AN INTEGRATED QUALITY MANAGEMENT FRAMEWORK TO IMPROVE PROJECT THROUGHPUT RATE IN A SELECTED LABORATORY ENVIRONMENT

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----------	27 November 2023 ----------
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ABSTRACT

Recently there is growing consensus on the importance of advisability and reliability of testing laboratories adopting a Quality Management System (QMS) to support their activities. It has been noted, through literature that laboratories involved in research and development have specific difficulties implementing a QMS, due to the peculiar nature of their activities. In addition, literature indicates Lean Manufacturing provides useful tools and techniques to assist with improvement of quality and throughput rate of laboratories in industry. This study analyses the main challenges encountered by professionals, when implementing a QMS in a research and development laboratory, based on the literature reviewed. Furthermore, it has been noted the International Organisation for Standardisation (ISO) has a specific standard set for testing and calibrations laboratories to improve quality within the laboratory, namely ISO 17025:2017. The literature review analyses the pros and cons of ISO standards pertaining to laboratories and lean manufacturing tools which may assist to improve quality within the laboratory.

Sappi Centre Of Excellence (COE) laboratories which is a research and development laboratory is currently experiencing issues associated with delayed turnaround time of results, due to repeat work in ageing kinetics, viscose production and associated application tests within a project. The aim of this research was to reduce or eliminate repeat work during projects, in order to improve throughput time for project deliverables, through an integrated quality management framework.

To understand the cause of repeat work within a project, a pragmatic approach to the study was undertaken. A quantitative approach included the use of a self-administered pre-study questionnaire to understand the root cause of delays during the project, from the view of the participants within a project. Brainstorming sessions were used to encourage an interactive session between the researcher and teamsters to qualitatively understand challenges experienced during a project. A cause-and-effect diagram was constructed from information obtained through data analysed from the pre study questionnaire and brainstorming sessions, in order to outline the possible causes/challenges of repeat work. Value stream mapping was used to illustrate the flow of the process for ageing kinetics, viscose production, and application tests, proceeding from a macro perspective to the level of detail required to identify opportunities for

improvement. All data generated for the study were through employees from Sappi COE laboratories. Census sampling was used, since the population size of Sappi COE is smaller than 50. After possible causes of repeat work were identified and analysed, possible solutions were instituted through an integrated quality management framework. A post-study questionnaire was conducted to verify whether the implementation of various tools led to an improvement in quality and reduced time spent within a project.

The study results identified several major root causes that impact project duration within Sappi COE laboratories such as: lack of communication on all levels within the COE, inadequate systems available for sample management, lack of maintenance schedules for critical pieces of equipment, and unclear/outdated ISO procedures, as well as poor time management. An integrated quality management framework was developed and implemented considering the above root causes. The framework was primarily based on ISO 17025:2017 and lean manufacturing tools.

From the post questionnaire, a significant improvement in sample management within the department was evident. In addition, there was an improvement in equipment maintenance, however, more interventions are required to make a significant improvement.

DECLARATION BY CANDIDATE

I, Dolyn Govender, declare that unless otherwise indicated, this dissertation is my original work and it has not been submitted for any degree at another Tertiary Institution.

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November 2023

DEDICATION

This study is wholeheartedly dedicated to my beautiful mother, Mrs Vathanayagie Govender, who has been the source of inspiration throughout my life, who is my pillar of strength and best friend. Thank you for the continuous love, spiritual and emotional support you have shown me throughout my life. I would like to thank you for everything you do for me, from the bottom of my heart.

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LIST OF ACRONYMS

CIV	Cellulose in Viscose
COE	Centre of Excellence
CS_2	Carbon disulphide
CVI	Content validity index
DP	Degree of Depolymerisation
DUT	Durban University of Technology
DWP	Dissolving Wood Pulp
5S	Sort, Set in order, Shine, Standardize, Sustain
I-CVI	Item Content validity index
IQMF	Integrated Quality Management Framework
IQMS	Integrated Quality Management System
ISO	International Organization for Standardization
JIT	Just-in-Time
LM	Lean Manufacturing
LSS	Lean six sigma
MPJO	Modified planned job observation
MS	Management Sponsor
NVA	Non-Value Added
PDCA	Plan, Do, Check, Act
PM	Project Manager
POLCA	Paired-cell overlapping loops of cards with authorisation
QA	Quality Assurance
QMF	Quality Management Framework
QMS	Quality Management System
SIV	Soda in Viscose
SOP	Standard Operating Procedure
TAT	Turnaround time
TPS	Toyota Production System

TQM	Total Quality Management
VA	Value Added
VSM	Value Stream Mapping

GLOSSARY OF TERMS

ISO	The International Organisation for Standardisation is an international standard development organisation comprising representatives from the national standards organisations of more than 160 member countries. International standards ensure products and services used are safe, reliable and of high quality, with ISO guiding businesses in the adoption of sustainable and ethical practices.
Quality	Degree in which a set of inherent characteristics of an object (product, service, process, person, resource, and so on) meet the requirements/performance levels (established need or expectation, generally implicit or mandatory), also including the value and benefit perceived by customers.
Management	Coordinated activities to direct and control an organization.
System	A set of interrelated or interacting elements.
Laboratory	A body that performs one or more of the following activities: testing, calibration, sampling, associated with subsequent testing or calibration.
Pragmatic research	Research method that combines both qualitative and quantitative research approaches.
Quantitative research	A research strategy that focuses on quantifying the collection and analysis of data.
Qualitative research	A research method that relies on data obtained by the researcher from first-hand observation, interviews, questionnaires, and a focus groups, as well as participant-observation, recordings made in natural settings, documents, and artifacts.
Five S (5S)	This tool is a systematic method for organising, standardising and sustaining the workplace.

Questionnaire	A research instrument comprising a series of questions for the purpose of gathering information from respondents through survey or statistical study.
Sampling	The selection of a subset of individuals from within a statistical population to estimate characteristics of the entire population. Or Provision of a sample of the object of conformity assessment, according to a procedure.
Interlaboratory comparisons	Organisation, performance and evaluation of measurements or tests on the same or similar items by two or more laboratories, in accordance with predetermined conditions.
Intralaboratory comparison	Organisation, performance and evaluation of measurements or tests on the same or similar items within the same laboratory, in accordance with predetermined conditions.
Testing	Determination of one or more characteristics of an object of conformity assessment, according to a procedure.
Proficiency testing	Evaluation of participant performance against pre-established criteria by means of interlaboratory comparisons.
Census	An official count of an entire population (all units in a set) and recording of certain information regarding each unit.
Interview schedule	The survey instrument used in face-to-face or telephone interviews.
Reliability	The extent to which a given measuring instrument produces the same result each time it is used; a measure of consistency.
Research design	The modes of observation that allow scientists to collect observations in systematic and structured ways.

Validity	Measuring the accuracy of a measure (variable); ensuring the measure (variable) measures what it intends to measure.
Sampling frame	The group of individuals that can be selected from the target population, given the sampling process used in the study.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

A change has, lately, been noted across laboratory testing businesses (Natakusuma, Hidayatullah and Purba 2018), and manufacturing industries (Schuh, Neugebauer and Uhlmann 2012). Recent studies indicate that clinical, research and testing laboratories no longer serve as a revenue generating centres and must now justify their existence by adding quality and safety to improve the generated results (Carey *et al.* 2018; Martínez-Perales, Ortiz-Marcos, and Ruiz2021; Dirnagl *et al.* 2018; Grochau and Caten 2012). Currently, customers require timeous results, with accuracy and precision, whereas previously, the focus was on quality of results, with accuracy and precision secondary factors. This change has occurred due to an increase in customer requirements, with regard to product / service delivery. Carey *et al.* (2018) elaborate further, stating laboratories should no longer serve as silos of information but as an integrated quality framework; to provide client-focused services. Dirnagl *et al.* (2018) noted methodology within research laboratories has become an area for improvement. Strong evidence, furthermore, indicates weaknesses in research planning, conducting, analysing, and (non)reporting as prevalent factors (Macleod *et al.* 2014). In addition, meta-research has indicated these problems may result in a decrease in research result reproducibility and predictiveness.

To cope with the challenges, associated with existing developments, flexible and well-organised production systems should be mandatory (Schuh *et al.* 2012). Moreover, chemical testing laboratories are required to speed up the testing process in an effort to support industry (Natakusuma *et al.* 2018). Michael, Naik and McVicker (2013) pointed out pathology laboratories require high-quality results and high-quality service; coupled with the enormous economic pressures facing the laboratories in maintaining cost effectiveness; while continuously improving service and patient safety. It is essential to reduce costs while using resources efficiently and effectively increasing production

capacity, as well as satisfying customer needs, in a process of continuous improvement (Doshi and Desai 2017).

According to Coetzee, Cassim and Glencross (2018), the National Health Laboratory Service within the public health sector in South Africa, which provides CD4 testing, has been struggling to achieve a given turnaround time (TAT) due to the increasing numbers of requisitions for tests. A CD4 cell count is an indicator of immune function in patients living with HIV, these cell counts are obtained from bloodwork as part of laboratory monitoring for HIV infection (US Dept. VA. 2020). A workflow analysis of CD4 laboratories with poor turn-around times, showed delays in testing are affected by a multitude of factors or combinations thereof. Some of these are: organisation of sample registration and processing, testing and evaluation of activities, pre-analytical delays and repeat work, and courier logistical issues, along with instrument capacity and downtime, personnel availability and competency, as well as optimal workflow.

In another example, Children's Health Care of Atlanta identified a significant delay in test results of 18 hours from commercial laboratories, as opposed to the expected TAT of 5.4hours (Rogers *et al*. 2019). The delay in results was due to several issues, such as lost specimens, cancelled tests, delayed TAT of test results, and problems centring reporting of critical results, in addition to missing reports, and communication issues. Furthermore, when laboratory testing systems are disrupted, tangible monetary costs are associated with delayed results.

Sappi's Centre of Excellence (COE) laboratories are experiencing similar issues associated with delayed TAT of results; due to repeat work in ageing kinetics, viscose production and associated application tests that form a significant part of a project (Kerr 2020). In Sappi COE, ageing kinetics, viscose production and application tests are packaged into a project. Viscose production is a demanding process that needs precise control over operational variables in order to produce a high-quality end product (viscose staple fibres). There are numerous parameters and aspects that need to be considered during the viscose process and it is best to deal with each step exclusively (Eriksson 2015). Ageing kinetics is the first process required to produce viscose. During the ageing kinetics process, cellulose pulp is steeped in aqueous sodium hydroxide. This facilitates

the conversion of cellulose I to cellulose II, termed mercerisation. In contrast to the metastable cellulose I, cellulose II appears to be a stable form due to the irreversible transition from cellulose I to cellulose II structure (Figure 1.1) (Cuissinat 2006; Dinand *et al.* 2002; Sayyed, Deshmukh and Pinjari 2019).

