation must first justify the project need, as the project is still a perceived need until one or more factor as already mentioned earlier (Mandate, market demand and cost reduction) is thoroughly addressed, the project remains a perceived need.

The World Nuclear Association (WNA) (2008:12-13), states that the prime participants in a nuclear project are:

- **Government** - This is responsible for overall energy policy and, in some cases, financing.
- **Market** - formed by electricity customers wanting electricity at a competitive price.

- **Utility (generator)** - which is ultimately responsible for developing the complete project.
- **EPC (engineering, procurement and contractor) contractors** - engineering, procurement and construction companies which are responsible to the owner for delivery according to schedule and budget.
- **Vendors** - which are responsible for supplying equipment and technology to either the owner, the EPC contractor, or as part of a joint venture or consortium, according to schedule and budget
- **Safety authority** - which is responsible for addressing all matters related to protecting public safety and the environment, from the design stage to plant operation and fuel management.

Stakeholder participation is a key to allaying legitimate concerns about waste management and the safety and security of nuclear installations. Public hearings and debate are sound means for improving dialogue and ultimately saving time. Providing information to the public and their representatives is essential to building social trust. Such information also serves a documentary function, placing in the open record what has been proposed and approved, to avoid the possibility of recurrent argument.

3.1.2 Pre-project planning and organisation

According to Pinkerton (2003:89), "pre-project is the planning that takes place before the project funding is appropriated, and which is both dependent on, and feels corporate strategic planning efforts". Divita, Fischer and Kunz (1998:2), describe Pre-project planning as "the process of creating, analyzing, and evaluating project alternatives during the early planning phase to support a decision whether or not to proceed with the project and to maximize the likelihood of project success". In a nuclear project, the International Atomic Energy agency (2007:16), states that this stage "Is defined as the period starting with the decision to consider nuclear energy as a potential source for producing electricity within the national energy system and ends with the launch of a pre-investment (feasibility) study for the first NPP project". This stage can be also described as conceptual preparatory activities that address the technical, economic, and regulatory investigations needed to justify the nuclear project. Pinkerton (2003:89), expresses the view that the benefits of the pre-project planning is that it provides the strategic information to address risks and to decide whether to commit corporate resources.

3.1.3 Design, procurement, and pre-testing

Pinkerton (2003:161-192), points out that project design and procurement of equipment, and materials are critical elements from planning to the execution of the project. This is the stage in the project in which the project team is assembled, subject matter experts and qualified vendors and suppliers are involved and guided by the inputs of the stakeholders. Project design consists of many factors, but can be highlighted as follows:

- Gathering input from a multidimensional project team,
- Evaluating and analysing team input for selection of the best design,
- Procuring on quality bases,
- Considering labour relations and incentives issues,
- Initiating training programme development,
- Planning for off-site integrated testing and inspection and,
- Revision and refinement of start-up planning and strategy based on design, schedule, and testing requirements.

3.1.4 Training

Schwalbe (2006:203), recommends that project managers must encourage the project team members to take specific training courses to improve individual and team development. Cooke and Tate (2005:158), are of the opinion that to maintain a qualified team training is needed. Although the team is selected to ensure that proper skills and experience necessary to do the work is available, training is needed to communicate the way tools and processes will be applied. Pinkerton (2003:142), holds the view that the operational and maintenance training is critical to the success of the project. Training plans must be initiated early to fund the training programme to ensure that the operating and maintenance personnel are fully trained and ready for pre-commissioning and commissioning participation.

IAEA (1998:107), states that one main responsibility of the utility is the training of operating personnel. This responsibility can be shared by other project partners and can be established in the contractual arrangements. The personnel should be trained in advance, 3 to 4 years before the start of the operation. The Power station manager must be appointed as early as possible to be involved in early activities in cooperation with the project manager. The project manager is responsible for ensuring that the training is appropriate and follows the plans and schedules. The personnel under training should participate in the commissioning of the plant and be involved in the preparation of the manuals and procedures for operation and maintenance, which should be drafted during this period.

3.1.5 Preoperational testing

Pinkerton (2003:215-221), defines preoperational testing as "a pre-emptive strike against start-up problems". If this testing is thoroughly executed the chances of having problems during the commissioning are minimal. The pre-operational tests are conducted when the project is about 75 to 80% complete. At this stage the project responsibilities are clearly defined to the team, the sequence test schedule is distributed to the organisation, the key events schedule is distributed as well, test results forms, and test procedures are designed, reviewed and signed.

According to Liu, Khan, Chen and Khan (2007:1-5), in nuclear projects this stage is also used to conduct seismic walkdown. The objectives of seismic walkdown are to:

- Provide an additional verification that seismically qualified structures, systems and components have been installed adequately.
- Verify that seismically qualified systems and components have been adequately protected by National Building Code of the country.
- Determine whether seismically qualified systems and components have been adversely affected by field changes.

- Ensure safe access from the main control room to the secondary control area after an earthquake.
- Uncover potential seismic induced hazards such as missiles, fire, flooding.
- Gather information and data about any observed design or installation deficiencies for further evaluations.
- Record good or bad designs and installations to be later used as feedback to the design process.

The seismic walkdown involves orientation training, walkdown planning, conducting walkdown, and documenting and closeout seismic walkdown.

3.1.6 Start-up (commissioning) and initial operations

Pinkerton (2003:233-246), is of the view that if the project is well planned, well designed, and well executed, the commissioning should be uneventful. The development of the commissioning plan should deal with start-up objectives, provide adequate staffing, develop the start-up procedures, ensure that as-built drawings are on hand, refinement of start-up objectives, review the commissioning plan with all the parties, and establish firm lines of communication and authority. Developing the start-up procedures includes the following procedures:

- Detailed checkout procedures,
- Valve lineout procedures,
- Detailed operating procedures,
- Procedures for heat-up or cool-down,
- Procedures for capturing technical data,
- Procedures for handling non-conformance items,
- Procedures for sampling and for quality control,
- Procedures for guaranteed performance testing, and
- Procedures for satisfying environmental-permitting requirements and, in the case of a nuclear project, nuclear safety requirements.

IAEA (2007:19), states that the activities performed during the plant operation and life management stage are mainly related to:

- Operation management;

- Outage management;
- Technical support;
- Maintenance management;
- Configuration management;
- Procurement management;
- Plant life management;
- Fuel cycle management;
- Waste management;
- Management systems;
- Training and re-training;
- Emergency plan rehearsals;
- Radiological protection and environmental surveillance;
- Safeguards;
- Physical protection;
- Licensing and regulatory surveillance; and
- Public information and public relations.

3.1.7 Closeout and make-benefit analysis

Pinkerton (2003:329-335), explains that after successful testing and stabilisation of plant operations, the project must be formally closed out. The aim of the project closeout is to leave the operation personnel with full control of plant without unresolved problems. Closeout usually consists of turnover of documentation which is imperative to recording everything learned during the project, the smooth demolition of the project team, closeout contracts and project critique which is conducted to assess the feeling of the way the project was managed.

Schwalbe (2006:264-272), expresses the view that the closing of the project involves the acceptance of the final product or service by the stakeholders and bringing the project to an orderly end. The organisation should have procedures for administrative and contract closure. The closeout includes, amongst other things, closing tasks for integration management and closing tasks for project procurement management. This phase may include the lessons learnt in the project.

3.2 ELEMENTS OF PROJECT MANAGEMENT

3.2.1 Scope management

According to Nayyar (1987:9), the scope of the project can be defined according to the functionality the project is intended to provide. Scope change can be influenced by change in capacity of functionality, change in quality of functionality or change in functionality.

Zack (2002:4), defines scope management as “the process that ensures the project scope includes all work necessary to deliver a successful project and then controls scope growth throughout project delivery”. The elements of scope management include cost/benefit analysis, alternatives identification, work breakdown structure, scope verification, and scope change control.

Schwalbe (2006:99-108), is of the opinion that a scope management “involves defining and controlling what work is or is not included in a project”. The scope planning is supposed to produce a scope management plan. “A scope management plan is a document that includes descriptions of how the team will prepare the scope statement, create the work breakdown structure, verify completion of the project deliverables, and control requests for changes to project scope”, (Schwalbe, 2006:100).

3.2.2 Time management

IAEA (1988:68), states that time management or schedule management is frequently used as a measure of good project management as it penetrates all phases and aspects of a project. The schedule can be presented in a form of a bar chart and must show specific project activities and times. In a nuclear project a project computerisation is recommended as a result of bigger data to be stored.

Cooke and Tate (2005:187-188), are of the opinion that "the duration of a project's sequenced tasks is used to define the time window during which the project will create and deliver its product or service, and its benefits". The schedule can be affected by many external environments like government reviews, external markets or delayed access to critical resources or approvals. The project management team should be prepared and cater for these delays.

The main monitoring and control of time project management is schedule control (Schalbe, 2006:235-238). Schedule problems are a major source of conflicts in the project, especially during the middle and latter stages of the project. There are many causes of schedule conflicts some of them are individual work styles and cultural differences.

3.2.3 Cost management

Zack (2002:4) defines cost management as "those processes required to see that a project is delivered within the approved budget". Cost management includes cost estimating, budgeting, and cost control. Schalbe (2006:239), considers that a project should have a change control system as this would define procedures for changing the baseline.

3.2.4 Quality management

Petrangeli (2006:93-94), citing the International Atomic Energy Agency (1988), defines quality assurance as "all the planned and systematic actions necessary to provide adequate confidence that an item or service will satisfy given requirements for quality". The responsibility of achie ving quality does not necessarily rest on those who are tasked to verify that it has been achieved, but on those who are performing the tasks. Bowen, Cattel, Hall, Edwards and Pear (2002:49), citing Vincent and Joel (1995), define total quality management as "the integration of all functions and processes within an organisation in order to achieve continuous improvement of the quality of goods and services. The goal is customer satisfaction". In order to achieve successful project quality management three separate drivers must be managed, namely, Integration, customer focus and process of continuous improvement.

According to Bowen, Cattel, Hall, Edwards and Pear (2002:49), the integration of the project team assists the team to have one common objective. A customer focused team will ensure that the provision of products and services meets customer needs. The project success must be measured and continuous improvement should be implemented.

3.2.5 Project integration management

Schalbe (2006:303) defines project integration management as "the process of coordinating all the project management knowledge areas throughout the project life cycle". Schalbe (2006:94) is of the opinion that the main tasks of integration management are creating a team contract and developing a project management plan.

3.2.6 Human resource management

Human resource management consists of those project systems designed to make the best possible use of the people involved in the project (Zack, 2002:5). Due to a cost engineer's familiarity with resource planning, in this particular area, cost engineers probably have a leg up on staff planning, manpower levelling, and subcontracting.

3.2.7 Communications management

Zack (2006:5), defines project communications management as "those processes required to collect and distribute appropriate information concerning the project to the proper recipients in a timely manner". This management involves project performance reporting. Status reports are normally used to indicate where the project stands with respect to schedule and budget. It also includes project forecasting based on past progress and current trends.

3.2.8 Risk management

Zack (2002:5) defines risk management as "the process of identifying, analyzing and responding to project risk events". Some of the risks can be identified as layout risks, resource overloading, activity interferences, coordination of subcontractors and vendors, and documentation reviews.

3.2.9 Procurement management

"Procurement management are the processes necessary to obtain goods and services from outside the organization for the prosecution of the project," (Zack, 2002:6). Areas of procurement management that fall within the expertise of a skilled cost engineer include market condition analysis, make-or-buy analysis, alternative selection, commitment curves, work package definition, project financing, contract type selection, independent estimates, and financial modelling. Additionally, analysis of change requests, implementation of contract change control systems, performance reporting, and operation of a payment management system are also skills that a qualified cost engineer will have.

3.3 NATIONAL AND INTERNATIONAL LEGAL FRAMEWORK

El Baradei, Nwogugu and Rames (1995:16), are of the opinion that the international community has mixed views when it comes to the nuclear power projects. It is difficult to distinguish between the material used in nuclear power plants and the material used in nuclear weapons. As a result, the international community has to make sure that nuclear power is used responsibly and safely. This is achievable through networks nationally and internationally. For a while nuclear regulation was the responsibility of the national authorities, but it recognised that other countries can be affected as well.

According to Petrangeli (2006:279-284), the Chernobyl reactor was a state of the art reactor built in Russia but it failed in 1986 as a result of lack of training of the personnel operating it. The accident led to the release of radioactive reactor core into the atmosphere. About thirty people died as the result of the accident from acute radiation poisoning.

Rautenbach, Tanhauser and Wetherall (2006:8), concur with Edwin *et al* that activities concerning nuclear safety have changed dramatically especially after the Chernobyl accident. Prior to the Chernobyl accident there was no way of legally binding international commitments in fields such as air safety or safety at sea, which were needed. In the light of the accident's trans-boundary consequences, nuclear safety is no longer a national responsibility, but is now international.

The IAEA (2006: v), states that the international atomic energy agency (IAEA) is the world's nuclear inspectorate, with more than four decades of verification experience. Its inspectors are tasked to monitor nuclear material and activities, and to ensure that they are not used for military purposes. The IAEA has more than 145 member states and is responsible for making sure that the agreements, as stated in the Non-Prolification of Nuclear Weapons (NPT), are adhered to and respected. The IAEA is also responsible for safeguarding the environment against nuclear disasters.

In terms of the National Regulator Act, Act No 47 of 1999 (South Africa, 1999:35), the National Nuclear Regulator (NNR) is the national institution established by the National Nuclear Regulator Act, Act No 47 of 1999, for the protection of the public, property and environment against nuclear damage. The regulator is governed and controlled in accordance with this Act by a Board of Directors and is operated by an Executive comprising of the chief executive officer and staff of the NNR. The Minister of Minerals and Energy is the Executive Authority responsible for the NNR and appoints the NNR Board. The NNR is a member of the IAEA, and is bound by its nuclear agreements.

3.4 NUCLEAR SAFETY

3.4.1 Introduction

Petrangeli (2006:1), is of the view that the objectives of nuclear safety is to ensure that the siting and the plant conditions meet the international health, safety, and radioactive protection principles. Siting means a piece of land or site that is identified for the construction of the nuclear power plant. This chosen site must guarantee the health of workers and the community and ensure that they are not going to suffer adverse radiation consequences. The safety objectives are general objectives, a technical objective, and radiation objectives.

Rautenbach *et al.* (2006:31) found that nuclear power plant safety was recognised in the 1990s by the international nuclear community. There is still a challenge of nuclear safety even in the countries that have strong regulatory oversight. The safe operation of nuclear power plants can never be considered completed. Although there are safety concerns, the attitude towards nuclear energy is changing as a result of environmental benefits compared to the other means of electric power sources, as it is considered cleaner.

The Institute of Nuclear Power Operations (2004:9), states that nuclear safety needs constant scrutiny by using different monitoring techniques. The balanced oversight can include a mix of self-assessment and independent oversight. An improvement can be achieved by conducting periodic culture assessments. The executives/senior management of the organisation can be informed of the results of these assessments in order to gain insight about safety performance.

According to Lee (1974:35), the objectives of special legislation dealing with nuclear facilities should be to provide a regulatory basis for securing a reasonable assurance for nuclear installations, without undue risk to public health and safety, and without any harmful environmental impact. This objective is covered by the National Nuclear Reactor act on installation, operation, and management of the reactor technical standards and safety measures for reactor facilities and handling of nuclear fissionable and source materials and related facilities, and to ensure adequate financial protection for third parties in the event of a nuclear accident. It is advisable that the legal framework is flexible in order to cope with the evolution of the nuclear requirements, licensing and regulatory guides, engineering codes, standards, and practices. An emphasis is therefore placed on the creation of a safety culture.

