COPYRIGHT AND CITATION CONSIDERATIONS FOR THIS THESIS/ DISSERTATION

- Attribution — You must give appropriate credit, provide a link to the license, and indicate if changes were made. You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

- NonCommercial — You may not use the material for commercial purposes.

- ShareAlike — If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original.

How to cite this thesis

Critical success factors for improving quality culture in a coal testing division

by

Mohlatlego Jonas Rasethe

200583519

Minor Dissertation

Submitted in partial fulfillment of the requirements for the degree

MAGISTER PHILOSOPHIAE (MPH 603)

in

ENGINEERING MANAGEMENT

in the

FACULTY OF ENGINEERING AND THE BUILT ENVIRONMENT

at the

UNIVERSITY OF JOHANNESBURG

Supervisor: Professor J-HC Pretorius

Co-supervisor: Dr A Wessels

July 2019
Declaration

This minor dissertation titled: Critical success factors for improving quality culture in a coal testing division

Dated: July 2019

I, Mohlatlego Jonas Rasethe, student number, 200583519, hereby declare that this minor dissertation and its contents are entirely my own work, and that I received no outside help in composing the dissertation, other than discussing it with my supervisor and co-supervisor. Anything else in this dissertation that is not my own work, like for example figures or photographs included for illustration purposes, is declared as such and its source indicated; the same is true for any quotes or text from other written sources.

Signed: Mohlatlego Jonas Rasethe

Date: July 2019
Abstract

The present study relates to a method of identifying critical success factors for improving quality culture in a coal testing division. Coal testing division plays a major integral role in the selling and buying process of coal commodity globally. Although this is not an experimental study conducted in a testing laboratory through preparation and analysis of coal samples, the researcher has however provided a brief discussion on coal processing, usage, testing methods and significance of coal testing for end users of coal in chapter two of this dissertation.

With the current competitive advantage, coal testing division has recently been faced with various challenges including the closing down of some of its business units. This has had a negative impact on the overall commercial business. The main objectives of this study are to demonstrate the benefits for maintaining ISO 17025 quality management system and identification of critical success factors for improving ISO 17025 quality management system in a coal testing division. These study objectives will be achieved through answering the following study questions:

I. Why does coal testing division has to maintain ISO 17025 quality management system?
II. How to improve ISO 17025 quality management system in a coal testing division?

The study adopted a mixed method research by triangulation of quantitative and qualitative data to source out data in order to answer the study questions and objectives. The research strategy used was a single case study by means of research questionnaire sent to coal testing division employees. Chapter three of this dissertation provides literature review on the current published information regarding the benefits for implementation of quality culture in testing environment subsequently applicable to coal testing division. The literature review chapter concludes by providing an extracted case study of company X commercial unit quality management system policy document. The extracted case study outline the requirements and level of quality implementation in coal testing division.

From the literature review, the benefits for maintaining ISO 17025 quality management system revealed include improved customer satisfaction, greater market share (Competitive advantage), operational credibility with government and customers, international recognition and stronger risk management. Based on feedback from the questionnaires, critical success factors were identified for improving quality culture within coal testing division. Through triangulation system comparison of the literature review, company X commercial unit case study and the study questionnaire feedback, it was found that quality policy and objectives together with customer requirements are not well communicated and understood by all coal testing division personnel. There are also no designated personnel stationed in the business units to ensure effective maintenance of ISO 17025-quality management system. Majority of the staff members expressed that they are not always provided with the necessary resources assisting them with continual improvement of ISO 17025-quality management system. An ineffective customer communication system was identified which must provide customer service information, handling of enquiries, orders and customer feedback. There is an ineffective measuring and monitoring system for service conformity to ensure compliance on all customer requirements. There is ineffective system to identify and control non-conformities to prevent their unintended use in coal testing division.
Dedication

This dissertation is dedicated to the following:

- My dear wife and family for their everlasting love! God bless you “Kolobe tsa Leote”.
Acknowledgements

My sincere gratitude to the following for their valuable support throughout the study:

- My study supervisor, Professor Jan-Ham Pretorius and Co-supervisor, Dr Arie Wessels for their guidance and patience throughout the duration of the study. Much appreciated Prof and Dr.
- My employer and the management of coal testing division for giving me permission to perform the study within coal testing division.
- Fellow colleagues at coal testing division for their time taken in completing the study questionnaire. Thanks so much colleagues and much appreciated.
- My lovely wife, Mabore Beverly Rasethe for her unconditional words of encouragement and her believe in me in that “YES I CAN”. Thanks and much appreciated wifey!
- My dear family, mother Matele Rasethe, brothers Joseph, Walter, Sello and sister Kholofelo Rasethe for their unparalleled academic support and financial assistance throughout. Keep up the good job “Kolobe Tsa Leote”.
- My great friend of all time Neo Benny Masutha for an unequivocally support throughout my studies and constant believe in the powers of education. Thanks “Badau!”
List of Figures

Figure 1-1 Coal testing division Organogram (Source: MSP Document for X commercial, 2017) ...................................................................................................................................... 1-4
Figure 1-2 Dissertation layout .................................................................................................................................................................................. 1-8
Figure 3-1 The Deming wheel or cycle (Source: Howell, 2010) ...................................................................................................................... 3-2
Figure 3-2 The meanings of quality (Source: Godfrey & Juran, 1998) ................................................................................................. 3-6
Figure 3-3 The three general processes of managing for quality (Source: Godfrey & Juran, 1998) .................................................................................... 3-8
Figure 3-4 The Juran trilogy diagram (Source: Godfrey & Juran, 1998) ................................................................................................. 3-8
Figure 3-5 Process of Developing Organization Culture ............................................................................................................. 3-9
Figure 3-6 QMS hierarchy of a laboratory (Source: UNODC, 2009) ........................................................................................................... 3-12
Figure 3-7 Steps in developing and implementing a QMS (Source: WOA, 2011) ............................................................................... 3-14
Figure 3-8 Scope of ISO/IEC 17025:2005 (Source: Bui, 2017) ................................................................................................................. 3-15
Figure 3-9 QMS essentials (Source: WHO, 2011) ................................................................................................................................. 3-16
Figure 3-10 Third party testing (middle-man) between seller and buyer (Source: Neuman, 2000) ......................................................................................... 3-22
Figure 3-11 Steps for acquiring accreditation (Source: Balgobin & Khodabocus, 2011) .............................................................................. 3-23
Figure 3-12 Benefits of a good laboratory QMS (Source: Tahir, 2017) .............................................................................................................. 3-24
Figure 3-13 Company X Commercial unit QMS documentation hierarchy (Source: MSP Document for X commercial, 2017) ...................................................................................................................................... 3-27
Figure 3-14 Coal testing division monitoring & measuring of customer satisfaction (Source: MSP Document for X commercial, 2017) ...................................................................................................................................... 3-28
Figure 4-1 Coal testing division case study qualitative data analysis process (Source: Biggam, 2008) ...................................................................................................................................... 4-4
Figure 4-2 Updated coal testing division case study data analysis process (Source: Biggam, 2008) ...................................................................................................................................... 4-5
Figure 4-3 Triangulation research process (Source: Rahman & Yeasmin, 2012) ...................................................................................... 4-6
Figure 5-1 CSF 1: Quality Management System ...................................................................................................................................... 5-5
Figure 5-2 CSF 2: Management commitment ...................................................................................................................................... 5-6
Figure 5-3 CSF 3: Customer focus .................................................................................................................................................. 5-7
Figure 5-4 CSF 4: Quality Policy .................................................................................................................................................. 5-8
Figure 5-5 CSF 5: Responsibility, Authority & Communication ............................................................................................................. 5-9
Figure 5-6 CSF 6: Resource Management ...................................................................................................................................... 5-10
Figure 5-7 CSF 7: Product Realization ...................................................................................................................................... 5-12
Figure 5-8 CSF 8: Measurement, analysis and improvement ............................................................................................................. 5-13
List of Tables

Table 3-1 International standards applicable to laboratories (Source: WHO, 2011) .......... 3-11
Table 3-2 CSFs common to the success of various improvement initiatives (Source: Howell, 2010) ........................................................................................................................................ 3-20
Table 4-1 Relevant situations for different research methods (Yin, 2016) ......................... 4-2
Table 4-2 Case study: Breakdown of themes and questions ............................................ 4-4
Table 5-1 CSF questionnaire variables significance ......................................................... 5-2
Table 5-2 Pearson correlation between variables ......................................................... 5-4
Table 5-3 CSF 1 (Questionnaire variables 1-3): Quality Management System .............. 5-5
Table 5-4 CSF 2 (Questionnaire variables 4-7): Management commitment .................... 5-6
Table 5-5 CSF 3 (Questionnaire variables 8-10): Customer Focus .................................. 5-7
Table 5-6 CSF 4 (Questionnaire variables 11-13): Quality Policy .................................... 5-8
Table 5-7 CSF 5 (Questionnaire variables 14-16): Responsibility, Authority & Communication .......................................................................................................................... 5-9
Table 5-8 CSF 6 (Questionnaire variables 17-22): Resource Management ..................... 5-10
Table 5-9 CSF 7 (Questionnaire variables 23-27): Product Realization ......................... 5-11
Table 5-10 CSF 8 (Questionnaire variables 28-30): Measurement, analysis and improvement ........................................................................................................................................ 5-13
## Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAC</td>
<td>Approval Advisory Committee</td>
</tr>
<tr>
<td>ASQ</td>
<td>American Society for Quality</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
</tr>
<tr>
<td>BIS</td>
<td>Bureau of Indian Standards</td>
</tr>
<tr>
<td>BSI</td>
<td>British Standards Institution</td>
</tr>
<tr>
<td>BU</td>
<td>Business Unit</td>
</tr>
<tr>
<td>CAB</td>
<td>Conformity Assessment Bodies</td>
</tr>
<tr>
<td>CEO</td>
<td>Chief Executive Officer</td>
</tr>
<tr>
<td>CSFs</td>
<td>Critical Success Factors</td>
</tr>
<tr>
<td>CQI</td>
<td>Continuous Quality Improvement</td>
</tr>
<tr>
<td>Dti</td>
<td>Department of Trade and Industry</td>
</tr>
<tr>
<td>EQA</td>
<td>External Quality Assessment</td>
</tr>
<tr>
<td>FS</td>
<td>Free State</td>
</tr>
<tr>
<td>GLP</td>
<td>Good Laboratory Practice</td>
</tr>
<tr>
<td>GP</td>
<td>Gauteng Province</td>
</tr>
<tr>
<td>ICS</td>
<td>International Classification for Standards</td>
</tr>
<tr>
<td>ILAC</td>
<td>International Laboratory Accreditation Cooperation</td>
</tr>
<tr>
<td>IQC</td>
<td>Internal Quality Control</td>
</tr>
<tr>
<td>ISO</td>
<td>International Standards Organization</td>
</tr>
<tr>
<td>KPIs</td>
<td>Key Performance Indicators</td>
</tr>
<tr>
<td>KZN</td>
<td>Kwazulu Natal</td>
</tr>
<tr>
<td>Mt</td>
<td>Megaton</td>
</tr>
<tr>
<td>MP</td>
<td>Mpumalanga Province</td>
</tr>
<tr>
<td>MRA</td>
<td>Mutual Recognition Agreement</td>
</tr>
<tr>
<td>OD</td>
<td>Operational Documents</td>
</tr>
<tr>
<td>PTS</td>
<td>Proficiency Testing Scheme</td>
</tr>
<tr>
<td>RBCT</td>
<td>Richards Bay Coal Terminal</td>
</tr>
<tr>
<td>RSA</td>
<td>Republic of South Africa</td>
</tr>
<tr>
<td>SA</td>
<td>South Africa</td>
</tr>
<tr>
<td>SABS</td>
<td>South African Bureau of Standards</td>
</tr>
<tr>
<td>SAC</td>
<td>Standardisation Administration of China</td>
</tr>
<tr>
<td>SANS</td>
<td>South African National Standards</td>
</tr>
<tr>
<td>SANAS</td>
<td>South African National Accreditation Systems</td>
</tr>
<tr>
<td>SOA</td>
<td>Schedule of Accreditation</td>
</tr>
<tr>
<td>SOP</td>
<td>Standard Operating Procedure</td>
</tr>
<tr>
<td>UNIDO</td>
<td>United Nations Industrial Development Organization</td>
</tr>
<tr>
<td>UNISA</td>
<td>University of South Africa</td>
</tr>
<tr>
<td>UNODC</td>
<td>United Nations Office On Drugs and Crime</td>
</tr>
<tr>
<td>USA</td>
<td>United States of America</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
</tbody>
</table>
# Table of Contents

**Chapter 1: Introduction** ................................................................................................................... 1-1

1.1 Introduction ....................................................................................................................................... 1-1

1.2 Introduction to company X commercial unit and coal testing division ..................................... 1-3

1.3 Description of the problem area ..................................................................................................... 1-5

  1.3.1 Objectives of the study ............................................................................................................ 1-5

  1.3.2 Research questions ................................................................................................................. 1-6

1.4 Value of the study and its contribution ............................................................................................ 1-6

1.5 Study assumptions .......................................................................................................................... 1-6

1.6 Study format ..................................................................................................................................... 1-7

1.7 Summary ......................................................................................................................................... 1-8

**Chapter 2: Background on Coal, Usage and Analysis** .................................................................... 2-1

2.1 Introduction ....................................................................................................................................... 2-1

2.2 Definition and brief background of coal .......................................................................................... 2-1

2.3 Overview of global coal usage, testing methods and coal testing division testing methods ........ 2-1

  2.3.1 International standards of coal sampling and analysis .......................................................... 2-2

  2.3.2 National standards of coal sampling and analysis .................................................................. 2-3

2.4 Brief overview of South African coal mining and coal usage ....................................................... 2-3

2.5 Coal analysis significance .............................................................................................................. 2-4

  2.5.1 Significance of coal analysis ................................................................................................. 2-4

2.6 South African and coal testing division coal analysis methods .................................................... 2-5

  2.6.1 South African coal analysis methods .................................................................................. 2-5

2.7 Coal testing division analysis methods ......................................................................................... 2-6

2.8 Summary ......................................................................................................................................... 2-6

**Chapter 3: Literature Review** ............................................................................................................ 3-1

3.1 Introduction ....................................................................................................................................... 3-1

3.2 Defining CSFs................................................................................................................................. 3-1

  3.2.1 Value addition of CSFs within organizations and testing laboratories ............................... 3-2

  3.2.2 Advantages of using CSFs in organizations ......................................................................... 3-2

  3.2.3 Benefits of using CSFs in testing laboratory operations ....................................................... 3-3

  3.2.4 Different CSFs and different information ............................................................................. 3-3

  3.2.5 The five prime sources of testing laboratory CSFs ............................................................... 3-3

  3.2.6 Useful classification of laboratory CSFs ............................................................................... 3-4

3.3 Definition of quality ....................................................................................................................... 3-5
3.3.1 Defining other key words of quality ................................................................. 3-6
3.3.2 Customer needs and conformance to specifications by testing laboratories .... 3-7

3.4 Managing testing laboratory quality: The Juran trilogy ..................................... 3-7

3.5 Definition of quality culture .................................................................................. 3-9
3.5.1 Maintaining quality culture within an organization ........................................... 3-9

3.6 Quality culture in the context of testing laboratories ............................................ 3-10

3.7 Impact of quality on the reliability of laboratory test results .............................. 3-11

3.8 Definition, development and implementation of laboratory QMS ....................... 3-13
3.8.1 Process steps for the development and implementation of laboratory QMS ....... 3-13

3.9 Background information on ISO 17025 standard ................................................. 3-14
3.9.1 The relationship between ISO 17025 and ISO 9001 QMS standards ................. 3-15

3.10 Quality system essentials for maintaining laboratory QMS ............................... 3-16

3.11 Critical success factors for improving quality culture of testing laboratories ......... 3-20

3.12 Definition of testing and its different types .......................................................... 3-20
3.12.1 First party testing ......................................................................................... 3-21
3.12.2 Second party testing ................................................................................... 3-21
3.12.3 Third party testing ....................................................................................... 3-21

3.13 Meaning of commercial laboratory ...................................................................... 3-22
3.14 Defining ISO 17025 accreditation in the South African context ......................... 3-22
3.14.1 The required elements of accreditation ....................................................... 3-22
3.14.2 Process steps of acquiring ISO 17025 SANAS accreditation in South Africa ... 3-23
3.14.3 Benefits of ISO 17025 accreditation ............................................................ 3-23
3.14.4 Outcomes of ISO 17025 accreditation .......................................................... 3-24

3.15 Case study of quality culture implementation in coal testing division ............... 3-25
3.15.1 Management System of company X commercial unit .................................. 3-25
3.15.2 Company X commercial unit laboratory services ......................................... 3-25
3.15.3 Coal testing division management system planning ..................................... 3-25
3.15.4 Management system of coal testing laboratories ......................................... 3-26
3.15.5 Management commitment ......................................................................... 3-26
3.15.6 Customer focus ......................................................................................... 3-26
3.15.7 Quality management system documentation ............................................... 3-27
3.15.8 Measurement, analysis and improvement ..................................................... 3-27
3.15.9 Monitoring and measurements ..................................................................... 3-27
3.15.10 Management review ................................................................................ 3-28
3.15.11 Communication ....................................................................................... 3-29
3.15.12 Resource management .............................................................................. 3-29
Chapter 1 : Introduction

1.1 Introduction

Company X coal testing division has provided testing services to the local and international mining industry since 1975. The division is a key third party service provider to the global mining industry in sampling and analysis worldwide (www.CompanyX.co.za Access date: 26/03/2018). Although the greater focus of testing service provided by company X to mining industry is in coal and iron ore, each of the tested commodities are used for different purpose(s) and the significance of their testing is as important as their daily use by mankind. This study will make reference to coal testing as the majority of testing laboratories of company X servicing mining industry are focused on coal testing.

Gates (2010) define Critical Success Factors (CSFs) as the most important areas where an organization has to perform well so that it will achieve its goals or objectives. This means that every organization has CSFs specific to its operations and it is through identification of CSFs that an organization will be able to create a universal point of operation in order to be able to track and make an assessment of how well it is doing. With CSF been universal point of reference, CSFs will greatly assist everyone to clearly understand issues or factors critical to the organization. By understanding of issues or factors critical to the organization, this means that CSFs will assist in ensuring that everyone within the organization understands clearly their duties and responsibilities. Every person in the organization will perform in the right direction gearing towards the same overall objectives (Gates, 2010). According to Howell (2010) identification of CSFs is one of the first step. After identification of organization CSFs, the organization must establish how to ensure top performance on those identified CSFs. The organization must also monitor progress and make changes as and when required.

The overall objectives of coal testing division of company X are to provide high quality, accurate and reliable testing service to the respective customers. In order to achieve these objectives, specific CSFs must be in place. Been the third party testing unit, this means that coal testing division performs sampling and testing activities to external customers. Such activities must therefore be performed in such a way that will maintain confidence to the customers by ensuring that the division has a well-structured and accredited Quality Management System (QMS) where necessary (Canten, 2010).

ISO 9000 (2015) series of standards define QMS as a set of organized activities of an organization in order to establish organizational policies and objectives and the process to achieve such organizational objectives. The QMS is designed to ensure that all laboratory processes are performed in a reputable and predictable manner by all laboratory personnel (Kent, 2016). The laboratory processes will be designed in such a way that there will be checks and balances to protect the integrity of the laboratory and the quality of the products and services. QMS serves as a road-map of how activities are performed within an organization (Kent, 2016). The QMS activities can be summarized by the term C³I which stands for command, control, communication and intelligence, each briefly described below (Kent, 2016):

- Command
Command specifies how laboratory activities are performed by clearly setting out the process used.