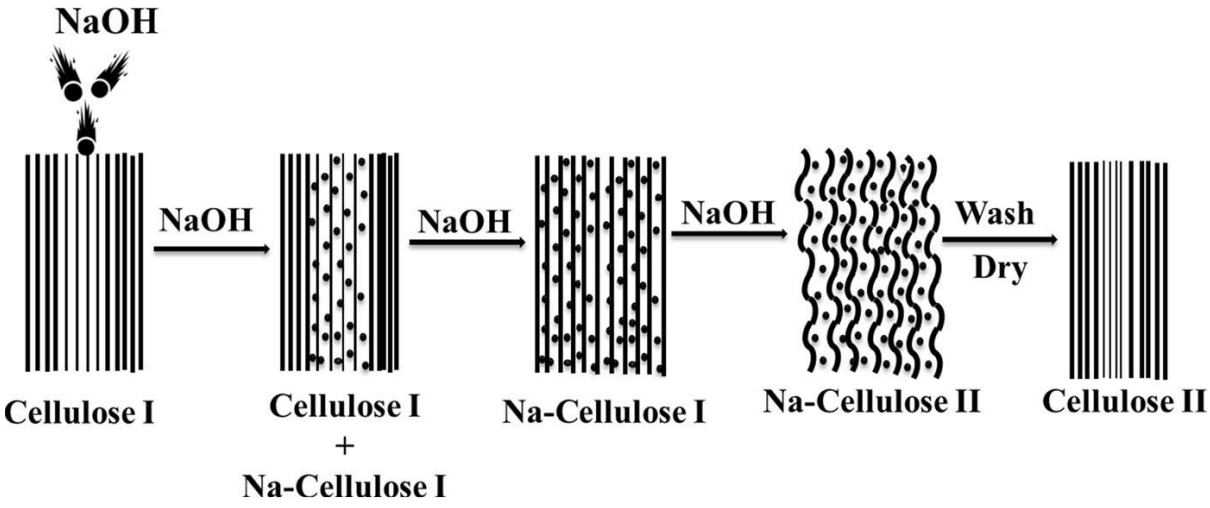

Figure 1.1: Schematic representation of the mercerisation process

Source: Sayyed et al. (2019)

The conversion of cellulose I to cellulose II is crucial for uniform substitution of the hydroxyl groups with carbon disulphide (CS_2) during xanthation in the production of viscose (Weißl *et al.* 2018). In addition, the steeping process facilitates the swelling of cellulose fibres, to allow for adequate chemical penetration during the xanthation process (Wilkes 2001; Cai *et al.* 2008). The steeped cellulose in aqueous sodium hydroxide solution is known as alkali cellulose or alkcell. Excess amounts of sodium hydroxide containing hemicellulose is removed from the steeped alkcell by pressing. This step of viscose production is crucial in ensuring a good quality viscose dope is produced.

Hemicellulose contains low molecular weight material in the form of short-chain, branched cellulose and degraded cellulose, formed due to harsh pulping and processing conditions (Strunk 2012; Wessels 2011). Elevated hemicellulose levels directly impact the customer process, due to the formation of by-products such as gel particles. In addition, the unnecessary consumption of CS_2 inhibits the degree of depolymerisation (DP) of long chain cellulose during xanthation (Gondhalekar *et al.* 2019).

The pressed alkcell is then shredded to increase the surface area, to enable an increased rate of reaction during xanthation and dissolution (Wilkes 2001, Wessels 2011). Following this, the shredded alkcell is aged over a period of zero to six hours at constant temperature, which facilitates the breakdown of cellulose chains to a required chain length, known as DP (Wessels 2011; Rana *et al.* 2014; Sayyed *et al.* 2019). At one-hour intervals, the alkcell is then neutralised using acetic acid and aqueous bicarbonate of soda. After this, the alkcell is rinsed with boiling water to prevent a further drop in DP (Wessels 2011). The aged alkcell is subsequently conditioned under a specific temperature and humidity for a period of time. Viscosity testing of aged alkcell is carried out to attain the ageing time required for viscose production. A process diagram of ageing kinetics is illustrated (Figure 1.2).

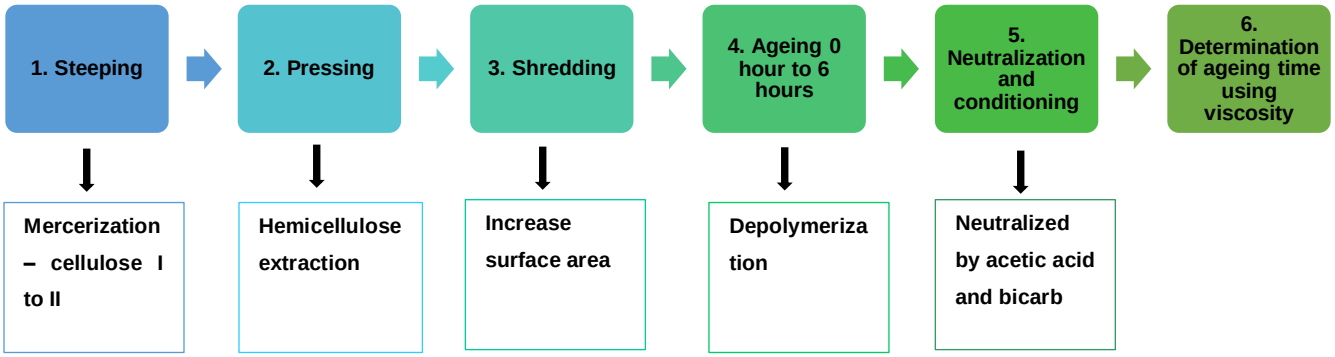

Figure 1.2: Ageing kinetics process at Sappi COE laboratories

Figure 1.3 illustrates the production of viscose dope. Steps 1 to 3 in the viscose process are similar to steps 1 to 3 of ageing kinetics. The ageing time of the sample, used to produce viscose, is obtained from the ageing kinetics process. The aged alkcell then undergoes xanthation. During xanthation, the three reactive hydroxyl groups situated on the cellulose molecule are derivatised using CS_2 to form cellulose xanthate (Wilkes 2001; Weißl *et al.* 2018; Sayyed *et al.* 2019; Gondhalekar *et al*. 2019). This derivatised cellulose xanthate is soluble in diluted solutions of sodium hydroxide during the dissolving and ripening process (Wessels 2011; Wilkes 2001; Sayyed *et al.* 2019).

Xanthation could be considered the most critical step to ensure good quality viscose (Weißl *et al.* 2018). Ripening requires no mechanical intervention and is purely controlled

by temperature and time, where this process ensures the re-distribution of xanthate groups to obtain stable viscose dope for spinning. The extent and uniformity of substitution affects the solution state of the viscose produced, that is, how well-solvated cellulose is. In general, the higher and more uniform degree of substitution, the better the solution state (Wessels 2011; Sayyed *et al.* 2019). This is a crucial step in viscose production; as a well solvated dope will typically be free of gels and unreacted fibres, enabling easier filtration.

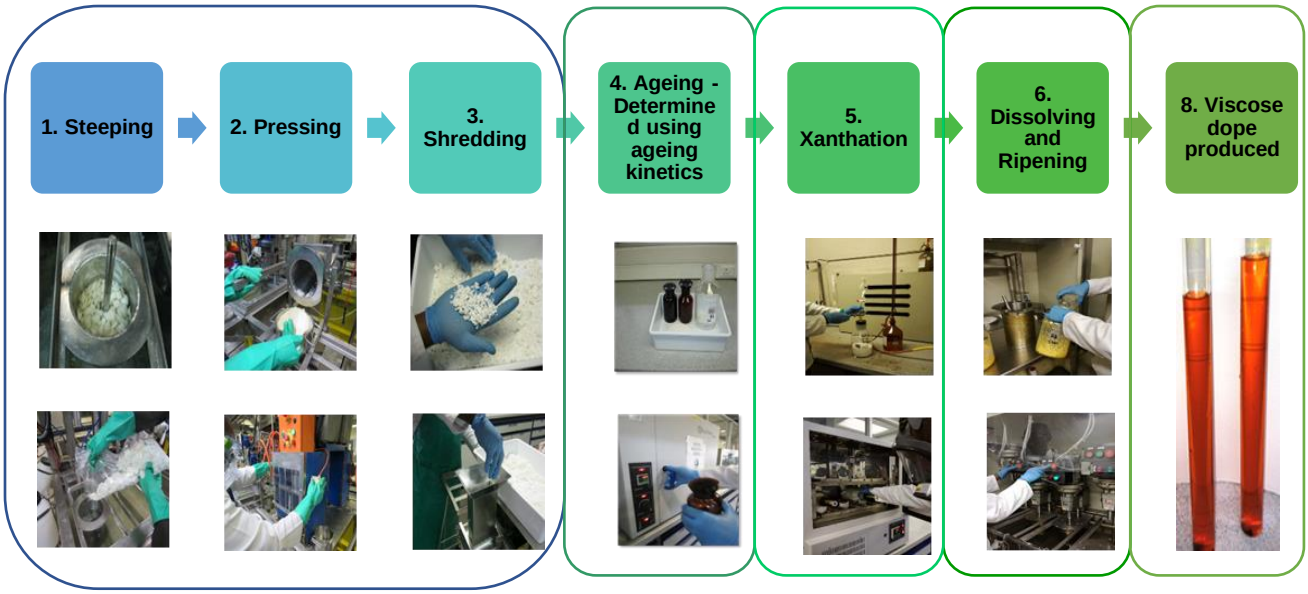

Figure 1.3: Viscose production process at Sappi COE laboratories

Figure 1.4 illustrates the application tests required to assess reactivity and quality of the viscose dope produced. The soda in viscose (SIV) test is carried out on ripened viscose dope, to assess the amount of sodium hydroxide carried through to viscose production. Excessive amounts of sodium hydroxide carried through reacts with CS_2 to form undesirable by products. In addition, this inhibits derivatisation of hydroxyl molecules by CS_2, affecting DP of cellulose negatively (Wilkes 2001). Whereas the cellulose in viscose (CIV) test allows one to determine the amount of cellulose in the viscose dope, the ball fall test is carried out to measure dope viscosity; the higher the ball fall, the higher the dope viscosity. Since there is a correlation between cellulose DP and viscose dope viscosity, the ball fall test is used in the viscose industry as an indirect indicator for alkcell DP; hence, the measure is used to control alkcell ageing (Wessels 2011).

A simple method of determining the viscose dope's filterability is the KW filterability test. It is a filtration factor determined by the volumes and rate at which a viscous dope passes through a filter pack at a predetermined pressure. Viscose dope contains microscopically visible macro gel particles and sub-microscopic micro gel particles. The particle count of the viscose dope is determined using the Beckman coulter counter. It is imperative the particle counts are kept relatively low, as this affects the customer process negatively by clogging spinnerets during the spinning process (Wessels 2011; Meister and Kosan 2015). The rheology of the viscose dope is measured using the Anton Paar rheometer. This instrument allows one to accurately determine zero shear viscosity, which is crucial in assessing pumping requirements for high viscosity dopes.