3.4.3 Safety culture

According to Lowe, Axelsson, Hayward and K. Branford (2008:2), the term 'safety culture' was first used in 1986 after the Chernobyl nuclear accident and was first used by the Nuclear Safety Advisory Group. The term has been used since then and was even used by the companies that wanted to appear safer than others, even though they conduct equally hazardous operations. Lowe *et al* (2008:2), citing the International Nuclear Safety Advisory Group (1991), defines safety culture as "that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance". Six elements of a safety culture can be identified in figure 3.2 below:

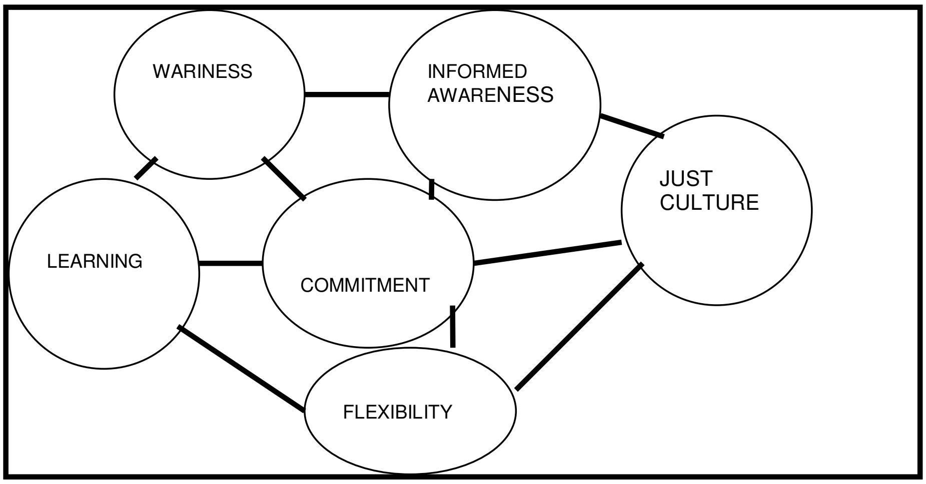

Figure 3.2: Elements of Safety Culture, (**source: Lowe et al. 2008:2**)

According to Alexander (2004:6), safety culture often arises in discussions following incidents at nuclear power plants. Although no single definition of safety culture is universally accepted, it commonly refers to the attitudes, behaviours, and conditions that affect safety performance. It is well known that the human factor poses a challenge for regulatory bodies. The role of regulators is to oversee licensee operations to ensure that licensees comply with safety requirements and not to intervene in management decisions until a serious incident has occurred or is imminent. The licensees retain full responsibility for the safe operation of their plants. Safety culture is a sensitive issue for the regulator because it is cross-cutting, involving both operational and management issues. If regulators were to be more proactive toward safety culture, as some critics suggest they should be, regulators would have to focus on those attributes of safety culture that are performance-based in order to avoid undue interference in licensee management.

The Institute of Nuclear Power Operations (2004:iii), describes a Safety culture as "an organisation's values and behaviours modelled by its leaders and internalised by its members, that serve to make nuclear safety the overriding priority". Petrangeli (2006:7) defines the safety culture concept as "the set of convictions, knowledge and behaviour in which safety is placed at the highest level in the scale of values in every activity concerning the use of nuclear energy". Its principles describe the attributes of a healthy nuclear safety culture. A safety culture applies to every employee from the executives to the lowest ranked. It encourages the safety conscious environment and promotes a questioning attitude.

According to Alexander (2004:6), a safety culture often arises in discussions following incidents at nuclear power plants. "The safety culture concept is defined as the set of convictions, knowledge and behaviour in which safety is placed at the highest level in the scale of values in every activity concerning the use of nuclear energy" (Petrangeli, 2006:7) . Although there are many definitions of a safety culture, it can be simplified as, 'the attitude and behaviour towards nuclear safety, as the human factor can pose a great challenge in regulatory bodies'. The role of the nuclear regulators is to ensure that the licensee is proactive and its operations comply with the safety requirements. It is the sole responsibility of the licensee to ensure that its plant is operating safely. A safety culture is seen by a regulator as a sensitive issue as it involves both operational and management issues. This means that the regulator can easily find itself interfering with the licensee management. The safety culture is also guided by the management system.

3.4.2 Management responsibility

Lowe *et al.* (2008:3) are of the opinion that in order for an organisation to drive the safety culture effectively there must be a management commitment. Lowe *et al.* (2008:3), citing Gaba *et al.,* 2003, describe Safety culture as "the aspects of an organisation's reliability that depends on 'shared values and norms of behaviour articulated by senior management and translated with high uniformity into effective work practices at the front line'". This description emphasises the influence of an organisation's leadership on the safety attitudes and behaviour of the employees. Lowe *et al*. (2008:3), citing Hopkins (2002), states that "It is 'management' culture, rather than the culture of the workforce in general, which is most relevant here". Lowe *et al*. (2008:3), citing Reason (1997) and Hudson (2003), state that the safety culture can be described by the following attributes:

- Informed Awareness – managers know what is going on in their organisation and the workforce is willing to report their own errors and near misses;
- Wariness – the organisation as a whole and its employees individually are on the lookout for unexpected events, and maintain a high degree of vigilance;
- Capacity for Learning – the organisation is ready to learn and has the will to implement reforms when they are required;
- Flexibility – the organisation reflects changes in demand and continues to operate effectively in high tempo and unusual circumstances as well as routine conditions; and
- Commitment to a Just Culture – the organisation has a 'no blame' approach to errors, but applies the appropriate penalties to unacceptable actions (violations).

IAEA (2006:7-8), states that Management at all levels shall demonstrate its commitment to the establishment, implementation, assessment and continual improvement of the management system and shall allocate adequate resources to carry out these activities. Senior management shall develop individual values, institutional values and behavioural expectations for the organisation to support the implementation of the management system and shall act as role models in the promulgation of these values and expectations. The expectations of interested parties shall be considered by senior management in the activities and interactions in the processes of the management system, with the aim of enhancing the satisfaction of interested parties while at the same time ensuring that safety is not compromised. Senior management shall develop the policies of the organisation. The policies shall be appropriate to the activities and facilities of the organisation. Senior management shall establish goals, strategies, plans and objectives that are consistent with the policies of the organisation. The organisation shall retain overall responsibility for the management system when an external organisation is involved in the work of developing all or part of the management system.

3.5 NUCLEAR POWER SUPPLY MARKET

3.5.1 Supply of nuclear power plants

The IAEA (2007:5) points out that the implementation of a first NPP project will generally be through importation from an experienced foreign supplier or suppliers. There will be national participation too, which will vary from case to case and will depend mainly on the available infrastructure of the country. A thorough evaluation of the supply market is needed in order to identify the reactor or reactor types and sizes that are commercially available offering distinct economic or technical attractiveness and to analyse how nuclear fuel cycle requirements can be met. The evaluation will support the selection of the reference concepts for detailed economic and technical analysis and comparison amongst each other and with alternative projects. The evaluation will also facilitate the final decisions to be taken after the project is firmly committed. The choice of reactor type for the first Nuclear Power Plant (NPP) should also be seen as a possible long-term commitment to that type for additional nuclear power plants to be built in the future, and also to the type of fuel cycle and associated supply requirements. 'Provenness and demonstrated licensability' of a nuclear power plant lead to the establishment of the national requirements and the criteria in the bidding process for a reference plant which serves the purpose of the project as a guideline for the following main features:

- Design,
- Performance,
- Scope of supply,
- Licensing criteria, and
- Operating experience.

3.5.2 Supply of nuclear fuel and fuel cycle services

According to Meckoni, Catlilin and Bennet (1977:1), in the case of purchase of nuclear fuel, the application of quality assurance might be faced with several difficulties because of the lack of standardization in nuclear fuel and the proprietary information of the fuel manufacturers on fuel design specifications and fuel manufacturing procedures. Due to the lack of generally acceptable standards, the successful application of the quality assurance concept to the procurement of fuel depends on how much information can be provided by the fuel manufacturer to the utility which is purchasing fuel, and in what form and how early this information can be provided.

3.6 FINANCIAL MARKET

3.6.1 The current global status

The IAEA (2006: iii) states that, as of June 2006, there were 441 nuclear power reactors in operation in 30 countries. They total about 370 gigawatts of generating capacity, and they supply about 16% of the world's electricity. This percentage has been roughly stable since 1986, indicating that nuclear power has grown at about the same rate as total global electricity for 20 years. The use of nuclear power has been concentrated in industrialized countries. In terms of new construction, however, the pattern is different. Sixteen of the twenty-seven new reactors under construction are in developing countries. And while the highest percentage of existing reactors is in North America and Europe, recent expansion has been most heavily centred in Asia. China currently has three reactors under construction, and plans a 5-to-6-fold expansion in nuclear generating capacity over the next 15 years. India has eight reactors under construction, and plans a 10-fold increase in capacity by 2022. Projections for future growth have increased in recent years.

3.6.2 Factors driving the resurgence of interest in nuclear power

The IAEA (2006: 6), states that the nuclear power's strong and sustained track record is reflected in nearly 12 000 reactor-years of experience, with continual reductions in plant down-time, lower generating costs and a progressively improved safety record. The Chernobyl accident in 1986 was clearly a setback to nuclear power. Many lives were lost and thousands suffered major health impacts, in addition to the significant environmental and social impacts. The accident was the result of less than optimal reactor design and gross human error. But ironically, it also brought about major changes in our approach to nuclear safety, including the development of a so-called international "nuclear safety culture" based on constant review and improvement, thorough analysis of operating experience, and consistent sharing of best practices. This safety culture has been demonstrating its effectiveness for two decades, and has not gone unnoticed by the public or by investors.

3.7 MANAGEMENT SYSTEM

3.7.1 Integrated approach

Dalling (2007:3) defines an Integrated Management System (IMS) as a single integrated system used by an organisation to manage the totality of its processes, in order to meet the organisation's objectives and equitably satisfy the stakeholders. In a nuclear environment, an integrated management system includes quality management and safety management; environment and health are not part of this and are dealt with separately. The requirements of a formal management system are described in figure 3.3 below:

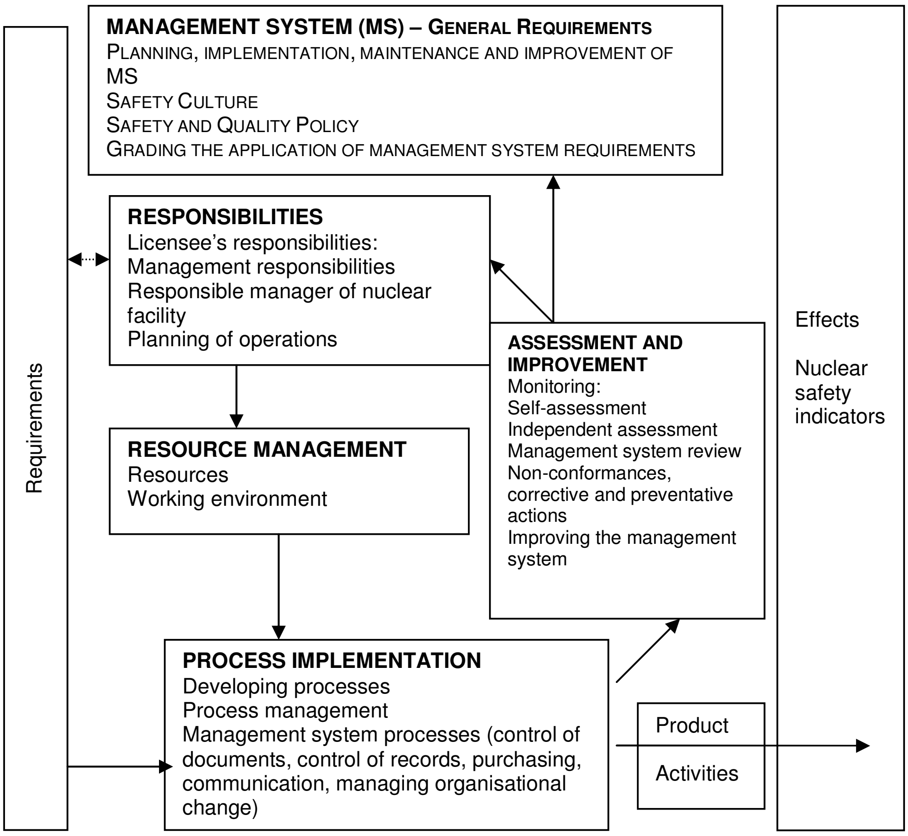

Figure 3.3: Requirements concerning a formal management system (**Source:** Leva 2010:4)

Dua (2006:1) explains that the IAEA is taking a lead role in the direction of integrating all elements of managing nuclear facilities and activities. The IAEA wants to ensure that all inter-related aspects, such as economic, health and safety, security, quality assurance and environment are not considered separate from nuclear safety, but rather as a single integrated management system that covers them all. The IAEA is developing a new standard on management system requirements (GS-R-3) that will cover all these aspects.

Riha (200:2), describes the management system as the system that serves to prevent human error, encourages personnel training and qualification, improves emergency response organisational performance, prevents unplanned reactor shutdowns and avoids regulatory findings. The self assessment part of management system can assist management in continuous improvement.

According to Kibrit and Zouain, (2005:2), the nuclear facilities of the IAEA Member States have their Quality Management System established by standards IAEA 50-C/SG-Q, ISO 9001:2000 and regulations of their own government regulator agency, for obtaining their operation license. Two interfaces are observed. The first interface is between the nuclear installation and the government regulator agency. The second interface is between the nuclear installation and the suppliers of items and services that developed a Quality Management System in conformity with ISO 9001:2000.

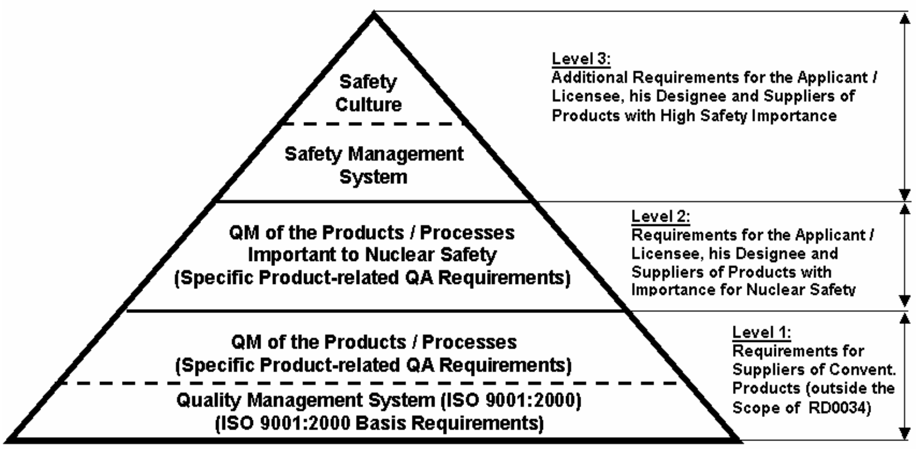

Figure 3.4: Structure of the Integrated Management System (**Source:** NNR (2008:11-12))

The National Nuclear Regulator (2008:11-12), states that the integrated management system structure consists of three level Safety Culture aspects as part of their IMS. (See figure 3.4):

Level 1: As a basis, the implementation of an appropriate Quality Management System compliant with ISO9001:2008 series or any equivalent international accepted QM standard is mandatory for all organisations involved in the activities related to an application for or operation of *a* nuclear installation. The QMS

requirements of the applied QM standard include the consideration of the Quality Assurance (QA) measures specified for the particular products of the organisation.
Level 2: For products important to nuclear safety, QM processes, design codes and standards have to be applied that are specific to nuclear installations. The safety classification and the application of these codes and standards require additional QM and product related QA measures which need to be adequately implemented in the QMS of the respective suppliers.
Level 3: The applicant / licensee, his designee as well as suppliers involved in the design, manufacture, supply and construction of products of high importance to nuclear safety must implement a Safety Management System as part of an Integrated Management System. These organisations are additionally required to consider

According to Majola (2006: 22-41), the main aims of an integrated management system are:

- Bringing together in a coherent manner all the requirements for managing the organisation;
- Describing the planned and systematic actions necessary to provide adequate confidence that all these requirements are satisfied; and
- Ensuring that health, environmental, security, quality and economic requirements are not considered separately from safety requirements, to avoid the possibility of their potential negative impact on safety.
- Safety is paramount within the management system, overriding all other demands. The management system identifies and integrates the requirements contained within the applicable codes, standards, statutory and regulatory requirements of the Member State as well as any requirements formally agreed with stakeholders.

According to Dua (2005:1), an integrated performance based management system for nuclear organisations and its compliance with national and international standards, quality assurance, and quality in general has evolved over the years. The nuclear industry is known for its stringent safety standards in the 60's and consensus-based quality control and quality assurance in the 80's and 90's. In the 90's the quality approach has further strengthened the focus on the quality system aspects to manage the safety and quality of products, services, and processes. Recently, quality was integrated as a process approach, thus elevating it to the next level.