- **Control**
  Control ensures that all laboratory personnel perform their activities according to the documented standard operating procedure (SOP).

- **Communication**
  Communication informs other laboratory personnel about the activities that took place and their outcomes.

- **Intelligence**
  Intelligence involves a review of activities to be taken in order to improve results.

ISO 17025 is the general standard acceptable for laboratories to enable them to demonstrate operational competency and thus generating valid and reliable test results (ISO 17025, 2017). Laboratory whose activities comply with the requirements of ISO 17025 generally will also operate in accordance with the principle of ISO 9001. ISO 9001 is the general standard that specifies the requirements for QMS. For laboratories wishing to comply with the requirements of ISO 17025 QMS, maintenance and improvement becomes two processes that are mutually inclusive. Once ISO 17025 QMS has been maintained, it will like any other system, require continual improvement. Therefore, in order to effectively maintain and continually improve ISO 17025, certain CSFs must be present in the laboratory (Joubert, 2002).

Been part of the commercial division of company X, the desirable end-result of coal testing division business strategy is to make as much reasonable profit as possible. This will result in stability within the business. These high-level strategies cannot be set by marketing division but are set by the organization’s top management. The marketing strategy to be implemented must reflect the goals such as profit targets that may include desired customer service set for coal testing division.

According to the South African Coal Processing Society (2002) document, the key feature of coal that is required for a coal marketer is knowledge of the product specification, and the significance of each of these specifications to the prospective end-user or customer. Amongst others, the key responsibilities of the coal marketing department are to identify the specification needs of the existing and prospective customer(s). Once such data has been compiled, a profile may be generated regarding the following:

- The possible outlets for each product(s); and
- Questions for coal preparation professionals on or regarding the possibilities of changing the product to suit the requirements of each customer.

Coal qualities are controllable through coal preparation as stipulated in the aforementioned South African coal processing society document. The type and specifications of the products produced by the coal preparation plants must be anticipated, thus forward planning is of prime importance to the coal marketer, so that customer reaction to any changes can be assessed and action taken. One of the aspects, which a marketer will look for, is consistency in the product specifications. The South African coal industry is in a sense fortunate because the quality of rare coal is rarely good enough for direct use. However, it has to go through a coal preparation stage in order to allow for an extensive set of quality controls to be instituted. This has helped
the industry to develop a deserved reputation for product consistency, which has significantly aided marketers in their task, particularly with export markets.

Coal product specifications are quoted differently and testing methods are different in individual countries. As an example, commonly in South Africa (SA) International Standard Organization (ISO) methods are used for coal testing adopted as South African National Standards (SANS) through the national standards body, the South African Bureau of Standards (SABS) while internationally both ISO and American Standards for Testing of Materials (ASTM) may be used. For most qualities of coal, except the testing of volatile matter at high temperature under ASTM, it will make no significant difference of employing either ISO or ASTM methods. The type of coal required will depend on the type of facility been operated by the coal consumers or end-users of coal. As an example, power utility ESKOM, the local industrial markets and the export component all of which are end-users or consumers of coal will require different types of coal (Www.chamberofmines.org.za Access date: 11/04/2018).

With different consumers or end-users of coal requiring different types of coal for different purposes, it is evident that the accurate analysis of coal samples is critical for the evaluation of coal reserves prior to commercial exploration and for the trade of this commodity (Www.chamberofmines.org.za Access date: 11/04/2018). The need for analysis of coal is more related to consumer needs than to the producer requirements. It is also due to the development of greater environmental constraints than it used to be in the past (Gouricharan & Rao, 2016). This study will look at how CSFs are revealed for improving quality culture in coal testing division in order to continue providing accurate and reliable service to the end users of coal.

1.2 Introduction to company X commercial unit and coal testing division

As already stated, coal testing division has been and is still the provider of third party testing service both locally and internationally. By third party testing, the laboratories within coal testing division are able to show competency and honesty through impartiality or independence in its sampling and analysis activities (Caten et al, 2010). Furthermore, impartiality or independence means that coal testing division personnel will be free from any undue financial or other forms of pressures which might influence them while performing testing activities and their technical judgement (Balgobin & Khodabocus, 2011). In order to avoid activities that will compromise the impartiality or independence of coal testing personnel, ISO 17025 QMS must be effectively implemented and maintained. As already stated, ISO 17025 is the widely acceptable standard used to assess the competency of different forms of testing laboratories. The maintenance of ISO 17025 QMS should ensure that any person or organisation external to the testing laboratory cannot have any influence on the results of tests performed and can assure the customer of the reliability of results (Balgobin & Khodabocus, 2011).

Since coal testing division is the provider of sampling and analysis to both the Republic of South Africa (RSA) and international buyers of the RSA coal, to ensure optimal service levels to the X customers, its testing laboratories are strategically located throughout the RSA in two categories, namely (Www.CompanyX.co.za Access date: 26/03/2018):

- Off-site laboratories; and
- On-site (mine-site) laboratories
Currently there are six commercial laboratories comprising of four off-site and two on-site (mine-site) laboratories. The six laboratories are spread across Gauteng Province (GP), Mpumalanga Province (MP) and Kwazulu Natal (KZN) Province of the RSA.

The related tested parameters on coal products include coal analysis of moisture, swelling index, hardgrove grindability index, proximate analysis, calorific value, total sulphur, carbon, hydrogen, nitrogen, fusibility of ash, chlorine, fluorine, ash constituents and screen analysis of samples (Www.CompanyX.co.za Access date: 26/03/2018). Although this is not an experimentation research conducted in the laboratory where samples were tested for these parameters, a brief description of the two levels of characterization, classification and evaluation covering these types of analysis is provided in chapter two of this dissertation.

Each of the abovementioned six laboratories has a Business Unit (BU) manager who in turn reports to the regional senior manager or coal testing division general manager. The coal testing division general managers reports to the laboratory services division executive who in turn reports to the chief executive officer (CEO) of company X (MSP Document for X commercial, 2017). The organogram of coal testing division is represented in figure 1-1.

![Coal testing division Organogram](Source: MSP Document for X commercial, 2017)

Of the total six laboratories, the four off-site laboratories are ISO 17025 accredited with South African National Accreditation Systems (SANAS). SANAS is the only national accreditation body in SA. It is responsible for carrying out accreditations in respect of conformity assessment, as mandated through the Accreditation for Conformity Assessment, Calibration and Good Laboratory Practice (GLP) Act (Act 19 of 2006) including the accreditation of physical (coal) testing laboratories. Laboratory accreditation means third-party accreditation related to conveying formal demonstration of their competence to carry out specific testing activities (Www.Sanas.co.za Access date: 01/05/2018). Each of the coal testing division accredited laboratories has a Certificate and Schedule of Accreditation (SOA). The Certificate together with the SOA can also be viewed on the SANAS website. Each laboratory’s SOA lists the scope for which SANAS has granted accreditation (Www.Sanas.co.za Access date: 01/05/2018). Coal testing division accredited laboratories provide sampling and analysis complying with the requirements of SANAS and issue coal test reports with SANAS logo. The accreditation circle is five years and there are series of SANAS assessments in between to...
monitor continued compliance with SANAS regulatory requirements aligned with the requirements ISO 17025.

SANAS accreditation is a requirement by some of the customers been serviced by coal testing division. The two non-accredited laboratories are not required by their customers (mines) to be accredited. However, company X requires that these laboratories conduct sampling, analysis and issue coal test reports complying with the requirements of ISO 17025. Therefore, all the two non-accredited laboratories are audited annually by an internal auditor from an independant and impartial department of company X called Y Department.

Since coal testing division is in a commercial business, the provision of excellent service to their customer is important in ensuring the survival of both its laboratory segments. With customer retention, the unique function for the off-site laboratories is continued maintenance of ISO 17025 accreditation with SANAS. This study will therefore be collectively identifying CSFs for improving quality culture for the entire coal testing division in order to continue providing high quality, cost effective and accurate service to its customer and maintenance of SANAS accreditation for the off-site laboratories.

1.3 Description of the problem area

The main aim of this study is identification of the CSFs for improving quality culture in a coal testing division of company X. In this modern world where competition is so rife and no one is given leniency in the business environment, it is important that coal testing division is prepared to deal with all forms of uncertainties within the business environment. The past few decades saw very radical changes in the business world. With such changes, there is little or no guarantee that the factors or competency strategies which had the potential of bringing success to a business can still do the same. In the context of laboratory operation, they might even lead an organization to its downfall (Ehlers & Lazenby, 2010).

In the past few years, coal testing division has been faced with various challenges including the closing down of some of the business units within the division. This has had a negative impact on the overall commercial business. The division experienced loss of revenue which resulted in loss of employment.

As a commercial division, coal testing division is obliged to reconfigure and introduce the strategies such as re-engineering process within their practices. Through the re-engineering process, the division will be able to fundamentally rethink and radically reformulate business processes to achieve dramatic continual improvements in critical, contemporary measures of performance, including cost, quality, service and speed (Dale et al, 2007). Therefore, with effective implementation of the re-engineering process through identification of CSFs for improving quality culture, coal testing division will be able to reach its intended goals and objectives. This study will be road testing the vision and strategy for coal testing division against a range of scenarios for the division to continue achieving its goals and objectives.

1.3.1 Objectives of the study

The main objectives of this study are to:

I. To demonstrate the benefits for maintaining ISO 17025 quality management system
II. Identification of critical success factors for improving ISO 17025 quality management system in a coal testing division

1.3.2 Research questions

Central to this study within the context of coal testing division is the need to answer the following questions:

I. Why does coal testing division has to maintain ISO 17025 quality management system?
II. How to improve ISO 17025 quality management system in a coal testing division?

1.4 Value of the study and its contribution

This study will contribute significantly to the research community, namely, coal testing division of company X, the existing body of literature of coal testing division and the researcher. The new competitive advantage which is also applicable to coal testing division could be achieved by organizations through strategies such as lower operational costs and a wider range of services (Ehlers & Lazenby, 2010). Colella et al (2006) states that the competitive advantage results when a testing laboratory can perform much better than its competitors within the industry. This will enable the laboratory to offer a more valuable services to its customers. In a service delivery environment like coal testing division laboratories, this will require availability of a reliable and maintained QMS performing the desired function at a lower cost in order to have a competitive edge in the market (Rooney, 2011). An unreliable QMS which is not maintained will have undesirable consequences such as loss of profit and customers.

As mentioned above, this study will contribute to the research community on the improvement of a reliable, competitive and fit for use system required to maintain a good customer base (Robledo, 2001). This will be done firstly through provision of a critical review of issues which are applicable to the maintenance of ISO 17025 QMS in testing laboratory environment since any system improvement process begin with system maintenance. Secondly, by identifying existing CSFs for improving ISO 17025 QMS in a coal testing division. Thirdly, through obtaining the views of various internal stakeholders (staff/study participants) on existing practices regarding CSFs for improving quality culture of coal testing ISO 17025 QMS. This will result in the development of a rich picture of CSFs for improving coal testing division ISO 17025 QMS. This will allow meaningful comparison between theory and practice, from which a more improved understanding of CSFs for the improvement of ISO 17025 QMS at coal testing division can be derived.

Upon completion of this study and submission of minor dissertation, the author will fulfil the requirements for the Degree, Master of Philosophy in Engineering Management at the University of Johannesburg.

1.5 Study assumptions

The following assumptions were made for the study:

- Participants are aware that participation on the study is voluntary
- Participants have basic knowledge of ISO 17025 QMS and SANAS accreditation
• Participants have basic knowledge of coal sampling and analysis technologies
• Participants are aware of the different laboratory segments
• Participants will respond truthfully and are aware that there are no known or unknown risks for participating in the study
• Sample of participants is adequate for the study

1.6 Study format

This dissertation consists of the following six chapters:

Chapter One: Introduction
Chapter one provides the reader with background information on coal testing division of company X and its relationship with coal producers and end users of coal in the RSA and the world. It further provides a description of the following in relation to the study; description of the problem area, value of this study and its contribution and study assumptions.

Chapter Two: Background on Coal, Usage and Analysis
This Chapter provides a brief background information on coal, coal mining, coal usage, global and coal testing division coal testing methods and significance.

Chapter Three: Literature Review
This chapter provides a review of the current published information regarding the implementation of quality culture in testing laboratory which are also applicable to coal testing.

Chapter Four: Research Methodology
Chapter four is a description of the research design and methods used in the study.

Chapter Five: Discussion of Results
Chapter five is about the results and discussions.

Chapter Six: Conclusions and Recommendations
Chapter six concludes the dissertation by discussing the conclusions and recommendations for the study by linking the research findings with the literature review.

References and appendices are also included

A complete layout of this study is summarized in the form of flowsheet in figure 1-2.
1.7 Summary

The aim of this chapter was to provide background information about the study. An outline of the study was also provided. The next chapter will be about background on coal, usage and analysis.
Chapter 2: Background on Coal, Usage and Analysis

2.1 Introduction

Although this was not an experimental study conducted directly in the laboratory by performing coal sampling in mine-site and performing coal analysis in the laboratory, the author found it beneficial to first note the methods used for coal analysis, application of coal and its impact on the society as tested by coal testing division of company X. The aim of this chapter is to briefly discuss the definition of coal, global coal usage, testing methods including for coal testing division and the significance of coal analysis.

2.2 Definition and brief background of coal

Schweinfurth (2009) define coal as a combustible black or dark brown rock. It is primarily composed of carbonized plant matter found mainly in underground seams. Coal is a key player in sustainability development due to its widespread application in electricity generation and in the production of steel (Gouricharan & Rao, 2016).

2.3 Overview of global coal usage, testing methods and coal testing division testing methods

The main use of coal is as a source of energy for both domestic and industrial use. The demand of energy in emerging markets like SA, India and China has increased the use of coal for energy production (Chimuka, 2011). Billions of tonnes of coal are sold in the national and international market annually (Zhu, 2014). The overall worldwide coal resources are estimated to be 11 billion tons of which 909 million tonnes are extractable reserves. This represents less than 10% of the total coal resources (Gouricharan & Rao, 2016). Coal reserves are sold to serve various purposes including the following (Zhu, 2014):

- Electricity generation
- Steel manufacturing
- Cement manufacturing

During the sale of coal, the price of coal does not only represent the quantity of coal but it is also a representation of the relationship of a desirable property or a combination of properties to performance of coal under service conditions. Coal properties form the basis of coal trade. Payment for coal is based on the laboratory analytical results (Zhu, 2014). Coal is a very heterogeneous material. Coal produced from operating mines is much more variable due to the inclusion of non-coal bands and it exhibits various physical properties (Gouricharan & Rao, 2016). The analysis of coal in a laboratory is carried on the coal samples taken from the bulk stockpile material and not from the individual components.

Given the abovementioned complexity of coal, coal-sampling procedures must be in such a way that they provide material representing the lot sampled (Schweinfurth, 2009). To ensure a representative sample is collected, correct sampling SOP should be followed and certain rules adhered to by coal samplers as stipulated in the relevant standard. Following correct coal
sampling SOP will also assist in obtaining repeatable and reproducible results (Schweinfurth, 2009). According to the South African Coal Processing Society (2002), the coal analyses need to be sufficiently accurate to prevent negative scientific or economic consequences.

2.3.1 International standards of coal sampling and analysis

Zhu (2014) define a standard as a document established through an agreement and approved by regulatory body through provision of rules, guidance or characteristics of activities for common and repeated use. Various organizations produce standards worldwide used for various purpose (Rumane, 2011). Kaziliunas (2010), points out that the application of international standards benefit manufacturers, service providers, end-users, consumers and regulators. Standards use also support global sustainable development (Zhu, 2014). As an example, before coal can be sold in the local or international markets, many industry bodies and trade associations will require confirmation of compliance to the relevant standard. This means that standards use is becoming a requirement to worldwide trade (Zhu, 2014).

The setting of standard is one of the first features in the development of a QMS. Instead of creating their own standards, many organizations are increasing dependant on existing standards (Rumane, 2011). Every published standard document should be (Rumane, 2011):

- Unambiguous and written in simple English
- Clear in setting specifications
- Convenient for users to understand
- Measurable for the organizations to know if they meet requirements
- Achievable in such a way that organizations have resources to meet the requirements of the standards
- Constructible

Extensive research work together with the formation of many international and national standards organizations, led to the development of standard methods for coal testing. Table 2.1 lists examples of the organizations for coal methods development and standardisation operating at national level. Organizations operating at international level include the following (Zhu, 2014):

I. ISO Standards

ISO Standards used for coal sampling, preparation and bias test, coal characterisation and coal analysis are listed in the category of international classification for standards (ICS) 73.040: Coals (including lignite) and ICS 75.160.10: Solid fuels. The full lists of coal ISO Standards are available on the ISO’s websites:

- ICS 73.040: Coals at www.iso.org (Access date: 21/05/2018)
- ICS 75.160.10: Solid fuels at www.iso.org (Access date: 21/05/2018)

Many countries have adopted various ISO Standards through their national standards bodies as national standards. ISO Standards are most widely accepted and applied in global markets for the sale of coal (Zhu, 2014).
II. ASTM International

A complete list of coal and gas standards developed by ASTM is available at ASTM’s website (www.astm.org Access date: 21/05/2018). ASTMs are helpful in the testing and chemical analysis of coal, coke, natural gas, other gaseous fuels and the combustion residues of coal and coke. ASTMs cater for materials in the form of lump coke, pulverised coal, bituminous coal, coke and coal ash, reformed gas, and polishing and etching coal (Zhu, 2014). The use of ASTMs allows laboratories for efficient testing to ensure these fuels are handled and used in a safe manner (Rumane, 2011). ASTMs coal testing standards are adopted in the United States of America (USA) and Canada. They are acceptable in the USA/Canada domestic coal markets or in the international coal market where USA/Canada coal exporter are involved. ASTMs coal standards are used in wide range of universities and research laboratories academic studies in coal. They are also used in research and development laboratories of new coal analysis techniques.

2.3.2 National standards of coal sampling and analysis

Various countries have national standard bodies which are member bodies representing them in ISO. Table 2.1 lists some of the national standards bodies across the globe (Zhu, 2014).

Table 2.1 National Standard Bodies (Source: Zhu, 2014)

<table>
<thead>
<tr>
<th>Country</th>
<th>Standard Body</th>
<th>Coal Standards website</th>
<th>Access date: 21/05/2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>United Kingdom</td>
<td>British Standards Institution (BSI)</td>
<td><a href="http://www.bsigroup.com/">www.bsigroup.com/</a></td>
<td>Access date: 21/05/2018</td>
</tr>
<tr>
<td>China</td>
<td>Standardisation Administration of China (SAC)</td>
<td><a href="http://www.sac.gov.cn/">www.sac.gov.cn/</a></td>
<td>Access date: 21/05/2018</td>
</tr>
<tr>
<td>India</td>
<td>Bureau of Indian Standards (BIS)</td>
<td><a href="http://www.bis.gov.in/">www.bis.gov.in/</a></td>
<td>Access date: 21/05/2018</td>
</tr>
<tr>
<td>South Africa</td>
<td>South African Bureau of Standards (SABS)</td>
<td><a href="http://www.store.sabs.co.za/">www.store.sabs.co.za/</a></td>
<td>Access date: 21/05/2018</td>
</tr>
<tr>
<td>Australia</td>
<td>Standards Australia</td>
<td><a href="http://www.saiglobal.com/">www.saiglobal.com/</a></td>
<td>Access date: 21/05/2018</td>
</tr>
</tbody>
</table>

2.4 Brief overview of South African coal mining and coal usage

Below is a summary of South African coal reserves and usage (www.chamberofmines.org.za Access date: 11/04/2018):

- SA coal resources amount to an estimated 30 billion tonnes of coal, which is a representation of about 3.5% of the world’s total coal resources. SA produces an estimated 3.3% of the global annual coal production.
- 83% of coal produced in SA is mined in MP with the residual produced in Limpopo, KZN, and the Free State (FS) Provinces. SA is a net exporter of coal. About 6% of total global exports are exported by SA ranking it as the world’s 6th largest coal-exporting nation.
- In 2016, SA produced 253.1 Megaton (Mt) of coal. 181.4Mt of these were traded locally with a value of R61.5 billion while 68.9Mt, with a value of R50.5 billion, were exported.
- The Richards Bay Coal Terminal (RBCT) is the primary export port of SA and has a dedicated coal railway.
• Coal has three major uses in S.A, namely, electricity generation, industrial process and manufacture of gas and liquid fuels providing 82% of the power produced by power utility Eskom.
• Currently, Eskom has thirteen power stations, namely, Arnot, Hendrina, Komati, Camden, Grootvlei, Kriel, Duvha, Matla, Lethabo, Matimba, Tutuka, Majuba and Kendal (former Khutala) powerstations.
• ESKOM is currently building two additional power stations, Medupi and Kusile planned for commissioning in 2021.
• Cement/concrete and paper industry, for example Lafarge and Sappi use coal to produce heat through burning.
• Steel industries, for example, Arcelormittal make use of coking coal in their furnaces to convert iron ore into iron to manufacturer steel.
• Sasol is currently mining about 40Mt of coal per annum for use in gasification and conversion into liquid fuels.