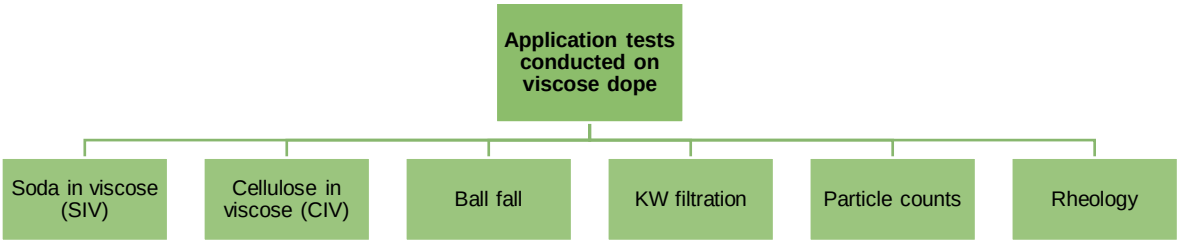

Figure 1.4: Application tests performed on viscose dope at Sappi COE laboratories

The delay in real-time results from specific projects has a significant impact on process adjustments within the relevant mills; therefore, this will negatively affect the production of prime dissolving wood pulp (DWP) (Wessels 2021a; Wessels, 2021b). In addition, delayed feedback to customers may negatively influence the use of the product (DWP) within their processes. Due to the dramatic successes of quality management tools in the manufacturing sector, there is a rising interest in laboratories in the health / pharmaceutical sector, to implement quality management tools (for example, Lean principles) to accomplish goals such as decreased cycle time, reduction in the amount of waste, improvement in communication with customers and improved quality; both in the production and in testing laboratories (Shelly 2018).

In addition, a quality management system (QMS) can be implemented to achieve improved process efficiency, by reducing product variability, decreasing waste and managing rework (John and Areshankar 2018). These practices typically include just-in-time (JIT) inventory systems, ISO 9000, ISO 17025, Six Sigma quality programs, Total

Quality Management (TQM), and employee empowerment (Putri *et al.* 2017). Quality management tools such as Lean and Lean Six Sigma (LSS) have been developed to improve quality, process performance with low levels of variability, customer satisfaction and waste reduction (Lizarelli and Alliprandini 2020; Syahputri *et al.* 2018). Although these practices differ in content, they are used to achieve the same goals, based on a philosophy of continuous improvement and incremental progress towards organisational efficiency.

It has been noted employee satisfaction, reduced repeat work, long range thinking, and process alignment, in addition to customer focus, team-based problem solving, involved employee participation and teamwork, facilitated an increase in the level of autonomy and empowerment (Putri *et al.* 2017). In light of the foregoing literature survey, this project will endeavour to identify the quality standard shortfalls at Sappi's COE laboratories.

1.2 PROBLEM STATEMENT

The primary objective of the COE laboratories at Sappi, is to provide technical support to Sappi Dissolving Pulp Mills and Sappi customers. Several projects (13 of 23 projects) conducted in Sappi's COE laboratories in the previous financial year (October 2020 to September 2021), exceeded the time allocated to the projects by two to 15 days (Kerr 2020). This significantly impacted critical decision-making for the business. Delays in real-time feedback of crucial results to the mills then require the rescheduling of necessary adjustments to critical parameters within the processes. This may hinder the production of prime DWP. In addition, continuous delays in project deliverables to customers will cast a poor image of the reputation of Sappi.

During the preliminary investigation, it was discovered several factors had influenced the delay of projects within COE laboratories, for example, inventory delays, mechanical breakdowns, absenteeism, and lack of competent personnel, in addition to Covid-19, repeat work of processes and tests. These include ageing kinetics, viscose production, and application tests, namely, SIV, CIV, KW filterability, and ball fall, along with microscope, rheology, and particle counts. However, the highest contributing factor to project delays was due to repeat work of processes and tests within a project. The root cause of the repeat work of processes and tests remains unknown and needs to be

investigated further to prevent future delays in project results. The problems experienced in Sappi COE are not specific to Sappi and are, in fact, experienced by several laboratories.

The health sector has experienced similar difficulties as mentioned above. In addition, a Clinical Pathology Laboratory of Hospital X required several materials, including reagents, consumables, controls, and calibrators, to perform critical tests. However, these items were mismanaged, resulting in delayed tests being carried out on patients (Hidayati *et al*. 2020). The Clinical Pathology Laboratory of Hospital X's incompetent and inefficient reagent management was evident from the numerous stockouts and stagnant reagents. This had caused significant delays with laboratory examination results being generated. It has, furthermore, been noted by the Namibian medical laboratory services that poor TAT of results generated during testing has been marked as a prevalent issue (Isack *et al.* 2018). A number of factors have been linked to poor TAT, including space limitations, an insufficient system for referring specimens, severe stock shortages, the sharing of specimens, an increased workload, a lack of qualified professionals, instrument breakdown, and test complexity (White *et al.* 2015; Isack *et al.* 2018).

In recent times, research laboratories have also come under the spotlight for prolonged testing deliverables. Prevalent factors that increase the duration of the research project have been highlighted as poor planning, conducting, analysing, and (non)reporting of research (Dirnagl *et al.* 2018). The above examples highlight an ongoing project management issue, with regard to delays in test results experienced across multiple disciplines.

1.3 AIM AND OBJECTIVES OF THE STUDY

1.3.1 Aim

The aim of this research undertaking is to reduce or eliminate repeat work during projects; to improve throughput time for project deliverables.

1.3.2 Objectives

- Objective One: Identify and analyse the prominent causes of repeat work within projects conducted in the selected project by the application of value stream

mapping (VSM) to illustrate the flow of a process of ageing kinetics, viscose production and application tests. This objective aligns with understanding the factors contributing to repeat work, as stated in the first research question.

- Objective Two: Evaluate and assess the identified gaps within Sappi COE's project management system that led to instances of repeat work, through brainstorming/focus group sessions and cause-and-effect analysis. This objective addresses the need to investigate specific deficiencies in the project management system, as indicated in the second research question.

- Objective Three: Determine the most suitable quality management tools that can be integrated to address identified gaps (by means of a survey questionnaire) and improve processes within Sappi COE. This objective focuses on identifying appropriate tools to enhance quality management practices, as per research questions three and four.

- Objective four: Develop an integrated quality management framework (IQMF). This objective focuses on developing, implementing, and assessing an appropriate IQMF within the laboratory environment, as indicated by the last research question.

1.3.3 Research questions

- What are the prominent causes of repeat work identified within a project?
- What are the gaps identified within Sappi COE's project management system that causes repeat work?
- What are the appropriate quality management tools that must be integrated to improve processes within Sappi COE?
- How will the implemented quality management framework (QMF) improve efficiency within a project?
- How effective is the developed integrated quality management framework (IQMF)?

1.4 RATIONALE FOR THE STUDY

It is evident from literature presented in this study that all types of laboratories, including those in the health care sector, research and development, as well as calibration and testing laboratories, are experiencing poor TATs in laboratory analyses, which essentially

lead to prolonged project deliverables. It has been established Sappi's COE laboratories have been similarly struggling, which has led to an investigation into the need for an integration of quality practices within the organisation, to minimise repeat work and essentially improve project deliverables.

The purpose of this study is to identify the potential cause/s of repeat work within a project at Sappi's COE laboratories and introduce an IQMS to solve the problems highlighted.

1.5 RESEARCH METHODOLOGY

1.5.1 Research Design

A pragmatic paradigm will be chosen for the purpose of this study, as it assists the researcher to optimally frame, examine and provide tentative answers to research questions by mixing approaches and methods (Onwuegbuzie, Johnson, & Collins 2009). The pragmatic design, according to Abusabha and Woelfel (2003), assists to collect data with components that combine the objective and subjective aspects.

1.5.2 Research Approach

The research approach for this study will consist of both qualitative (brainstorming sessions) and quantitative techniques (pre- and post-study questionnaires); hence, the study will undertake a mixed methods (pragmatic) approach. In accordance with the logic of mixed methods research, this approach uses both qualitative and quantitative points of view, data collection, a combination of analysis, and inference techniques to answer the research question(s) (Onwuegbuzie *et al*. 2009).

1.5.3 Data collection

Research tools can be defined as vehicles that broadly facilitate research and related activities. The use of research tools enables researchers to collect, organise, analyse, and visualise, as well as publicise research outputs (Ebrahim 2016). The research tools for this study are pre- and post-study questionnaires. A cause-and-effect diagram will, furthermore, be used as a visual tool to logically organise and outline possible factors for rework within projects.

1.5.4 Data analysis

The questionnaire will adopt both open-ended and close-ended questions. The closed-ended questions will be designed on a 5-point Likert scale, with the response range from ‘strongly disagree’ (1) to ‘strongly agree’ (5). The questionnaires will be analysed using R Statistical computing software of the R Core Team, 2020, version 3.6.3. (quantitative analyses) and NVIVO 12 (qualitative analyses).

1.5.5 Reliability and validity

Questionnaire reliability reveals a questionnaire's precision or accuracy as well as how consistently it functions (Hurst and Bird 2019). Item-rest correlation and Cronbach alpha will be used to evaluate a set of items' internal consistency. The Cronbach’s alpha and item-rest correlation calculation will be performed using R Statistical computing software of the R Core Team, 2020, version 3.6.3. to evaluate reliability of the questionnaire.

A questionnaire's validity is an indication of how well it measures the concept it is intended to measure and how well it assists the researcher in solving the research problem (Saunders, Lewis and Thornhill 2009). Content validity of this study will be assessed by sharing the instrument with professionals and experts to rate whether the instrument items cover all facets of the construct under study.

1.5.6 Main study - Target population and sample size

The questionnaire will be based on practical experience and knowledge, instead of general perception. The target population will include Sappi employees from the COE laboratories and technical teams. According to Saunders *et al.* (2009), a sampling technique is dependent on the feasibility and sensibility of collecting data to answer the research questions and to achieve the objectives. The census method for data collection will be adopted for this study, since the population size of Sappi COE is smaller than 50, through a probability sampling technique.

1.5.7 Pilot study - Target population and sample size

In order to ascertain whether the research questions are valid and reliable to answer and meet the study objectives, a pilot study needs to be conducted (Van Teijlingen and Hundley 2010). The pilot study assists to enhance the measuring instrument, such that participants can easily answer questions and provide data without difficulty (Van

Teijlingen and Hundley 2010; Hertzog 2008). The pilot study will be used to check for readability, accuracy and understanding; adjustments will be made where needed as suggested.

A target population of 10 participants will be chosen to voluntarily assess the questionnaire. The target population chosen for the pilot work will need to have ample experience in project management, hence their feedback will add significant value to streamline questions towards the objective of the study.

1.6 LAYOUT OF THE RESEARCH PROJECT

This dissertation will be separated into five chapters. Illustrated below is a brief description of the contents of each chapter:

Chapter 1: Orientation of the study

As indicated above this chapter included, the background of the study, problem statement, research aims and objectives, and rationale, as well as the research methodology and layout of the research project.

Chapter 2: Literature review

The literature review will provide an extensive review into the definition of QMSs, review of QMS implemented within the laboratory environment. It will include an introduction and review of ISO standards, lean principles, tools, and implementation.

Chapter 3: Research methodology and design

This chapter will illustrate the type of research conducted, data collection methods and research instruments used, as well as analysis of pilot questionnaire, including content validity of the questionnaire and data interpretation.

Chapter 4: Results and Discussion

The results and discussion will disclose the study findings. The IQMS will be discussed in this chapter.

Chapter 5: Conclusions and recommendations

The conclusion and suitable recommendations of the study will be presented in this chapter.

1.7 CHAPTER SUMMARY

This chapter introduced the significance of the study and provided evidence of a problem highlighted across laboratories in multiple sectors. In addition, the proposed research methodology was outlined to accomplish the study objectives. The next chapter will present a review of literature relating to possible research philosophies used during this investigation.