Pieroni (1996:33), found that the review in the 1980s also showed that effective implementation of requirements encountered a number of difficulties depending on the particular country or organization. The IAEA thus tried to identify specific causes. Some typical issues that were identified include:

- Interpreting quality assurance requirements as solely regulatory, as if they had no beneficial effect on work performance.
- Viewing a good quality assurance programme as only demanding many written documents and procedures, i.e., it is only concerned with "paper work".
- Assigning responsibility for quality only to the quality assurance unit.
- Auditing for compliance with formal requirements without analyzing the final results.
- Not recognizing that management and workers have the main responsibilities in the achievement of quality assurance results.
- Being unaware of the importance of adequate qualification and motivation of personnel.
- Not assessing the effectiveness of the quality assurance programme.
- Not providing clear management support and commitment to the implementation of the quality assurance programme.

Hawkins and Pieroni (1991: 29) researched and found that a quality assurance programme is often incorrectly interpreted as only a regulatory demand and/or paperwork, with no effective impact in the overall performance of the nuclear project. Over the past decade, however, the nuclear industry has experienced a loss of public confidence stemming from real shortcomings in performance. This has led to dramatic changes in the perception of quality and how to achieve it. In short, the nuclear industry as a whole has found that its traditional perception of quality assurance was not contributing to plant safety and reliability as meaningfully as it could and should do.

Hawkins and Pieroni (1991: 29) noted that the perception has significantly changed in recent years. Quality assurance programmes may vary somewhat according to the cultural, historical, and industrial experience of the nations and organizations involved. It is generally agreed, however, that an effectively implemented quality assurance programme governing all aspects of a nuclear power project is an essential management tool. Today, new challenges are demanding that quality assurance programmes and their management be improved.

According to Petrangeli (2006:93-94), the legal framework for the nuclear power plants of each country requires that an effective quality assurance programme be established and maintained. It is the responsibility of the nuclear plant owner to establish and maintain the quality programme, although it may delegate this to other organisations, but it remains the owner's responsibility.

3.8 REGIONAL AND INTERREGIONAL COOPERATION

According to Lee (1974:34), the Korean Atomic Energy Law, licensing regulations and regulatory practices are based on a combination of the American and Japanese systems. Before implementing a nuclear power programme, it is essential that adequate legislative action be taken at the earliest possible stage in order to establish a proper legal framework. Alongside this legal framework, the infrastructure for executing the programme has to be set up for appropriate communications and co-ordination among the various governmental agencies such as the Economic Planning Board, the Ministry of Commerce and Industry, the Ministry of Construction etc., as well as for control and supervision of the nuclear power project. In order to assure public health and safety, stringent safety requirements for nuclear power plants have to be enforced.

3.9 CONCLUSION

Nuclear energy is an alternative energy source lately, taking into consideration the green house emissions that need to be reduced. There are legal and safety requirements that have to be met before building these nuclear sites. If nuclear projects are not properly managed, there is a risk of environmental and huge cost impacts. The steps to assure proper management are as follows:

- Training (long term measure)
- Technical assistance (short term measure)
- Project management
- Contract management
- Quality assurance

CHAPTER 4: QUALITY MANAGEMENT SYSTEM DURING THE IMPLEMENTATION OF PEBBLE BED MODULAR REACTOR PROJECT SURVEY DESIGN AND METHODOLOGY

4.1 THE SURVEY ENVIRONMENT

The PBMR project is a nuclear project supported by various function areas. The various functional areas, which will serve as the research environment, include the following:

- Project Management.
- Quality Management.
- Senior Management support.

4.2 AIM OF THIS CHAPTER

The aim of this chapter and the survey contained therein is to determine the importance of the Quality Management System when implementing the nuclear project. The ultimate objective being to solve the research problem as defined in Chapter 1, Paragraph 1.5, and which reads as follows:

"Is the implementation of a Quality Management System necessary when implementing a nuclear project and what impact would the absence thereof has on overall project execution".

4.3 CHOICE OF SAMPLING METHOD

The PBMR (Pty) Ltd consists of various functional areas, each with a unique role in the delivery of the pebble bed modular reactor project. The various functional areas, which will serve as the individual strata for the research survey, include the following:

- Project Management
- Senior Management.

- Quality Management.

To ensure that each identifiable strata of the population were taken into account (Hussey & Hussey, 1997) (Easterby-Smith, Thorpe & Lowe, 1996), 3 respondents were selected from the Quality department, 5 from the Project management department and 6 from Management.

4.4 THE TARGET POPULATION

With any survey, it is necessary to clearly define the target population, which Hussey & Hussey (1997), define as follows:

> *"A population is any precisely defined set of people or collection of items which is under consideration".*

The 'sampling frame' (defined by Vogt (1993), is 'a list or record of the population from which all the sampling units are drawn. For this survey, 8 employees were systematically selected from the Quality management and Project management departments. 100% participation from both the Project management and Quality management departments was achieved, with 3 Quality management department participants and 5 Project management department participants. 6 managers were randomly selected from PBMR (Pty) Ltd representing 60 managers participated in the survey. This results in 14 employees from different organisation levels being randomly selected from the following identified research strata:

- Project Management
- Senior Management.
- Quality Management.

The organisation has a five level hierarchy, which is made up as follows:

- **Executive:** the executive, support the organisations' directors and managers, a business divisional area.
- **Strategic Business Unit Manager (SBU):** responsible to the Executive and manages a functional area.

- **Business Unit Manager (BU):** responsible to a SBU manager and manages a business unit within a functional area.
- **Managerial Unit Manager (MU):** responsible to a BU and manages a Managerial Unit within a functional area.
- **Certified Professional (CP):** A professional individual.

The 'managerial' levels can also include senior technical employees or 'specialists', which are referred to as Managerial Unit Specialists (MUS) or Business Unit Specialists (BUS). Their primary role is to provide technical guidance and expertise to their managerial counterparts. The target population was specifically chosen in order to validate the practicality of the concepts as presented here. The risk of bias, which cannot be statistically eliminated, is recognised by the author based on the very definition of the target population as well as the number of respondents selected.

4.5 DATA COLLECTION

According to Emory and Cooper (1995), three primary types of data collection (survey) methods can be distinguished namely:

- Personal interviewing.
- Telephone interviewing.
- Self-administered questionnaires/surveys.

While all of the above listed methods were used, the primary data collection method used in this survey is the personal interview, described by Burgess (1982), as:

> *"…the opportunity for the researcher to probe deeply to uncover new clues, open up new dimensions of a problem and to secure vivid, accurate inclusive accounts that are based on personal experience".*

Interviews, according to Hussey & Hussey (1997), are associated with both positivist and phenomenological methodologies. They are a method of collecting data in which selected participants are asked questions in order to find out what they do, think or feel. The use of personal interviews as an additional element to the data collection process is, in the opinion of the author, important, since this allows for the identification of issues within the target environment, which may not be readily identifiable using a pure survey questionnaire. Furthermore, according to Hussey & Hussey (1997), interviews are associated with both positivist and phenomenological methodologies as employed within the ambit of this dissertation.

The data collection method used in the survey, falls within the context of a survey, defined by Hussey & Hussey (1997), as:

> *"A sample of subjects being drawn from a population and studied to make inferences about the population"*

More specifically, the survey conducted in this dissertation falls within the ambit of a 'descriptive survey' as defined by Ghauri, Grønhaug and Kristianslund (1995). One survey will be conducted to collect 'primary data' using the 'personal interview' method to conduct the interviews, an approach which maps to accepted data collection methods (Remenyi *et al.*, 2002).

The data collection method used falls within the ambit of both the definitions attributed to the concepts 'survey' and 'field study'. 'Survey', according to Gay and Diebl (1992:238), is an attempt to collect data from members of a population in order to determine the current status of that population with respect to one or more variables, while Kerlinger (1986:372), defines 'field study' as non-experimental scientific inquiries aimed at discovering the relations and interactions among … variables in real … structures. As in the case of most academic research, the collection of data forms an important part of the overall dissertation content.

4.6 MEASUREMENT SCALES

The survey will be based on the well-known Lickert scale, whereby respondents were asked to respond to questions or statements (Parasuraman 1991:410). The reason for choosing the Lickert scale is the fact that the scale can be used in both respondent-centred (how responses differ between people) and stimulus-centred (how responses differ between various stimuli) studies, most appropriate to glean data in support of the research problem in question (Emory and Cooper 1995:180-181). The advantages in using the popular Lickert scale according to Emory and Cooper (Emory and Cooper 1995:180-181) are:

- Easy and quick to construct.
- Each item meets an empirical test for discriminating ability.
- The Lickert scale is probably more reliable than the Thurston scale, and it provides a greater volume of data than the Thurston differential scale.
- The Lickert scale is also treated as an interval scale.

According to Remenyi, Money & Twite (1995:224), interval scales facilitate meaningful statistics when calculating means, standard deviation and Pearson correlation coefficients.

4.7 THE DEMAND FOR A QUALITATIVE RESEARCH STRATEGY

While this author acknowledges that a number of strategies can be applied in similar research projects, the well-known concepts of objectivity, reliability etcetera, inherited from the empirical analytical paradigm, are suggested for business research in more or less the traditional way. Quoting Thorndike & Hagen, these concepts are defined by Emory & Cooper (1995:156), as follows:

- **Practicality:** Practicality is concerned with a wide range of factors of economy, convenience, and interpretability.
- **Validity:** Validity refers to the extent to which a test measures what we actually wish to measure. Yin (2003) identifies 3 subsets to the concept validity, namely: Construct validity, internal validity and external validity.

- **Reliability:** Reliability has to do with the accuracy and precision of a measurement procedure.

4.8 SURVEY SENSITIVITY

Research conducted in areas of a sensitive nature, as in the case of this survey, pose particular challenges to the researcher. The following guidelines from various academics serve to illustrate the mitigation process, which can be deployed in an instance where research is conducted in areas of a sensitive nature:

- A qualitative investigation of a particularly sensitive nature conducted by Oskowitz & Meulenberg-Buskens (1997: 83), qualified the importance of handling mission critical issues as identified above when the authors stated:

> *"Thus any type of qualitative investigation could benefit from the researchers being skilled and prepared, and the sensitive nature of an investigation into a stigmatizing condition made the need for such an undertaking even more imperative in the current study".*

- The sensitivity of certain issues and issues identified as impacting the research negatively in the environments being evaluated, not only demands intimate personal involvement, but also demands the 'personal and practical experience' of the researcher. This view was upheld by Meulenberg-Buskens (1997), as being imperative to assure quality in qualitative research being undertaken. Checkland (1989: 152). supports this view, but extends the concept with the opinion that: "The researcher becomes a participant in the action, and the process of change itself becomes the subject of research".

4.9 SURVEY DESIGN

Hussey & Hussey (1997), are of the opinion that, 'if research is to be conducted in an efficient manner and make the best of opportunities and resources available, it must be organised. Furthermore, if it is to provide a coherent and logical route to a reliable outcome, it must be conducted systematically using appropriate methods to collect and analyse the data. A survey should be designed in accordance with the following stages:

- **Stage one:** Identify the topic and set some objectives.
- **Stage two:** Pilot a questionnaire to find out what people know and what they see as the important issues.
- **Stage three:** List the areas of information needed and refine the objectives.
- **Stage four:** Review the responses to the pilot.
- **Stage five:** Finalise the objectives.
- **Stage six:** Write the questionnaire.
- **Stage seven:** Re-pilot the questionnaire.
- **Stage eight:** Finalise the questionnaire.
- **Stage nine:** Code the questionnaire.

The survey design to be used in this instance is that of the descriptive survey as opposed to the analytical survey. The descriptive survey is, according to Hussey & Hussey (1997), frequently used in business research in the form of attitude surveys. The descriptive survey as defined by Ghauri, Grønhaug and Kristianslund (1995), has furthermore the facility to indicate how many members of a particular population have a certain characteristic (Watkins, 2004). Particular care was taken to avoid bias in the formulation of the questions.

The statements within the survey have been designed with the following principles in mind:

- Avoidance of double-barrelled statements.
- Avoidance of double-negative statements.
- Avoidance of prestige bias.
- Avoidance of leading statements.
- Avoidance of the assumption of prior knowledge.

Statements were formulated so as to allow the same respondents to respond to each of the three questionnaires, to determine the impact of Quality Management System during the pebble bed modular reactor project..

4.10 THE VALIDATION SURVEY QUESTIONS

The author has developed three separate survey questionnaires. Due to the fact that face-to-face interviews are highly structured, questions were prepared and piloted to ensure they reflected a high degree of 'validity' (Easterby-Smith, Thorpe & Lowe (1996).

4.10.1 SENIOR MANAGEMENT QUESTIONNAIRE: MANAGEMENT SUPPORT

Question 1: Management made sure that systems were established and implemented during the conceptual stage of the project life cycle, and can demonstrate their commitment to the project. To what extent do you agree with this statement?

Question 2: Management was responsible for the activities and behaviours necessary to foster a strong safety culture during the project life cycle**.** To what extent do you agree with this statement?

Question 3: Management made sure that goals, strategies, plans, and objectives defined for the management system were achieved during the project life cycle. To what extent do you agree with this statement?

Question 4: Management made sure that each stage of the nuclear installations' life cycle was preceded by monitoring and a pre-assessment to identify the impact of the life cycle specific processes. To what extent do you agree with this statement?

4.10.2 QUALITY MANAGEMENT QUESTIONNAIRE:

Question 1: Senior Management made sure that systems were established and implemented during the planning stage of the project life cycle, and demonstrated their commitment to the project. To what extent do you agree with this statement?

Question 2: Senior Management at all levels can demonstrate its commitment to the implementation, assessment and continual improvement of the management system during the project life cycle To what extent do you agree with this statement?

Question 3: The successful implementation of the 'knowledge management' concept was largely attributed to a 'top down' approach, focussed on 'changing by force' the pattern of the internal organisation. To what extent do you agree with this statement?

Question 4: Senior Management was responsible for the activities and behaviours necessary to foster a strong safety culture during the project life cycle. To what extent do you agree with this statement?

Question 5: Senior Management made sure that goals, strategies, plans and objectives defined for the management system were achieved during the project life cycle. To what extent do you agree with the statement?

Question 6: IMS (combination of QMS and SM) was introduced at all phases of the life cycle of the nuclear installation as it is required by RD0034. To what extent do you agree with this statement?

Question 7: The Quality department never experienced any compliance problems as a result of not implementing QMS in the planning stage of the project life cycle. To what extent do you agree with the statement?

Question 8: All processes needed to achieve the quality and safety goals of the organization were identified, and their development was planned, implemented, assessed and continually improved since the planning stage of the project life cycle. To what extent do you agree with this statement?

Question 9: The Quality department did not have to retrofit some of the processes as a result of QMS not implemented at the planning stage of the project life cycle. To what extent do you agree with this statement?

Question 10: All the suppliers were easily qualified as a result of the implementation of the QMS at the planning stage of the life cycle. To what extent do you agree with this statement?

4.10.2 PROJECT MANAGEMENT QUESTIONNAIRE:

Question 1: Senior Management made sure that systems were established and implemented during the conceptual stage of the project life cycle, and can demonstrate their commitment to the project. To what extent do you agree with this statement?

Question 2: Senior Management was responsible for the activities and behaviours necessary to foster a strong safety culture during the project life cycle. To what extent do you agree with this statement?

Question 3: Senior Management made sure that goals, strategies, plans and objectives defined for the management system were achieved during the project life cycle. To what extent do you agree with this statement?

Question 4: Senior Management made sure that each stage of the nuclear installations' life cycle was preceded by monitoring and a pre-assessment to identify the impact of the life cycle specific processes. To what extent do you agree with this statement?

Question 5: The QMS was implemented during the planning stage of the project. To what extent do you agree with the statement?

Question 6: After implementation of QMS there has been visible improvement in controlling project scope. To what extent do you agree with this statement?

Question 7: After implementation of QMS there has been visible improvement in controlling project costs. To what extent do you agree with the statement?

Question 8: After implementation of QMS there has been visible improvement in controlling project schedule. To what extent do you agree with this statement?

Question 9: The QMS implementation ensured that minimum regulatory requirements were met when applying for licensing. To what extent do you agree with this statement?

Question 10: During the implementation of QMS the project management team played an influential role to ensure success. To what extent do you agree with this statement?

Question 11: During all phases of the life cycle of the nuclear installation PBMR/ licensee or designee planned and developed the processes required to achieve a safe installation. To what extent do you agree with this statement?