2.5 Coal analysis significance

2.5.1 Significance of coal analysis

According to ISO 14001, an organization will achieve sustainable development by balancing the three pillars of sustainability. The three pillars of sustainability are the environment, the society and the economy. Within the context of coal industry and end-users of coal, in order to balance the three pillars of sustainability, organizations using coal for various purposes must ensure that the coal used is first tested by a competent laboratory for various parameters of coal before usage. In most cases, these tests are carried out by accredited third party laboratories. Securing the right coal type is the key to smooth process flow in electricity generation by means of a boiler (Andrews et al, 2012). This means that if a well beneficiated coal will be used during the process of electricity generation, it will yield the following benefits (Gouricharan & Rao, 2016):

  • An increase in generation efficiency and plant availability
  • Enhanced equipment system capacity
  • Reduced demand of electricity generation equipment
  • A decrease in investment costs
  • Less wear and reduced fuel costs resulting in a decrease in operational and maintenance costs
  • A decrease in the costs of transportation and energy saving within the transport sector
  • Fewer impurities and improvement in coal quality
  • A decrease in load on the air pollution system
  • Reduction of solid waste to be disposed
  • Minimise Carbon Dioxide emissions

If not well beneficiated, coal presents some operational and societal challenges. Firstly, a coal that is not well beneficiated will have some negative effects such as pollution of the environment maybe due to by-products released from its use (Chimuka et al, 2011).

On the other hand, coal quality variations may have negative impact on a process such as Clean Coal Technology process, which is aimed at providing a description of a new generation of
electricity generation process and fuels from coal (Gouricharan & Rao, 2016). Such coal quality variations may also result in inefficient equipment (pulverized fuel boilers, chain grate boiler and cement manufacturer) operation (Andrews et al, 2012). A pulverized fuel boiler may have ignition and combustion difficulties when using coal from different zones in the coal sequence due to coal quality variations:

2.6 South African and coal testing division coal analysis methods

2.6.1 South African coal analysis methods

With coal said to be available in various types and having a wide range of applications, this requires extensive characterization, classification, and evaluation of this commodity (Falcon & Ham, 1988). The evaluation of South African coal can be performed on two levels, namely, empirical and fundamental level as explained briefly below (Falcon & Ham, 1988). Some coal tests performed are simple while others require involved manipulations, sophisticated equipment, and complex interpretation (Gouricharan & Rao, 2016).

I. Empirical levels

Falcon & Ham (1998) points out that the empirical determinations of coal include two main analytical classifications, namely, proximate and ultimate analyses. Proximate analyses are used for determination of the following:

- Inherent moisture
- Ash content

The ultimate analyses separate the coal into its ultimate chemical components, which are the elements Carbon, Hydrogen, Oxygen, Nitrogen and Sulphur.

There are other important characteristics of coal, which requires to be measured in addition to inherent moisture and ash content. Caloric value and swelling index are the most important characteristics of coal that also require to be measured too (Falcon & Ham, 1988).

Falcon & Ham (1998) states that, in addition to the aforementioned coal analyses, there are upto sixty analyses used for testing of the physical, chemical, and technological properties of coal. These analyses are important for coal used for specific purposes such as gasification, liquefaction and carbonization (manufacturing of coke) (Falcon & Ham, 1988).

According to Falcom & Ham (1998), two more analyses performed in addition to combustion testing is theremogravimetric analyses and drop-tube furnace tests. Both of these analyses are used to assess the rate of devolitalization and carbon consumption of coals under various experimental conditions, each set to emulate boilers of different types. Theremogravimetric analyses and drop-tube furnace tests must be regarded as empirical in nature unless conducted in conjunction with fundamental analysis (Falcon & Ham, 1988).

II. Fundamental levels

Falcon & Ham (1998) further states that apart from characterizing coal by means of its empirical (chemical and physical) properties, coal can be categorized by means of its basic or fundamental components, that is, organic and inorganic properties that are the “building blocks” of coal. The main difference between empirical tests and the fundamental or
petrographic analyses of coal is that, the fundamental or petrographic analyses are performed using a microscope. The fundamental composition of coal falls into three major categories of coal; organic matter, mineral matter, and rank or degree of metamorphism (Falcon & Ham, 1988).

2.7 Coal testing division analysis methods

Coal testing division developed its coal testing methods from a combination of ASTM and ISO adopted through the SABS as SANS together customer developed methods. As per the requirements of ISO 17025 QMS, each testing facility within coal testing division has validated all its testing methods and deemed them fit for use or purpose.

2.8 Summary

This chapter summarily presented global coal processing and usage together with analysis techniques including for coal testing division of company X. Societal impact of coal analysis was also presented. The next chapter is on literature review.
Chapter 3 : Literature Review

3.1 Introduction

All service providers know that business success depends upon customers’ satisfaction with the service rendered. This means that the quality of service provided meets the customers’ expectations (Coombs et al, 1995). Furthermore, any successful service provider will also agree that it is important at all times to be able to meet customers ever changing needs (Jacobsen, 2011). According to Kaziliunas (2010), quality may be considered as one of the strategic competitiveness tool and no organization can afford ignoring the strategic implications of equality for their competitive position. In this modern world, it is without any doubt clear that, quality forms the basis of a very healthy business competition (Drinke, 2011). As such, it is always important for organizations providing any form of service to ensure that their services or products comply with the relevant quality criteria. As an example, before sale or trade, commodities used in electricity production or steel manufacturer must first be tested for quality compliance. Laboratories on which testing is conducted must be able to demonstrate competency to provide high quality and accurate service to their customers or end users of such commodities.

The aim of this chapter is to establish literature review relevant to the research questions and objectives. This chapter will commence by providing a description of the CSFs and the significance of CSFs within organizations and testing laboratories. The chapter will continue by providing a description of quality, organizational quality culture, application of quality in a laboratory and quality impact on reliability of laboratory results. The concept of QMS, laboratory QMS and CSFs for improving laboratory QMS are discussed. ISO 17025 will be defined together with its similarities and differences with ISO 9001. The benefits of ISO 17025 accreditation will be discussed. An outline of the different types of testing will be made. This chapter concludes by providing an extract of case study from “Management System Policy” (MSP) Document for company X commercial unit on the requirements and level of quality implementation in coal testing division.

The literature review exercise was undertaken on each of the objectives to answer the research problems and to achieve the objectives of this study. The literature study serves to document current viewpoints and principles on the stated research subjects. From the literature study an outline of the benefits for the maintenance of CSFs together with identification of CSFs for improving quality culture in testing laboratories applicable to coal testing was made. This means that the literature review represent data for this study.

3.2 Defining CSFs

Howell (2010) points out that as far back as 1961, organizations have been dependent on CSFs as a means of defining things that must go right in order to achieve its goals. Bullen & Rockart (1981) summarily define CSFs as been the key areas where an organization must consistently produce reliable results to achieve its mission. Gates (2010) point out the following three areas where CSFs can be derived:

- Document review process
• Analysing goals and objectives of key managerial personnel
• Interviewing key organizational personnel on their areas of operation and challenges they encountered in reaching their goals.

3.2.1 Value addition of CSFs within organizations and testing laboratories

Central to the roles and responsibilities of every organizational management is the need to establish their goals. It is also important to establish the basic structural variables affecting the organization’s success or failure in the pursuit of such goals. CSFs are these structural variables and are of great importance such that they need utmost attention of the organizational management. The current status of performance in each area of the organization should be continually monitored and the performance status information should be made accessible for the management's use (Bullen & Rockart, 1981).

3.2.2 Advantages of using CSFs in organizations

Howell (2010) summarised the following advantages of using CSFs in an organization (testing laboratory):

• CSFs are easy to understand.
• CSFs focus attention of the laboratory in specific factors which are critical to the success of an organization separating failure and success.
• CSFs can assist an organization in its strategic planning process, system implementation improvement or re-engineering process, improvement of job performance, or driving manager’s pursuit.
• CSFs can be easily monitored with great benefits.

The most important benefits of applying CSFs within an organization’s process is that they are drivers. CSFs are not initiative on their own right. This means that CSFs can be used to enrich existing organization process improvement programs (Howell, 2010). This is demonstrated on how CSFs relate to the Deming wheel of continuous improvements Plan-Do-check-Act (PDCA) in figure 3.1:

![The Deming wheel or cycle](Source: Howell, 2010)
As may be seen in figure 3.1, in each stage of the Deming wheel, there is a corresponding phase of CSF implementation.

3.2.3 Benefits of using CSFs in testing laboratory operations

According to Crandall & Crandall (2008), CSF analysis will be most effective if it is a top-down management approach and technique that will enable success in a laboratory’s improvement initiatives. CFSs provides great focus for beginning the implementation of an improvement initiative.

The application of CSFs in a laboratory will:
- Decrease risk failure in laboratory and its strategic goals achievements
- Increase laboratory management understanding in the requirements of successful strategic plan implementation.
- Attainment of an increased internal laboratory stakeholders buy-in to process improvement.
- Increase in the use of value-added technique in planning, systems implementation and process improvement in laboratory.
- Facilitation of continuous improvement of laboratory process operations and performance.

3.2.4 Different CSFs and different information

For different managers of organizations, Bullen & Rockart (1981) states that CSFs relate to a specific manager’s operating condition and CSFs must be in such a way that they are tailored to the industry, the company, and the interviewee. As per each manager’s different level of responsibility or authority in the organization, CSFs will differ from one manager to another. CSFs will also normally change with changes on the industry’s environment or when the organization’s position in an industry changes. They may also change as a result of certain problems or opportunities arising for a specific manager (Bullen & Rockart, 1981).

Of great importance is the need to understand what is not meant by CSFs. CSFs are not "key performance indicators (KPIs)." KPIs are a standard set of measure and can be applied across all divisions of an organization (Bullen & Rockart, 1981). The main difference between CSFs and KPIs in a laboratory environment will be that, KPIs are not limited to factors which can be reported merely by historical, aggregated and accounting data while CSFs looks at the laboratory from a laboratory manager’s current operating perspective. CSFs also refers to specific areas of great importance to a specific laboratory manager at a particular point in time and they require specific and various situational measures. There is no standard set of organization-wide KPIs which can provide the required operating information (Bullen & Rockart, 1981).

3.2.5 The five prime sources of testing laboratory CSFs

According to Crandall (2008), CSFs are the characteristics, conditions, or variables impacting significantly on the success of the laboratory. Analysis of CSFs assist in the strategic
development process. Bullen & Rockart (1981) states that CSFs arise from the following five major sources. Every potential CSF interviewer should research them during the preparation of interview process:

I. The testing industry
Testing laboratory industry has a set of CSFs determined by the characteristics of the industry. Each laboratory within the industry must pay attention to these factors for efficient operation. The upcoming sections of this chapter will reveal CSFs for improving quality culture within testing industry space (Bullen & Rockart, 1981).

II. Testing industry competition analysis
Every laboratory in the testing industry is in its individual position determined by both its history and its current competing strategy. Such a laboratory's position in the industry calls for some CSFs. As an example, a much smaller laboratory within the testing industry must at all times be concerned with protecting its position in the industry. Also, if a specific testing industry space, for example coal testing is dominated by a single major organization, a CSF for all the other testing laboratories is based on understanding the leader's strategies including their possible impacts. The geographic location of the laboratory can also generate specific CSFs. An example of this could be a commercial off-site coal laboratory which may have transportation of sample from the mine-site to the laboratory as a CSF while for commercial on-site laboratory this is less important.

III. Environmental analysis
Environmental analysis refers to an examination of those areas over which a laboratory doesn’t have much control. While accomplishing its goals and objectives, the laboratory must also ride the tides of possible environmental change. The two well-known environmental sources of CSFs are the changes of the economy and current status of national politics. Other laboratories are sensitive to additional factors such as regulatory trends.

IV. Temporal Factors
These are areas of activity within a laboratory becoming critical for a specific period of time due to something out of the ordinary happening and it would generally not generate CSFs. An example of this could be the resignation of a large number of managers within testing division. This would generate the short term CSFs of restructuring the testing laboratory division management team.

V. Laboratory managerial Position
Each and every functional laboratory manager position has its associated generic set of CSFs. An example of this could be the common shared goal of almost all commercial testing laboratories managers who are much more oriented towards producing accurate, reliable and timely laboratory test results.

3.2.6 Useful classification of laboratory CSFs

According to Bullen & Rockart (1981), one useful way of classifying CSFs is along the following three major dimensions:

I. Internal versus external factors
II. Monitoring versus building-adapting
III. All the aforementioned five prime sources of CSFs
All the aforementioned dimensions represent ways of classifying CSFs. The emerging trend of CSFs will provide a good insight into the laboratory manager’s viewpoint of the world. The emerging trend can also serve an interviewer as a source of questions. The following are two dimensions not yet discussed:

I. Internal factors versus external factors
According to ISO 9001 (2015), every organization shall determine internal and external factors which are relevant to its purpose and strategic direction affecting laboratory’s ability to achieve its anticipated results. In a testing laboratory, internal factors deal with issues that management can control and influence which include issues arising from values, culture and laboratory performance. External factors of a laboratory deals with situations generally less under the management control and include issues such as competition, market, social and economic environments. In a testing laboratory, an example of external factor could be the availability or unavailability of a Proficiency Testing scheme (PTS) for certain coal parameters.

II. Monitoring versus building/adapting CSFs
Laboratory managers who are concerned with emphasizing near term operating results invest most of their time in tracking and guiding their laboratory’s performance. Monitoring CSFs in a testing laboratory means the continued analysis of existing operational conditions and almost all laboratory managers will have monitoring CSFs (Bullen & Rockart, 1981). Monitoring CSFs may include actual performance versus budget or the current status of a specific product cost or testing service cost and personnel turnover rates.

Testing laboratory managers who are doing hands-on management of daily operations of the laboratory invest much of their time in building or adapting mode. Such laboratory managers are future planners who are concerned with the primary responsibility of implementing major change programs with the aim of adapting the laboratory to a new intended environment (Bullen & Rockart, 1981). CSFs in this area include the successful implementation of major hiring and training initiatives. Generally, laboratory managers will have a mix of monitoring and building or adapting CSFs and in most cases there is a strong tendency towards one of these various types of CSFs. This three dimensional classification can be used to visualize the clustering of a particular laboratory managers CSFs through a combination of the characteristics as per the following examples (Bullen & Rockart, 1981):

- Company acquisitions is an external, building CSF as a result testing industry competition analysis.
- New skills acquisition is an internal, building CSF as a result of testing industry competition analysis.
- Employee morale is an internal monitoring CSF, possibly temporal, as a result of a current problem area.
- Interest rate levels is an external, monitoring CSF which is generated by the environmental analysis.

3.3 Definition of quality

The word quality has different meanings for different people. The obvious and easy question of what is meant by quality may be too difficult to answer. There are various definitions of quality and an organization may choose to use a definition that is well tailored to meet its needs.
(Kent, 2016). American Society of Quality (ASQ) glossary of terms defines quality as follows (Rumane, 2011).

A subjective word whereby every person has their own definition in technical operations and has the following two meanings:

I. Quality means those product or service features with the potential to meet stated customer needs. Godfrey & Juran (1998) states that the greater focus of this meaning is on the income generated from service or product income sale. The aim of such higher quality is provision of higher customer satisfaction with the hope of increasing income.

II. Quality means freedom from deficiencies by a product or service. Godfrey & Juran (1998) states that the greater focus of this meaning of quality is on the costs, and generally, higher quality “costs less”.

Figure 3-2 extensively deliberates on the abovementioned meanings of quality.

<table>
<thead>
<tr>
<th>Product features that meet customer needs</th>
<th>Freedom from deficiencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher quality enables companies to:</td>
<td>Higher quality enables companies to:</td>
</tr>
<tr>
<td>Increase customer satisfaction</td>
<td>Decrease operational error</td>
</tr>
<tr>
<td>Make products marketable</td>
<td>Decrease rework, waste</td>
</tr>
<tr>
<td>Gain competitive advantage</td>
<td>Decrease field failures &amp; warranty charges</td>
</tr>
<tr>
<td>Increase market share</td>
<td>Decrease customer complaints</td>
</tr>
<tr>
<td>Provide sales income</td>
<td>Reduce inspection</td>
</tr>
<tr>
<td>Secure premium prices</td>
<td>Reduce time of introducing new products on the market</td>
</tr>
<tr>
<td>The major effect is on sales</td>
<td>Increase yield, capacity</td>
</tr>
<tr>
<td>Usually, higher quality costs more</td>
<td>Improve service delivery</td>
</tr>
</tbody>
</table>

**Figure 3-2 The meanings of quality (Source: Godfrey & Juran, 1998)**

Chandrupatla (2009) cited out the following approaches in defining quality:

I. In product manufacturing environment, the customer recognizes the quality of fit, finish, appearance, function, and performance.

II. In service delivery environment, the customer may measure the “quality” of service based on the degree of satisfaction or dissatisfaction.

On the other hand, in ISO 9000 (2015) series of standards, quality is defined as the degree to which a set of inherent characteristics of an object fulfills requirements.

### 3.3.1 Defining other key words of quality

Godfrey & Juran further states that the above definitions of “quality” include the following key words, which need to be defined:

**Product:** This refers to process output produced without any transaction performed between the organization and the customer (ISO 9000, 2015).

**Product feature:** This refers to a specific property possessed by products or services aiming to meet the needs of customer (Godfrey & Juran, 1998).
Customer: This refers to a person or organization receiving a product or a service intended for this person or organization. A customer can be either internal or external to the organization (ISO 9000, 2015).

Customer satisfaction: This refers to customer’s perception of the extent to which their expectations have been met (ISO 9000, 2015).

Deficiency: Refers to any non-conformance impairing a product or service’s fitness for purpose. Such deficiencies may take forms such as errors, power outages, failures to meet agreed turnaround times and so on (ISO 9000, 2015).

Customer dissatisfaction: This refers to the state of affairs in which products or service deficiencies result in customer annoyance, complaints and so on (Godfrey & Juran, 1998).

3.3.2 Customer needs and conformance to specifications by testing laboratories

For most testing laboratories forming part of organizations providing other services apart from testing, the all-time definition of quality was “conformance to specification.” Their assumption was that products or services complying with the required specifications would also meet customer needs (Godfrey & Juran, 1998). Since laboratories hardly had direct contact with the customer, this was a logical assumption. It is however important to note that the assumption can have major errors since customer needs include many factors not within product or service specifications such as service explanations in simple language, confidentiality and so on (Godfrey & Juran, 1998).