CHAPTER TWO

REVIEW OF LITERATURE: QUALITY MANAGEMENT STANDARDS AND LEAN

2.1 INTRODUCTION

Chapter two outlines the theoretical background of QMS and pioneers that facilitated the introduction of quality within industry and laboratory environments. The information was collected from sources selected from peer reviewed academic journals, grey literature, relevant books, periodicals, newspaper articles and websites. A critical analysis of literature will highlight the advantages and disadvantages with regard to quality management standards employed in a research laboratory environment. The advantages of implementing a quality management standard in a research environment, lies in it being the means to illustrate how aligning the goals and objectives of the organisation will assist in gaining a competitive advantage in the laboratory arena.

A review of the history of lean practices within industry will be analysed in this chapter, with lean philosophy and management also explained. In addition, a critical analysis of lean techniques will be undertaken. Literature will, therefore, highlight the benefits of implementing lean techniques in a laboratory environment to improve quality. Furthermore, due to the dynamics of a laboratory environment, the chapter will highlight the barriers and enablers of lean management, while literature will illustrate the potential benefits of an IQMS. Figure 2.1 provides a schematic overview of the literature reviewed within this chapter.

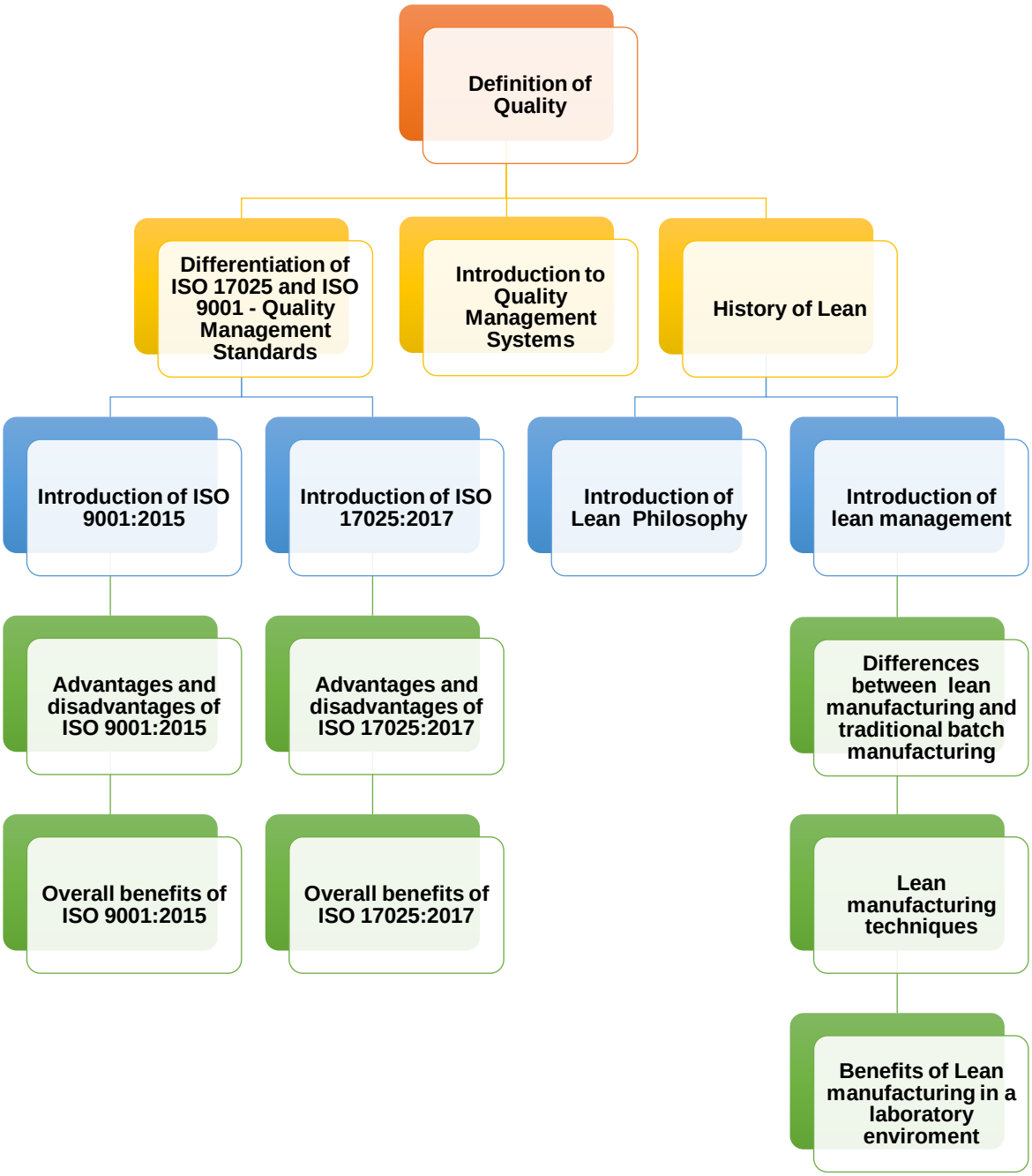

Figure 2.1: Schematic overview of literature review

2.2 DEFINITION OF QUALITY

Quality is often used to imply ‘excellence’ of a product or service. Many speak of ‘Rolls-Royce quality’ and ‘top quality’. For example, in many engineering firms, the term "quality" designates a metal component that has to meet specific physical dimensions; these requirements are frequently expressed as "tight" specifications. The word "quality" may

be be used to describe a certain level of "professionalism" in a hospital. To define quality in a way that it is useful in its '*management',* quality assessment must be included as requirements of 'customer needs and expectations' (Oakland 2014).

Quality can, therefore, be defined simply as *meeting the requirements of customers.* This has been expressed in many ways by various authors, illustrated below (Neyestani 2017, Oakland 2014; Koskela, Tezel and Patel 2019):

- "Fitness for purpose or use" – Joseph M. Juran.
- "Quality must be focused at the needs of the consumer, present and future' – W. Edwards Deming.
- "The total composite product and service characteristics of marketing, engineering, manufacture and maintenance through which the product and service in use will meet the expectations of the customer" – Arman V. Feigenbaum.
- "Conformance to requirements" –Philip B. Crosby.

2.3 INTRODUCTION TO QUALITY MANAGEMENT SYSTEMS (QMS)

In the 1970s, US cars had a significant number of quality problems, with Japanese cars deemed much more reliable since then. Stringent quality management was introduced within the production process that assisted the Japanese car manufacturer to gain this competitive advantage; this fundamentally led to the Japanese motor industry dominating the motor car market for decades to come. Due to the success of the Japanese motor industry, many industries, including US car manufacturers, the health and pharmaceutical industries, as well as clinical medicine, have developed sophisticated QMS; to which they allocate a portion of their annual budget to maintain and improve their systems (Dirnagl *et al.* 2018).

The evident success of quality management tools in the manufacturing sector (Shelly 2018), has led to an increase in implementation of quality management techniques in laboratories within the health care sector (Durur and Akbulut 2019; Molinéro-Demilly *et al.* 2018). A similar approach has been used in testing and calibration laboratories (Martínez-Perales *et al.* 2021; Valdivieso-Gómez and Aguilar-Quesada 2018). However, the development of a QMS for research/academia laboratories is currently still in the

developmental phases and needs to be fine-tuned to suit the research and academic arena (Dirnagl *et al.* 2018; Martínez-Perales *et al.* 2021).

Shah and Shrivastava (2013) reported micro, small and medium enterprises (MSMEs) have employed a spectrum of prevailing QMS and quality tools. These quality tools and techniques include Quality Function Deployment, TQM, Lean management, and Six Sigma, as well as Kaizen, Zero Defect Programme, and Robust Engineering (Taguchi method), and have been used to ensure competitiveness and improve quality. Since the introduction of structured QMS , there has been positive results in terms of increasing profit by lowering production costs, reduction of waste, greater flexibility and improved response to changing client demand. This has inherently transformed entire industries that previously suffered from inferior quality (Dwivedi 2013).

2.3.1 Definition of a QMS

According to Carey *et al.* (2018) and the World Health Organization (WHO) (2011), a laboratory QMS is a methodical set of integrated activities used to create and control work procedures from pre-analytical through to post-analytical processes. A QMS is used to manage resources, conduct evaluations, and create continual improvements to ensure reliable quality results. However, Valdivieso-Gómez and Aguilar-Quesada (2018) refer to a QMS as a system that plans, controls and improves elements that impact the desired results within the laboratory for customer satisfaction. Dirnagl *et al.* (2018) characterise a QMS as modular in the sense that it includes support processes such as guidelines/regulations, training/education, along with crucial procedures like institutional policy, organisational framework, responsibilities, data management and more. In addition, laboratory staff must be adequately trained on how to integrate the processes and procedures within the QMS of organisations.

2.3.2 What is a QMS used to achieve within the laboratory environment?

A QMS is imperative for guidance within the laboratory. It is used to implement new processes and procedures. It guarantees that every factor will be taken into account before implementing a new procedure or changing an existing one. A critical element of quality, which is commonly misunderstood, is quality assurance (QA). In QA, quality controls and quality indicators are tracked, and trends are analysed (WHO 2011;

Valdivieso-Gómez and Aguilar-Quesada 2018). This entails monitoring the following: supplies, equipment calibration and maintenance, procedures, competency of personnel, proficiency testing, specimen collection (in a clinical setting), transportation, accuracy, and timely result reporting (WHO 2011).

A functional QMS integrates all critical elements of quality into the work process, which results in an exceptional quality product or service rendered (Ndihokubwayo *et al.* 2016). The addition of new tests within the laboratory requires quality assurance and control (QA) procedures are taken into account, along with purchasing and inventory management, staff training, test system evaluation, instrument qualification, information technology support, and document control (Wadhwa *et al.* 2012). The key to an effective QMS is, therefore, tracking inconsistences within the process/test, identifying their root causes, and fixing the system to prevent reoccurrence. In summary, a QMS is built on a set of coordinated activities that serve as building blocks for the overall improvement of quality within the laboratory. The QMS model (Figure 2.2) outlines 12 quality system essentials for all laboratory activities. It is crucial all the quality essentials are managed effectively, in order to ensure accuracy and reliability throughout the workflow process (WHO 2011).

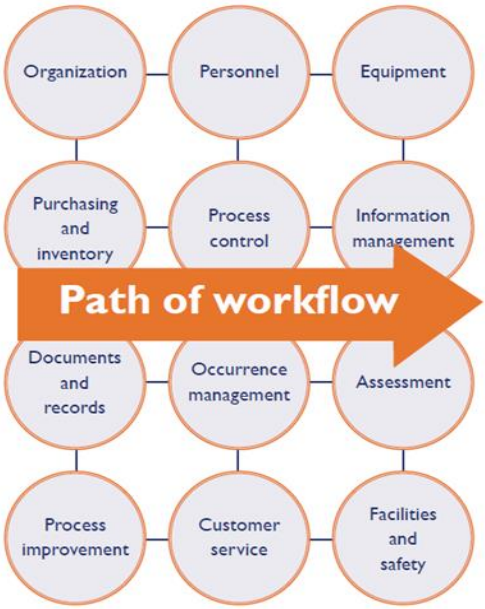

Figure 2.2: The QMS model

Source: WHO (2011)

2.3.3 Pioneers who founded QMS and tools

According to the WHO (2011), historically, quality management concepts have risen from manufacturing and shop processes, implemented throughout the world since the early 20th century. Quality management is not new; it developed out of the work of pioneers who delineated quality more than 80 years ago. It was not until the 1940s that quality control methods were applied in laboratories. Several prominent critical thinkers and innovators contributed to the concept, including Arman Feigenbaum, Dr Kaoru Ishikawa, Dr W. Edwards Deming, and Dr Joseph M. Juran, as well as Philip Bayard Crosby and Genichi Taguchi (WHO 2011; Neyestani 2017). Table 2.1 sets out the quality management contributions by various prominent pioneers.