4.11 CONCLUSION

In this chapter, the 'knowledge management' survey design and methodology was addressed under the following functional headings:

- Survey environment.
- Aim of the chapter.
- Choice of sampling method.
- Target population.
- Data collection.
- Measurement scales.
- Demand for a qualitative research strategy.
- Survey sensitivity.
- Survey design.
- Survey questions.

In Chapter 5, results from the survey will be analysed in detail and conclusions drawn.

CHAPTER 5: DATA ANALYSIS

5.1 INTRODUCTION

Data analysis is “the process of bringing order, structure and meaning to the mass of collected data” (de Vos 2002, 339). This chapter discusses the statistical analysis of the questionnaire compiled by L Zamxaka for the purpose of obtaining a Magister Technologiae: Quality in the Faculty of Engineering at the Cape Peninsula University of Technology. The aim of this study is to determine whether the implementation of a Quality Management System (QMS) is necessary and if so; the impact on the overall project execution when implementing a nuclear project at Pebble Bed Modular Reactor (Pty) Limited (PBMR). In this chapter the data obtained from the completed questionnaires will be presented and analysed.

In most social research the analysis entails three major steps done in the following order:

- Cleaning and organising the information that was collected which is called the data preparation step,
- Describing the information that was collected (Descriptive Statistics); and
- Testing the assumptions made through hypothesis and modelling (Inferential Statistics).

The responses to the questionnaire developed by the researcher for the purpose of obtaining information regarding the implementation of a QMS at PBMR; the commitment of the senior management of PBMR in implementing the QMS in the planning stage of the project life cycle; whether project management experienced problems as a result of QMS not implemented in the planning stage of the project life cycle and whether the PBMR quality department experienced any compliance problems as a result of a QMS not being implemented in the planning stage of the project life cycle have been analysed by using SAS software.

5.2 METHOD OF ANALYSIS

5.2.1 VALIDATION OF SURVEY RESULTS

A descriptive analysis of the survey results returned by the research questionnaire respondents is reflected below. The responses to the questions obtained through the questionnaires are indicated in table format for ease of reference. Data validation is the process of ensuring that a programme operates on clean, correct and useful data. The construct validation however can only be taken to the point where the questionnaire measures what it is supposed to measure. Construct validation should be addressed in the planning phases of the survey and when the questionnaire is developed. This questionnaire is supposed to measure the impact of implementing a QMS at PBMR in Gauteng.

5.2.2 DATA FORMAT

The data was received in questionnaire format, which was coded and captured on a database that was developed on Microsoft Access for this purpose. These questionnaires are captured twice and then the two datasets are compared to ensure that the information was correctly captured. When the database was developed, use was made of rules with respect to the questionnaire that set boundaries for the different variables (questions). For instance if the Likert scale is used as follows:

- Strongly agree is coded as 1
- Agree is coded as 2
- Undecided is coded as 3
- Disagree is coded as 4
- Strongly disagree is coded as 5.

A boundary is set on Microsoft Access as less than 6. This means if the number 6 or more than 6 is captured, an error will show until a number less than 6 is captured. It was then imported into SAS-format through the SAS ACCESS module. This information which was double checked for correctness is then analysed by the custodian of this document.

5.2.3 PRELIMINARY ANALYSIS

The reliability of the statements in the questionnaire posed to the respondents from PBMR is measured by using the Cronbach Alpha tests. (See paragraph 5.3.1). An Uni-variate descriptive analysis was performed on all the original variables; displaying frequencies, percentages, cumulative frequencies, cumulative percentages, means, standard deviations, range, median, mode etc. These descriptive statistics are discussed in paragraphs 5.3.2 and 5.3.3. (See also computer printouts in Annexures B & C).

5.2.4 INFERENTIAL STATISTICS

Inferential statistics that will be used are:

- Cronbach Alpha test. Cronbach's Alpha is an index of reliability associated with the variation accounted for by the true score of the "underlying construct". Construct is the hypothetical variables that are being measured (Cooper & Schindler, 2001:216-217). Another way to put it would be that Cronbach's alpha measures how well a set of items (or variables) measures a single uni-dimensional latent construct. When data has a multidimensional structure, Cronbach's Alpha will usually be low.
- Chi-square tests for nominal data. The Chi-square (two-sample) tests are probably the most widely used nonparametric test of significance that is useful for tests involving nominal data, but they can be used for higher scales as well like cases where persons, events or objects are grouped in two or more nominal categories such as 'yes-no' or cases A, B, C or D. The technique is used to test for significant differences between the observed distribution of data among categories and the expected distribution based on the null hypothesis. It has to be calculated with actual counts rather than percentages (Cooper & Schindler, 2001:499).

- The SAS software computes a P-value (Probability value) that measures statistical significance when comparing variables with each other, determining relationships between variables or determining associations between variables. Results will be regarded as significant if the p-values are smaller than 0.05, because this value presents an acceptable level on a 95% confidence interval ($p \leq 0.05$). The p-value is the probability of observing a sample value as extreme as, or more extreme than, the value actually observed, given that the null hypothesis is true. This area represents the probability of a Type 1 error that must be assumed if the null hypothesis is rejected (Cooper & Schindler, 2001:509).
- The p-value is compared to the significance level (α) and on this basis the null hypothesis is either rejected or not rejected. If the p value is less than the significance level, the null hypothesis is rejected (if p value $<\alpha$, reject null). If the p value is greater than or equal to the significance level, the null hypothesis is not rejected (if p value $\geq\alpha$, don't reject null). Thus with $\alpha=0.05$, if the p value is less than 0.05, the null hypothesis will be rejected. The p value is determined by using the standard normal distribution. The small p value represents the risk of rejecting the null hypothesis.
- A difference has statistical significance if there is good reason to believe the difference does not represent random sampling fluctuations only. Results will be regarded as significant if the p-values are smaller than 0.05, because this value is used as cut-off point in most behavioural science research.

5.2.5 ASSISTANCE TO RESEARCHER

The conclusions made by the researcher, are validated by the statistical report. Help is given to interpret the outcome of the data. The final report written by the researcher is to be validated and checked by the statistician to exclude any misleading interpretations.

All inferential statistics are discussed in paragraphs 5.3.4, 5.3.5 and 5.3.6.

5.2.6 SAMPLE

The target population is senior management, project managers and quality management of PBMR. A systematic sample of 8 was drawn from the quality management department and project management department. A random sample of 6 was drawn from PBMR Pty Ltd who will represent a population of 60 managers.

5.3 ANALYSIS

In total 14 respondents completed the questionnaire. Descriptive statistics will be given for each variable and only the respondents who completed the entire questionnaire will be utilized in the inferential statistics.

5.3.1 RELIABILITY TESTING

Reliability tests (Cronbach's Alpha Coefficient) are done on the questions/statements (which is the measuring instrument in this case) posed to the employees of PBMR for each questionnaire.
The results of the Cronbach Alpha tests for the raw variables are shown in annexure A table 5.1, 5.2 & 5.3 and Annexure C. It shows the correlation between the respective item and the total sum score (without the respective item) and the internal consistency of the scale (coefficient alpha) if the respective item would be deleted. By deleting the items (statements) one by one each time with the statement with the highest Cronbach Alpha value, the Alpha value will increase. In the right-most column of Annexure A table 5.1, it can be seen that the reliability of the scale would be higher if any of these statements is deleted.

For instance if statement Q02 in Annexure A table 5.1 is deleted from this measuring scale then the Cronbach Alpha Coefficient will increase to 0.8170. This however is not needed as the overall alpha is greater than 0.70.

For the project management questionnaire Annexure A table 5.2 shows the overall Cronbach Alpha for the raw variables is 0.4889 which means that this instrument is either inconsistent or that these items measure more than one construct. As can be seen if statement Q02 in Annexure A table 5.2 is deleted from this measuring scale, then the overall Cronbach Alpha Coefficient will increase to 0.6393 and then, if statement Q04 is deleted from the scale, the overall Cronbach Alpha Coefficient will increase to 0.7232 (shown in Annexure A table 5.3). The overall Cronbach's Alpha Coefficient without Q02 and Q04 is then more than 0.70 (the acceptable level according to Nunnally, 1978**:** 245), thus the items (statements) in the questionnaire for project management prove to be reliable and consistent for the remaining items in the scale.

The Cronbach Alpha for the original quality management questionnaire is 0.9268, but due to the fact that variable (Statement) Q09 is a constant (all the answers were 4=Disagree), if not used in the scale the overall Cronbach Alpha coefficient will be 0.9384. Annexure A, Table 5.4 and Annexure C will show the table without Q09 but the original iteration where all the questions (items) are included will only be shown in Annexure C.

The overall Cronbach's Alpha Coefficient is more than 0.70 (the acceptable level according to Nunnally, 1978**:** 245), thus the items (statements) in the questionnaire for quality management prove to be reliable and consistent for the remaining items in the scale.

5.3.2 DESCRIPTIVE STATISTICS

Annexure A, Table 5.2 shows the descriptive statistics for all the categorical variables with the frequencies in each category and the percentage out of total number of questionnaires. Take note that the descriptive statistics are based on the total sample. These descriptive statistics are also shown in Annexures C & D.

5.3.3 UNI-VARIATE GRAPHS

With regard to the 4 questions posed to the senior management which were also posed to the project management and quality management departments, a comparison can be made to see whether the departments differed with respect to their responses. These 4 questions will be shown in 4 graphs in paragraph 5.3.4 as it will show how the responses compared. Although the number of respondents is insufficient to do statistically significant testing, the comparison graphs of the responses between the different environments for the 4 statements are shown in the paragraph discussing inferential statistics.

The rest of the questions posed to the project management department and quality management department will be shown in graphs in paragraphs 5.3.3.1 and 5.3.3.2 for the project management questionnaire and the quality management questionnaire respectively.

Take note that the scoring is weighted according to the coding. By weighting the responses as follows:

- Strongly agree = 1 times number of responses,
- Agree = 2 times number of responses,
- Undecided = 3 times number of responses,
- Disagree = 4 times number of responses,
- Strongly disagree = 5 times number of responses, will indicate that the higher the sum of scores is, the more the respondents disagree with the statement. After sorting these scores, it could be determined which statements the respondents agreed with more and which the respondents disagreed with more.

5.3.3.1 Project management graphs

It is to be noted that there are only 5 respondents for the project management questionnaire and depending on the total number of project managers, this survey may be biased, as these 5 respondents were chosen on a systematic basis.

The respondents agreed the most with statement 'The QMS was implemented during the planning stage of the project' (60.0% agree to strongly agree). However, the respondents were equally distributed between agree and disagree for statements:

- The QMS implementation ensured that minimum regulatory requirements were met when applying for licensing. (40% agree to strongly agree and 40% disagree to strongly disagree, the rest were undecided)
- During all phases of the life cycle of the nuclear installation PBMR licensee or designee planned and developed the processes required to achieve a safe installation. (40% agree to strongly agree and 40% disagree to strongly disagree, the rest were undecided)

The statements that the respondents disagreed with the most are as follows:

- Senior management made sure that goals, strategies, plans and objectives defined for the management system were achieved during the project life cycle. (80% disagree)
- During the implementation of the QMS the project management team played an influential role to ensure success. (80% disagree)
- After implementation of QMS there has been visible improvement in controlling project costs. (60% disagree)
- Senior management made sure that each stage of the nuclear installations' life cycle was preceded by monitoring and a pre-assessment to identify the impact of the life cycle specific processes. (60% disagree)
- After implementation of QMS there has been visible improvement in controlling project schedule. (60% disagree)

- Senior management made sure that systems were established and implemented during the conceptual stage of the project life cycle, and can demonstrate their commitment to the project. (80% disagree)
- Senior management was responsible for the activities and behaviours necessary to foster a strong safety culture during the project life cycle. (60% disagree)

Note should be taken that 40% of the respondents did not respond to the statement 'After implementation of the QMS there has been visible improvement in controlling project scope'.

5.3.3.2 Quality management graphs

It should be noted that there are only 3 respondents for the quality management questionnaire and, depending on the total number of quality managers. this survey may be biased as these 5 respondents were chosen on a systematic basis. The respondents were equally distributed between agree and disagree for statements:

- Senior management made sure that goals, strategies, plans and objectives defined for the management system were achieved during the project life cycle. (33.3% agree, 33.3% disagree and 33.3% were undecided)
- Senior management made sure that each stage of the nuclear installations' life cycle was preceded by monitoring and a pre-assessment to identify the impact of the life cycle specific processes. (33.3% agree, 33.3% disagree and 33.3% were undecided)

The statements that the respondents disagreed with the most are as follows:

- Quality department did not have to retrofit some of the processes as a result of QMS not implemented at the planning stage of the project life cycle. (100% disagree)
- Quality department never experienced any compliance problems as a result of not implementing QMS in the planning stage of the project life cycle. (66.7% disagree to strongly disagree)
- All the suppliers were easily qualified as a result of the implementation of the QMS at the planning stage of the life cycle. (66.7% disagree)

- Senior management at all levels can demonstrate its commitment to the implementation, assessment and continual improvement of the management system during the project life cycle (66.7% disagree)
- Senior management was responsible for the activities and behaviours necessary to foster a strong safety culture during the project life cycle. (66.7% disagree)
- Senior management made sure that systems were established and implemented during the conceptual stage of the project life cycle, and can demonstrate their commitment to the project. (66.7% disagree)
- All processes needed to achieve the quality and safety goals of the organisation were identified, and their development was planned, implemented, assessed and continually improved since the planning stage of the project life cycle. (66.7% disagree to strongly disagree)
- IMS (combination of QMS and SM) was introduced at all phases of life cycle of the nuclear installation as it is required by RD0034. (66.7% disagree)

5.3.4 INFERENTIAL STATISTICS

Due to the small numbers in this survey no statistical comparisons were made, as they will be invalid. The 4 graphs in Annexure B show how the senior management, project management and quality management agree/disagree with respect to the 4 statements that were posed to all three environments.

For statement Q01 of the senior management questionnaire (senior management / Management made sure that systems were established and implemented during the conceptual stage of the project life cycle, and can demonstrate their commitment to the project) it seems that the project management respondents agreed the least (20% agree to strongly agree) with the statement.

For statement Q02 of the senior management questionnaire (SM responsible for activities and behaviours necessary to foster a strong safety culture during project life cycle) it seems that the quality management department agreed the least (33.3% agree to strongly agree) with the statement.

For statement Q03 of the senior management questionnaire (Senior Management made sure that the goals, strategies, plans and objectives defined for the management system were achieved during project life cycle) it seems that the project management respondents do not agree at all with the statement.

For statement Q04 of the senior management questionnaire (SM made sure that each stage of the project life cycle was preceded by monitoring and a pre-assessment to identify the impact of the life cycle specific processes) it seems that the project management respondents as well as senior management did not agree at all with this statement.

5.4 DISCUSSIONS AND CONCLUSSIONS

As for the results obtained through the survey of the project management department on whether the implementation of a Quality Management System is necessary when implementing a nuclear project, the following analogies can be drawn from this research:

- Senior management did not ensure that goals, strategies, plans and objectives defined for the management system were achieved during the project life cycle.
- During the implementation of the QMS the project management team didn't play an influential role to ensure success.
- After implementation of the QMS there hasn't been visible improvement in controlling project costs.
- Senior management didn't ensure that each stage of the nuclear installations' life cycle was preceded by monitoring and a pre-assessment to identify the impact of the life cycle specific processes.
- After implementation of QMS there hasn't been visible improvement in controlling project schedule.
- Senior management didn't ensure that systems were established and implemented during the conceptual stage of the project life cycle, and couldn't demonstrate their commitment to the project.

- Senior management wasn't responsible for the activities and behaviours necessary to foster a strong safety culture during the project life cycle.

As for the results obtained through the survey of the quality management department on whether the implementation of a Quality Management System is necessary when implementing a nuclear project the following analogies can be drawn from this research:

- The Quality department did have to retrofit some of the processes as a result of QMS not implemented at the planning stage of the project life cycle.
- The Quality department experienced compliance problems as a result of not implementing QMS in the planning stage of the project life cycle.
- All the suppliers weren't easily qualified as a result of the implementation of the QMS at the planning stage of the life cycle.
- Senior management at all levels can't demonstrate its commitment to the implementation, assessment and continual improvement of the management system during the project life cycle.
- Senior management wasn't responsible for the activities and behaviours necessary to foster a strong safety culture during the project life cycle.
- Senior management didn't ensure that systems were established and implemented during the conceptual stage of the project life cycle, and can demonstrate their commitment to the project.
- All processes needed to achieve the quality and safety goals of the organisation weren't identified, and their development wasn't planned, implemented, assessed and continually improved since the planning stage of the project life cycle.
- IMS (combination of QMS and SM) wasn't introduced at all phases of the life cycle of the nuclear installation as is required by RD0034.