3.4 Managing testing laboratory quality: The Juran trilogy

For testing laboratories to be able to achieve the required level of quality, they must start by establishing their “vision” along with quality policies and goals. Managerial process is a sequence of activities producing the intended results of an organization. This process involves converting goals into results, and thus making quality happen (Godfrey & Juran, 1998). Management of testing laboratory quality makes use of three managerial processes as summarized pictorially by figure 3-3:
Quality planning  |  Quality control  |  Quality improvement
---|---|---
Establish quality goals  |  Evaluate actual performance  |  Prove the need
Identify who the customers are  |  Compare actual performance with quality goals  |  Establish the infrastructure
Determine the needs of the customers  |  Act on the difference  |  Identify the improvement projects
Develop product features that respond to customers’ needs  |  |  Establish project teams
Develop processes able to produce the product features  |  |  Provide the teams with resources, training, and motivation to:
Establish process controls; transfer the plans to the operating forces  |  |  Diagnose the causes
|  |  |  Stimulate remedies
|  |  |  Establish controls to hold the gains

Figure 3-3 The three general processes of managing for quality (Source: Godfrey & Juran, 1998)

The abovementioned three processes are called the Juran trilogy and they are interrelated as depicted pictorially in figure 3-4. The first activity in the Juran trilogy is quality planning. The planners are responsible to establish the laboratory customers and their needs. The planners then engage in the development of product and process designs responding to identified laboratory customer needs (Keller & Pyzdek, 2013). In the end, the planners convert the plans over to the operating forces. The laboratory process runs, produce the product features and meets the needs of the customers (Godfrey & Juran, 1998).

Figure 3-4 The Juran trilogy diagram (Source: Godfrey & Juran, 1998)
3.5 Definition of quality culture

According to Professor Steenkamp (2012) of the University of South Africa (UNISA) centre for business management, for a better understanding of the meaning of quality culture, it is important to first understand the concept of organizational culture since all organizations have organizational culture. Similar to the word “quality”, various definitions exist for organizational culture. Joubert (2002) define organization culture as representing the behaviour of people in an organization as a means to communicate with each other and people within the society. Organizational culture reveals behavioural trends, customs, practices and beliefs that people in the same organization share (Joubert, 2002). Steenkamp & Schoor (2013) point out that organizational culture is a pattern of shared basic assumptions learned by a group as it solved its problems of external adaption and internal integration. Such shared basic assumptions have worked well for consideration as been valid to be taught to new members as the standard way of operating and feel in relation to those problems. Other writers, Colella et al (2006) define organizational culture as been based on the shared values by the same stakeholders and managers leading to norms governing them.

The process of culture development and reinforcement is shown pictorially by figure 3-5. The lack of a clear quality culture can present a barrier to the organization and problem solving across the organization.

![Figure 3-5 Process of Developing Organization Culture](image)

Davis & Goetsch (2010) states that an organizational culture has the following elements:
- The business environment;
- Organizational values, rites, rituals and customs; and
- Cultural transmitters

3.5.1 Maintaining quality culture within an organization

For every organization, establishing a quality culture is a challenging process. Maintaining quality culture is even considered the challenging part. According to Professor Steenkamp (2012), for organizations to maintain quality culture, they must foster the following behaviours:
- Maintenance of quality awareness as a key cultural issue
- Ensuring sufficient evidence of management’s leadership commitment
- Empowering employees by encouraging self-development and initiative
- Recognizing and rewarding positive behaviours supporting maintenance of quality culture

### 3.6 Quality culture in the context of testing laboratories

According to ISO 9001(2015), an organization which is focused on quality promotes a culture resulting in the behaviour, attitudes, activities and processes delivering value through fulfilling the customers’ needs and expectations including other relevant interested parties of the organization. For such an organization, the quality of its products and services are determined by the capability to meet customers’ needs together with the intended and unintended impact on interested parties. Furthermore, the quality of products and services does not only include their intended purpose and performance, but also include issues such as products and services perceived value and benefit to the end-user.

Mishra & Sandiya (2009) express the need for testing laboratories to provide quality-testing service to ensure that final products meets the specifications with desired performance. According to World Health Organization (WHO) document (2011), quality when applied in the context of testing laboratories is defined as the accuracy and reliability of laboratory test results. This means that the test results arising from testing laboratory must be both reliable and accurate as much as possible. All features of the testing laboratory operations must be accurate and reliable, by ensuring that reporting of the results is timely for use by the public (WHO, 2011). As an example, the reliability of coal test results is crucial due to its application in electricity generation. The laboratory results must also be reported to the customer as per the agreed turnaround time. In the process of making measurements, there will always be some level of inaccuracy. Given the limitation of testing systems, the greatest challenge is to reduce or minimize the level of inaccuracy as much as possible. For a system with many events occurring like a testing laboratory, an accuracy level of 99% may appear acceptable in the first time, but the resulting 1% error can become very large over time (WHO, 2011).

If inaccurate results are produced in testing laboratories, the consequences can be very undesirable. Such consequences result in increased cost in operational time and personnel effort (WHO, 2011). To achieve the highest level of accuracy and reliability in testing laboratory operations, it is important to have a better performance of all processes and procedures in the laboratory. Many testing laboratories are complex systems, which involves many steps of activity and people. System complexity requires proper performance of many processes and procedures (WHO, 2011). Laboratories wishing to attain GLP are expected to establish a QMS based on the requirements of the relevant ISO standard (WHO, 2011). There are many international accepted standards applicable to testing laboratories as listed in table 3-1.
Table 3-1 International standards applicable to laboratories (Source: WHO, 2011)

<table>
<thead>
<tr>
<th>International standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO/IEC 17025</td>
<td>General requirements for the competence of testing and calibration laboratories</td>
</tr>
<tr>
<td>ISO 15189</td>
<td>Medical laboratories - particular requirements for quality and competence</td>
</tr>
<tr>
<td>ISO/IEC 17043</td>
<td>Conformity assessment - general requirements for proficiency testing</td>
</tr>
<tr>
<td>ISO 13528</td>
<td>Statistical methods for use in proficiency testing by inter-laboratory comparison</td>
</tr>
<tr>
<td>OECD GLP</td>
<td>OECD principles on GLP</td>
</tr>
<tr>
<td>ISO Guide 34</td>
<td>General requirements for the competence of reference material producers</td>
</tr>
<tr>
<td>ISO 8402</td>
<td>Quality management and quality assurance – vocabulary</td>
</tr>
<tr>
<td>ISO 19011</td>
<td>Guidelines for quality and/or environmental management system auditing</td>
</tr>
<tr>
<td>ISO 9001</td>
<td>Quality management systems – requirements</td>
</tr>
</tbody>
</table>

As can be seen from the above table, majority of the testing laboratory standards have been developed by ISO. The standards have been adopted in different countries through their national standards bodies. In a testing laboratory, the use of standards will ensure that desirable characteristics of products and services are met. Such characteristics include quality, safety, reliability, efficiency and reproducibility. ISO standards are accepted for use worldwide (Rumane, 2011). The use of ISO standards is voluntary and ISO has no legal authority to enforce the implementation of its standards (WHO, 2011). As an example, for coal testing laboratories, there is ISO 17025. As indicated in Chapter 2 of this dissertation, majority of testing methods of coal are also based on ISO standards.

### 3.7 Impact of quality on the reliability of laboratory test results

According to Rooney (2011), the following two definitions of reliability exists:

- The reliability of a system or an item is the probability that the system or an item performs a specified function under specified operational and environmental conditions at a specified time. Quantitatively, reliability is the probability of success.
- A collection of planned activities through formal and informal management systems effectively working together to prevent loss of system function.

A closer look into the first definition indicates the need to define many terms (Coombs et al, 1995). Firstly, in order for a system to perform its functions properly, it must not fail completely. As an example, coal total moisture oven may be able to analyse coal samples but provide unreliable coal total moisture results due to the total moisture oven not being calibrated.

Secondly, time interval could be time measured by customer required service turnaround time or the number of operational cycles which is not measured in hours or months or years. Operational conditions statement should provide information about the nature of environmental condition during analysis. As an example, environmental factors to be recorded, monitored and controlled during coal testing refer to room temperature and humidity.

A closer look into the second definition of reliability reveals that the definition is a managed approach to maintain the reliability of system functions. Both definitions do however refer to the system and maintaining the functionality of a system (Coombs et al, 1995).

If proper attention is given to the quality of laboratory test results, their failure will also be minimized (Mishra & Sandiya, 2009). The quality of laboratory test results not only improve reliability of laboratory QMS but also adds to the value of laboratory tests results. Overall, if the laboratory will be evaluating reliability of its test results, the reliability of each part of its...
QMS is also considered. High quality laboratory test results also increase customer confidence (Mishra & Sandiya, 2009).

As mentioned above, it is clear that many procedures and processes are performed in the testing laboratory. Each of these must be performed correctly in order to ensure reliability of testing activities. Any mistake in any part of the process can produce a poor laboratory result. According to the United Nations Industrial Development Organization (UNIDO) document (2009), an error detecting method is needed at each phase of testing if quality laboratory results are to be produced. A well implemented laboratory QMS will ensure that there is reliability on final laboratory test results. The QMS will provide the laboratory with measurement traceability, non-conformity occurrence preventative actions and possible ways of initiating corrective action when system errors are picked up (Balgobin & Khodabocus, 2011). According to United Nations Office on Drugs and Crime (UNODC) 2009 document, the hierarchy of laboratory QMS is presented in Figure 3-6.

Figure 3-6 QMS hierarchy of a laboratory (Source: UNODC, 2009)
3.8 Definition, development and implementation of laboratory QMS

Professor Steenkamp (2012) of UNISA define QMS as been consist of all organization’s policies, procedures, plans, resources, process, and a description of responsibilities and authorities, all aimed at achieving product or service quality level consistent with customer satisfaction and the organization’s objectives. When these policies, procedures, plans, and so forth are taken together, they define how the organization operates and its quality management. Such activities interact and they are affected by being part of the system. This means that the isolation and study of each one in detail will not lead to an understanding of the whole system.

The main thrust of a QMS is in defining the processes, resulting in the production of quality products and services, not just in detecting defective products or services after been produced. Effective implementation of the relevant QMS in a laboratory environment means that all aspects of the laboratory operation, including the laboratory organizational structure, processes and procedures, must be addressed to produce quality.

3.8.1 Process steps for the development and implementation of laboratory QMS

Quality standards are the most important part of the laboratory QMS. They are designed in such a way that they assist to meet regulatory requirements, including local regulations, and monitor laboratory functions by ensuring both laboratory safety and consistency of performance (Rumane, 2011). A laboratory QMS can be developed and implemented in a step-wise manner as shown in figure 3-7.
Figure 3-7 Steps in developing and implementing a QMS (Source: WOA, 2011)

### 3.9 Background information on ISO 17025 standard

This section provides a description of ISO 17025 QMS history. Before the release of ISO 17025:1999, there was no internationally accepted standard for laboratory QMS which provided a globally accepted basis for laboratory accreditation. Laboratory accreditation was based on national standards (UNIDO, 2009).

ISO 17025 document begin life as ISO 17025:1999 as a revised version of ISO Guide 25. ISO 17025:1999 was revised to publish ISO 17025:2005 to create reasonable commonalities with ISO 9001:2000. Such commonalities were created to ensure that ISO 9001 becomes the master standard being a specific application of that standard to testing laboratories (Balgobin &
Khodabocus, 2011). ISO 17025 QMS standard refers to testing and calibration laboratories work including sampling identification, labelling, testing, analysis and documenting test results as summarized pictorially by Figure 3-9.

![Figure 3-8 Scope of ISO/IEC 17025:2005 (Source: Bui, 2017)](image)


3.9.1 The relationship between ISO 17025 and ISO 9001 QMS standards

Balgobin & Khodabocus (2011) states that ISO 9001 QMS specifies the requirements aimed primarily at giving confidence in the products and services provided by an organization and thereby enhancing customer satisfaction. The standard however does not cater for the technical competence of a laboratory and can therefore not assure accurate and reliable laboratory results. An ISO 17025 accredited laboratory is a laboratory which has been evaluated by the relevant accreditation body and found to be competent on the following areas which confirms its ability to render accurate and reliable testing service (Balgobin & Khodabocus, 2011):

- Technical competency of personnel
- Methods validation
- Equipment calibration and maintenance
- Measurement traceability
- Estimation of uncertainty of measurement
- Assurance of quality test results

Some of the quality system elements of ISO 9001 are covered in ISO 17025 (Balgobin & Khodabocus, 2011). Therefore, laboratories complying with the requirements of ISO 17025 also comply with the requirements of ISO 9001 applicable to testing activities (ISO 17025, 2017). However, there are different methods of assessment of laboratories under ISO 9001 as compared to ISO 17025 assessments (UNIDO, 2009).

ISO 17025 assessment bodies will always use technical assessors who are specialists and who carry out a peer review of the methods being used by the laboratory and the way in which those methods are applied. An ISO 9001 external audit to determine suitability for certification does
not include this peer review of technical aspects and the auditors are not required to be technical specialists (UNIDO, 2009).

From laboratory customers’ viewpoint, laboratories meeting the requirements of ISO 17025 fulfil all the relevant requirements of ISO 9001 when acting as subcontractors. The practical effect of this is that if an organisation certified to ISO 9001 is using an ISO 17025 accredited laboratory as a sub-contractor, it can treat it as an ISO 9001 certified sub-contractor for any work within the laboratory’s scope of ISO 17025 accreditation. There will be, for example, no necessity to carry out quality audits of the sub-contractor (UNIDO, 2009).

3.10 Quality system essentials for maintaining laboratory QMS

ISO standards categorize laboratory processes into pre-examination, examination and post-examination categories (WHO, 2011). Similar terms include, pre-analytic, analytic and post-analytic processes; or pre-test, test and post-test processes. The whole set of activities occurring in testing is called the path of workflow (WHO, 2011). This is the key to the quality model or the QMS, and it has to be considered when developing laboratory QMS. An example of this could be a contaminated or altered sample due to improper collection or transportation. Such a sample cannot provide a reliable laboratory result. Another example could be a delayed or poorly written laboratory test report. Such a report can negate all the effort of performing the laboratory testing activities well.

If laboratory procedures and processes are organized in an understandable and practical structure, the opportunity to ensure that all are appropriately managed will rise (WHO, 2011). To achieve this, one of the quality model used organizes all the laboratory activities into 12 quality system essentials as illustrated in figure 3-8 (WHO, 2011). These quality system essentials are a set of coordinated activities serving as building blocks for QMS and each has to be addressed to achieve overall improvement of laboratory QMS.

![Diagram of QMS essentials](https://via.placeholder.com/150)

**Figure 3-9 QMS essentials (Source: WHO, 2011)**

Assuring accuracy and reliability throughout the path of workflow is dependent on good management of all the 12 quality essentials as defined below (WHO, 2011):
I. Organization
For a testing laboratory to have an effective QMS, the laboratory’s structure and management must be in such a way that quality policies can be established with strong support from the entire organizational structure including top management. Measures must be in place for the implementation and monitoring of laboratory QMS (WHO, 2011).

II. Personnel
The most important resource of every laboratory is competent and motivated staff. According to Lepsinger & Lucia (1999), a competency model is a description of specific combination of knowledge, skills, and characteristics required for laboratory personnel to perform their duties effectively. Human Resources Departments also use it as an instrument for selection, training and development. Personnel competency can be assessed through a combination of the relevant work experience and qualifications. An organization can only be successful with successful employees. According to Gomiscek et al (2012), the success of laboratory employees depends on their qualifications (knowledge, skills and responsibilities) and motivation to perform the work.

Different job levels within the laboratory, ranging from operators, analysts, test officers, technicians and managers require different experience and qualifications. It is the responsibility of the laboratory manager to clearly define job requirements for each job level and provide each laboratory staff member with their own job description (Agyemang-Yeboah & Sarfo, 2013). Specific job description will provide laboratory personnel with a clear understanding of what are their expected output, projected-training and development, which can assist in their personal development (Lepsinger & Lucia, 1999). According to Mauch (2010), a job description is a documentation of the requirements of a job and the work performed.

III. Equipment
Different types of equipment are used in testing laboratory from sampling, sample preparation to analysis of samples (Agyemang-Yeboah & Sarfo, 2013). Selecting the right equipment, installing it correctly, ensuring that new equipment works properly, and having a system for maintenance all forms part of the equipment management programme within a QMS (Agyemang-Yeboah & Sarfo, 2013). Competent personnel must commission all new equipment in a testing laboratory. The laboratory must have a programme of calibration, verification and maintenance for each piece of equipment to ensure each piece of equipment continue functioning properly. Each piece of equipment must be operated according to the relevant equipment SOPs or manufacturer’s instructions as stipulated in the equipment manual. Records of installation, calibration, verification, maintenance, operation, service and repair should be kept as a “life-history” of the equipment (Agyemang-Yeboah & Sarfo, 2013).

III. Purchasing and inventory
Reagents and supplies management in a laboratory may be a challenging task. It is the responsibility of the laboratory to identify the critical supplies and support services needed for operational of testing laboratory through establishment of acceptance criteria for each supplier of critical service (Agyemang-Yeboah & Sarfo, 2013). Suppliers of critical service can be the supplier of reagents, calibration services and so on. The procedures that are a part of management of purchasing and inventory are designed to ensure that all reagents and supplies are of good quality, and that they are used and stored in a manner preserving integrity and reliability (WHO, 2011).
IV. Process control
Process control is the laboratory’s process of identification, management and improvement of its major processes focusing on its functions performance (Drinke, 2011). The quality of laboratory QMS performance can be measured by means of its performance characteristics by verifying test results using the established target values within upper/lower specifications for each performance tested (Mishra & Sandiya, 2009). It is important to know that a specific laboratory process has capabilities of producing test results with specified upper/lower limits (Mishra & Sandiya, 2009). Laboratory personnel are very familiar with the elements of process control. Quality control plays a vital role in ensuring accuracy and reliability of testing processes (WHO, 2011).

V. Information Management
The product of testing laboratory processes is information available in the form of a legible test report. A laboratory test report needs careful management to ensure accuracy and confidentiality (WHO, 2011). Laboratory test reports may be sent out to the respective customers either by hard copy system or electronically depending on customer preference. Whatever form test reports take, handling of this information must be in a much secure format at all times (Agyemang-Yeboah & Sarfo, 2013).

VI. Documents and records
In a testing laboratory operation, ISO 17025 QMS must be well documented since it communicates important organizational and operational information to laboratory personnel. Documents serve as a communication channel from management to staff on what needs to be done, how it is done, and its effect on the overall laboratory process. The laboratory must have established document control system for compiling and approving of documents, periodic review of documents and removal of obsolete documents on laboratory QMS documentation system to prevent their unintended use (Agyemang-Yeboah & Sarfo, 2013). Laboratory QMS documents must be well maintained for ease access by the relevant personnel (WHO, 2011).

VII. Occurrence management
An “occurrence” can be an error, accident or customer complaint having the potential of ruining the reputation of the laboratory (Agyemang-Yeboah & Sarfo, 2013). This refers to non-compliance with standards and regulations resulting in a non-conformance been raised. The laboratory must have an established system for detection of these non-conformances, handling them properly, and learning from mistakes, taking corrective and preventive actions to prevent their recurrence (WHO, 2011).

VIII. Assessment
Assessment process is used to examine laboratory performance by comparing it to standards, benchmarks or the performance of other laboratories through participation in PTS. It forms an important part of the laboratory QMS and is a key element in the ISO 17025 QMS. The quality assessments are normally conducted at scheduled time interval to ensure that the laboratory has clearly defined internal quality monitoring processes linked to effective action (Mauch, 2010).