Table 2.1: Prominent pioneers and their contribution to TQM

Pioneer	Year	Quality Management
W.E. Deming	1950	14 Principles in Quality, 7 deadly sins and plan, do, check, act – PDCA (Bahri, Hamzah and Yusuf 2012). The 'Demings cycle' has recently been applied extensively in the development and deployment of quality polices such as: define, measure, analyse, improve, control-DMAIC (Six sigma), and project life cycle (PLC). The PDCA cycle has also recently been used in quality management standards such as ISO 9001. It has assisted to improve the efficiency of processes within the organisation and achieve successful customer satisfaction and quality objectives (Neyestani 2016).
AV. Feigenbaum	1961	Concept: Make it right the first time (Bahri *et al.* 2012). Armand Feigenbaum was the first to propose the definition of Total quality control (TQC), which later became Total Quality management (TQM) (Subramaniam 2021).
Kaoru Ishikawa	1943/1979	Dr. Kaoru Ishikawa made important contributions to the management aspects of quality in terms of root cause analysis (Subramaniam 2021), statistical approach in quality control and the cause-and-effect diagram, also known as the fishbone or Ishikawa diagram (Figure 2.3) (Bahri *et al.* 2012; Hristoski *et al.* 2017). Dr Ishikawa found many employees were overwhelmed by confusion when exposed to the number of activities associated with processes. He observed a window of opportunity to develop a tool to help them cope with these processes. The cause-and-effect diagram was, subsequently,

Pioneer	Year	Quality Management
		industrialised to categorise possible problem causes and take appropriate action to resolve them (Neyestani 2017; Sharma and Suri 2017). According to Ilie and Ciocoiu (2010), the fishbone diagram was created to identify and group causes that generate a quality problem. The data required to develop the fishbone diagram usually arise through brainstorming sessions and are typically categorised. The initials for the most well-known Ishikawa models are 4M, 5M, and 6M, which stand for materials, methods, man, machines, mother nature, and measurement, respectively. Sub-clauses can be allocated to each category above (Liliana 2016). Careful analyses and evaluation of each cause is then undertaken from the data supplied, with the team involved subsequently deciding which causes have the greatest impact on the process (Suárez-Barraza and Rodríguez-González 2019). According to Lilana (2016) and Neyestani (2017), a cause-and-effect diagram can be beneficial in a number of ways, as it can provide critical information for factors contributing to the root cause of a problem.
Philip B. Crosby	1979	Top Management in Quality, 14 steps for quality (Bahri *et al.* 2012).
Joseph M. Juran	1988	Cost of quality, SPC Quality, and Juran's quality triangle (Bahri *et al.* 2012).
Genichi Taguchi	1980	Kaizen (continuous improvement), Robust Design, Taguchi method (Bahri *et al.* 2012). Dr. Genichi Taguchi made a tremendous contribution to quality engineering (Subramaniam 2021).

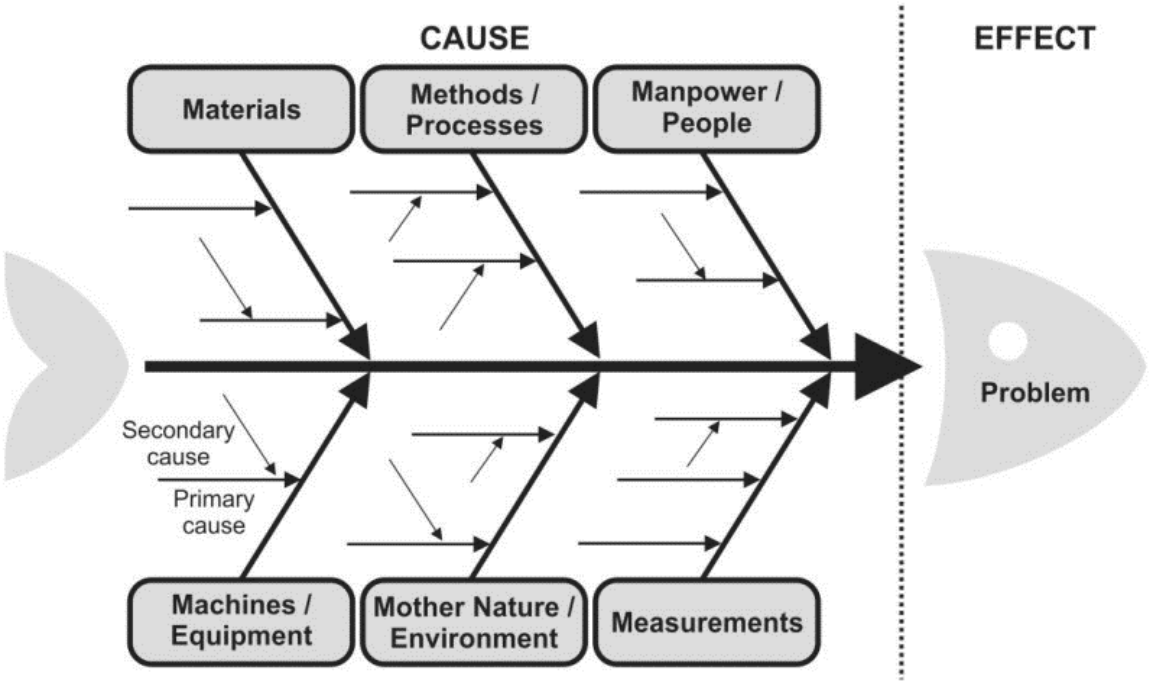

Figure 2.3: Schematic representation of a fishbone diagram

Source: Hristoski et al. (2017)

2.3.4 Requirements for laboratory QMS

The requirements for QMS for laboratories vary depending on the standard. ISO 9001 provides guidelines for manufacturing and service industries. It can be applied to many types of organizations, as it provides general requirements for integrating a QMS into the organization. Whereas ISO 15189 offers guidelines for high quality clinical laboratories and services, ISO 17025 establishes guidelines for testing and calibration laboratories (Valdivieso-Gómez and Aguilar-Quesada 2018). For the purpose of this study, two QMS namely, ISO 9001 and ISO 17025, will be reviewed.

2.4 DIFFERENTIATION OF QMS STANDARDS ISO 17025 AND ISO 9001

Several authors have examined the positive effects of ISO 17025 QMS implementation on laboratory performance. However, they have requested specific standards for research testing laboratories, which have not yet been developed (Cammann and Kleiböhmer 1997; Krapp 2001; Mathur-De-Vré 1997; Vermaercke 2000). Several testing laboratories today reference two standards for their QMS : ISO 17025 (Valdivieso-Gómez

and Aguilar-Quesada 2018) and ISO 9001 (Ingason 2015; Valdivieso-Gómez and Aguilar-Quesada 2018). ISO 17025 and ISO 9001 standards both address aspects of quality management. However, significant differences exist between the two standards. ISO 17025 specifies the general requirements for competency of laboratories that perform testing and calibration, whereas ISO 9001 addresses the requirements for QMS in all organizations, regardless of their sector or the activity being developed.

In essence, ISO 17025 technical and management requirements are outlined for acquiring the competence of testing laboratories, while ISO 9001 outlines the requirements for acquiring the ability to provide products and services that meet regulatory and customer requirements (Valdivieso-Gómez and Aguilar-Quesada 2018; Martínez-Perales *et al.* 2021). ISO 17025 requirements contain principles established by ISO 9001. The compliance to ISO 17025 implies compliance to ISO 9001 standards (and not *vice versa*) (International Electrotechnical Commission (IEC) 2017; Martínez-Perales *et al.* 2021). The most recent version of the ISO 17025 standard, the 2017 edition, has been released by the International Organization for Standardization (ISO). The revision of the standard was intended to promote a higher sense of confidence, accuracy, and trustworthiness in the operation of testing and calibration of laboratories (Valdivieso-Gómez and Aguilar-Quesada 2018; IEC 2017).

The ISO 17025 standard assists laboratories to deliver reliable data and technically valid results to their customers, in order to be deemed competent. It is important to note this standard is also applicable but not tailored to all institutions that perform laboratory activities, including universities, research centres, and more, while it can also be used by Inspection bodies and/or conformity assessment bodies. The standard, furthermore, plays a valuable part in promoting continuous improvement of data quality and laboratory effectiveness. The use of ISO 17025 will not only promote competence, it will also diminish undesired impacts and possible failures in laboratory activities (IEC 2017).

2.5 INTRODUCTION TO ISO 9001:2015

ISO 9001:2015 QMS holds a significant place in history. The process evolved during the Industrial Revolution from traditional inspections to quality control, QA, and eventually, to TQM. Around the world, ISO 9001 is widely accepted as a quality management standard.

This standard is one of the most popular ISO standards used to establish, implement, and maintain a QMS for companies, regardless of their industry, capital, or size (Lai 2017). The plan, do, check, act (PDCA) cycle and High-Level Structure form the basis of the revised edition ISO 9001: 2015 and depicts a common framework for all ISO management systems (Figure 2.4). Incorporation of the PDCA cycle in most QMS was thought to constantly analyse processes and adapt to changes that foster continuous improvement (Figure 2.5) (Dirnagl *et al.* 2018).

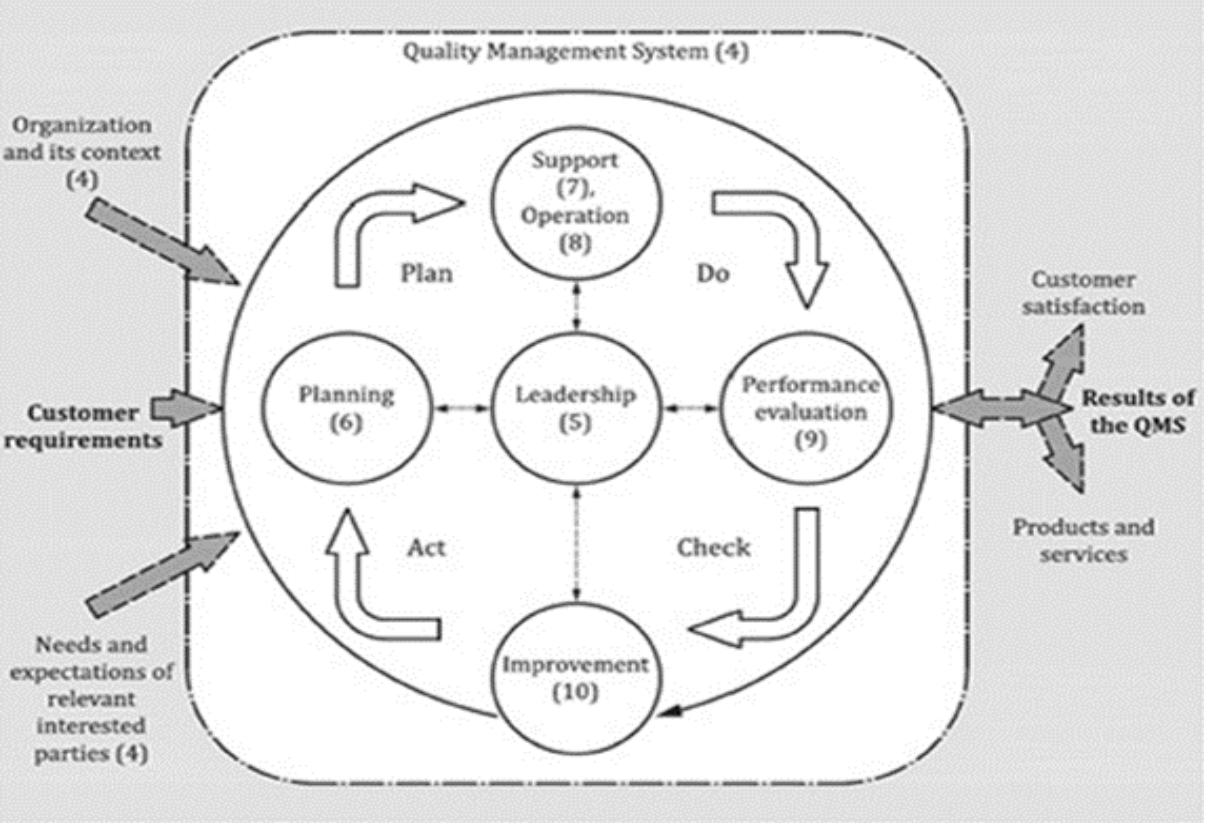

Figure 2.4: The QMS model ISO 9001:2015

Source: Lai (2017)