Project management individuals were the respondents who mostly thought that Senior Management didn't ensure that systems were established and implemented during the conceptual stage of the project life cycle, and that they couldn't demonstrate their commitment to the project and also thought that Senior Management didn't ensure that the goals, strategies, plans and objectives defined for the management system were achieved during project life cycle.

Quality management was the department who mostly thought that Senior Management wasn't responsible for activities and behaviours necessary to foster a strong safety culture during the project life cycle.

Project management and senior management themselves felt more than quality management that senior management didn't make sure that each stage of the project life cycle was preceded by monitoring and a pre-assessment to identify the impact of the life cycle specific processes.

CHAPTER 6: RECOMMENDATIONS AND CONCLUSION

6.1 THE RESEARCH THUS FAR

The aim of this research was to determine the benefits of implementing the Quality Management System in a nuclear project management. PBMR project was used for the purpose of this research. The experiences or lessons learnt from the PBMR project can assist future nuclear projects to be more proactive. The benefits can include a shortened period for nuclear license application, preventing unnecessary project delays, defined processes, high staff morale, reduction of project costs and confidence from stakeholders.

There are many benefits in implementing Quality Management Systems in nuclear projects; one of them is assuring a common understanding of key aspects of a safety culture within the organisation. In a nuclear environment individuals and teams need organisational support to carry out their tasks safely and successfully, this is possible if the Quality Management System is implemented.

Project management is a technique for efficient expenditure of resources to achieve a desired result. In a nuclear project this can be more complex as it involves nuclear safety. Stringent international nuclear regulations must be met during the implementation of the nuclear project. The failure to meet these requirements can lead to the cancellation or non-issue of the nuclear licence, the project can be stopped resulting in huge costs and delays, and individuals can be arrested. If a credible Quality Management System is implemented these previously mentioned issues can be avoided.

The nuclear safety is the core of the nuclear project, from the siting, construction, operation and decommissioning of the nuclear power plant. The organisation issued with the licence must meet the international health, safety, and radioactive protection principles. Nuclear safety needs constant scrutiny by using different monitoring techniques. The balanced oversight can include a mix of self-assessment and independent oversight, including periodic culture assessments.

It is impossible for quality management to be effective if the management of the organisation does not show its commitment to it. Quality management is effective if it is entrenched in the strategy and values of the organisation. Senior management is responsible for developing the policies of the organisation that support the development and implementation of the Quality Management System.

The survey was conducted at PBMR Ltd offices in Centurion. Three functional areas were targeted for the purpose of this project, namely Project management, Quality management and Senior Management support. To ensure that each identifiable strata of the population were sampled, 3 respondents were selected from Quality department, 5 from Project management and 6 from Management. Questionnaires were used to collect data. The statements within the survey were designed to avoid double-barrelled statements, double-negative statements, prestige bias, leading statements and assumption of prior knowledge. The statements were formulated to allow the participants to respond so as to determine the impact of a Quality Management System during the pebble bed modular reactor project.

The data analysis was conducted on data received (see Chapter 5). The organisation of information, description of information and testing assumptions were conducted. The data analysis graph and results are shown in Annexures A, B, C and D.

6.2 FINDINGS

As for the results obtained through the survey of the Project management department regarding whether the implementation of a Quality Management System is necessary when implementing a nuclear project, the following analogies can be drawn from this research:

- Senior management did not ensure that goals, strategies, plans and objectives defined for the management system were achieved during the project life cycle.

- During the implementation of the QMS, the project management team did not play an influential role to ensure success.
- After implementation of the QMS, there has not been visible improvement in controlling project costs.
- Senior management did not ensure that each stage of the nuclear installations' life cycle was preceded by monitoring and a pre-assessment to identify the impact of the life cycle specific processes.
- After implementation of QMS, there has not been visible improvement in controlling project schedule.
- Senior management did not ensure that systems were established and implemented during the conceptual stage of the project life cycle, and could not demonstrate their commitment to the project.
- Senior management was not responsible for the activities and behaviours necessary to foster a strong safety culture during the project life cycle.

As for the results obtained through the survey of the Quality management department on whether the implementation of a Quality Management System is necessary when implementing a nuclear project, the following inferences can be drawn from this research:

- The Quality department did have to retrofit some of the processes as a result of QMS not being implemented at the planning stage of the project life cycle.
- The Quality department experienced compliance problems as a result of not implementing QMS in the planning stage of the project life cycle.
- All the suppliers were not easily qualified as a result of the implementation of the QMS at the planning stage of the life cycle.
- Senior management at all levels cannot demonstrate its commitment to the implementation, assessment and continual improvement of the management system during the project life cycle.
- Senior management was not responsible for the activities and behaviours necessary to foster a strong safety culture during the project life cycle.
- Senior management did not ensure that systems were established and implemented during the conceptual stage of the project life cycle, and can demonstrate their commitment to the project.

- All processes needed to achieve the quality and safety goals of the organisation were not identified, and their development was not planned, implemented, assessed and continually improved since the planning stage of the project life cycle.
- IMS (combination of QMS and SM) was not introduced at all phases of the life cycle of the nuclear installation as is required by RD0034.

Project management were the respondents who mostly thought that Senior Management didn't ensure that systems were established and implemented during the conceptual stage of the project life cycle, and that they couldn't demonstrate their commitment to the project and that Senior Management didn't ensure that the goals, strategies, plans and objectives defined for the management system were achieved during the project life cycle.

Quality management was the department which mostly thought that Senior Management wasn't responsible for activities and behaviours necessary to foster a strong safety culture during project life cycle.

Project management and Senior Management themselves felt more than Quality management that Senior Management didn't make sure that each stage of the project life cycle was preceded by monitoring and a pre-assessment to identify the impact of the life cycle specific processes.

6.3 ANALOGIES DRAWN FROM THE LITERATURE REVIEW

A project is unique, temporary, requires resources, has a sponsor, and involves uncertainty. The project is composed of eight elements as follows:

- Project origination and definition,
- Pre-project planning and organisation,
- Design, procurement, and pre-testing,
- Construction and installation,
- Training,
- Preoperational testing,
- Start-up(commissioning) and initial operations and,

- Closeout and make-good analysis.

Key elements of the project management framework are as follows:

- Scope management,
- Time management,
- Cost management,
- Quality management,
- Project integration management,
- Human resource management,
- Communications management,
- Risk management, and
- Procurement management.

The start of a nuclear power plant project involves several complex and interrelated activities of long duration. The time between the initial policy decisions by a State to consider nuclear power up to the start of operation of its first nuclear power plant is about 10 to 15 years and, before specific project management can proceed, several key infrastructure issues have to be in place.

The prime participants in a nuclear project are:

- **Government** - This is responsible for overall energy policy and, in some cases, financing.
- **Market** - formed by electricity customers wanting electricity at a competitive price.
- **Utility (generator)** - which is ultimately responsible for developing the complete project.
- **EPC (engineering, procurement and contractor) contractors** - engineering, procurement and construction companies which are responsible to the owner for delivery according to schedule and budget.
- **Vendors** - which are responsible for supplying equipment and technology to either the owner, the EPC contractor or as part of a joint venture or consortium, according to schedule and budget

- **Safety authority** - which is responsible for addressing all matters related to protecting public safety and the environment, from the design stage to plant operation and fuel management.

Public hearings and debate are sound means for improving dialogue and ultimately saving time. Providing information to the public and their representatives is essential to building social trust. Such information also serves a documentary function, placing on open record what has been proposed and approved, to avoid the possibility of recurrent argument.

Quality assurance is “all the planned and systematic actions necessary to provide adequate confidence that an item or service will satisfy given requirements for quality”. The responsibility of achieving quality does not necessary rest on those who are tasked to verify that it has been achieved, but on those who are performing the tasks. The goal is customer satisfaction”. In order to achieve a successful project quality management three separate drivers must be managed, namely: Integration, customer focus and process of continuous improvement.

In terms of the National Regulator Act, Act No 47 of 1999 (South Africa, 1999:35), the National Nuclear Regulator (NNR) is the national institution established by the National Nuclear Regulator Act, Act No 47 of 1999, for the protection of the public, property and environment against nuclear damage. The regulator is governed and controlled in accordance to this ‘Act by’ a Board of Directors and is operated by an Executive comprising the chief executive officer and staff of the NNR. The Minister of Minerals and Energy is the Executive Authority responsible for the NNR and appoints the NNR Board. The NNR is a member of the IAEA, and is bound by its nuclear agreements.

Nuclear safety needs constant scrutiny by using different monitoring techniques. The balanced oversight can include a mix of self-assessment and independent oversight. An improvement can be achieved by conducting periodic culture assessments. The executives can be informed of the results of these assessments in order to gain insight into safety performance.

A safety culture often arises in discussions following incidents at nuclear power plants. The safety culture concept is defined as the set of convictions, knowledge and behaviour in which safety is placed at the highest level in the scale of values in every activity concerning the use of nuclear energy. Although there are many definitions of a safety culture, it can be simplified as, 'the attitude and behaviour towards nuclear safety, as the human factor can pose a great challenge in regulatory bodies'. The role of the nuclear regulators is to ensure that the licensee is proactive and its operations comply with the safety requirements. It is the sole responsibility of the licensee to ensure that its plant is operating safely. A safety culture is seen by a regulator as a sensitive issue as it involves both operational and management issues. This means that the regulator can easily find itself interfering with the licensee management. The safety culture is also guided by the management system.

The Management at all levels shall demonstrate its commitment to the establishment, implementation, assessment and continual improvement of the management system and shall allocate adequate resources to carry out these activities. Senior management shall develop individual values, institutional values and behavioural expectations for the organisation to support the implementation of the management system and shall act as role models in the promulgation of these values and expectations. The expectations of interested parties shall be considered by senior management in the activities and interactions in the processes of the management system, with the aim of enhancing the satisfaction of interested parties while at the same time ensuring that safety is not compromised. Senior management shall develop the policies of the organisation. The policies shall be appropriate to the activities and facilities of the organisation. Senior management shall establish goals, strategies, plans and objectives that are consistent with the policies of the organisation. The organisation shall retain overall responsibility for the management system when an external organisation is involved in the work of developing all or part of the management system.

6.4 THE RESEARCH PROBLEM REVISITED

The research problem statement as written in Chapter 1 is as follows: "the adverse impact on the pebble bed modular reactor project licensing process, due to the non implementation of a Quality Management System"

Although the majority of respondents agreed that the Quality Management System was implemented at the planning stage of the project, however there were some concerns as follows:

- The QMS implementation ensured that minimum regulatory requirements were met when applying for licensing. (40% agree to strongly agree and 40% disagree to strongly disagree, the rest were undecided)
- During all phases of the life cycle of the nuclear installation PBMR licensee or designee planned and developed the processes required to achieve a safe installation. (40% agree to strongly agree and 40% disagree to strongly disagree, the rest were undecided)

The survey results above show that although the Quality Management System was implemented at the planning stage of the project life cycle, the Quality Management System was not effective.

6.5 THE RESEARCH QUESTION REVISITED

The research question as in chapter 1 is as follows:
'Is the implementation of a Quality Management System necessary when implementing a nuclear project and what effect would the absence thereof have on the overall project execution'

According to the finding in chapter 5 (see 5.4), the Quality department did have to retrofit some of the processes as result of QMS not implemented at the planning stage of the project life cycle. The Quality department experienced compliance problems as a result of not implementing QMS at the planning stage of the project life cycle. All suppliers were not easily qualified as a result of the implementation of the QMS at the planning stage of the project life cycle. All processes needed to achieve the quality and safety goals of the organization weren't identified, and their development wasn't planned, implemented, assessed and continually improved.

6.6 KEY RESEARCH OBJECTIVES REVISITED

The key research objectives as per chapter 1 are as follows:

- Is the implementation of Quality Management System necessary when implementing the Nuclear Project, and are there any lessons learnt by not implementing a Quality Management System at the planning stage of the Project Life Cycle? The research survey results in chapter 5 show that it is necessary to implement the Quality Management System when implementing the Nuclear Project. The Quality department had to retrofit some of the processes as a result of QMS not being implemented at the planning stage of the project life cycle. The problem with retrofitting is that the project gets delayed, it can be costly and, if the processes involve suppliers or contractors, it can result in contract review. The Quality department experienced compliance problems as a result of not implementing QMS at the planning stage of the project life cycle. In paragraph 3.2.4 quality assurance can be defined as all the planned and systematic actions necessary to provide adequate confidence that an item or service will satisfy given requirements for quality. The QMS is a guide and control in execution of these processes and if this QMS is not there then the environment is a recipe for disaster.

- Was there any commitment of the PBMR senior management in implementing the Quality Management System at the planning stage of the project life cycle? The results of the survey show that the senior management did not ensure that goals, strategies, plans, and objectives defined for the management system were achieved during the project life cycle. Paragraph 3.3.2 shows that it is important to have a committed management. Nuclear projects emphasize nuclear safety and nuclear culture, which is described as the aspects of an organisation's reliability that depends on 'shared values and norms of behaviour articulated to senior management and translated with high uniformity into effective work practices at the front line'. IAEA (2006:6-7), states that the Management at all levels shall demonstrate its commitment to the establishment, implementation, assessment and continual improvement of the management system and shall allocate adequate resources to carry out these activities.

- Did the PBMR Project management department experience problems as a result of a Quality Management System not being implemented at the planning stage of the project life cycle? Although the survey results show that Project management did not see any benefits when QMS was implemented, they experienced problems with supplier qualifications prior to the effective implementation of the QMS. Suppliers play a very important role in nuclear projects as the nonconforming suppliers can lead to the stop work order being given to the licensee and result in delays and huge costs.

- Did the PBMR Quality department experience any compliance problems as a result of a Quality Management System not being implemented at the planning stage of the life cycle project? According to the survey the Quality department experienced compliance problems as a result of not implementing QMS at the planning stage of the project life cycle.

6.7 RECOMMENDATIONS AND CONCLUSSION

This research confirmed the importance of implementing QMS in the planning stage of the project life cycle. Building a nuclear power plant can be costly and risky as compared to other energy sources, therefore it is important to have a system that will guide and control the execution of this project. QMS plays a big role in giving nuclear regulators confidence that the project will be executed, operated and decommissioned safely.

The research also highlighted the importance of the management involvement in the implementation of the QMS. The QMS must be embedded in the goals, strategies, plans and objectives of the organisation. This assists in instilling organisational values and norms. Employees can actually see the importance of QMS when it is demonstrated by their leaders.

The research results show that there are contradicting results about the effectiveness of the QMS and what really happened. The Project management department feels it did not benefit after the implementation of the QMS, whilst the Quality department believes that the processes were not clearly defined and it has to retrofit some of the processes. ISO 9001:2008 QMS requires that the management system be measured, analysed and improved. The measurement takes place in the form of self assessments, audits and quality controls. The analysis can be the result of the self assessments or audits and the statistical analysis of the non conformances from the quality control interventions. Continuous improvement can be achieved through the corrective action programme and management reviews.

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ANNEXURES

Annexure A

TABLE 5.1: Cronbach's Alpha Coefficient for all the items of the senior management questionnaire.

Statements (Test all statements without current one's input)	Variable nr.	Correlation with total	Cronbach's Alpha Coefficient
1. Management made sure that systems were established and implemented during the conceptual stage of the project life cycle and can demonstrate their commitment to the project.	Q01	0.7624	0.5841
2. Management was responsible for the activities and behaviours necessary to foster a strong safety culture during the project life cycle.	Q02	0.2988	0.8170
3. Management made sure that the goals, strategies, plans and objectives defined for the management system were achieved during the project life cycle.	Q03	0.6794	0.6346
4. Management made sure that each stage of the nuclear installations' life cycle was preceded by monitoring and pre-assessment to identify the impact of the life cycle specific processes.	Q04	0.6048	0.7005
Cronbach's Coefficient Alpha for standardized variables			**0.7672**
Cronbach's Coefficient Alpha for raw variables			**0.7605**

TABLE 5.2: Cronbach's Alpha Coefficient for all the items of the original project management questionnaire.