There are internal and external laboratory quality assessments. Internal assessment may be conducted by the laboratory using staff within the organization. External assessment may be conducted by a group or agency outside the laboratory (Mauch, 2010). Laboratory quality standards are an important part of the assessment process, serving as benchmarks for the laboratory (WHO, 2011). In SA, SANAS is the provider of accreditation for testing laboratories.
and is responsible for conducting external assessment in such laboratories (Agyemang-Yeboah & Sarfo, 2013).

IX. Process improvement
The primary goal of an effective QMS is continuous improvement of the laboratory processes. These processes must be done in a systematic manner. There are a number of tools that are useful for process improvement which includes ISO 17025 internal audits, ISO 17025 QMS review, participation in PTS, use of competent personnel, and so on.

X. Customer service
Kent (2016) states that, in some laboratories, customers can be either external or internal to the laboratories. In terms of providing satisfactory services to the customers, it does not matter much if the customer serviced is external or internal. It is however known that external customers have a higher degree of selection in terms of who their supplier can be. Understanding, satisfying and exceeding customer needs and expectations is the primary goal of each laboratory (Abbaszadeh et al, 2010). It is the responsibility of every laboratory to continuously monitor employee satisfaction level as well as customer satisfaction level (Agyemang-Yeboah & Sarfo, 2013).

Customer service is one concept that has often been overlooked in laboratory practice. It is crucial for commercial laboratories or organizations operating commercial laboratories to note that the commercial laboratory is a service organization. This means that, it is always important to ensure that service levels meet customer requirements (Dale et al, 2007). The laboratory should understand who their customers are, make an assessment of their needs and use customer feedback, maybe in the form of customer satisfaction surveys, audits and so on for service improvements (WHO, 2011). According to Canten et al, 2010, customer satisfaction surveys are a valuable tool to evaluate laboratory performance and to identify opportunities for improvement in the laboratory.

XI. Facilities and security
Both laboratory internal and external environment should be safe to staff, visitors and customers (Agyemang-Yeboah & Sarfo, 2013). A number of factors must be part of the quality management of testing facilities and safety as defined in table 3-2.

Table 3-1 QMS factors of facilities and safety (Source: WHO, 2011)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Security</td>
<td>This refers to the process of preventing unwanted risks and hazards from entering the testing laboratory environment.</td>
</tr>
<tr>
<td>Containment</td>
<td>This seeks to minimize risks and prevention of hazards from exiting the testing laboratory environment and causing environmental harm to the communities.</td>
</tr>
<tr>
<td>Safety</td>
<td>This includes policies and procedures established to prevent harm to workers, visitors and the community.</td>
</tr>
<tr>
<td>Ergonomics</td>
<td>This addresses facility and equipment adaptation to allow safe and healthy working conditions at the testing laboratory environment.</td>
</tr>
</tbody>
</table>

In the QMS model, all the 12 QMS essentials must be addressed to produce accuracy, reliability of laboratory test results, and to ensure that there is quality throughout the laboratory operations. Implementation of the 12 QMS essentials may be in any order best suiteing the testing laboratory. Approaches to implementation will differ with the local situation. For
laboratories not implementing a good QMS, they will be guaranteed many errors and problems occurring that may go undetected within their processes (WHO, 2011). Effective implementation of the 12 QMS essentials may not only guarantee a laboratory that is free from errors, but it will generate the needed confidence among end users or consumers of the tested product that the testing laboratory will satisfy the quality requirements (Agyemang-Yeboah & Sarfo, 2013).

3.11 Critical success factors for improving quality culture of testing laboratories

Factors refer to a set of facts, circumstances or influences contributing to the success of any business organization. Such factors either will influence or facilitate business success. The same factors contribute to the failure or success of a business organization (Makabate, 2016). For an organization to continue improving its products, processes and quality to achieve full customer satisfaction, there is a need to clearly establish CSFs (Aigbavboa, 2017).

In the pursuit of performance excellence within testing laboratory space and with an increasing awareness of quality culture in testing laboratories, laboratories have no other option than to implement relevant laboratory QMS with clear CSFs. The complexity of testing laboratory system requires CSFs to be addressed to produce quality laboratory results. Howell (2010) points out that CSFs differ from laboratory to laboratory due to their location and testing service rendered. Table 3-2 list CSFs, which are common to the success of various improvement initiatives for organizations also applicable to testing laboratories together with their associated variable(s).

Table 3-2 CSFs common to the success of various improvement initiatives (Source: Howell, 2010)

<table>
<thead>
<tr>
<th>CSF</th>
<th>Variable(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>QMS</td>
<td>✔ Documentation requirements</td>
</tr>
<tr>
<td>Management commitment</td>
<td>✔ Defined management responsibility</td>
</tr>
<tr>
<td>Customers focus</td>
<td>✔ Customer data analysis</td>
</tr>
<tr>
<td></td>
<td>✔ Assessment of customer needs</td>
</tr>
<tr>
<td>Quality policy</td>
<td>✔ Quality policy appropriateness</td>
</tr>
<tr>
<td></td>
<td>✔ Commitment towards continual improvement</td>
</tr>
<tr>
<td>Responsibilities, authorities and</td>
<td>✔ Roles and responsibilities communicated</td>
</tr>
<tr>
<td>communication</td>
<td>✔ Effective communication system</td>
</tr>
<tr>
<td>Resource management</td>
<td>✔ Resources provision</td>
</tr>
<tr>
<td>Product realization</td>
<td>✔ Production and service provision</td>
</tr>
<tr>
<td></td>
<td>✔ Planning of product realization</td>
</tr>
<tr>
<td>Measurement, analysis and improvement</td>
<td>✔ Monitoring and measurement</td>
</tr>
<tr>
<td></td>
<td>✔ Control of non-conforming products/services</td>
</tr>
<tr>
<td></td>
<td>✔ Analysis of data</td>
</tr>
<tr>
<td></td>
<td>✔ Improvement</td>
</tr>
</tbody>
</table>

3.12 Definition of testing and its different types

Testing is defined as the technical operations which determines one or more characteristics of a given product by following specific SOPs (EuroLab, 2000). According to EuroLab (2000) there are three different parties involved in testing activities as briefly described below:
• First party testing: This type of testing is carried out by laboratories of product manufacturers and suppliers
• Second party testing: This type of testing is performed by laboratories of product buyers, users or consumers
• Third party testing: This type of testing is carried out by laboratories independent of the abovementioned parties.

3.12.1 First party testing

This refers to testing performed by the manufacture on their products (Rumani, 2011). Testing activities are performed in an in-house testing facility belonging to the manufacturer of products tested. It is a large sector used for example as an Internal Quality Control (IQC) measure that the products or services provided comply with the requirements expressed in legislation, standards, technical specification and customer contracts. The declaration of the manufacturers’ conformance expressed by various ways of labelling the product is often based on the outcome of these tests (Eurolab, 2000).

3.12.2 Second party testing

This refers to testing performed by the receiver of the products for verification of the agreed product requirements and specifications. For ordinary consumers, testing can be performed by organizations buying products (Eurolab, 2000).

3.12.3 Third party testing

This type of testing is required for the results having a direct influence or effect on public or societal issues, in particular related to health, environmental safety and large economic values (Eurolab, 2000). As depicted in figure 3-10, third party testing operates as a middle-man between the buyer and the seller to eliminate possible cheating and considerable misconduct or when crucial risks and consequences of wrong or manipulated results exist. According to Keller & Pyzdek (2013), in third party testing, the testing laboratory does not have any relationship with the buyer and the seller that may compromise its judgement. This means that the laboratory is expected to offer a non-biased view and a better confidence in the test results.

The public sectors prefer to use independent third party testing laboratories since it provides objective evidence and facts for studies, evaluations, analysis and technical support for decision-making processes. The mandatory part of the public sector is clear-cut; either the authorities require or the legislation demands that only results of third-party testing laboratories are accepted. Third party testing is also recommended when there is a risk of a major dispute or conflict of interest (Eurolab, 2000). Third party testing is offered by commercial laboratories.
3.13 Meaning of commercial laboratory

A commercial laboratory is a laboratory rendering specific testing service by charging a fee. It accepts samples from the public and may be accredited in or more parameters by the relevant national or international body (Ramphal & Ratseou, 2014).

3.14 Defining ISO 17025 accreditation in the South African context

Whenever a laboratory requires recognition of its ability to use quality practices while performing its work, standards are used. The laboratory can meet the requirements of standards voluntary or it may be a legal requirement. One of the processes used to confirm that the laboratory complies with the relevant standards is called accreditation (WHO, 2011).

Balgobin & Khodabocus (2011) define laboratory accreditation as the process through which a regulatory body grants formal recognition that a laboratory or person is competent to carry out specific tasks with independence. Representatives from an accreditation body will visit the laboratory to check evidence of compliance with standards, policies, procedures, requirements and regulations, and observe laboratory staff to ensure that they perform functions and duties correctly and competently. According to Froese (2016), laboratory accreditation allows for increased confidence in the test results and professional recognition of the quality of service provided to customers. Since acquiring laboratory accreditation require a preparation of the necessary documentation, such documentation may also be useful for training assistance of new staff or personnel earmarked for much higher positions. There are many accreditation bodies throughout the world (Froese, 2016). SANAS is the only national body responsible for carrying out laboratory accreditations in the RSA (Www.sanas.co.za Access date: 01/05/2017).

3.14.1 The required elements of accreditation

According to Balgobin & Khodabocus (2011), the testing laboratory accreditation process requires the following:

- Accreditation body overseeing the assessment process and grant laboratory accreditation;
- The ISO 17025 standard for the laboratory to comply with in order to be accredited;
• Competent accreditation body assessors to establish compliance with the ISO 17025 standard through conducting of assessments; and
• A user-laboratory seeking to comply with ISO 17025 standard.

### 3.14.2 Process steps of acquiring ISO 17025 SANAS accreditation in South Africa

The decision for a laboratory to be accredited is a lengthy procedure having costs implications and it requires financial support from laboratory top management (Balgobin & Khodabocus, 2011). Laboratory accreditation could begin with one part of the laboratory and then continue with the other sections. According to Balgobin & Khodabocus (2011), seeking laboratory ISO 17025 QMS accreditation with SANAS in the RSA will require the steps in figure 3-11 to be followed by CAB in sequence.

#### Stage 1
- Submission of the following by CAB to SANAS:
  - Completed application form, relevant documentation & payment

#### Stage 2
- Review of application documents & providing feedback by SANAS

#### Stage 3
- Appointment of Assessors to conduct on-site assessment at applicant’s office
- Compiling of assessment findings & recommendations

#### Stage 4
- SANAS forms an Accreditation Approval Advisory Committee (AAC)
- AAC reviews the report and makes a recommendation regarding accreditation to the CEO of SANAS

#### Stage 5
- CEO decides to approve or not approve accreditation based on evaluation report of the AAC
- If approval is granted, a Certificate of Accreditation and SOA are then issued
- If accreditation is not approved, the applicant is advised of the reasons for the decision
- A further application may be considered at a later date

**Figure 3-11 Steps for acquiring accreditation (Source: Balgobin & Khodabocus, 2011)**

### 3.14.3 Benefits of ISO 17025 accreditation

According to Professor Steenkamp (2012) of UNISA, organizations with a developed and continually improving quality culture will be different compared to organizations with only a traditional culture. Successful maintenance and continual improvement of ISO 17025 QMS and its accreditation can yield many benefits for the CAB. This means that a laboratory that has maintained and continually improving ISO 17025 QMS and received its accreditation will have different competitive edge over its competitors due to international recognition for technical competence (Tahir, 2017).
Since accreditation process is performed by an impartial national or international body, it will assure laboratory customers of the reliability of results. The information generated in accredited testing laboratory is reliable enough for government bodies and other regulators to base their decisions on (Bal gobin & Khodabocus, 2011). On the other hand, a poor ISO 17025 QMS will have the potential of destroying a laboratory’s reputation. A laboratory with a well maintained and accredited ISO 17025 QMS will bring additional benefits to the laboratory as illustrated by figure 3-12:

![Figure 3-12 Benefits of a good laboratory QMS (Source: Tahir, 2017)](image)

**3.14.4 Outcomes of ISO 17025 accreditation**

The outcomes of ISO 17025 QMS laboratory accreditation are:
- The laboratory QMS strength and integrity measurement
- Continual monitoring of the laboratory QMS
- Appreciation of staff efforts

In PTS participation, accredited testing laboratories perform very well compared to other laboratories. Such laboratories are more likely to have a working QMS. As already indicated, laboratory accreditation is a valuable tool to determine the effectiveness of the QMS. However, been granted accreditation is not the ultimate goal. As soon as accreditation status has been granted, the greatest challenge will be its maintenance and continual improvement over time (WHO, 2011).

A laboratory that is well managed will have checks and balances to measure if it is meeting its goals. Within the laboratory, accreditation should be viewed as one form of audit that the quality managed laboratory establishes to ensure proper functioning of the system.
accreditation status must be renewed according to the timelines set by the accreditation body (WHO, 2011).

3.15 Case study of quality culture implementation in coal testing division

This section presents a case study documenting the requirements for implementation of quality culture applicable to all company X’s commercial unit individual divisions and departments which includes coal testing division. The level of quality culture implementation in coal testing division is also outlined. These requirements, practices, principles and policies presented are a representation of the CSFs as documented in MSP Document for company X commercial. When applied consistently throughout the coal testing division, these CSFS will give assurance that the various reports issued by management accurately represent the test results of coal testing division laboratories and will provide:

- Baseline for an internal control system
- Business process decision-making criteria
- Standardized transactions, procedures, and records throughout the organization

As part of company X’s commercial unit, all coal testing division BUs policies and procedures should comply with MSP document for company X commercial unit requirements. Changes to policies and procedures to be reviewed to avoid conflicts with MSP document for company X commercial unit requirements.

3.15.1 Management System of company X commercial unit

Company X commercial unit shall develop, implement and maintain an integrated management system that covers all the conformity assessment services that it provides.

3.15.2 Company X commercial unit laboratory services

Company X commercial unit shall apply the principles and requirements of ISO 17025 QMS and its associated SANAS regulatory documents, international electrotechnical commission (IEC) operational documents (OD) and ILAC guides for its laboratory services. Company X commercial unit to ensure that relevant laboratories remain accredited by a national or internationally recognized accreditation body that is part of Mutual Recognition Agreement (MRA) of the ILAC.

3.15.3 Coal testing division management system planning

The management system used across coal testing division is a dynamic and evolving system. By analyzing reports and data from coal testing division operations, top management shall ensure that policies and data from the entire coal testing division operations are maintained and improved. When changes to the management system are required, any new procedures or changes to existing procedures shall be verified and validated before being put into practice to avoid compromising QMS when changes are made.
3.15.4 Management system of coal testing laboratories

Coal testing division shall develop, implement and maintain QMS based on the requirements of ISO 17025. The management system of coal testing division shall cover all necessary activities of company X, from customer interface to delivery of service and, where applicable, after sales service.

All conformity assessment services provided, that is, coal testing are based on well proven documented policies, practices and procedures that comply with national and/or international standards, protocols, specifications, codes of best practices, guides and methods in accordance with SANAS regulatory requirements where applicable.

3.15.5 Management commitment

As evidence of commitment for the implementation and maintenance of QMS, each member of company X commercial unit executive management, on behalf of the organization, shall formulate, sign, publish and improve a quality policy. In addition, laboratory service division executive management shall publish and promote a quality policy aligned to the overall quality policy for company X commercial laboratories.

Executive management of X commercial laboratories shall define measurable objectives, including quality objectives, applicable to all functions and levels, as appropriate. Executive management of company X commercial laboratories shall provide and make available adequate resources to meet stakeholder and operational requirements.

To ensure that the coal testing division QMS remains valid to maintain accreditation and to satisfy customer and operational needs, executive management shall review the QMS at regular intervals. In the event that accreditation cannot be maintained or is compromised, such that accreditation is suspended, coal testing division executive shall ensure conformance to the regulatory requirements of SANAS in this regard.

The general manager of Y department will be responsible for the development of processes and procedures for overall testing activities in line with ISO 17025. The OD which are technical shall be developed by relevant BU managers and the Y Department manager shall make sure that they are aligned to the ISO 17025 requirements.

3.15.6 Customer focus

ISO 274 (2004) states that customer service organizations depend on their customers. This means that organizations should understand current and future customer needs. By so doing, organizations should be able to meet and exceed customer requirements and expectations. X commercial recognizes that all members of coal testing division management and staff have the responsibilities to ensure that customer requirements are understood and that customer satisfaction is the key to the continued growth of the organization. Coal testing division BU managers shall ensure that their staff members are aware and conversant with the marketplace in which the division operates.
3.15.7 Quality management system documentation

Company X commercial unit shall establish and maintain a formal QMS and also ensure that its QMS is adequately understood and effectively implemented by coal testing division. The scope of the QMS is controlled and maintained up-to-date. The QMS documentation consists of a three-tier system as depicted in figure 3-13.

![Diagram of QMS documentation hierarchy]

**Figure 3-13 Company X Commercial unit QMS documentation hierarchy (Source: MSP Document for X commercial, 2017)**

3.15.8 Measurement, analysis and improvement

Company X commercial unit shall plan and implement the relevant monitoring, measurement and analysis processes for ensuring that coal testing division and customer requirements are met and that the conformity and improvement of ISO 17025 QMS is maintained.

3.15.9 Monitoring and measurements

Company X commercial unit requires that coal testing division establish a systematic approach of monitoring and measuring customer service levels. Such an approach needs organizational framework support to enable planning, operation, maintenance and improvement of processes for monitoring and measuring of customer service levels. Coal testing division has implemented the following for monitoring and measuring customer satisfaction:

I. Customer satisfaction
   As a customer service division, coal testing division should ensure effective monitoring and measuring of customer service by:
   - Identifying customer perception
   - Gathering customer satisfaction data
   - Analyzing customer satisfaction data
   - Communicating customer satisfaction information
   - Monitoring customer satisfaction on an ongoing basis
These activities and their relationship are depicted in figure 3-14.

![Diagram](image)

**Figure 3-14 Coal testing division monitoring & measuring of customer satisfaction**  
*(Source: MSP Document for X commercial, 2017)*

II. Internal audits
In addition to internal self-audits arranged by management of individual BU of coal testing division, a programme of independent and impartial internal QMS audits shall be established by Y department. This will give confidence to the executive of company X commercial laboratory services division that coal testing division QMS remains in conformity with the requirements of ISO 17025 and that the division’s conformity assessment services remain compliant with SANAS requirements. Internal ISO 17025 QMS audits shall also be used as a tool to identify opportunities for improvement or increase coal testing division business efficiency. The internal ISO 17025 QMS audit process shall reflect the actual working processes, practices and business needs of coal testing division.

III. Monitoring and measurements of company X services
Coal testing division shall implement a monitoring and measurement process of all its services delivery activities to ensure confidence that the delivered service and conformity assessment meets requirements. This shall be achieved through a short term interval control and supervision process that monitors, measures and evaluates all operational support and service delivery activities. In the event of corrections or corrective action being identified in any process, necessary arrangements shall be made in accordance with a formal corrective action process.

3.15.10 Management review

ISO 17025 requires that top management review coal testing division QMS. QMS must be reviewed at planned intervals to ensure its continued suitability, adequacy and effectiveness.
Such reviews must be aligned with the organization’s strategic goals. The QMS review process of coal testing division shall reflect the actual working processes, practices and business needs of company X commercial unit.

3.15.11 Communication

Communication across coal testing division is categorized into two basic types:

I. Internal communication
Coal testing division supports and promotes open communication throughout its individual BUs. Formal methods of communication shall be established by means of regular management meetings, notice boards, communiqués, e-mails and other formal meetings. Instructions provided through the e-mail system shall be valid and regarded as formal direct communication.