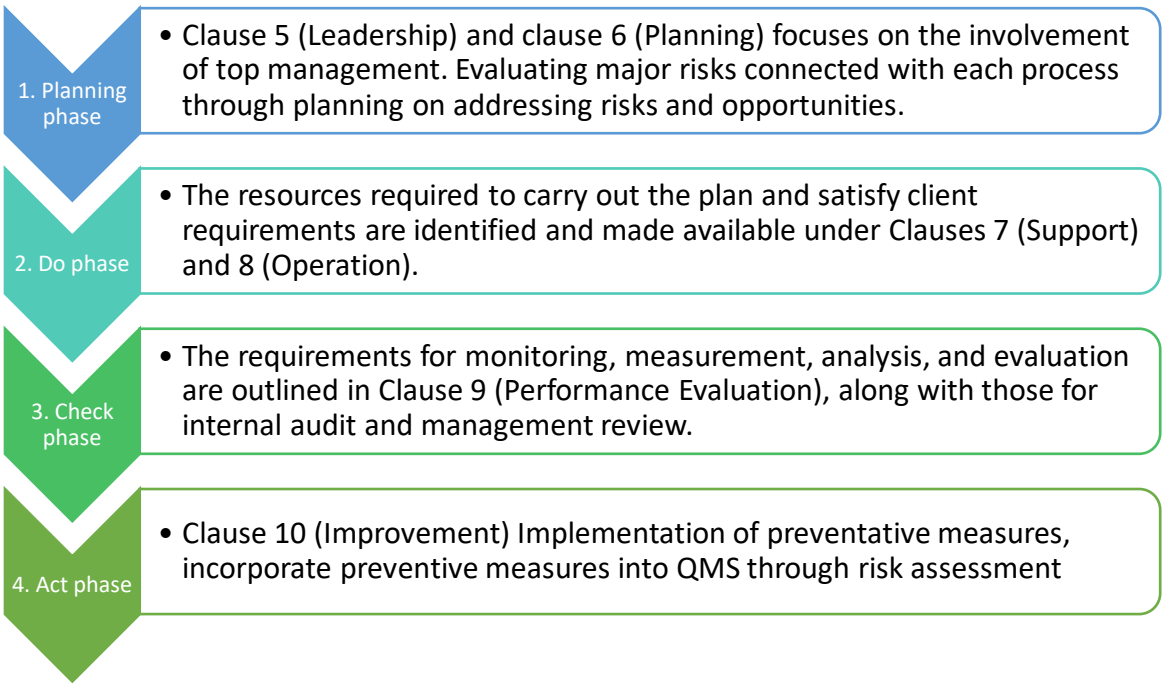

Figure 2.5: Systematic representation of PDCA cycle in relation to ISO 9001:2015, *Source: Lai (2017).*

Once external and internal issues are determined relevant to its purpose (or intended outcome), implementation of the QMS can proceed from clause 4, namely Context of the Organization (Lai 2017). Table 2.2 indicates the 10 key clauses required to be fulfilled for successful ISO 9001:2015 implementation within the manufacturing and service industries (Valdivieso-Gómez and Aguilar-Quesada 2018).

Table 2.2: The ten key clauses ISO 9001:2015

ISO 9001:2015
0. Introduction
1. Scope
2. Normative references
3. Terms and definitions
4. Context of organisations 4.1 Understanding the organisation and its context 4.2 Understanding the needs and the expectations of interested parties 4.3 Determining the scope of the QMS 4.4 QMS and its processes

ISO 9001:2015
5. Leadership 5.1 Leadership and commitment 5.2 Policy 5.3 Organizational roles, responsibilities, and authorities
6. Planning 6.1 Actions to address risks and opportunities 6.2 Quality objectives and planning to achieve them 6.3 Planning of changes
7. Support 7.1 Resources 7.2 Competence 7.3 Awareness 7.4 Communication 7.5 Documented information
8. Operation 8.1 Operational planning and control 8.2 Requirements for products and services 8.3 Design and development of products and services 8.4 Control of externally provided processes, products, and services 8.5 Production and service provision 8.6 Release of products and service 8.7 Control of nonconforming outputs
9. Performance evaluation 9.1 Monitoring, measurement, analysis, and evaluation 9.2 Internal audit 9.3 Management review
10. Improvement 10.1 General 10.2 Nonconformity and corrective action 10.3 Continual improvement

2.6 ADVANTAGES AND DISADVANTAGES OF IMPLEMENTING A QMS BASED ON ISO 9001 STANDARDS IN A RESEARCH TESTING LABORATORY

When a QMS, based on ISO 9001 standards, is considered for a research testing laboratory, increased focus should be given to the suitability of the standard in the context

of the laboratory environment. Therefore, a critical analysis of the advantages and possible disadvantages of implemented systems was conducted. Table 3 describes the various advantages and disadvantages noted by several authors, with regard to implementation of the system in research laboratories.

Table 2.3: Advantages vs disadvantages of implementing a QMS based on ISO 9001 standards in a research testing laboratory

Advantages and benefits	**Disadvantages and limitations**
Advances company image and allows the company to gain market share (Valdivieso-Gómez and Aguilar-Quesada 2018; Vianna *et al*. 2022; Lai 2017).	Could potentially restrict creativity and curiosity of the research process (Dirnagl *et al.* 2018).
Improvement of business efficiency (Valdivieso-Gómez and Aguilar-Quesada 2018), as well as improved distribution of responsibilities within work groups (Dirnagl *et al.* 2018; Lai 2017).	Lack of auditing systems tailored for research laboratories, fear of breach of confidentiality during auditing process (Dirnagl *et al*. 2018).
Enhances chances of qualification for access to tenders (Valdivieso-Gómez and Aguilar-Quesada2018)	Lack of support and funding by universities and sponsors to implement QMS within the research realm (Dirnagl *et al.* 2018).
Improves internal processes (Valdivieso-Gómez and Aguilar-Quesada 2018), such as error management, data management and systematic and comprehensive training and education (Dirnagl *et al.* 2018; Vianna *et al.* 2022).	Lack of infrastructure to set up and maintain a QMS in a research environment, for example, no internal and external quality structure. Auditing does not cover essential elements of the scientific method, since auditors are not familiar with the research process (Dirnagl *et al.* 2018).
Enables achievement of strategic objectives (Valdivieso-Gómez and Aguilar-Quesada 2018; Dirnagl *et al.* 2018).	QMS too rigid in case of noncompliance for a research laboratory; no flexibility allowed for errors within research (Dirnagl *et al.* 2018).
Creates mechanisms for continuous improvement of service quality (Valdivieso-Gómez and Aguilar-Quesada 2018; Vianna *et al.* 2022), such as enhanced record keeping, exchange of resources, communication of knowledge, and devices, as well as more sophisticated culture of dealing with errors (Dirnagl *et al.* 2018; Vianna *et al.* 2022).	QMS based on ISO 9001 can be too rigid and resource intensive. The overall design does not support the eccentricities of research purposes; such as experimental design, data storage or validity problems, for instance, performance, detection, or attrition bias (Dirnagl *et al.* 2018).

Advantages and benefits	Disadvantages and limitations
Attains customer satisfaction, loyalty (Valdivieso-Gómez and Aguilar-Quesada 2018), and focus (Vianna *et al.* 2022; Lai 2017)	

2.7 OVERALL BENEFITS OF ISO 9001:2015 IMPLEMENTATION

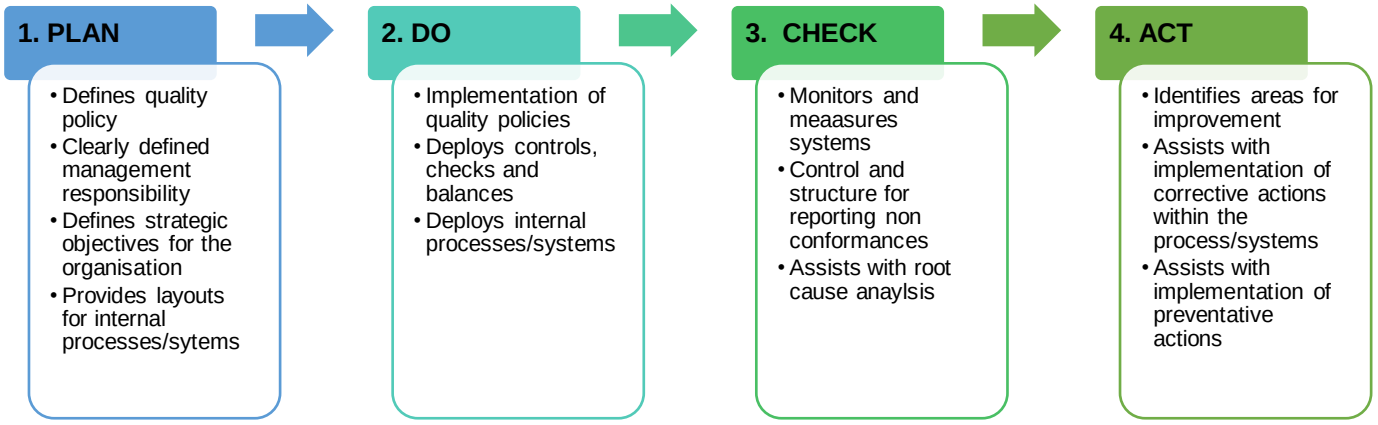

Figure 2.6: Diagrammatic representation of ISO 17025:2017 benefits

2.8 INTRODUCTION TO ISO 17025:2017

Relevant modifications have been made to ISO 17025, including a new vocabulary update and a reorganised structure that is in line with related system standards (such as ISO 9000 and others). Along with an interpretation of and requirements for sampling activities, the revised standard specifically introduced changes to the concept of impartiality, risk-based thinking, process-based approach, and a higher focus on clients. The updated structure examined the guidelines for statements of conformance and provided a flexible framework for organisations thinking about making the switch to digital (Ribeiro *et al.* 2020). Furthermore, ISO 17025:2017 mandates the recording of "technical requirement" processes, which are defined as those elements such as personnel, surroundings, tools, or samples that materially impact the validity, reliability, and accuracy of tests and calibrations. These requirements equate to human resource management (HRM) (specifically in terms of qualification and competence or infrastructure) and are due to test and calibration specificity and sensitivity (Valdivieso-Gómez and Aguilar-Quesada 2018). Table 2.4, indicates the eight key clauses required to be fulfilled for

successful ISO 17025:2017 implementation within a laboratory environment (Ribeiro *et al.* 2020).