Statements (Test all statements without current one's input)	Variable nr.	Correlation with total	Cronbach's Alpha Coefficient
1. Senior Management made sure that systems were established and implemented during the conceptual stage of the project life cycle and can demonstrate their commitment to the project.	Q01	0.5000	0.3086
2. Senior Management was responsible for the activities and	Q02	-0.4096	0.6393

Statements (Test all statements without current one's input)	**Variable nr.**	**Correlation with total**	**Cronbach's Alpha Coefficient**
behaviours necessary to foster a strong safety culture during the project life cycle.			
3. Senior Management made sure that the goals, strategies, plans and objectives defined for the management system were achieved during the project life cycle.	Q03	0.6934	0.3846
4. Senior Management made sure that each stage of the nuclear installations' life cycle was preceded by monitoring and pre-assessment to identify the impact of the life cycle specific processes.	Q04	-0.8030	0.6140
5. The QMS was implemented during the planning stage of the project.	Q05	0.9286	0.3401
6. After implementation of QMS there has been visible improvement in controlling project scope.	Q06	0.1890	0.4762
7. After implementation of QMS there has been visible improvement in controlling project costs.	Q07	0.9286	0.3401
8. After implementation of QMS there has been visible improvement in controlling project schedule.	Q08	0.5000	0.3704
9. The QMS implementation ensured that minimum regulatory requirements were met when applying for licensing.	Q09	0.1147	0.4873
10. During the implementation of QMS the project management team played an influential role to ensure success.	Q10	-0.0640	0.5464
11. During all phases of the life cycle of the nuclear installation PBMR/licensee or designee planned and developed the processes required to achieve a safe installation.	Q11	0.6934	0.3846
Cronbach's Coefficient Alpha for standardized variables			**0.5927**
Cronbach's Coefficient Alpha for raw variables			**0.4889**

TABLE 5.3: Cronbach's Alpha Coefficient for project management questionnaire without questions 2 and 4.

Statements (Test all statements without current one's input)	Variable nr.	Correlation with total	Cronbach's Alpha Coefficient
1. Senior Management made sure that systems were established and implemented during the conceptual stage of the project life cycle and can demonstrate their commitment to the project.	Q01	0.3974	0.7218
3. Senior Management made sure that the goals, strategies, plans and objectives defined for the management system were achieved during the project life cycle.	Q03	0.5852	0.6888
5. The QMS was implemented during the planning stage of the project.	Q05	0.9774	0.6482
6. After implementation of QMS there has been visible improvement in controlling project scope.	Q06	0.3871	0.7119
7. After implementation of QMS there has been visible improvement in controlling project costs.	Q07	0.9774	0.6482
8. After implementation of QMS there has been visible improvement in controlling project schedule.	Q08	0.6547	0.6531
9. The QMS implementation ensured that minimum regulatory requirements were met when applying for licensing.	Q09	0.0000	0.7619
10. During the implementation of QMS the project management team played an influential role to ensure success.	Q10	0.1147	0.7519
11. During all phases of the life cycle of the nuclear installation PBMR/licensee or designee planned and developed the processes required to achieve a safe installation.	Q11	0.5852	0.6888
Cronbach's Coefficient Alpha for standardized variables			**0.8280**
Cronbach's Coefficient Alpha for raw variables			**0.7232**

TABLE 5.4: Cronbach's Alpha Coefficient for all the items of the quality management questionnaire.

Statements (Test all statements without current one's input)	Variable nr.	Correlation with total	Cronbach's Alpha Coefficient
1. Senior Management made sure that systems were established and implemented during the planning stage of the project life cycle and can demonstrate their commitment to the project.	Q01	0.9976	0.9172
2. Senior Management at all levels can demonstrate its commitment to the implementation, assessment and continual improvement of the management system during the project life cycle.	Q02	0.9979	0.9305
3. Senior Management was responsible for the activities and behaviours necessary to foster a strong safety culture during the project life cycle.	Q03	0.9976	0.9172
4. Senior Management made sure that the goals, strategies, plans and objectives defined for the management system were achieved during the project life cycle.	Q04	0.8660	0.9265
5. Senior Management made sure that each stage of the nuclear installations' life cycle was preceded by monitoring and pre-assessment to identify the impact of the life cycle specific processes.	Q05	0.8660	0.9265
6. IMS (combination of QMS and SM) was introduced at all phases of life cycle of the nuclear installation as it is required by RD0034.	Q06	0.9971	0.9194
7. Quality department never experienced any problems as a result of not implementing QMS in the planning stage of the project life cycle.	Q07	0.7924	0.9302
8. All the processes needed to achieve the quality and safety goals of the organisation were identified and their development was planned, implemented, assessed and continually improved since the planning stage of the project life cycle.	Q08	0.8885	0.9252
10. All the suppliers were easily qualified as a result of the implementation of QMS at the planning stage of the life cycle.	Q10	-0.5000	0.9702
Cronbach's Coefficient Alpha for standardized variables			**0.9252**

Statements (Test all statements without current one's input)	Variable nr.	Correlation with total	Cronbach's Alpha Coefficient
Cronbach's Coefficient Alpha for raw variables			**0.9384**

TABLE 5. 5: Descriptive statistics for all the variables in senior management questionnaires.

Variables	Categories	Frequency	Percentage out of total
1. Management made sure that systems were established and implemented during the conceptual stage of the project life cycle and can demonstrate their commitment to the project.	Agree to strongly agree	3	50.0%
	Undecided	0	0.0%
	Disagree to strongly disagree	3	50.0%
2. Management was responsible for the activities and behaviours necessary to foster a strong safety culture during the project life cycle.	Agree to strongly agree	5	83.3%
	Undecided	0	0.0%
	Disagree to strongly disagree	1	16.7%
3. Management made sure that the goals, strategies, plans and objectives defined for the management system were achieved during the project life cycle.	Agree to strongly agree	1	16.7%
	Undecided	1	16.7%
	Disagree to strongly disagree	4	66.7%
4. Management made sure that each stage of the nuclear installations' life cycle was preceded by monitoring and pre-assessment to identify the impact of the life cycle specific processes.	Agree to strongly agree	0	0.0%
	Undecided	2	33.3%
	Disagree to strongly disagree4	4	66.7%

TABLE 5. 6: Descriptive statistics for all the variables in project management questionnaires.

Variables	Categories	Frequency	Percentage out of total
1. Senior Management made sure that systems were established and implemented during the conceptual stage of the project life cycle and can demonstrate their commitment to the	Agree to strongly agree	1	20.0%
	Undecided	0	0.0%
	Disagree to strongly	4	80.0%

Variables	Categories	Frequency	Percentage out of total
project.	disagree4		
2. Senior Management was responsible for the activities and behaviours necessary to foster a strong safety culture during the project life cycle.	Agree to strongly agree	2	40.0%
	Undecided	0	0.0%
	Disagree to strongly disagree4	3	60.0%
3. Senior Management made sure that the goals, strategies, plans and objectives defined for the management system were achieved during the project life cycle.	Agree to strongly agree	0	0.0%
	Undecided	1	20.0%
	Disagree to strongly disagree4	4	80.0%
4. Senior Management made sure that each stage of the nuclear installations' life cycle was preceded by monitoring and pre-assessment to identify the impact of the life cycle specific processes.	Agree to strongly agree	0	0.0%
	Undecided	2	40.0%
	Disagree to strongly disagree	3	60.0%
5. The QMS was implemented during the planning stage of the project.	Agree to strongly agree	3	60.0%
	Undecided	0	0.0%
	Disagree to strongly disagree4	2	40.0%
6. After implementation of QMS there has been visible improvement in controlling project scope.	Agree to strongly agree	1	20.0%
	Undecided	1	20.0%
	Disagree to strongly disagree	1	20.0%
	Unknown	2	40.0%
7. After implementation of QMS there has been visible improvement in controlling project costs.	Agree to strongly agree	0	0.0%
	Undecided	2	20.0%
	Disagree to strongly disagree	3	60.0%
8. After implementation of QMS there has been visible improvement in	Agree to strongly agree	1	20.0%

Variables	Categories	Frequency	Percentage out of total
controlling project schedule.	Undecided	1	20.0%
	Disagree to strongly disagree	3	60.0%
9. The QMS implementation ensured that minimum regulatory requirements were met when applying for licensing.	Agree to strongly agree	2	40.0%
	Undecided	1	20.0%
	Disagree to strongly disagree	2	40.0%
10. During the implementation of QMS the project management team played an influential role to ensure success.	Agree to strongly agree	1	20.0%
	Undecided	0	0.0%
	Disagree to strongly disagree	4	80.0%
11. During all phases of the life cycle of the nuclear installation PBMR/licensee or designee planned and developed the processes required to achieve a safe installation.	Agree to strongly agree	2	40.0%
	Undecided	1	20.0%
	Disagree to strongly disagree	2	40.0%

TABLE 5. 7: Descriptive statistics for all the variables in quality management questionnaires

Variables	Categories	Frequency	Percentage out of total
1. Senior Management made sure that systems were established and implemented during the planning stage of the project life cycle and can demonstrate their commitment to the project.	Agree to strongly agree	1	33.3%
	Undecided	0	0.0%
	Disagree to strongly disagree	2	66.7%
2. Senior Management at all levels can demonstrate its commitment to the implementation, assessment and continual improvement of the management system during the project life cycle.	Agree to strongly agree	0	0.0%
	Undecided	1	33.3%
	Disagree to strongly disagree	2	66.7%

Variables	Categories	Frequency	Percentage out of total
3. Senior Management was responsible for the activities and behaviours necessary to foster a strong safety culture during the project life cycle.	Agree to strongly agree	1	33.3%
	Undecided	0	0.0%
	Disagree to strongly disagree	2	66.7%
4. Senior Management made sure that the goals, strategies, plans and objectives defined for the management system were achieved during the project life cycle.	Agree to strongly agree	1	33.3%
	Undecided	1	33.3%
	Disagree to strongly disagree	1	33.3%
5. Senior Management made sure that each stage of the nuclear installations' life cycle was preceded by monitoring and pre-assessment to identify the impact of the life cycle specific processes.	Agree to strongly agree	1	33.3%
	Undecided	1	33.3%
	Disagree to strongly disagree	1	33.3%
6. IMS (combination of QMS and SM) was introduced at all phases of life cycle of the nuclear installation as it is required by RD0034.	Agree to strongly agree	1	33.3%
	Undecided	0	0.0%
	Disagree to strongly disagree	2	66.7%
7. Quality department never experienced any problems as a result of not implementing QMS in the planning stage of the project life cycle.	Agree to strongly agree	0	0.0%
	Undecided	1	33.3%
	Disagree to strongly disagree	2	66.7%
8. All the processes needed to achieve the quality and safety goals of the organisation were identified and their development was planned, implemented, assessed and continually improved since the planning stage of the project life cycle.	Agree to strongly agree	1	33.3%
	Undecided	0	0.0%
	Disagree to strongly disagree	2	66.7%
9. Quality department did not have to retrofit some of the processes as a	Agree to strongly agree	0	0.0%

Variables	Categories	Frequency	Percentage out of total
result of QMS not implemented at the planning stage of the project life cycle.	Undecided	0	0.0%
	Disagree to strongly disagree	3	100.0%
10. All the suppliers were easily qualified as a result of the implementation of QMS at the planning stage of the life cycle.	Agree to strongly agree	0	0.0%
	Undecided	1	33.3%
	Disagree to strongly disagree	2	66.7%

TABLE 5. 8: Descriptive statistics – Mean, Median, Standard Deviation and Range for senior management questionnaire

Variable	N	Mean	Std Dev	Median	Range
1. Management made sure that systems were established and implemented during the conceptual stage of the project life cycle and can demonstrate their commitment to the project.	6	3.67	0.5774	4.0	1.0
2. Management was responsible for the activities and behaviours necessary to foster a strong safety culture during the project life cycle.	6	2.33	0.8165	2.0	2.0
3. Management made sure that the goals, strategies, plans and objectives defined for the management system were achieved during the project life cycle.	6	3.67	1.0328	4.0	3.0
4. Management made sure that each stage of the nuclear installations' life cycle was preceded by monitoring and pre-assessment to identify the impact of the life cycle specific processes.	6	3.83	0.7528	4.0	2.0

TABLE 5. 9: Descriptive statistics – Mean, Median, Standard Deviation and Range for project management questionnaire

Variable	N	Mean	Std Dev	Median	Range
1. Senior Management made sure that systems were established and implemented during the conceptual stage of the project life cycle and can demonstrate their commitment to the project.	5	3.40	1.3416	4.0	3.0
2. Senior Management was responsible for the activities and behaviours necessary to foster a strong safety culture during the project life cycle.	5	3.20	1.0954	4.0	2.0
3. Senior Management made sure that the goals, strategies, plans and objectives defined for the management system were achieved during the project life cycle.	5	3.80	0.4472	4.0	1.0
4. Senior Management made sure that each stage of the nuclear installations' life cycle was preceded by monitoring and pre-assessment to identify the impact of the life cycle specific processes.	5	3.60	0.5477	4.0	1.0
5. The QMS was implemented during the planning stage of the project.	5	2.80	2.0494	2.0	4.0
6. After implementation of QMS there has been visible improvement in controlling project scope.	3	2.67	1.5275	3.0	3.0
7. After implementation of QMS there has been visible improvement in controlling project costs.	5	3.60	0.5477	4.0	1.0
8. After implementation of QMS there has been visible improvement in controlling project schedule.	5	3.40	0.8944	4.0	2.0
9. The QMS implementation ensured that minimum regulatory requirements were met when applying for licensing.	5	3.20	1.3038	3.0	3.0
10. During the implementation of QMS the project management team played an influential role to ensure success.	5	3.60	0.8944	4.0	2.0
11. During all phases of the life cycle of the nuclear installation PBMR/licensee or designee planned and	5	3.00	1.0000	3.0	2.0

Variable	N	Mean	Std Dev	Median	Range
developed the processes required to achieve a safe installation.					

TABLE 5. 10: Descriptive statistics – Mean, Median, Standard Deviation and Range for quality management questionnaire

Variable	N	Mean	Std Dev	Median	Range
1. Senior Management made sure that systems were established and implemented during the planning stage of the project life cycle and can demonstrate their commitment to the project.	3	3.33	1.1547	4.0	2.0
2. Senior Management at all levels can demonstrate its commitment to the implementation, assessment and continual improvement of the management system during the project life cycle.	3	3.67	0.5774	4.0	1.0
3. Senior Management was responsible for the activities and behaviours necessary to foster a strong safety culture during the project life cycle.	3	3.33	1.1547	4.0	2.0
4. Senior Management made sure that the goals, strategies, plans and objectives defined for the management system were achieved during the project life cycle.	3	3.00	1.0000	3.0	2.0
5. Senior Management made sure that each stage of the nuclear installations' life cycle was preceded by monitoring and pre-assessment to identify the impact of the life cycle specific processes.	3	3.00	1.0000	3.0	2.0
6. IMS (combination of QMS and SM) was introduced at all phases of life cycle of the nuclear installation as it is required by RD0034.	3	3.00	1.7320	4.0	3.0
7. Quality department never experienced any problems as a result of not implementing QMS in the planning stage of the project life cycle.	3	4.00	1.0000	4.0	2.0
8. All the processes needed to achieve the quality and safety goals of the organisation were identified and their development was planned, implemented, assessed	3	3.60	1.5275	4.0	3.0

Variable	N	Mean	Std Dev	Median	Range
and continually improved since the planning stage of the project life cycle.					
9. Quality department did not have to retrofit some of the processes as a result of QMS not implemented at the planning stage of the project life cycle.	3	4.00	0.0000	4.0	0.0
10. All the suppliers were easily qualified as a result of the implementation of QMS at the planning stage of the life cycle.	3	3.67	0.57745	4.0	1.0