II. External communication
Coal testing division shall communicate to regulators, stakeholders and customers any changes that may affect the accreditation status of its laboratories service. In the event of changes to coal testing division laboratories status, such changes and their impacts shall be timeously communicated. Such communication shall be by direct contact or through company X website.

3.15.12 Resource management

Resource management refers to the organization’s efficient and effective development of resources whenever needed. Resources within coal testing division include the following:

I. Human or personnel resources
Coal testing division believes that every employee, including subcontracted personnel, performs work resulting in quality service to the customer. BU Managers shall therefore ensure that all personnel are competent at all times to fulfill their duties and responsibilities. BU Managers shall determine the competency requirements for each job within their respective BU. Detailed records of job descriptions, competency profiles, training and performance evaluations shall be maintained. The records of conformity assessment management and staff shall include details of their formal education, training, skills and their technical workplace experience prior to employment.

II. Infrastructure
Through stakeholder involvement, coal testing division provides adequate infrastructure to achieve and maintain conformance to accreditation, statutory, regulatory and customer requirements to ensure and contribute to customer and employee satisfaction. Provision of capital equipment, services and accommodation shall be a management responsibility based on available data and future requirements resulting in formal budgetary requirements. The maintenance of the workplace, process equipment and supporting services shall be included in the QMS specific operating procedures.

III. Work environment
Coal testing division shall ensure that the work environment is conducive for its staff to produce high levels of quality conformity assessment services to its customers. Coal testing division
shall ensure proper management of the work environment to achieve conformance with accreditation, statutory, regulatory and customer requirements that ensure and contribute to customer and employee satisfaction; and necessitate a safe working, safe travelling, health and housekeeping conditions. Coal testing division shall also compile and formally document arrangements as well as requirements in specific operating procedures.

3.16 Summary

This chapter discussed and engaged literature on CSFs, CSFs for improving quality culture of testing laboratory, concept of quality and its application in laboratory environment. Laboratory ISO 17025 QMS was defined together with its relationship and difference(s) with ISO 9001. This chapter further discussed the difference between first, second and third party testing laboratories. The chapter concludes by providing a case study extracted from MSP document of company X commercial unit, which governs coal testing.

The next chapter will be a discussion of the research methodology.
Chapter 4 : Research Methodology

4.1 Introduction

This chapter aims to establish design of the study to answer the questions and objectives of the study. Chapter three of this dissertation indicated that the study questions together with research objectives will be answered through studying company X profile. Below is a recap of the study objectives:

- To demonstrate the benefits for maintaining ISO 17025 quality management system
- Identification of critical success factors to improve ISO 17025 quality management system in a coal testing division

The research questions reads as follows:

- Why does coal testing division has to maintain ISO 17025 quality management system?
- How to improve ISO 17025 quality management system in a coal testing division?

Objective number 1 will be answered through secondary data from both existing data of company X on the maintenance of ISO 17025 QMS in a coal testing division and the literature review on maintenance of testing laboratories QMS. Objective number 2 will be answered through the gaps identified in literature review which called for a further study by collecting empirical data in order to improve ISO 17025 QMS in a coal testing division.

4.2 Research strategy

The literature review chapter of this dissertation has made a provision to continue with an empirical study to further answer the research objectives through studying company X profile. This is because the literature review has been able to reveal in greater depth, the benefits for maintenance of ISO 17025 QMS within testing laboratories, which ultimately is applicable to company X coal testing division. On the contrary, too little information was revealed on the CSFs required for improving ISO 17025 QMS within testing laboratories, which is also applicable to coal testing division. This has therefore resulted in the need to collect an empirical data. In order to collect empirical data, the research strategy adopted was a single case study.

The study adopted mixed methods research process. According to Clark & Ivankova (2016), mixed methods research is a research process whereby researchers incorporate quantitative and qualitative methods of data collection and analysis for a better understanding of research aims. In a given study, this process unfolds in a manner shaped by mixed methods research content considerations and researchers’ personal, interpersonal, and social contexts. The greatest advantage of this method is that it offers strengths balancing the weaknesses of both quantitative and qualitative study (Clark & Ivankova, 2016).

According to Biggam (2008), a single case study observes the characteristics of an individual unit. This could be a class, a school or a community. The main aim of such observation is to investigate deeply and to analyse intensely the different phenomena forming the life cycle of the unit. According to this definition, a case study is concerned with closely observing the behaviour of a particular population group within a particular context (Biggam, 2008). A case
study approach aids this researcher’s drive to investigate deeply into coal testing division’s response to quality culture, through dedicating time and energy by concentrating on certain aspects of quality culture within coal testing division. Yin (2016) indicates that there are 3 conditions applicable for researchers intending to use a case study as defined in table 4.1. As already stated, this study seeks to answer the how and why questions in order to maintain quality culture within coal testing division. With this type of study, the researcher does not to any extent, have control over behavioural events. Again, the researcher focuses on current events than on historical events only (Yin, 2016).

### Table 4-1 Relevant situations for different research methods (Yin, 2016)

<table>
<thead>
<tr>
<th>Method</th>
<th>Form of research question (1)</th>
<th>Requires control of behavioural events (2)</th>
<th>Focuses on contemporary events (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment</td>
<td>How, why?</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Survey</td>
<td>Who, what, where, how many, how much?</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Archival analysis</td>
<td>Who, what, where, how many, how much?</td>
<td>No</td>
<td>Yes/no</td>
</tr>
<tr>
<td>History</td>
<td>How, why?</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Case study</td>
<td>How, why?</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

4.3 Sampling procedure

For every study conducted, the researcher must engage in establishing a sampling procedure using the criteria below (Clark and Creswell, 2011):

- Location or site for the study,
- The participants providing data for the study
- How to sample study participants
- The number of participants needed to answer the research questionnaires
- The recruitment procedures for participants

As already stated, the study was conducted within coal testing division of company X. The research participants were coal testing division BU Managers, Technical personnel and quality officer. The reason for selecting these employees is that they are involved in the daily operation, implementation and maintenance of ISO 17025 and management of testing facilities. During this study, technical personnel will categorically refer to SANAS technical signatories/test officers/analysts. The research questionnaires were sent to study participants via email and twenty-three set of questionnaires were sent to study participants. The sampled population of participants is enough for the study. According to Cardon et al, (2013), about 15-30 participants are required for participation in a single case study type.

The sampling technique that was used is called convenience sampling. This sampling method is also referred to as accidental sampling or opportunity sampling (Alvi, 2016). This type of sampling involves simply taking what the researcher can get where it is most easily to get (Davies & Hughes, 2014). The researcher includes participants who are readily accessible for participation in the study (Alvi, 2016). The researcher opted for this method because he is working at company X. And, it is also because of easy access to research subjects and time issues.
4.4 Source of evidence for the study

Neuman (2000) states that, for every study, a researcher will collect data using one or more sources. This section will provide a description of the main sources used to collect data for the study. Yin (2014), point out that sources of information that are normally used in case studies are, documentation, archival records, interviews, direct observations, participant-observation, and physical artefacts. There is a wide range of list of sources that can be used for each type of study. For this study, the researcher used three sources of evidence as defined below:

I. Documentation
This type of data source is likely to be relevant to every case study topic except for the preliterate society. Documentation can take various forms and should be the object of clear data collection plans (Yin, 2014). During this study, the researcher used internal records from MSP document for company X commercial unit and internal audits feedback as sources of data. This is in agreement with the benchmark set in Chapter three of the dissertation for collecting data for CSFs using document review.

II. Structured questionnaires
The study used survey interviews by means of structured questionnaires to source out data for identification of CSFs for improving ISO 17025 QMS. According to Yin (2014), survey interview is an important source of case study evidence. According to Howell (2010), survey interviews with key personnel of an organization can result in accurate information generated. This will result in gaining buy-in for stated study objectives since it will identify critical issues to achieve improvement initiatives.

The intended questionnaires variables of this study are in Appendix B. Evidence of completed questionnaire variables are in Appendix D. Relevant questionnaire adopted from Biredy (2007) on Quality Management-Implementation of Quality Systems was used. A five-point lickert scale was used for each questionnaire variable. According to Dale (2006), a five-point lickert scale works much better. A few three-point lickert scale may result in insufficient response for revelation of existing group differences. On the other hand, a many twelve-point lickert scale may result in unreliable responses due to many choices available.

In order to minimize bias, each participant was sent questionnaires directly to their own email address and was requested to answer questionnaires on their own and email them back to the researcher.

III. Participant-observation
This is a special method of observation whereby the researcher is an active observer and may assume a wide range of responsibilities within a fieldwork situation by participating on the activities being studied (Yin, 2014). The researcher is an internal auditor from Y department of company X responsible for conducting internal audits for compliance with the requirements of ISO 17025. He has been conducting independant or impartial internal audits through verbal engagements with BU managers, test officers, analysts and quality officer for more than five years in coal testing division. During this tenure, the internal auditor has also been attending external assessments conducted by SANAS and customers. Some of the research findings will therefore be linked to the information acquired during these excercises.
4.5 Data analysis framework

To effectively analyse data, each of the identified CFSs common to the success of various improvement initiatives in table 3-1 of the literature review will have its own questionnaire variables. In order to help focus the questionnaire variables to serve as a reflection of the main objectives of this study and for simplicity of quantitative data analysis, the variables will be structured according to the CSFs as per table 4.2. These CSFs represent the main aim and objectives in the study. The CSFs echo the main areas which emerged from the literature review and it is important not to view them as separate topics but view them as inter-related topics. All of the eight CSFs could have been placed under the topic “improvement of quality culture”. Questionnaire variables will be same for all participants due to all questionnaire variables been specifically related to what motivates or demotivates staff to become involved in quality culture improvement.

Table 4-2 Case study: Breakdown of themes and questions

<table>
<thead>
<tr>
<th>Critical Success Factor</th>
<th>Questionnaire variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. QMS</td>
<td>3</td>
</tr>
<tr>
<td>2. Management commitment</td>
<td>4</td>
</tr>
<tr>
<td>3. Customer focus</td>
<td>3</td>
</tr>
<tr>
<td>4. Quality policy</td>
<td>3</td>
</tr>
<tr>
<td>5. Responsibility, authority &amp; communication</td>
<td>3</td>
</tr>
<tr>
<td>6. Resource management</td>
<td>6</td>
</tr>
<tr>
<td>7. Product Realization</td>
<td>5</td>
</tr>
<tr>
<td>8. Measurement, analysis and improvement</td>
<td>3</td>
</tr>
</tbody>
</table>

Figure 4.1 is a pictorial representation of the process that will be used to analyse data from the case study. Data analysis will be based around iterative process of description, analysis and interpretation of the collected data, particularly regarding the extraction and understanding of CSFs that will emerge.

Figure 4-1 Coal testing division case study qualitative data analysis process (Source: Biggam, 2008)
The important part of this study is analysis of case study results by comparing it and contrasting BU managers, technical personnel and quality officer perspective while reflecting on the case study results with respect to the literature review findings. Figure 4.2 has now been updated to show this overarching reflective process.

For data analysis, the BU managers/technical personnel/Quality Officer’s case study results will be described and analysed. This will be done by first coding study variables and lickert scale ratings on microsoft excel 2016. Statistical analysis of data was conducted by establishing correlations, descriptive statistics by calculation of mean and standard deviation of variables and plotting graphs for participants feedback on questionnaire variables. According to Rose (2015), excel is also an authenticated research data analysis tool due to convenience for use and less cost implications. Relevant literature review findings will be compared and contrasted with the case study results. This will be done to avoid comments repeating with reference to the literature review results.

**4.6 Study limitations and potential problems**

Shell (1992) states that one of the disadvantages of a single case study methodology used in this study is its little scope of generalization at the end of the study. As such, the outcomes of this study cannot be used to represent the wider research community. This means that, the outcomes of this study cannot be deemed or used to represent company X. Although BU managers, technical personnel and quality officer will be participating in the study, and company X commercial unit overhead organizational documentation will be used as reference, the study of a different project group in company X, on the improvement of quality culture, may lead to different results.
4.7 Study validation

According to Biggam (2008), central to every empirical study is the need to answer the question of reliability and validity. This will ensure that the research is acceptable to the research community. Shell (1992) argue that in order to overcome the lack of single case study’s ability to provide a more generalized conclusion, the researcher must triangulate the study with other research methods as a validation strategy. This study adopted a validation strategy called triangulation or greater validity to validate research findings. Rahman & Yeasmin (2012) define triangulation as a verifying process increasing validity through an integration of various views and methods. Triangulation process is a combination of two or more theories, sources of data, research methods or investigators in one study of a single phenomenon with the aim of converging on a single construct (Rahman & Yeasmin, 2012). This study adopted triangulation process through a combination of both quantitative and qualitative studies as depicted in figure 4.3.

![Triangulation research process](image)

**Figure 4-3 Triangulation research process (Source: Rahman & Yeasmin, 2012)**

The researcher attended a class on research methodologies at the University of Johannesburg on the 26th March 2018. The researcher was also assigned a supervisor and co-supervisor who throughout this study have provided supervision through different communication channels (consultation and emails communication). The interaction with the supervisors has helped the researcher to produce reliable work.

4.8 Summary

This chapter provided the research methodology applied for this study. The next chapter is a discussion of study results.
Chapter 5: Discussion of Results

5.1 Introduction

The aim of this chapter is to reveal the results of the case study described in chapter four (research methods) of this dissertation. The results is a presentation and interpretation of study structured questionnaire feedback which concentrated on three groups of stakeholders, namely, BU managers, technical staff and quality officer who all have a direct influence on the maintenance and continual improvement of ISO 17025 QMS. There are few challenges which were experienced during the study. Amongst others, the researcher experienced some difficulties in acquiring authorization from coal testing division management in order to conduct this study. Authorization was acquired or granted two months after the initial request. Upon acquiring authorization, a number of the participants returned questionnaires late and incomplete. Incomplete questionnaire were returned to participants to be completed in full. In the end, all twenty-three questionnaires sent out were returned.

As indicated in Chapter four of this dissertation, data analysis tool used was Microsoft excel 2016. The results will be compared through correlation of variables, calculation of mean and standard deviation for variables and bar charts to compare participants’ feedback per questionnaire variable.

5.2 The process of analysis and description of study results

5.2.1 Analysis of the variables in the questionnaires

Table 5-1 list the significance of each questionnaire variable per CSF based on feedback of participants on study questionnaire variables.
Table 5-1 CSF questionnaire variables significance

<table>
<thead>
<tr>
<th>Critical Success Factor</th>
<th>Questionnaire variables</th>
<th>Total number of respondents</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality Management System</td>
<td>V3</td>
<td>23</td>
<td>4.70</td>
<td>0.47</td>
</tr>
<tr>
<td></td>
<td>V2</td>
<td>23</td>
<td>4.52</td>
<td>0.51</td>
</tr>
<tr>
<td></td>
<td>V1</td>
<td>23</td>
<td>4.48</td>
<td>0.51</td>
</tr>
<tr>
<td>Management commitment</td>
<td>V4</td>
<td>23</td>
<td>4.09</td>
<td>0.51</td>
</tr>
<tr>
<td></td>
<td>V5</td>
<td>23</td>
<td>3.91</td>
<td>0.73</td>
</tr>
<tr>
<td></td>
<td>V6</td>
<td>23</td>
<td>3.87</td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td>V7</td>
<td>23</td>
<td>3.65</td>
<td>0.65</td>
</tr>
<tr>
<td>Customer Focus</td>
<td>V9</td>
<td>23</td>
<td>4.26</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>V8</td>
<td>23</td>
<td>4.13</td>
<td>1.06</td>
</tr>
<tr>
<td></td>
<td>V10</td>
<td>23</td>
<td>4.13</td>
<td>1.06</td>
</tr>
<tr>
<td>Quality Policy</td>
<td>V11</td>
<td>23</td>
<td>4.30</td>
<td>0.47</td>
</tr>
<tr>
<td></td>
<td>V12</td>
<td>23</td>
<td>4.30</td>
<td>0.47</td>
</tr>
<tr>
<td></td>
<td>V13</td>
<td>23</td>
<td>4.09</td>
<td>0.51</td>
</tr>
<tr>
<td>Responsibility, Authority &amp; Communication</td>
<td>V16</td>
<td>23</td>
<td>4.09</td>
<td>0.51</td>
</tr>
<tr>
<td></td>
<td>V14</td>
<td>23</td>
<td>4.04</td>
<td>0.82</td>
</tr>
<tr>
<td></td>
<td>V15</td>
<td>23</td>
<td>3.78</td>
<td>0.85</td>
</tr>
<tr>
<td>Resource Management</td>
<td>V18</td>
<td>23</td>
<td>4.04</td>
<td>0.64</td>
</tr>
<tr>
<td></td>
<td>V19</td>
<td>23</td>
<td>4.04</td>
<td>0.47</td>
</tr>
<tr>
<td></td>
<td>V20</td>
<td>23</td>
<td>4.00</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>V17</td>
<td>23</td>
<td>3.78</td>
<td>0.74</td>
</tr>
<tr>
<td></td>
<td>V22</td>
<td>23</td>
<td>3.65</td>
<td>1.11</td>
</tr>
<tr>
<td></td>
<td>V21</td>
<td>23</td>
<td>3.57</td>
<td>0.99</td>
</tr>
<tr>
<td>Product Realization</td>
<td>V23</td>
<td>23</td>
<td>4.35</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>V26</td>
<td>23</td>
<td>4.26</td>
<td>0.54</td>
</tr>
<tr>
<td></td>
<td>V25</td>
<td>23</td>
<td>4.17</td>
<td>0.65</td>
</tr>
<tr>
<td></td>
<td>V24</td>
<td>23</td>
<td>4.13</td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td>V27</td>
<td>23</td>
<td>3.96</td>
<td>0.88</td>
</tr>
<tr>
<td>Measurement, analysis and improvement</td>
<td>V29</td>
<td>23</td>
<td>4.22</td>
<td>0.52</td>
</tr>
<tr>
<td></td>
<td>V30</td>
<td>23</td>
<td>4.04</td>
<td>0.71</td>
</tr>
<tr>
<td></td>
<td>V28</td>
<td>23</td>
<td>4.00</td>
<td>0.74</td>
</tr>
</tbody>
</table>

5.2.2 Linear correlation analysis of questionnaire variables

As part of quantitative data analysis, linear correlation of questionnaire variables was performed using Pearson. Pearson is used to establish the extent of relationship between variables in an interdependent relationship to measure relationship between variables, the correlation coefficient “r” ranging between -1 and 1, where 1 indicates strong negative
correlation, 0 indicates no correlation and 1 indicates a strong positive correlation (Tamara, 2016).