Table 2.4: Eight key clauses for ISO 17025:2017

ISO 17025:2017
0. Introduction
1. Scope
2. Normative references
3. Terms and definitions
4. General requirements 4.1 Impartiality 4.2 Confidentiality
5. Structural requirements
6. Resource requirements 6.1 General 6.2 Personnel 6.3 Facilities and environmental conditions 6.4 Equipment 6.5 Metrological traceability 6.6 Externally provided products and services
7. Process requirements 7.1 Review of requests, tenders, and contracts 7.2 Selection, verification, and validation of methods 7.3 Sampling 7.4 Handling of test or calibration items 7.5 Technical records 7.6 Evaluation of measurement uncertainty 7.7 Ensuring the validity of results 7.8 Reporting of results 7.9 Complaints 7.10 Nonconforming work 7.11 Control of data and information management
8. Management system requirements 8.1 Options (A and B) 8.2 Management system documentation (Option A) 8.3 Control of management documents (Option A) 8.4 Control of records (Option A) 8.5 Actions to address risks and opportunities (Option A) 8.6 Improvement (Option A) 8.7 Corrective actions (Option A) 8.8 Internal audits (Option A) 8.9 Management reviews (Option A)

2.9 ADVANTAGES AND DISADVANTAGES OF IMPLEMENTING A QMS BASED ON ISO 17025 STANDARDS IN A RESEARCH TESTING LABORATORY

Since Sappi COE is considered a research testing laboratory, increased focus should be given to the suitability of ISO 17025 standards. Therefore, a critical analysis of the advantages and possible disadvantages of the implemented system should be prioritised. Table 2.5 describes the various advantages and disadvantages noted by several researchers, with regard to implementation of the system in research laboratories.

Table 2.5: Advantages vs disadvantages of implementing a QMS based on ISO 17025 standards in a research testing laboratory

Advantages and benefits	Disadvantages and limitations
It will enable the laboratory to comply with quality management methods comparable to those in industry. The QMS will enable the laboratory to have the possibility of becoming a supplier, subcontractor or partner (Counte and Meurer 2001; Grochau *et al.* 2010; Silva *et al.* 2015). Improvement of qualification to access tenders (Valdivieso-Gómez and Aguilar-Quesada 2018).	The rigidity of a QMS has a tendency to limit the creative work which is sturdily attached to research (Mathur-De-Vré 1997; Silva *et al.* 2015).
In order to facilitate cooperation or funding, it promotes mutual trust among all parties (customers, sponsors, scientists, authorities) (Mathur-De-Vré, 1997, 2000; Krapp 2001; Grochau and Caten 2012). Improvement of company image, allowing for gains in market share (Valdivieso-Gómez and Aguilar-Quesada 2018).	Excessive rigidity in a QMS increases administration and paperwork associated with implementation and management (Krapp 2001; Silva *et al.* 2015).
Guarantee and development of technical and scientific competencies of staff members (Mathur-De-Vré 1997, 2000; Krapp 2001; Grochau and Caten 2012; Valdivieso-Gómez and Aguilar-Quesada 2018).	The intricacy of the research activity (with diverse requirements, multiple groups, technical uncertainty) is incompatible with a QMS (Mathur-De-Vré 1997, 2000).
Ensure comparable and reliable results within or between laboratories during stages of a project (Mathur-De-Vré 1997, 2000; Krapp 2001; Grochau *et al.* 2010; Silva and Ribeiro 2019). Creation of mechanisms for continuous improvement of service quality (Valdivieso-Gómez and Aguilar-Quesada 2018).	There is a lack of standardisation for defining a QMS within research organisations (Mathur-De-Vré1997, 2000; Valcárcel and Ríos 2003).

Advantages and benefits	Disadvantages and limitations
Laboratory activities are managed more efficiently through improved scientific and technical management (Mathur-De-Vré 1997; Zapata-García, Llauradó and Rauret 2007; Silva and Ribeiro 2019). Improvement of internal processes (Valdivieso-Gómez and Aguilar-Quesada 2018).	Results of research are not limited to test results, but also include scientific production, repeatability, and opinion (Mathur-De-Vré 1997).
Improvements in the structure of the organization through a clearer definition of responsibilities and functions (Mathur-De-Vré 1997; Zapata-García *et al.* 2007). Development and achievement of strategic objectives and competitive advantage (Valdivieso-Gómez and Aguilar-Quesada 2018; Silva and Ribeiro 2019).	In a research environment it is difficult to measure the cost of "non-quality", this makes it difficult to justify investments in quality management tasks and secure funding (Outaki *et al.* 2019).
Enhancement of equipment control (Zapata-García *et al.* 2007; Silva *et al.* 2015). Improvement of business efficiency (Valdivieso-Gómez and Aguilar-Quesada 2018).	Inadequate training in quality management amongst the research staff (Vermaercke 2000; Outaki *et al.* 2019)
Improvement of current working habits (Krapp 2001). Growth of staff competencies (Valdivieso-Gómez and Aguilar-Quesada 2018).	There is a lack of commitment from researchers and managers to quality management ((Mathur-De Vré 2000; Vermaercke 2000; Outaki *et al.* 2019)
Promotion of knowledge management and staff qualification (Mathur-De-Vré 1997; Grochau *et al.* 2010; Grochau and Caten 2012: Valdivieso-Gómez and Aguilar-Quesada 2018).	Absence of human resources dedicated to support the QMS (Zapata-García *et al.* 2007; Grochau and Caten 2012).
Enhancement of staff commitment in meeting customer requirements and achievement of customer satisfaction (Valdivieso-Gómez and Aguilar-Quesada 2018).	Resistance to change within the organisation (Outaki *et al.* 2019).

2.10 OVERALL BENEFITS OF ISO 17025:2017 IMPLEMENTATION

Figure 2.7: Overall benefits of ISO 17025:2017 implementation

2.11 SUMMARY OF ISO STANDARDS

The foregoing literature review reveals ISO standards improve the credentials of any laboratory in question, from testing laboratories to research laboratories. In order to maximise sales and profits, organisations must develop strategic planning and continuous improvement, which requires a QMS that complies with ISO standards. Customers use product and service quality as a gauge of safety and dependability when comparing them to less valuable options. Customers who receive high-quality goods and services from suppliers typically remain faithful, which is crucial for businesses. Ultimately, it guarantees consumer protection, fair competition, transparency, and conformance for a supervisory body.

In this light, Sappi COE laboratories aim to produce reliable high-quality results within a reasonable time-frame and improve services to support customer relations. It is evident from literature that a QMS built on ISO principles has the following guiding principles: relationship management, evidence-based decision making, continuous effort to resolve issues and reduce errors (improvement), leadership, customer focus, and employee engagement. Thus, the implementation of an integrated quality framework with ISO standards is imperative for the sustainability of Sappi COE laboratories within the global market.

2.12 HISTORY OF LEAN

2.12.1 Early developments

The origins of lean management can be traced back to 1799 and Eli Whitney, a famous inventor (Figure 2.8). His accomplishments included the invention of the cotton gin. However, this was insignificant, compared to his perfection of the concept of interchangeable parts (Iuga and Kifor 2013).

Over the next century, manufacturers focused primarily on developing engineering drawings and modern machines. During this period, Dwivedi (2013) finds an evident lack of concern regarding:

- What happens between processes.
- How multiple processes can be arranged effectively.
- How chain processes can function as a system.
- The route an employee used in completing a job/task.

In the late 1890's, a change was noted in terms of standardising work methods and behavioural characteristics of employees. Frederick W Taylor assessed individual workers and work methods that promoted time studies and standardised work (Figure 2.8). His approach and ideas were noted as Scientific Management. While the application of scientific management was sound it, however, ignored the effects of employee behaviour (Dave 2020).

Frank Gilbreth, on the one hand, added to motion studies and invented process charting; this enabled all work elements, including non-value adding (NVA) elements, to be highlighted between the processes. On the other hand, Lillian Gilbreth brought psychology into the mix, by studying factors that motivate employees and how the attitudes of employees contribute to the outcome of the process (Figure 2.8) (Iuga and Kifor 2013).

These early inventors highlighted the different elements of waste and originated the idea of eliminating waste, a key tenet of Just-in-Time (JIT) and LM.

2.12.2 The Ford System

Established in 1910, Henry Ford and his right-hand man, Charles E. Sorensen, developed the first comprehensive Manufacturing Strategy (Figure 2.8). The Model T automobile, which revolutionised transportation, was manufactured by skilfully assembling all the components of a manufacturing system, including personnel, equipment, tools, and products, into a continuous system (Lee 2004; Bayraktar *et al.* 2007). Ford is considered by many to be the first practitioner of JIT and LM. The Ford production system largely depended on a labour force that inherently broke down with a changing world. The opulence of the 1920's and the advent of labour unions produced conflict with the Ford system. In addition, the numerous products, yearly model modifications, and variety of colors and options did not suit the inflexible Ford system (Curcio 2013; Meyer 2013).

Alfred P. Sloan at General Motors pursued a more pragmatic approach to production and created business plans for overseeing broad companies with a range of goods. In the mid 1930's, General Motors had surpassed Ford in domination of the automotive market. However, many basic elements of Ford production were sound, although in a new age (Figure 2.8). A pivotal factor in the allied victory of World War II was due to Ford's methods and derivatives (Bresser-Pereira 2021).

2.12.3 The Toyota Production System (TPS)

The associated victory of World War II using Ford's practices caught the attention of Japanese industrialists. They examined American production techniques, paying exceptional attention to Ford's methods, in conjunction with statistical quality control techniques developed by Joseph Juran, Edwards Deming, and Kaoru Ishikawa (Durakovic *et al.* 2018; Lee 2004). Taichii Ohno and Shigeo Shingo began integrating Ford production methods, statistical process control, and additional approaches in the early 1940s to create the Toyota Motor Company's TPS methodology (Figure 2.8). Although Ohno and Shingo recognised the inconsistencies and shortcomings of the Ford system, with respect to the central role of inventory, they also noted the importance of respect and communication to employees (Lee 2004; Emiliani 2006). Toyota soon uncovered that factory workers had a lot more to contribute than merely muscle power; this emerged in team development and cellular manufacturing (Dwivedi 2013).

During the 1950's, a sequential workflow that produced goods was Ohno's vision of the ideal production system using JIT to attain minimal inventory between workstations. This facilitated a dynamic shift from the traditional "batch and queue" mass production philosophy, to "one piece flow", also known as pull production (Worley and Doolen 2006). During this era, JIT, Kanban, Quality Circles, and Kaizen emerged, along with Cell Manufacturing, as TPS became a globally recognised process that resulted in productivity and quality gains. In order to learn these concepts, American executives travelled to Japan, and primarily adopted superficial concepts such as JIT and Kanban, which proved to be successful in the long run (Lee 2004).