Annexure B

5.3.3.1 Project management graphs

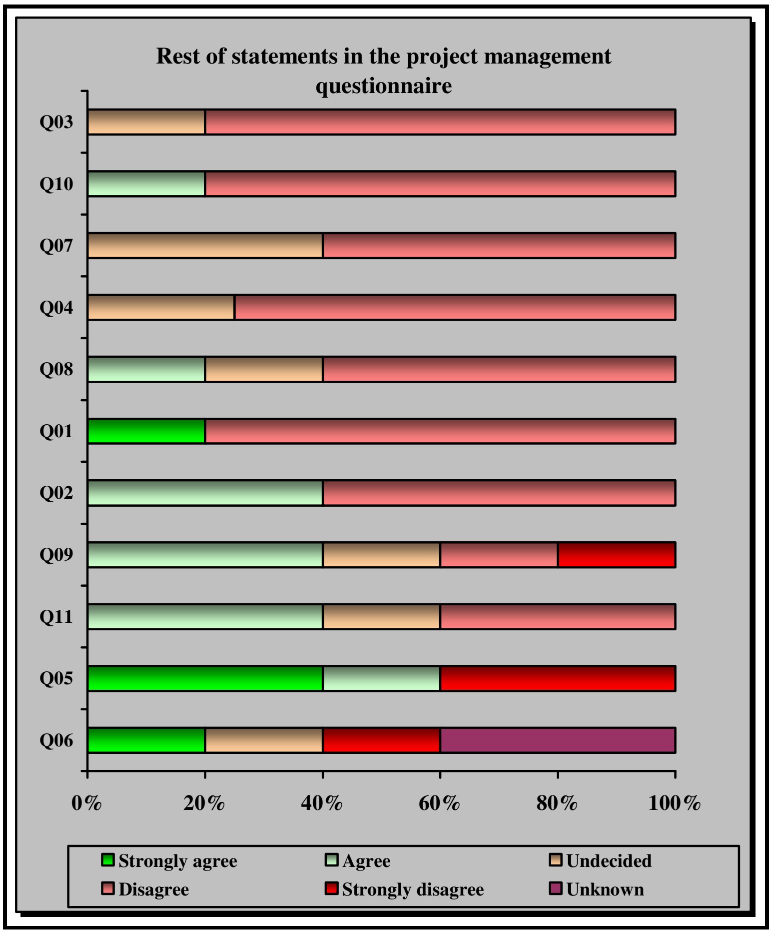

FIGURE 5. 1: Statements in project management questionnaire

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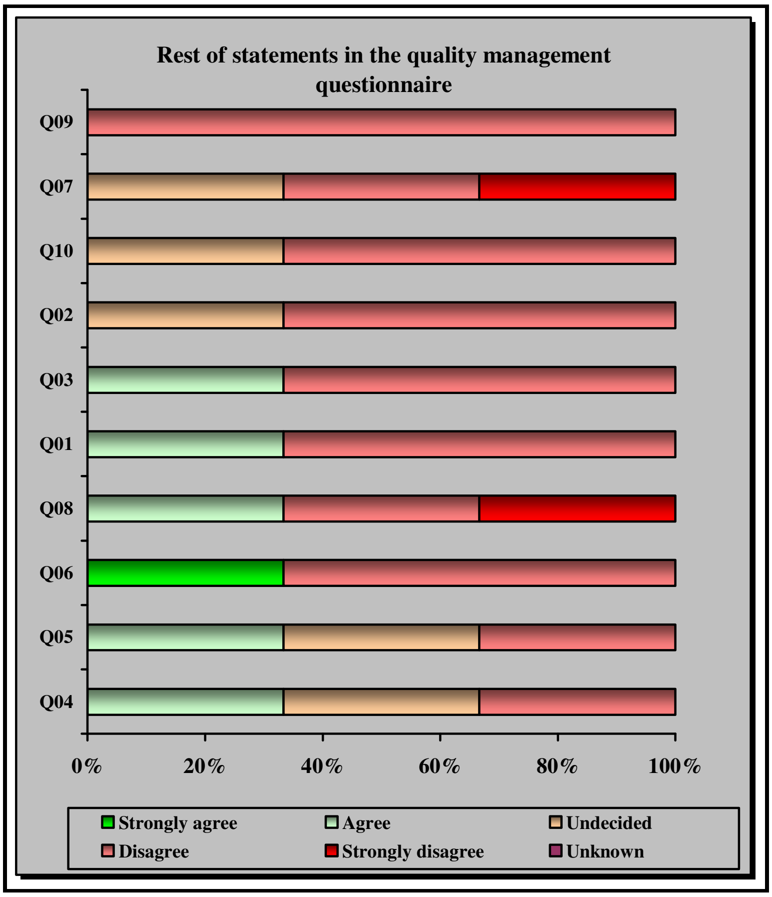

FIGURE 5. 2: Statements in quality management questionnaire

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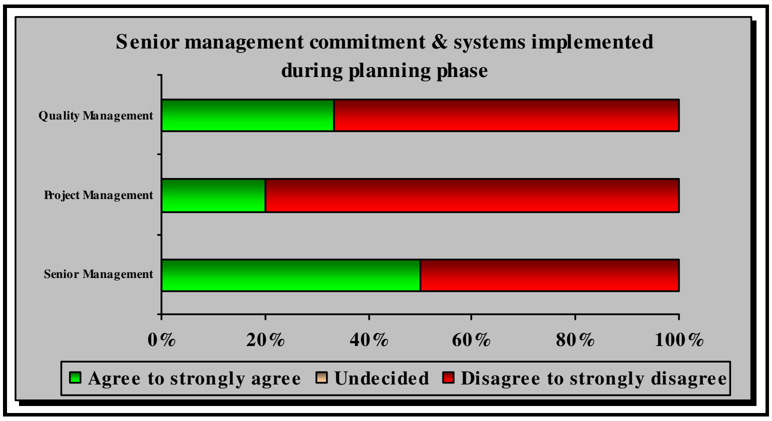

FIGURE 5. 3: SM commitment & systems implemented during planning phase

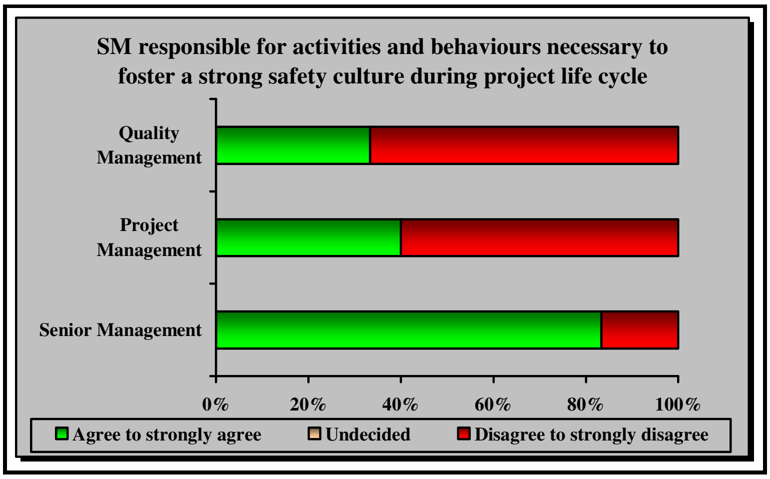

FIGURE 5. 4: SM responsible for activities and behaviours necessary to foster a strong safety culture during project life cycle

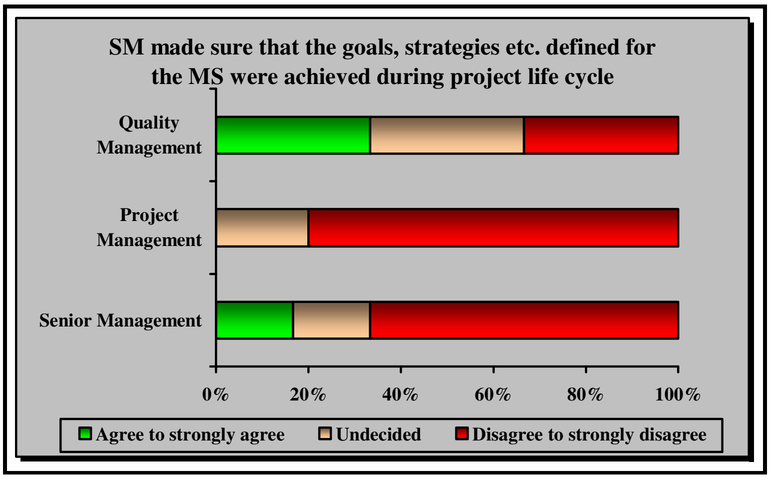

FIGURE 5. 5: SM made sure that the goals, strategies etc. defined for the MS were achieved during project life cycle

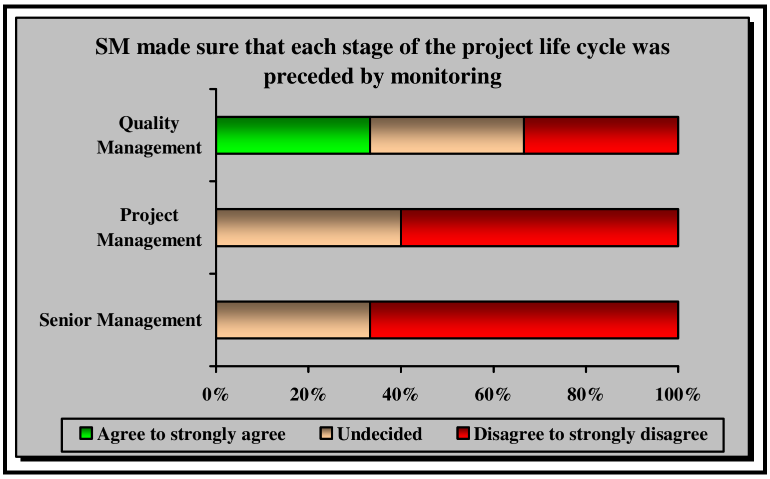

FIGURE 5. 6: SM made sure that each stage of the project life cycle was preceded by monitoring

Annexure C

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Cronbach Alpha Coefficients
Project management questionnaire

Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	Label
Q01	3	3.00000	1.73205	9.00000	1.00000	4.00000	Q01
Q02	3	2.66667	1.15470	8.00000	2.00000	4.00000	Q02
Q03	3	3.66667	0.57735	11.00000	3.00000	4.00000	Q03
Q04	3	3.33333	0.57735	10.00000	3.00000	4.00000	Q04
Q05	3	1.33333	0.57735	4.00000	1.00000	2.00000	Q05
Q06	3	2.66667	1.52753	8.00000	1.00000	4.00000	Q06
Q07	3	3.33333	0.57735	10.00000	3.00000	4.00000	Q07
Q08	3	3.00000	1.00000	9.00000	2.00000	4.00000	Q08
Q09	3	4.00000	1.00000	12.00000	3.00000	5.00000	Q09
Q10	3	3.33333	1.15470	10.00000	2.00000	4.00000	Q10
Q11	3	3.66667	0.57735	11.00000	3.00000	4.00000	Q11

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Cronbach Coefficient Alpha

Variables	Alpha
Raw	0.488889
Standardized	0.592676

Cronbach Coefficient Alpha with Deleted Variable

	Raw Variables		Standardized Variables		
Deleted Variable	Correlation with Total	Alpha	Correlation with Total	Alpha	Label
Q01	0.500000	0.308642	0.639999	0.476066	Q01
Q02	-.409644	0.639269	-.376110	0.695594	Q02
Q03	0.693375	0.384615	0.639999	0.476066	Q03
Q04	-.802955	0.614035	-.824160	0.766096	Q04
Q05	0.928571	0.340136	0.916826	0.399168	Q05
Q06	0.188982	0.476190	0.327327	0.553554	Q06
Q07	0.928571	0.340136	0.916826	0.399168	Q07
Q08	0.500000	0.370370	0.515832	0.507987	Q08
Q09	0.114708	0.487329	0.123961	0.598980	Q09
Q10	-.064018	0.546448	-.011497	0.627195	Q10
Q11	0.693375	0.384615	0.639999	0.476066	Q11

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Cronbach Coefficient Alpha

Variables	Alpha
Raw	0.639269
Standardized	0.695594

Cronbach Coefficient Alpha with Deleted Variable

	Raw Variables		Standardized Variables		
Deleted Variable	Correlation with Total	Alpha	Correlation with Total	Alpha	Label
Q01	0.277350	0.649038	0.470759	0.651568	Q01
Q03	0.500000	0.597656	0.470759	0.651568	Q03
Q04	-.654654	0.723214	-.715363	0.828032	Q04
Q05	0.993399	0.532895	0.985432	0.546315	Q05

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Q06	0.458957	0.573980	0.525961	0.641203	Q06
Q07	0.993399	0.532895	0.985432	0.546315	Q07
Q08	0.720577	0.519231	0.696063	0.607900	Q08
Q09	-.101361	0.693493	-.056262	0.740278	Q09
Q10	0.188982	0.642857	0.193482	0.700483	Q10
Q11	0.500000	0.597656	0.470759	0.651568	Q11

Cronbach Coefficient Alpha

Variables	Alpha
Raw	0.723214
Standardized	0.828032

Cronbach Coefficient Alpha with Deleted Variable

	Raw Variables		Standardized Variables		
Deleted Variable	Correlation with Total	Alpha	Correlation with Total	Alpha	Label
Q01	0.397360	0.721805	0.614382	0.800946	Q01
Q03	0.585206	0.688845	0.614382	0.800946	Q03
Q05	0.977356	0.648188	0.946402	0.759519	Q05
Q06	0.387147	0.711944	0.414147	0.823849	Q06
Q07	0.977356	0.648188	0.946402	0.759519	Q07
Q08	0.654654	0.653061	0.593478	0.803409	Q08
Q09	0.000000	0.761905	0.102167	0.856604	Q09
Q10	0.114708	0.751880	0.078400	0.858959	Q10
Q11	0.585206	0.688845	0.614382	0.800946	Q11

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Quality management questionnaire

Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	Label
Q01	3	3.33333	1.15470	10.00000	2.00000	4.00000	Q01
Q02	3	3.66667	0.57735	11.00000	3.00000	4.00000	Q02
Q03	3	3.33333	1.15470	10.00000	2.00000	4.00000	Q03
Q04	3	3.00000	1.00000	9.00000	2.00000	4.00000	Q04
Q05	3	3.00000	1.00000	9.00000	2.00000	4.00000	Q05
Q06	3	3.00000	1.73205	9.00000	1.00000	4.00000	Q06
Q07	3	4.00000	1.00000	12.00000	3.00000	5.00000	Q07
Q08	3	3.66667	1.52753	11.00000	2.00000	5.00000	Q08
Q09	3	4.00000	0	12.00000	4.00000	4.00000	Q09
Q10	3	3.66667	0.57735	11.00000	3.00000	4.00000	Q10

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Cronbach Coefficient Alpha

Variables	Alpha
Raw	0.926804
Standardized	.