The other objective of performing Pearson correlation analysis was to establish the extent of influence of analyzed variables on each other in order to deepen meaningful relationship between the variables (Tamara, 2016):

- Positive correlation – an increase in one variable will result in an increase on the other variable
- Negative correlation – an increase in one variable will result in a decrease on the other variable
- No correlation – an increase in one variable will neither increase nor decrease the other variable

This is achieved through the frequency table X and Y variables and the number of cases “n” as demonstrated by Table 5-2. Pearson correlation was performed between all variables. However, only those variables which strongly correlated or have no correlation will be reported.
Table 5-2 Pearson correlation between variables

<table>
<thead>
<tr>
<th></th>
<th>V4</th>
<th>V5</th>
<th>V6</th>
<th>V8</th>
<th>V10</th>
<th>V11</th>
<th>V12</th>
<th>V17</th>
<th>V18</th>
<th>V20</th>
<th>V21</th>
<th>V24</th>
<th>V27</th>
</tr>
</thead>
<tbody>
<tr>
<td>V4</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V5</td>
<td>0.382</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V6</td>
<td>0.497</td>
<td>0.879</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V7</td>
<td>0.368</td>
<td>0.604</td>
<td>0.738</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V8</td>
<td>0.145</td>
<td>-0.102</td>
<td>-0.091</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V9</td>
<td>0.409</td>
<td>-0.039</td>
<td>-0.017</td>
<td>0.584</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V10</td>
<td>0.396</td>
<td>-0.278</td>
<td>-0.205</td>
<td>0.756</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V11</td>
<td>0.261</td>
<td>0.476</td>
<td>0.499</td>
<td>0.282</td>
<td>0.191</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V12</td>
<td>0.449</td>
<td>0.607</td>
<td>0.627</td>
<td>0.282</td>
<td>0.191</td>
<td>0.795</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V13</td>
<td>0.313</td>
<td>0.021</td>
<td>0.147</td>
<td>0.646</td>
<td>0.646</td>
<td>0.637</td>
<td>0.449</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V14</td>
<td>0.098</td>
<td>-0.294</td>
<td>-0.282</td>
<td>0.671</td>
<td>0.775</td>
<td>0.316</td>
<td>0.199</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V15</td>
<td>0.253</td>
<td>-0.105</td>
<td>-0.046</td>
<td>0.185</td>
<td>0.235</td>
<td>-0.054</td>
<td>0.173</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V16</td>
<td>-0.030</td>
<td>0.021</td>
<td>0.030</td>
<td>0.312</td>
<td>0.396</td>
<td>0.449</td>
<td>0.449</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V17</td>
<td>0.292</td>
<td>-0.037</td>
<td>0.028</td>
<td>0.681</td>
<td>0.564</td>
<td>0.462</td>
<td>0.462</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V18</td>
<td>0.403</td>
<td>0.300</td>
<td>0.389</td>
<td>0.530</td>
<td>0.261</td>
<td>0.408</td>
<td>0.560</td>
<td>0.699</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V19</td>
<td>0.542</td>
<td>0.664</td>
<td>0.649</td>
<td>0.079</td>
<td>-0.102</td>
<td>0.345</td>
<td>0.549</td>
<td>0.289</td>
<td>0.444</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V20</td>
<td>0.443</td>
<td>-0.078</td>
<td>-0.075</td>
<td>0.593</td>
<td>0.700</td>
<td>0.242</td>
<td>0.242</td>
<td>0.542</td>
<td>0.179</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V21</td>
<td>0.434</td>
<td>0.071</td>
<td>0.163</td>
<td>0.759</td>
<td>0.663</td>
<td>0.199</td>
<td>0.296</td>
<td>0.550</td>
<td>0.462</td>
<td>0.459</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V22</td>
<td>0.611</td>
<td>0.017</td>
<td>0.106</td>
<td>0.736</td>
<td>0.736</td>
<td>0.298</td>
<td>0.298</td>
<td>0.625</td>
<td>0.471</td>
<td>0.768</td>
<td>0.845</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>V23</td>
<td>0.237</td>
<td>0.598</td>
<td>0.499</td>
<td>0.261</td>
<td>0.173</td>
<td>0.707</td>
<td>0.707</td>
<td>0.347</td>
<td>0.388</td>
<td>0.351</td>
<td>0.139</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V24</td>
<td>0.203</td>
<td>0.021</td>
<td>-0.048</td>
<td>0.602</td>
<td>0.659</td>
<td>0.266</td>
<td>0.394</td>
<td>0.624</td>
<td>0.458</td>
<td>0.376</td>
<td>0.563</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>V25</td>
<td>0.360</td>
<td>0.224</td>
<td>0.140</td>
<td>0.098</td>
<td>0.230</td>
<td>0.116</td>
<td>0.265</td>
<td>0.273</td>
<td>0.200</td>
<td>0.350</td>
<td>0.123</td>
<td>0.506</td>
<td>1</td>
</tr>
<tr>
<td>V26</td>
<td>0.731</td>
<td>0.174</td>
<td>0.309</td>
<td>0.335</td>
<td>0.574</td>
<td>0.388</td>
<td>0.567</td>
<td>0.492</td>
<td>0.493</td>
<td>0.316</td>
<td>0.390</td>
<td>0.468</td>
<td></td>
</tr>
<tr>
<td>V27</td>
<td>0.109</td>
<td>-0.006</td>
<td>-0.009</td>
<td>0.692</td>
<td>0.643</td>
<td>0.144</td>
<td>0.254</td>
<td>0.548</td>
<td>0.409</td>
<td>0.260</td>
<td>0.708</td>
<td>0.830</td>
<td>1</td>
</tr>
<tr>
<td>V28</td>
<td>0.359</td>
<td>0.000</td>
<td>0.000</td>
<td>0.466</td>
<td>0.698</td>
<td>0.131</td>
<td>0.262</td>
<td>0.335</td>
<td>0.096</td>
<td>0.463</td>
<td>0.620</td>
<td>0.650</td>
<td>0.701</td>
</tr>
<tr>
<td>V29</td>
<td>0.267</td>
<td>0.291</td>
<td>0.307</td>
<td>0.112</td>
<td>0.112</td>
<td>0.089</td>
<td>0.275</td>
<td>0.130</td>
<td>0.382</td>
<td>-0.110</td>
<td>0.192</td>
<td>0.388</td>
<td>0.421</td>
</tr>
<tr>
<td>V30</td>
<td>0.239</td>
<td>0.008</td>
<td>0.096</td>
<td>0.662</td>
<td>0.601</td>
<td>0.369</td>
<td>0.506</td>
<td>0.719</td>
<td>0.702</td>
<td>0.404</td>
<td>0.548</td>
<td>0.840</td>
<td>0.737</td>
</tr>
</tbody>
</table>

From table 5-2, there is a strong correlation between:

- Variable 4 and variable 26
- Variable 5 and variable 6
- Variable 6 and variable 7
- Variable 8 and variables 10, 21 and 22
- Variable 10 and variables 14, 20 and 22
- Variable 11 and variables 12 and 22
- Variable 17 and variable 20
- Variable 18 and variable 30
- Variable 20 and variable 22
- Variable 21 and variables 22 and 27
- Variable 24 and variables 27 and 30
- Variable 27 and variables 28 and 30
There is no correlation between:
- Variable 5 and variable 28
- Variable 6 and variable 28

### 5.2.3 Bar charts analysis of questionnaire variables

According to Howell (2010), graphs (a bar/column chart or line) are used in order to get a clear picture of CSFs performance. During this study, bar charts were used to demonstrate the performance of each CSF variables. Tables 5.3 – 5.10 list the total number of respondents per questionnaire variables. Figures 5.1-5.8 reports the total number of respondents per questionnaire variable in the form of percentage using bar charts.

**CSF 1: Quality Management System**

This CSF consists of three questionnaire variables addressing the level of ISO 17025 QMS within coal testing division. Table 5-3 below provides a summary of respondents for questionnaire variables under this CSF. Using a scale of 1-5 as indicated on the table, respondents were required to indicate their level of agreement or disagreement with questionnaire variables under this CSF.

**Table 5-3 CSF 1 (Questionnaire variables 1-3): Quality Management System**

<table>
<thead>
<tr>
<th>Questionnaire variables</th>
<th>Extent to which you agree or disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree</td>
</tr>
<tr>
<td>V1</td>
<td>0</td>
</tr>
<tr>
<td>V2</td>
<td>0</td>
</tr>
<tr>
<td>V3</td>
<td>0</td>
</tr>
</tbody>
</table>

**Figure 5-1 CSF 1: Quality Management System**
From figure 5-1, of the total respondents:
52% and 48% agree and strongly agree respectively that there is an established and maintained ISO 17025 quality manual.
48% and 52% agree and strongly agree respectively that document control systems are established tracking revision levels of all OD.
30% and 70% agree and strongly agree respectively that quality internal audits are performed on the ISO 17025 QMS.

Overall, the entire population of participants sampled all agree and strongly agree that the entire coal testing division has a documented ISO 17025 QMS.

**CSF 2: Management commitment**

This CSF consists of four questionnaire variables addressing management commitment relating to quality within coal testing division. Table 5-4 below provides a summary of respondents for questionnaire variables under this CSF. Using a scale of 1-5 as indicated on the table, respondents were required to indicate their level of agreement or disagreement with questionnaire variables under this CSF.

**Table 5-4 CSF 2 (Questionnaire variables 4-7): Management commitment**

<table>
<thead>
<tr>
<th>Questionnaire variables</th>
<th>Extent to which you agree or disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree</td>
</tr>
<tr>
<td>V4</td>
<td>0</td>
</tr>
<tr>
<td>V5</td>
<td>0</td>
</tr>
<tr>
<td>V6</td>
<td>0</td>
</tr>
<tr>
<td>V7</td>
<td>0</td>
</tr>
</tbody>
</table>

**Figure 5-2 CSF 2: Management commitment**
From figure 5-2, of the total respondents:
9% is unsure, 74% agree and 17% strongly agree that divisional management ensures that quality policies and objectives are reviewed regularly.
30% is unsure, 48% agree and 22% strongly agree that executive conduct is consistent with the values relevant to quality and continuous quality improvement.
35% is unsure, 43% agree and 22% strongly agree that executive showed an ability in managing the changes needed to improve the quality and services.
43% is unsure, 48% agree and 9% strongly agree that executive take action on suggestions to improve the quality and services.

For respondents under this theme, it is worrisome to note that there is an uncertainty of 9%, 30%, 35% and 43% for questionnaire variables 4, 5, 6 and 7. This somehow does not provide a clear picture of top management commitment on the advancement of quality and continuous quality improvement.

CSF 3: Customer Focus

This CSF consists of three questionnaire variables addressing BU quality service level to the customer. Table 5-5 below provides a summary of respondents for questionnaire variables under this CSF. Using a scale of 1-5 as indicated on the table, respondents were required to indicate their level of agreement or disagreement with questionnaire variables under this CSF.

Table 5-5 CSF 3 (Questionnaire variables 8-10): Customer Focus

<table>
<thead>
<tr>
<th>Questionnaire variables</th>
<th>Extent to which you agree or disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree</td>
</tr>
<tr>
<td>V8</td>
<td>1</td>
</tr>
<tr>
<td>V9</td>
<td>0</td>
</tr>
<tr>
<td>V10</td>
<td>1</td>
</tr>
</tbody>
</table>

![Figure 5-3 CSF 3: Customer focus](image)
From Figure 5-3, of the total respondents:
4% strongly disagree, disagree and 4% is unsure while 39% and 48% agree and strongly agree respectively that the current customer needs and expectations are assessed.
4% disagree and are unsure respectively while 52% and 39% agree and strongly agree respectively that customer complaints are studied for identification of trend analysis and to prevent recurring of customer complaints.
4% strongly disagree and disagree respectively while 9% is unsure, 39% agree and 43% strongly agree that data from customers is used to improve services.

On average, about 4% strongly disagree, agree and is unsure that there is a clear customer focus by coal testing division.

**CSF 4: Quality Policy**

This CSF consists of three questionnaire variables addressing coal testing division quality policy. Table 5-6 below provides a summary of respondents for questionnaire variables under this CSF. Using a scale of 1-5 as indicated on the table, respondents were required to indicate their level of agreement or disagreement with questionnaire variables under this CSF.

**Table 5-6 CSF 4 (Questionnaire variables 11-13): Quality Policy**

<table>
<thead>
<tr>
<th>Questionnaire variables</th>
<th>Extent to which you agree or disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>0</td>
</tr>
<tr>
<td>Disagree</td>
<td>0</td>
</tr>
<tr>
<td>Unsure</td>
<td>2</td>
</tr>
<tr>
<td>Agree</td>
<td></td>
</tr>
<tr>
<td>Strongly agree</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 5-4 CSF 4: Quality Policy**
From figure 5-4, of the total respondents:
70% agree and 30% strongly agree respectively that the present coal testing division quality policy is appropriate.
70% agree and 30% strongly agree respectively that coal testing division quality policy commits to the continual improvement.
9% is unsure, 74% agree and 17% strongly agree that quality policy is communicated and well understood.

Overall, except for small percentage for questionnaire variable 13, a higher percentage of respondents in this CSF agree and strongly agree that quality policy is appropriate, commits to continual improvement and is communicated and well understood.

CSF 5: Responsibility, Authority & Communication

This CSF consists of three questionnaire variables addressing the responsibilities, authorities & communication relating to QMS implementation & maintenance within the coal testing division. Table 5-7 below provides a summary of respondents for questionnaire variables under this CSF. Using a scale of 1-5 as indicated on the table, respondents were required to indicate their level of agreement or disagreement with questionnaire variables under this CSF.

Table 5-7 CSF 5 (Questionnaire variables 14-16): Responsibility, Authority & Communication

<table>
<thead>
<tr>
<th>Questionnaire variable</th>
<th>Extent to which you agree or disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree</td>
</tr>
<tr>
<td>V14</td>
<td>0</td>
</tr>
<tr>
<td>V15</td>
<td>0</td>
</tr>
<tr>
<td>V16</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 5-5 CSF 5 : Responsibility, Authority & Communication
From figure 5-5, of the total respondents:
9% disagree, 4% is unsure, 61% agree and 26% strongly agree that personnel responsibilities and authorities are clearly defined and communicated within coal testing division.
13% disagree, 9% is unsure, 65% agree and 13% strongly agree that key personnel responsible for establishment and maintenance of ISO 17025 QMS are appointed at coal testing division individual BUs.
9% is unsure, 78% agree and 13% strongly agree that there is a good communication system in place for an effective ISO 17025 QMS.

Respondents under this CSF expressed mixed feelings in terms of defining and communicating to personnel their responsibilities and authorities in terms of establishment and effective maintenance of ISO 17025 QMS.

CSF 6: Resource Management

This CSF consists of six questionnaire variables addressing resource availability within coal testing division. Table 5-8 below provides a summary of respondents for questionnaire variables under this CSF. Using a scale of 1-5 as indicated on the table, respondents were required to indicate their level of agreement or disagreement with questionnaire variables under this CSF.

Table 5-8 CSF 6 (Questionnaire variables 17-22): Resource Management

<table>
<thead>
<tr>
<th>Questionnaire variables</th>
<th>Extent to which you agree or disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree</td>
</tr>
<tr>
<td>V17</td>
<td>0</td>
</tr>
<tr>
<td>V18</td>
<td>0</td>
</tr>
<tr>
<td>V19</td>
<td>0</td>
</tr>
<tr>
<td>V20</td>
<td>1</td>
</tr>
<tr>
<td>V21</td>
<td>0</td>
</tr>
<tr>
<td>V22</td>
<td>2</td>
</tr>
</tbody>
</table>

Figure 5-6 CSF 6: Resource Management
From figure 5-6, of the total respondents:

9% disagree, 13% is unsure, 70% agree and 9% strongly agree that sufficient resources are provided to implement, maintain and improve ISO 17025 QMS.

4% strongly disagree and is unsure respectively while 74% agree and 17% strongly agree that the required infrastructure for conformance with service requirements is provided and maintained.

9% is unsure, 78% agree and 13% strongly agree that the resources required to establish and control working conditions are provided to ensure service quality.

4% is unsure and strongly disagree, 74% agree and 17% strongly agree that education and training on how to identify and act on quality improvement opportunities are provided to staff.

26% disagree, 65% agree and 9% strongly agree that education and training in statistical and other quantitative methods supporting quality improvement are provided to staff.

9% strongly disagree and disagree, 4% is unsure, 65% agree and 13% strongly agree that the required education and training to improve job skills and performance are provided to staff.

The general feeling is that not all respondents are fully satisfied about resource availability on quality improvement.

**CSF 7: Product Realization**

This CSF consists of five questionnaire variables addressing service and product specifications. Table 5-9 below provides a summary of respondents for questionnaire variables under this CSF. Using a scale of 1-5 as indicated on the table, respondents were required to indicate their level of agreement or disagreement with questionnaire variables under this CSF.

**Table 5-9 CSF 7 (Questionnaire variables 23-27): Product Realization**

<table>
<thead>
<tr>
<th>Questionnaire variables</th>
<th>Extent to which you agree or disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly disagree</td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td></td>
</tr>
<tr>
<td>Unsure</td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td></td>
</tr>
<tr>
<td>Strongly agree</td>
<td></td>
</tr>
<tr>
<td>V23</td>
<td>0</td>
</tr>
<tr>
<td>V24</td>
<td>0</td>
</tr>
<tr>
<td>V25</td>
<td>0</td>
</tr>
<tr>
<td>V26</td>
<td>0</td>
</tr>
<tr>
<td>V27</td>
<td>0</td>
</tr>
</tbody>
</table>
From Figure 5-7 above, of the total respondents:
65% and 35% agree and strongly respectively, that quality objectives and requirements of the service are clearly defined.
4% disagree, 9% is unsure, 61% agree and 26% strongly agree that service specific processes are clearly established and documented.
13% is unsure, 61% agree and 26% strongly agree that reviews are done to ensure capability to provide requested service.
4% is unsure, 65% agree and 30% strongly that records are kept to confirm that the process and service rendered meet requirements.
9% disagree, 13% is unsure, 52% agree and 26% strongly agree that an effective customer communication is established for providing service information, handling enquiries, orders and customer feedback.

Overall there are respondents disagreeing about service specification processes been established and effective customer communication.

**CSF 8: Measurement, analysis and improvement**

This CSF consists of three questionnaire variables addressing service quality measurement, analysis and improvement. Table 5-10 below provides a summary of respondents for questionnaire variables under this CSF. Using a scale of 1-5 as indicated on the table, respondents were required to indicate their level of agreement or disagreement with questionnaire variables under this CSF.
Table 5-10 CSF 8 (Questionnaire variables 28-30): Measurement, analysis and improvement

<table>
<thead>
<tr>
<th>Questionnaire variables</th>
<th>Extent to which you agree or disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree</td>
</tr>
<tr>
<td>28</td>
<td>0</td>
</tr>
<tr>
<td>29</td>
<td>0</td>
</tr>
<tr>
<td>30</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 5-8 CSF 8: Measurement, analysis and improvement

From figure 5-8 above, of the total respondents:
4% disagree, 13% is unsure, 61% agree and 22% strongly agree that conformance to service is measured and monitored to ensure that all requirements are met.
4% is unsure, 70% agree and 26% strongly agree that a system is established to eliminate the causes of potential non-conformances to occur.
4% disagree, 9% is unsure, 65% agree and 22% strongly agree that an effective system is established to ensure that non-conforming process is identified and controlled to prevent its unwanted use.

Respondents under this CSF expressed regarding conformance to service been measured and monitored, establishment of system to eliminate cause of potential non-conformances and that an effective system is established to ensure non-conforming process is identified and controlled.

Furthermore to the feedback provided, two of the respondents gave the following critical comments as indicated in appendix D:

Comments by participant 12 – “In general, QMS documentation, procedures and policies are handled exceptionally well. There is a high level of trust in current top management although staff desires more HR-type interaction. General - and customer communications can improve, there is currently not a general culture of open communication and to share information on junior levels. Many staff members are not on an education level where they can effectively be trained on statistical and quantitative methods. A LIMS system is used that’s very effective for
most aspects relating to coal-specific testing, but there is a lack of reporting tools to measure e.g. TAT and various technical aspects such as repeatability. Time consuming SOC procurement requirements sometimes cause delays for obtaining urgent resources in the region.”

**Comments by participant 21** – “QMS is adopted reactively more than proactively”.

Both of these comments are very critical in improving quality culture of coal testing division in order for the division to continue providing the desired service levels.
Chapter 6 : Conclusions and Recommendations

6.1 Introduction

This Chapter will provide a summary of research findings and conclusion and the recommendations.

6.2 Research objectives: Summary of findings and conclusions

6.2.1 Research objective 1: To demonstrate the benefits for maintaining ISO 17025 quality management system

➢ Summary

The literature review including extracted case study of MSP document of company X commercial unit identified the benefits for effective maintenance of ISO 17025 QMS in testing laboratories. Such benefits also serve as the motive for effective maintenance of ISO 17025 QMS in coal testing division. The benefits identified include the following:

- Improved coal testing division management policies
- More effective and efficient coal testing division operations
- Stronger risk management strategies within coal testing division
- Reduction in incidents within coal testing division operations
- Enhanced team awareness within coal testing division
- Coal testing division operational credibility with government and customers
- Greater marketing edge (competitive advantage) of coal testing division
- Coal testing division increased customer satisfaction
- Professional self-respect of coal testing division
- Coal testing division international recognition

➢ Conclusion

To answer the research question on “why does coal testing division has to maintain ISO 17025 quality management system?,” based on the findings for this objective, it is concluded that in order to achieve the added abovementioned operational and economic benefits, there must be a maintained ISO 17025 QMS in coal testing division which requires continual improvement. The following section outlines the CSFs identified for improving ISO 17025 QMS within coal testing division.

6.2.2 Research objective 2: Identification of critical success factors for improving ISO 17025 quality management system within coal testing division

The research methodology chapter of this dissertation made provision to source out data to answer the research question by identification of CSFs for improving quality culture through structured questionnaires. The type of case study used is a single case study using structured questionnaire. In designing the questionnaires, each of the identified CFSs common to the
success of various improvement initiatives in table 3-1 of the literature review had its own questionnaire variables. Respondents were asked to rate each questionnaire variables on the provided likert scale of 1-5. CSFs identified for improving ISO 17025 QMS within coal testing division are outlined below together with a brief description of each based on participants’ feedback on each questionnaire variable per CSF.

CSF 1: QMS

The study results revealed that there is a well-established and maintained ISO 17025 QMS across coal testing division, which is continuously audited for compliance with regulatory requirements by an independent and impartial internal auditor. However, one of the respondents made a worrisome comment by saying that “QMS is adopted reactively more than proactively.” This suggests that there is a less hands-on commitment in QMS adoption. Internal auditor from Y department of company X also picks up this deficiency during internal audits timeously. According to the extracted case study from MSP document of company X commercial unit, it is a requirement for the division to develop, implement and maintain an integrated management system covering all services provided by the cluster.

CSF 2: Management commitment

The study results revealed that there is full management commitment on the advancement of ISO 17025 QMS implementation and maintenance across coal testing division. According to the extracted case study from MSP document of company X commercial unit, in order for QMS to remain valid to maintain accreditation and to satisfy customer and operational needs, top management shall review the QMS periodically.

CSF 3: Customer focus

The study results revealed that there is not full compliance in terms of offering quality service to the customer and there are some levels of uncertainties in some areas. The division must focus on assessing the current customer requirements and expectations through studying of customer complaints and using customer data to improve services. Studying customer data may include analysis of customer satisfaction questionnaire feedback and make improvements where required. This is further highlighted on the extracted case study from MSP document of company X commercial by stating that coal testing division management and staff have the responsibility to ensure that they understand customer requirements and that customer satisfaction is the key to the continued growth of the organization. Coal testing division BU managers shall ensure that their staff members are aware and familiar with the marketplace in which the cluster operates.

CSF 4: Quality policy

The study results revealed that the coal testing division has an appropriate quality policy committed for continual improvement. However, there is some little uncertainty of whether the quality policy is communicated and well understood by all coal testing division personnel. The literature review established that for a laboratory to have a functional QMS, its structure and management must be in such a way that quality policy can be established, implemented and maintained.
CSF 5: Responsibility, authority and communication

The study results revealed that the responsibilities, authorities and communication within coal testing division are not clearly defined and there is a need to appoint key personnel for establishment, implementation and maintenance of ISO 17025 QMS in the BUs. Although some areas within coal testing division have demonstrated greater performance of this CSF, there are greater levels of uncertainty in some areas. The literature review revealed that, for efficiency within testing laboratory operations, the laboratory manager must clearly define job requirements for each job level and issue a job description for each laboratory staff member.

CSF 6: Resource management

The study results revealed that good performance is lacking for this CSF in coal testing division. There is a need to provide staff with needed education and training for implementation, maintenance and improvement of ISO 17025 QMS. Greater focus should be placed on providing the necessary education and training in statistical and other relevant quantitative methods supporting QMS improvement. This was also cited out in some comments made by one of the respondents. In the context of coal testing, this includes the use of control charts, which identifies the process changes, and trends of coal parameters tested over time and show the effects of corrective actions.

Study results also revealed that the cluster does not provide infrastructures to establish control and maintaining of working conditions needed to assure service quality. Differing geographical locations requires monitoring and control of different conditions, which includes temperature and humidity in coal testing.

The study results also revealed that there is some level of uncertainty on the extent of implementation and maintenance of this CSF in coal testing division. According to the extracted case study from MSP document of company X commercial unit, top management shall provide and make available adequate resources to meet stakeholder and operational requirements. In the context of coal testing, the most important laboratory resource is staff members with the necessary competency and motivation to perform their daily activities. The internal auditor from Y department picked up this issue of resource scarcity on several areas within coal testing division when conducting internal audits.

CSF 7: Product realization

The study results revealed a mixed feeling in terms of clearly defining quality objectives and requirements of the service to be rendered by coal testing division. Although there is implementation of this CSF in many areas within the division, there is also some level of uncertainty and a need for implementation and improvement in some areas. Greater focus should be placed on establishing an effective customer communication system for providing service information, handling enquiries, orders and customer feedback. According to the literature review, the final product of a testing laboratory is a legitimate laboratory test report. Test reports must be carefully managed to ensure they are accurate and confidential. Whatever format tests reports takes, either soft or hardcopy, it has to be safe and secure.
CSF 8: Measurement, analysis and improvement

While the study results demonstrated that there is greater implementation and improvement of this CSF in some areas within coal testing division, there is however some level of uncertainty in some areas and the need to foster implementation and improvement by:

- Measuring and monitoring service conformity to ensure that all requirements are met.
- Having an effective system that will ensure that non-conforming process is identified and controlled to prevent its unwanted use.

The extracted case study from MSP Document for company X commercial unit revealed that company X commercial unit requires coal testing division to establish a well-organized approach to monitor and measure customer satisfaction. Such an approach needs an organizational framework support in order to enable planning, operation, maintenance and improvement of processes to monitor and measure customer satisfaction.

**Conclusion**

This journey on the identification of CSFs for improving of quality culture within coal testing division in company X was a successful one. The main conclusion and lessons drawn from this study are that, in order for coal testing division to enjoy the benefits stated in 6.2.1, there must be continual improvement of ISO 17025 QMS taking into consideration the issues addressed in the abovementioned CSFs. Based on the feedback from study participants on the abovementioned CSFs and the literature review, it was found that the abovementioned CSFs might not necessarily guarantee a laboratory that is free from deficiencies. However, it will provide the needed confidence among end users of the coal that the coal tested by coal testing division will satisfy coal quality requirements.

With regard to answering the question on “how to improve ISO 17025 QMS within coal testing division? The following must be addressed as per identified CSFs questionnaire variables feedback to improve ISO 17025 QMS in order to fulfill coal testing division goals and objectives of providing accurate and reliable service to its customers:

- Enforcement of customer requirements awareness to ensure everyone within coal testing division is familiar with customer requirements.
- Creation of an effective and open communication system on quality policy and objectives for all coal testing division personnel.
- Empowerment managed by designated personnel stationed in the BUs to ensure an ongoing improvement of ISO 17025 QMS which will result in the reduction of reaction time to quality related issues.
- Provision of education and training to coal testing division staff members at all levels providing them with the necessary knowledge to allow them to continuously improve ISO 17025 QMS.
- Establishment of an effective customer communication system within coal testing division for providing customer service information, handling of enquiries, orders and customer feedback.
- Establishment of measuring and monitoring system for service conformity ensuring all customer needs are met.
- Creation of a system for identification and control of non-conformances and to prevent their unwanted use.

Table 5-1 in chapter five is a summary of the identified CSFs and the scores of their associated questionnaire variables. The rank of each questionnaire variable is a representation of the
influential level of the questionnaire variable per CSF. The higher the rank, the higher the influence of the CSF questionnaire variable.

Table 5-2 in chapter five is a summary of the correlation between questionnaire variables. Correlations is a representation of the relationship between questionnaire variables with -1 and +1. Values closer to -1 represent negative correlation, values closer to 0 represent no correlation and values closer to +1 represent positive correlation between questionnaire variables.

6.3 Recommendations

The following recommendations can be made based on the study findings on CSFs for improving quality culture in coal testing division:

- Designated personnel should lead the process of ISO 17025 QMS maintenance and improvement on fulltime basis in each BU within coal testing division who will also provide induction to coal testing division staff members on customer requirements.
- Before any attempt is made on the maintenance and improvement of ISO 17025 QMS, there must be a genuine commitment from the entire top management level.
- Top management must invest in skills development to assist staff members with required skills for maintenance and improvement of ISO 17025 QMS. This can be achieved through introduction of standardized skill-evaluation matrix for assessing training needs and conducting training accordingly. This will ensure the availability of skilled resources, regardless of employee turnover.
- Maintaining and continually improving ISO 17025 QMS are long processes and require more time. Therefore, it is important for laboratory management to be realistic when setting timelines for maintenance process to be fully functional.
- Top management must remember that quality improvement does not have a completion date and must promote the spirit of ISO 17025 improvement as an ongoing activity.
- To encourage staff to be more involved in the maintenance and continual improvement of ISO 17025 QMS, coal testing division top management must celebrate success as a means to boost staff morale and learn from mistakes.

6.4 Recommendations for further study

During the present study, the researcher was able to provide description of quality and QMS. The extent of impact of ISO 17025 QMS maintenance on coal testing division was outlined and CSFs for improving ISO 17025 were also outlined. Chapter three of this dissertation pointed out that a single case study has little scope of generalization at the end of the study. During this study, the researcher was not able to provide a more generalized view on the impact of quality and QMS on the entire X testing division since the CSFs operate different from KPIs. Therefore, the following should be considered for further research:

- A detailed study of the measurements of quality and quality KPIs with the aim of producing standard measures and indicators for the entire testing division in company X.
- Studies on the reason for the failure of QMS implemented in the entire company X testing laboratories.
The abovementioned factors require a more detailed study and are beyond the scope of this study. They are recommended for future studies.
References


34. ISO 14001., 2015. Environmental management systems - requirements with guidance for use.
47. Mauch, D.T., Quality Management: Theory and Application. Boca Raton. Taylor & Francis Group, LLC.
75. X Commercial Management System Policy Document., Published: 15/03/2017. South Africa.
Appendices

Appendix A: Request for permission to conduct study at company X coal testing division

MEMORANDUM

To : Chief Digital Officer
From : Jonas Rasethe
Date : 28 March 2018
Subject : Request for permission to collect research data for Master of Philosophy (MPHIL) Degree in Engineering Management Qualification

PURPOSE

The purpose of this submission is to obtain approval to collect research data at the X for the completion of a Master of Philosophy (MPHIL) Degree in Engineering Management.

MOTIVATION

I am currently studying towards MPHIL Degree in Engineering Management through the University of Johannesburg which requires me to complete a minor dissertation. I therefore request permission to conduct study within the coal testing division of company X. The study topic is titled “Critical success factors for improving quality culture in a coal testing division”. Both quantitative and qualitative research methodologies will be used. The primary data will be collected using questionnaire to the identified research population. Data will be collected by sending questionnaire to the study participants, which is P5 – P18. Secondary data will be collected from existing accreditation management department and coal testing division data. Participation in the questionnaire is voluntary and there are no known or unknown risks for participating in the study. The study questionnaire will purely be on the basis of gathering data from the respondents in support of the study aims. All information provided will be used in utmost confidentiality and would be used only for academic purposes. Respondents and organization’s names will not appear in any dissertation/publication unless agreed upon.

The problem that has been identified and will be addressed through the study based on identifying, examining and formulating the critical success factors for the improvement of quality culture in coal testing division of company X. Like other commercial organizations, coal testing division needs to be adaptable for future external business uncertainties such as shift in economies/markets, a breakthrough in technology, etc. The study aims to focus on coal testing division quality management system improvement. This study will how to road test the vision and strategy for coal testing division against these scenarios. The study aims to recommend key strategies in order for coal testing division of company X to continue providing high quality, cost effective and accurate service to its customer.
After the data have been analysed, a copy of the executive summary will be made available to Company X. An electronic copy (e.g. PDF) of the entire dissertation will be made available when required.

I believe that this study paper will add value to the company X coal testing division considering the current transition from ISO 17025:2005 to ISO 17025:2017.

<table>
<thead>
<tr>
<th>Requested by:</th>
<th>Approved by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principal Internal Auditor: Laboratory Systems Accreditation</td>
<td>Executive: Chief Digital Officer</td>
</tr>
<tr>
<td>Supported by:</td>
<td></td>
</tr>
<tr>
<td>Human Capital Business Partner</td>
<td></td>
</tr>
</tbody>
</table>

Comments by the Approver:

__________________________________________
__________________________________________
__________________________________________
## Appendix B: Study questionnaire variables codes

<table>
<thead>
<tr>
<th>Variables</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1</td>
<td>There is an established and maintained ISO 17025 quality manual</td>
</tr>
<tr>
<td>V2</td>
<td>Document control systems are established tracking revision levels of all OD</td>
</tr>
<tr>
<td>V3</td>
<td>Quality internal audits are performed on the ISO 17025 QMS</td>
</tr>
<tr>
<td>V4</td>
<td>Top management ensures that quality policies and objectives are reviewed regularly</td>
</tr>
<tr>
<td>V5</td>
<td>Top management behaviour is consistent with values relevant to quality and continuous quality improvement</td>
</tr>
<tr>
<td>V6</td>
<td>Top management demonstrated an ability to manage the changes needed to improve the quality and services</td>
</tr>
<tr>
<td>V7</td>
<td>Top management act on suggestions to improve the quality and services</td>
</tr>
<tr>
<td>V8</td>
<td>Current customer needs and expectations are assessed</td>
</tr>
<tr>
<td>V9</td>
<td>Customer complaints are studied for identification of trend analysis and to prevent recurring of customer complaints</td>
</tr>
<tr>
<td>V10</td>
<td>Data from customers is used to improve services</td>
</tr>
<tr>
<td>V11</td>
<td>Present Quality policy is appropriate</td>
</tr>
<tr>
<td>V12</td>
<td>Quality policy commits to the continual improvement</td>
</tr>
<tr>
<td>V13</td>
<td>Quality Policy is communicated and well understood</td>
</tr>
<tr>
<td>V14</td>
<td>Responsibilities and authorities are clearly defined and communicated</td>
</tr>
<tr>
<td>V15</td>
<td>Key personnel responsible for establishment, implementation and maintenance of ISO 17025 QMS is appointed</td>
</tr>
<tr>
<td>V16</td>
<td>A good communication system is established for an effective ISO 17025 QMS</td>
</tr>
<tr>
<td>V17</td>
<td>Sufficient resources are allocated to implement, maintain and improve ISO 17025 QMS</td>
</tr>
<tr>
<td>V18</td>
<td>The required infrastructure for conformance with service requirements is provided and maintained</td>
</tr>
<tr>
<td>V19</td>
<td>Resources required to establish and control working conditions are provided to ensure service quality</td>
</tr>
<tr>
<td>V20</td>
<td>Education and training on how to identify and act on quality improvement opportunities are provided to staff</td>
</tr>
<tr>
<td>V21</td>
<td>Education and training in statistical and other quantitative methods supporting quality improvement are provided to staff</td>
</tr>
<tr>
<td>V22</td>
<td>The require education and training to improve job skills and performance are provided to staff</td>
</tr>
<tr>
<td>V23</td>
<td>Quality objectives and requirements of the service are clearly defined</td>
</tr>
<tr>
<td>V24</td>
<td>Service specific processes are clearly established and documented</td>
</tr>
<tr>
<td>V25</td>
<td>Reviews are done to ensure capability to provide requested service</td>
</tr>
<tr>
<td>V26</td>
<td>Records are kept to confirm that the process and resulting service meet requirements</td>
</tr>
<tr>
<td>V27</td>
<td>An effective customer communication is established for providing service information, handling enquiries, orders and customer feedback</td>
</tr>
<tr>
<td>V28</td>
<td>Service conformity is measured and monitored to ensure that all requirements are met</td>
</tr>
<tr>
<td>V29</td>
<td>A system is established to eliminate the causes of potential nonconformities to occur</td>
</tr>
<tr>
<td>V30</td>
<td>An effective system established to ensure that non-conforming process is identified and controlled to prevent its unintended use</td>
</tr>
</tbody>
</table>
Appendix C: Lickert scale codes

<table>
<thead>
<tr>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Unsure</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
Appendix D: Study results of participants per questionnaire variable

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comments by participant 22: In general, QMS documentation, procedures and policies are handled exceptionally well. There is a high level of trust in current top management although staff desires more HR-type interaction. General- and customer communications can improve, there is currently not a general culture of open communication and to share information on junior levels. Many staff members are not on an education level where they can effectively be trained on statistical and quantitative methods. A LIMS system is used that's very effective for most aspects relating to coal-specific testing, but there is a lack of reporting tools to measure e.g. TAT and various technical aspects such as repeatability. Time consuming SOC procurement requirements sometimes cause delays for obtaining urgent resources in the region.

Comments by participant 21: QMS is adopted reactively more than proactively.
Appendix E: Combined participants feedback per questionnaire variable in percentage

In this appendix, study results presented in Chapter 5 bar charts comparisons were converted into percentage using percentage calculation formula as per below:

\[
\% \text{ Respondents per questionnaire} = \frac{\text{Total number of respondents per questionnaire}}{\text{Total Number of Respondents}} \times 100
\]

As an example, for research questionnaire number 1, of the 23 participants, 12 agree that there is an established and maintained ISO 17025 quality manual. Therefore, the percentage for that feedback is calculated as follows:

\[
\% \text{ Respondents per questionnaire variable} = \frac{12}{23} \times 100
\]

\[
\% \text{ Respondents per questionnaire variable} = 52\%
\]

Therefore, the results on the table below are in \% Respondents per questionnaire variable

<table>
<thead>
<tr>
<th>Critical Success Factors</th>
<th>Questionnaire variables</th>
<th>Extent to which you agree or disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Strongly disagree</td>
</tr>
<tr>
<td>Quality management system Implementation</td>
<td>V1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>V2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>V3</td>
<td>0</td>
</tr>
<tr>
<td>Top management commitment</td>
<td>V4</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>V5</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>V6</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>V7</td>
<td>0</td>
</tr>
<tr>
<td>Customer focus</td>
<td>V8</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>V9</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>V10</td>
<td>4</td>
</tr>
<tr>
<td>Quality Policy</td>
<td>V11</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>V12</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>V13</td>
<td>0</td>
</tr>
<tr>
<td>Responsibility, Authority &amp; Communication</td>
<td>V14</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>V15</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>V16</td>
<td>0</td>
</tr>
<tr>
<td>Resource management</td>
<td>V17</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>V18</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>V19</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>V20</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>V21</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>V22</td>
<td>9</td>
</tr>
<tr>
<td>Product realization</td>
<td>V23</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>V24</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>V25</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>V26</td>
<td>V27</td>
</tr>
<tr>
<td>------------------</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Measurement, analysis and improvement</td>
<td>0 4 65</td>
<td>0 9 13 65</td>
</tr>
</tbody>
</table>