Cronbach Coefficient Alpha with Deleted Variable

	Raw Variables		Standardized Variables		
Deleted Variable	Correlation with Total	Alpha	Correlation with Total	Alpha	Label
Q01	0.997609	0.902866	.	.	Q01
Q02	0.997949	0.915984	.	.	Q02
Q03	0.997609	0.902866	.	.	Q03
Q04	0.866025	0.911982	.	.	Q04
Q05	0.866025	0.911982	.	.	Q05
Q06	0.997176	0.905075	.	.	Q06
Q07	0.792406	0.915698	.	.	Q07
Q08	0.888459	0.910714	.	.	Q08
Q09	.	0.938389	.	0.925227	Q09
Q10	-.500000	0.955000	.	.	Q10

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Cronbach Coefficient Alpha

Variables	Alpha
Raw	0.938389
Standardized	0.925227

Cronbach Coefficient Alpha with Deleted Variable

	Raw Variables		Standardized Variables		
Deleted Variable	Correlation with Total	Alpha	Correlation with Total	Alpha	Label
Q01	0.997609	0.917197	0.985547	0.899674	Q01
Q02	0.997949	0.930523	0.985547	0.899674	Q02
Q03	0.997609	0.917197	0.985547	0.899674	Q03
Q04	0.866025	0.926458	0.906191	0.905041	Q04
Q05	0.866025	0.926458	0.906191	0.905041	Q05
Q06	0.997176	0.919441	0.985547	0.899674	Q06
Q07	0.792406	0.930233	0.719487	0.917233	Q07
Q08	0.888459	0.925170	0.850509	0.908740	Q08
Q10	-.500000	0.970159	-.480049	0.982249	Q10

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Senior management questionnaire

Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	Label
Q01	6	2.83333	1.32916	17.00000	1.00000	4.00000	Q01
Q02	6	2.33333	0.81650	14.00000	2.00000	4.00000	Q02
Q03	6	3.66667	1.03280	22.00000	2.00000	5.00000	Q03

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```
Q04              6       3.83333       0.75277       23.00000       3.00000       5.00000    Q04

                                   Cronbach Coefficient Alpha
                                  Variables              Alpha
                                  ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
                                  Raw                 0.760563
                                  Standardized        0.757234

                         Cronbach Coefficient Alpha with Deleted Variable
                             Raw Variables             Standardized Variables
         Deleted      Correlation                     Correlation
         Variable      with Total           Alpha      with Total           Alpha    Label
         ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
         Q01            0.762386        0.584071        0.756859        0.582596    Q01
         Q02            0.298807        0.816964        0.265871        0.844453    Q02
         Q03            0.679366        0.634615        0.667703        0.636218    Q03
         Q04            0.604798        0.700508        0.578360        0.687145    Q04
```

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Annexure D

Descriptive statistics: Frequency tables
Project management questionnaire

Q01	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree-Strongly agree	1	20.00	1	20.00
Disagree-Strongly disagree	4	80.00	5	100.00

Chi-Square Test for Equal Proportions

Chi-Square	1.8000
DF	1
Pr > ChiSq	0.1797

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.

Sample Size = 5

Q02	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree-Strongly agree	2	40.00	2	40.00
Disagree-Strongly disagree	3	60.00	5	100.00

Chi-Square Test for Equal Proportions

Chi-Square	0.2000
DF	1
Pr > ChiSq	0.6547

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.

Sample Size = 5

Q03	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Undecided	1	20.00	1	20.00
Disagree-Strongly disagree	4	80.00	5	100.00

Chi-Square Test for Equal Proportions

Chi-Square	1.8000
DF	1
Pr > ChiSq	0.1797

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.

Sample Size = 5

Q04	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Undecided	2	40.00	2	40.00
Disagree-Strongly disagree	3	60.00	5	100.00

Chi-Square Test for Equal Proportions

Chi-Square	0.2000
DF	1
Pr > ChiSq	0.6547

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.

Sample Size = 5

Q05	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree-Strongly agree	3	60.00	3	60.00
Disagree-Strongly disagree	2	40.00	5	100.00

Chi-Square Test for Equal Proportions

Chi-Square	0.2000
DF	1
Pr > ChiSq	0.6547

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.

Sample Size = 5

Q06	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree-Strongly agree	1	33.33	1	33.33
Undecided	1	33.33	2	66.67
Disagree-Strongly disagree	1	33.33	3	100.00

Chi-Square Test for Equal Proportions

Chi-Square	0.0000
DF	2

Pr > ChiSq 1.0000
WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.
Effective Sample Size = 3
Frequency Missing = 2
WARNING: 40% of the data are missing.

Q07	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Undecided	2	40.00	2	40.00
Disagree-Strongly disagree	3	60.00	5	100.00

Chi-Square Test
for Equal Proportions
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Chi-Square 0.2000
DF 1
Pr > ChiSq 0.6547
WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.
Sample Size = 5

Q08	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree-Strongly agree	1	20.00	1	20.00
Undecided	1	20.00	2	40.00
Disagree-Strongly disagree	3	60.00	5	100.00

Chi-Square Test
for Equal Proportions
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Chi-Square 1.6000
DF 2
Pr > ChiSq 0.4493
WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.
Sample Size = 5

Q09	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree-Strongly agree	2	40.00	2	40.00
Undecided	1	20.00	3	60.00
Disagree-Strongly disagree	2	40.00	5	100.00

Chi-Square Test
for Equal Proportions
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Chi-Square 0.4000
DF 2
Pr > ChiSq 0.8187
WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.
Sample Size = 5

Q10	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree-Strongly agree	1	20.00	1	20.00
Disagree-Strongly disagree	4	80.00	5	100.00

Chi-Square Test
for Equal Proportions
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Chi-Square 1.8000
DF 1
Pr > ChiSq 0.1797
WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.
Sample Size = 5

Q11	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree-Strongly agree	2	40.00	2	40.00
Undecided	1	20.00	3	60.00
Disagree-Strongly disagree	2	40.00	5	100.00

Chi-Square Test
for Equal Proportions
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Chi-Square 0.4000
DF 2
Pr > ChiSq 0.8187
WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.
Sample Size = 5

Q01	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Strongly agree	1	20.00	1	20.00
Disagree	4	80.00	5	100.00

Chi-Square Test
for Equal Proportions
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ

Chi-Square	1.8000
DF	1
Pr > ChiSq	0.1797

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.

Sample Size = 5

Q02	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree	2	40.00	2	40.00
Disagree	3	60.00	5	100.00

Chi-Square Test for Equal Proportions

Chi-Square	0.2000
DF	1
Pr > ChiSq	0.6547

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.

Sample Size = 5

Q03	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Undecided	1	20.00	1	20.00
Disagree	4	80.00	5	100.00

Chi-Square Test for Equal Proportions

Chi-Square	1.8000
DF	1
Pr > ChiSq	0.1797

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.

Sample Size = 5

Q04	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Undecided	2	40.00	2	40.00
Disagree	3	60.00	5	100.00

Chi-Square Test for Equal Proportions

Chi-Square	0.2000
DF	1
Pr > ChiSq	0.6547

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.

Sample Size = 5

Q05	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Strongly agree	2	40.00	2	40.00
Agree	1	20.00	3	60.00
Strongly disagree	2	40.00	5	100.00

Chi-Square Test for Equal Proportions

Chi-Square	0.4000
DF	2
Pr > ChiSq	0.8187

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.

Sample Size = 5

Q06	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Strongly agree	1	33.33	1	33.33
Undecided	1	33.33	2	66.67
Disagree	1	33.33	3	100.00

Chi-Square Test for Equal Proportions

Chi-Square	0.0000
DF	2
Pr > ChiSq	1.0000

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.

Effective Sample Size = 3

Frequency Missing = 2

WARNING: 40% of the data are missing.

Q07	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Undecided	2	40.00	2	40.00
Disagree	3	60.00	5	100.00

Chi-Square Test for Equal Proportions

ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Chi-Square 0.2000
DF 1
Pr > ChiSq 0.6547
WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.
Sample Size = 5

Q08	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree	1	20.00	1	20.00
Undecided	1	20.00	2	40.00
Disagree	3	60.00	5	100.00

Chi-Square Test
for Equal Proportions
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Chi-Square 1.6000
DF 2
Pr > ChiSq 0.4493
WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.
Sample Size = 5

Q09	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree	2	40.00	2	40.00
Undecided	1	20.00	3	60.00
Disagree	1	20.00	4	80.00
Strongly disagree	1	20.00	5	100.00

Chi-Square Test
for Equal Proportions
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Chi-Square 0.6000
DF 3
Pr > ChiSq 0.8964
WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.
Sample Size = 5

Q10	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree	1	20.00	1	20.00
Disagree	4	80.00	5	100.00

Chi-Square Test
for Equal Proportions
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Chi-Square 1.8000
DF 1
Pr > ChiSq 0.1797
WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.
Sample Size = 5

Q11	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree	2	40.00	2	40.00
Undecided	1	20.00	3	60.00
Disagree	2	40.00	5	100.00

Chi-Square Test
for Equal Proportions
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Chi-Square 0.4000
DF 2
Pr > ChiSq 0.8187
WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.
Sample Size = 5

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Quality management questionnaire

Q01	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree-Strongly agree	1	33.33	1	33.33
Disagree-Strongly disagree	2	66.67	3	100.00

Chi-Square Test
for Equal Proportions
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Chi-Square 0.3333
DF 1
Pr > ChiSq 0.5637
WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.
Sample Size = 3

Q02	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Undecided	1	33.33	1	33.33

Disagree-Strongly disagree	2	66.67	3	100.00

Chi-Square Test
for Equal Proportions

Chi-Square	0.3333
DF	1
Pr > ChiSq	0.5637

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.
Sample Size = 3

Q03	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree-Strongly agree	1	33.33	1	33.33
Disagree-Strongly disagree	2	66.67	3	100.00

Chi-Square Test
for Equal Proportions

Chi-Square	0.3333
DF	1
Pr > ChiSq	0.5637

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.
Sample Size = 3

Q04	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree-Strongly agree	1	33.33	1	33.33
Undecided	1	33.33	2	66.67
Disagree-Strongly disagree	1	33.33	3	100.00

Chi-Square Test
for Equal Proportions

Chi-Square	0.0000
DF	2
Pr > ChiSq	1.0000

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.
Sample Size = 3

Q05	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree-Strongly agree	1	33.33	1	33.33
Undecided	1	33.33	2	66.67
Disagree-Strongly disagree	1	33.33	3	100.00

Chi-Square Test
for Equal Proportions

Chi-Square	0.0000
DF	2
Pr > ChiSq	1.0000

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.
Sample Size = 3

Q06	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree-Strongly agree	1	33.33	1	33.33
Disagree-Strongly disagree	2	66.67	3	100.00

Chi-Square Test
for Equal Proportions

Chi-Square	0.3333
DF	1
Pr > ChiSq	0.5637

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.
Sample Size = 3

Q07	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Undecided	1	33.33	1	33.33
Disagree-Strongly disagree	2	66.67	3	100.00

Chi-Square Test
for Equal Proportions

Chi-Square	0.3333
DF	1
Pr > ChiSq	0.5637

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.
Sample Size = 3

Q08	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree-Strongly agree	1	33.33	1	33.33
Disagree-Strongly disagree	2	66.67	3	100.00

```
                    Chi-Square Test
                 for Equal Proportions
                 ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
                 Chi-Square      0.3333
                 DF                   1
                 Pr > ChiSq      0.5637
  WARNING: The table cells have expected counts less
           than 5. Chi-Square may not be a valid test.
                    Sample Size = 3

                                                   Cumulative    Cumulative
                       Q09    Frequency     Percent     Frequency      Percent
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Disagree-Strongly disagree           3      100.00             3       100.00

                    Chi-Square Test
                 for Equal Proportions
                 ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
                 Chi-Square      0.0000
                 DF                   0
                 Pr > ChiSq           .
                    Sample Size = 3

                                                   Cumulative    Cumulative
                       Q10    Frequency     Percent     Frequency      Percent
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Undecided                            1       33.33             1        33.33
Disagree-Strongly disagree           2       66.67             3       100.00

                    Chi-Square Test
                 for Equal Proportions
                 ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
                 Chi-Square      0.3333
                 DF                   1
                 Pr > ChiSq      0.5637
  WARNING: The table cells have expected counts less
           than 5. Chi-Square may not be a valid test.
                    Sample Size = 3

                                              Cumulative    Cumulative
                  Q01    Frequency     Percent     Frequency      Percent
    ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
    Agree                       1       33.33             1        33.33
    Disagree                    2       66.67             3       100.00

                    Chi-Square Test
                 for Equal Proportions
                 ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
                 Chi-Square      0.3333
                 DF                   1
                 Pr > ChiSq      0.5637
  WARNING: The table cells have expected counts less
           than 5. Chi-Square may not be a valid test.
                    Sample Size = 3

                                              Cumulative    Cumulative
                  Q02    Frequency     Percent     Frequency      Percent
    ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
    Undecided                   1       33.33             1        33.33
    Disagree                    2       66.67             3       100.00

                    Chi-Square Test
                 for Equal Proportions
                 ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
                 Chi-Square      0.3333
                 DF                   1
                 Pr > ChiSq      0.5637
  WARNING: The table cells have expected counts less
           than 5. Chi-Square may not be a valid test.
                    Sample Size = 3

                                              Cumulative    Cumulative
                  Q03    Frequency     Percent     Frequency      Percent
    ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
    Agree                       1       33.33             1        33.33
    Disagree                    2       66.67             3       100.00

                    Chi-Square Test
                 for Equal Proportions
                 ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
                 Chi-Square      0.3333
                 DF                   1
                 Pr > ChiSq      0.5637
  WARNING: The table cells have expected counts less
           than 5. Chi-Square may not be a valid test.
                    Sample Size = 3

                                              Cumulative    Cumulative
                  Q04    Frequency     Percent     Frequency      Percent
    ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
    Agree                       1       33.33             1        33.33
    Undecided                   1       33.33             2        66.67
    Disagree                    1       33.33             3       100.00

                    Chi-Square Test
                 for Equal Proportions
                 ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
                 Chi-Square      0.0000
```

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DF 2
Pr > ChiSq 1.0000
WARNING: The table cells have expected counts less
than 5. Chi-Square may not be a valid test.
Sample Size = 3

Q05	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree	1	33.33	1	33.33
Undecided	1	33.33	2	66.67
Disagree	1	33.33	3	100.00

Chi-Square Test
for Equal Proportions
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Chi-Square 0.0000
DF 2
Pr > ChiSq 1.0000
WARNING: The table cells have expected counts less
than 5. Chi-Square may not be a valid test.
Sample Size = 3

Q06	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Strongly agree	1	33.33	1	33.33
Disagree	2	66.67	3	100.00

Chi-Square Test
for Equal Proportions
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Chi-Square 0.3333
DF 1
Pr > ChiSq 0.5637
WARNING: The table cells have expected counts less
than 5. Chi-Square may not be a valid test.
Sample Size = 3

Q07	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Undecided	1	33.33	1	33.33
Disagree	1	33.33	2	66.67
Strongly disagree	1	33.33	3	100.00

Chi-Square Test
for Equal Proportions
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Chi-Square 0.0000
DF 2
Pr > ChiSq 1.0000
WARNING: The table cells have expected counts less
than 5. Chi-Square may not be a valid test.
Sample Size = 3

Q08	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree	1	33.33	1	33.33
Disagree	1	33.33	2	66.67
Strongly disagree	1	33.33	3	100.00

Chi-Square Test
for Equal Proportions
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Chi-Square 0.0000
DF 2
Pr > ChiSq 1.0000
WARNING: The table cells have expected counts less
than 5. Chi-Square may not be a valid test.
Sample Size = 3

Q09	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Disagree	3	100.00	3	100.00

Q10	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Undecided	1	33.33	1	33.33
Disagree	2	66.67	3	100.00

Chi-Square Test
for Equal Proportions
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Chi-Square 0.3333
DF 1
Pr > ChiSq 0.5637
WARNING: The table cells have expected counts less
than 5. Chi-Square may not be a valid test.
Sample Size = 3

Formatted: French (France)

Senior management questionnaire

Q01	Frequency	Percent	Cumulative Frequency	Cumulative Percent

Agree-Strongly agree	3	50.00	3	50.00
Disagree-Strongly disagree	3	50.00	6	100.00

Chi-Square Test
for Equal Proportions

Chi-Square	0.0000
DF	1
Pr > ChiSq	1.0000

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.

Sample Size = 6

Q02	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree-Strongly agree	5	83.33	5	83.33
Disagree-Strongly disagree	1	16.67	6	100.00

Chi-Square Test
for Equal Proportions

Chi-Square	2.6667
DF	1
Pr > ChiSq	0.1025

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.

Sample Size = 6

Q03	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree-Strongly agree	1	16.67	1	16.67
Undecided	1	16.67	2	33.33
Disagree-Strongly disagree	4	66.67	6	100.00

Chi-Square Test
for Equal Proportions

Chi-Square	3.0000
DF	2
Pr > ChiSq	0.2231

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.

Sample Size = 6

Q04	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Undecided	2	33.33	2	33.33
Disagree-Strongly disagree	4	66.67	6	100.00

Chi-Square Test
for Equal Proportions

Chi-Square	0.6667
DF	1
Pr > ChiSq	0.4142

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.

Sample Size = 6

Q01	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Strongly agree	1	16.67	1	16.67
Agree	2	33.33	3	50.00
Disagree	3	50.00	6	100.00

Chi-Square Test
for Equal Proportions

Chi-Square	1.0000
DF	2
Pr > ChiSq	0.6065

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.

Sample Size = 6

Q02	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Agree	5	83.33	5	83.33
Disagree	1	16.67	6	100.00

Chi-Square Test
for Equal Proportions

Chi-Square	2.6667
DF	1
Pr > ChiSq	0.1025

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.

Sample Size = 6

Q03	Frequency	Percent	Cumulative Frequency	Cumulative Percent

Agree	1	16.67	1	16.67
Undecided	1	16.67	2	33.33
Disagree	3	50.00	5	83.33
Strongly disagree	1	16.67	6	100.00

Chi-Square Test
for Equal Proportions

Chi-Square	2.0000
DF	3
Pr > ChiSq	0.5724

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.

Sample Size = 6

Q04	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Undecided	2	33.33	2	33.33
Disagree	3	50.00	5	83.33
Strongly disagree	1	16.67	6	100.00

Chi-Square Test
for Equal Proportions

Chi-Square	1.0000
DF	2
Pr > ChiSq	0.6065

WARNING: The table cells have expected counts less than 5. Chi-Square may not be a valid test.

Sample Size = 6