2.12.4 Introduction to Lean Management

Lean or TPS was introduced to the business world in 1990 through James Womack's book called "The machine that changed the world" (Figure 2.8). In addition to providing insight into automotive manufacturing history, this book also examines Japanese, American, and European automotive assembly plants. As a result of this study, it was evident the Japanese manufacturers outperformed American and Western European manufacturers in the automotive industry drastically, with regard to productivity, quality, and competitiveness. Due to the renowned success of the TPS and the valuable insight this book provided; the lean technique became generally accepted in manufacturing in the Western world (Pepper and Spedding 2010; Shah and Ward 2007; Worley and Doolen 2006; Buer, Strandhagen and Chan 2018; Singh *et al*. 2010).

Lean management is recognised as an organisational philosophy and toolkit that emerged from Toyota Motor Company's analysis of its business processes (Graban and Padgett 2008; Gellad and Day 2016). "Lean" operating principles started in manufacturing environments and are recognised by a multitude of synonyms, including Lean Manufacturing (LM), Lean Production, the TPS, and more (Kilpatrick 2003). According to Sugianto *et al*. (2015), ideologies surrounding lean production emphasize process analysis and improvement with a focus on waste reduction and high-quality output. The most well-known and prosperous businesses use lean manufacturing (LM) to cut costs, increase efficiency, and shorten delivery times (Rohac and Januska 2015). The National Institute of Standards and Technology Manufacturing Extension Partnership's Lean

Network defined lean, is as follows: “A systematic approach to identifying and eliminating waste through continuous improvement, flowing product at the pull of the customer in pursuit of perfection” (Kilpatrick 2003).

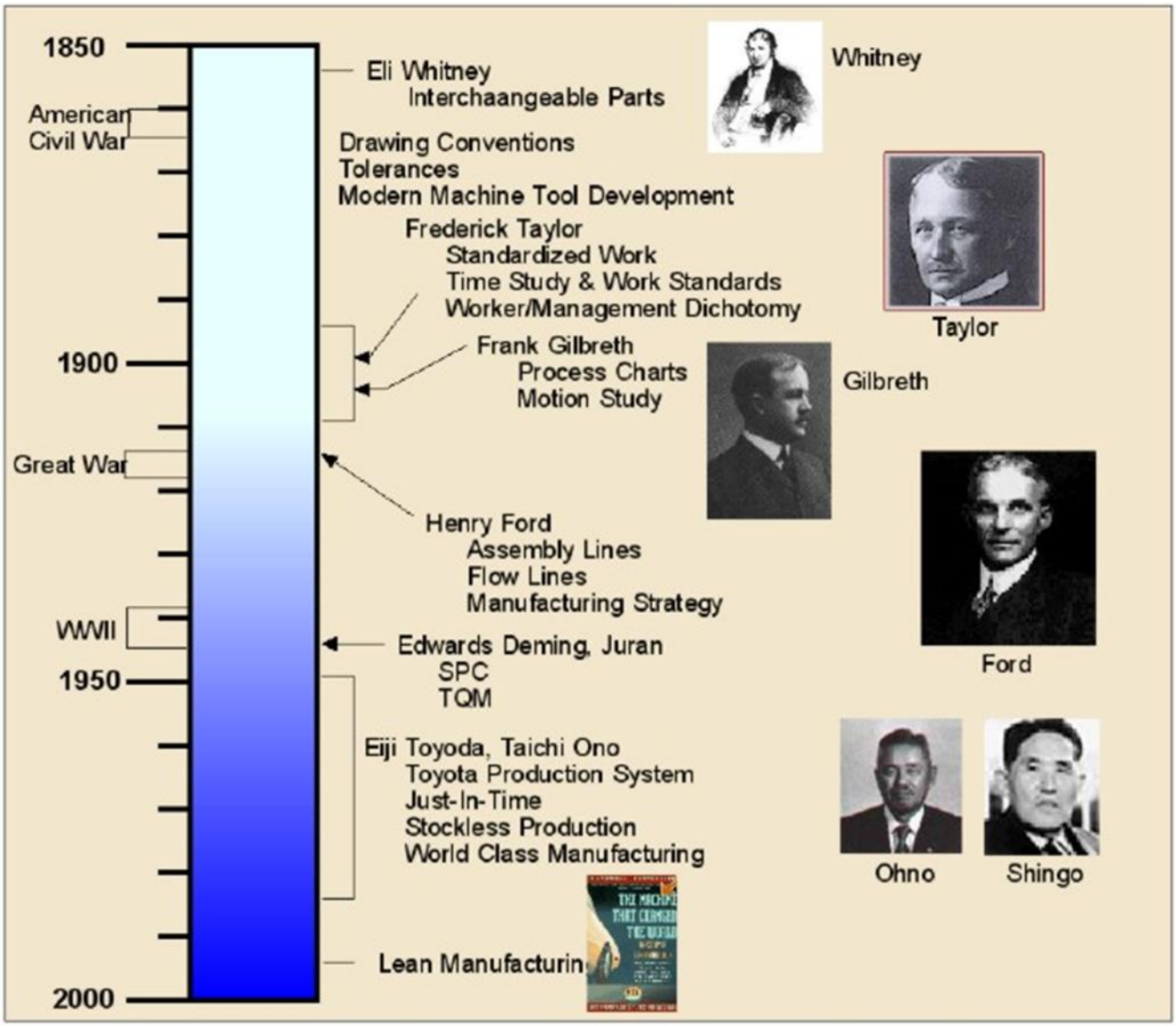

Figure 2.8: Timeline of lean management and early inventors

Source: Alkher (2019)

2.13 INTRODUCTION OF LEAN PHILOSOPHY

The definition of lean, its principles and main concepts, inherently fall under lean philosophy (Gupta and Jain 2013). In addition, Bhasin and Burcher (2006) emphasise lean is a philosophy, rather than a strategy. There are five primary steps that can define

lean as a process, which are in order: defining customer value, defining value stream, making it 'flow', and establishing pull, where the last step is striving for excellence (Womack and Jones 2003). According to Valamede and Akkari (2020), the five steps are essentially principles, as illustrated by Womack and Jones (2003) (Figure 2.9), with each principle further defined accordingly (Table 2.6).

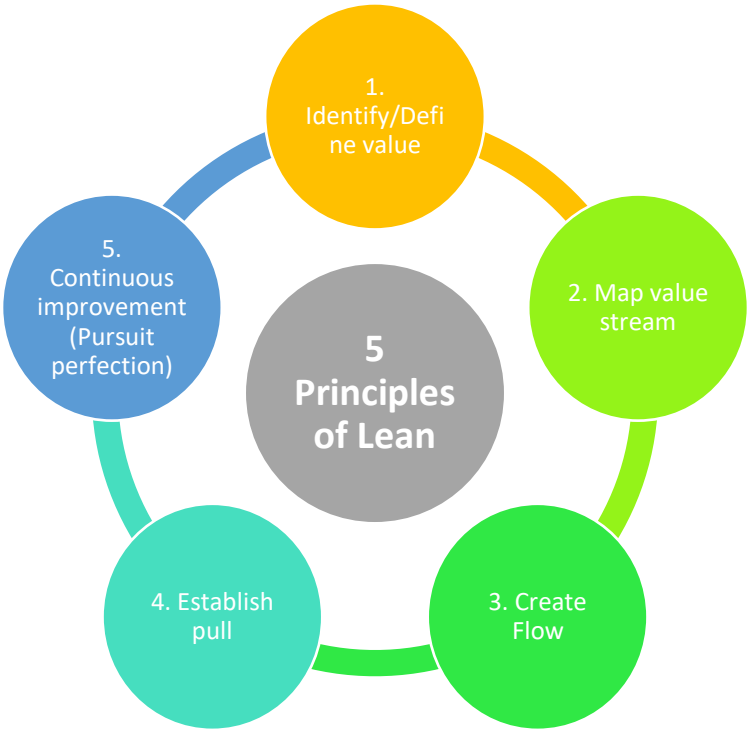

Figure 2.9: Diagrammatic representation of the 5 lean principles

Source: Womack and Jones (2003)

Lean principles and definitions, as detailed by Valamede and Akkari (2020), are tabled (Table 2.6) below:

Table 2.6: Lean principles and definitions

Lean Principle	Definition
Define Value	Value in terms of lean principles can be defined as the customer´s perspective, expressed in a product or a service that satisfy buyer needs at a specific price and time.
Map Value Stream	Map all activities linked to the manufacturing process. The value map allows the company to

Lean Principle	Definition
	assess the operations that do or do not add value; to eliminate those that generate waste.
Create Flow	Using a continuous flow introduce activities that add value, to prevent buffer stocks, increased lead times or unplanned rework.
Establish Pull	Created using JIT principles, it is essential to produce only what is needed, on the required date. Customer forecasts lead the manufacturing process.
Continuous Improvement	At all its operational levels the search for improvement is encouraged and completed for the entire organisation. This will essentially lead to the value chain flowing faster.

2.14 INTRODUCTION TO LEAN MANUFACTURING (LM)

Upadhye, Deshmukh and Garg (2010) state LM is the name allocated to a team-based systematic approach for discovering and eliminating various types of waste. Researchers that governed the International Motor Vehicle Program at the Massachusetts Institute of Technology (MIT) popularised the term “lean manufacturing”. During a five-year period, their study examined 52 assembly plants in 14 countries and the significant performance gap between Western and Japanese automotive industries (Bhasin and Burcher 2006). In order to fully understand Lean principles, the definition of types of waste should be thoroughly examined. To Lean practitioners, wastes are commonly referred to as NVA activities, with eight common wastes identified (Table 2.7).

These different types of wastes generated and the corresponding lean tool that can assist with the reduction of each type of waste, are tabled below (Dennis 2017; Kilpatrick 2003; Sugianto *et al.* 2015; Durur and Akbulut 2019; Graban and Padgett 2008; McManus 2005).

Table 2.7: Different types of wastes generated and the corresponding lean tool used to reduce each type

Types of waste	Definition	Causes	Lean tool/Technique
1) Overproduction	Producing more than what is required by the customer demands. Distribution of unnecessary information.	Tendency to "over-design". Over design too early. Poor understanding of customer needs that leads to uncontrolled processing. "Send all information to everyone," rather than to meet tailor and specific criteria for the customer.	Pull system
2) Waiting	Waiting for material, information, equipment, tools, including personnel to complete or start a task.	No access granted to the required personnel. Updating of databases not completed on time. Multiple approvals required. Incorrectly designed or completed process to provide information. Information created too early that may be outdated by the time it is required for use.	JIT
3) Transportation	Material must be delivered directly to the point of use. Transportation from various sites to be avoided (for instance, Passes through multiple warehouses).	No direct access due to IT limitations, organisational inadequacies, knowledge hoarding and security issues. No clear flow paths required for information sharing, resulting in failure of process to produce information required.	Point-of-use-storage (POUS)
4) Non-Value-Added-Processing	Reworking is a primary example of waste. The product must be correctly manufactured the first time. A good service should be rendered the first time. Parts must be produced free of burrs using correct tools for the job.	Lack of standardisation. Poor output design. Poor process controls.	Value Stream Mapping (VSM), Kaizen

Types of waste	Definition	Causes	Lean tool/Technique
	All parts should be produced statistical process control techniques to reduce the amount of inspection required.		
5) Excess Inventory	Relates to an excessive amount of production. Increased inventory stocks to meet customer demands negatively impacts cash flow and uses valuable floor space.	Poor understanding of process conditions and customer needs. Incorrect system design. Poor understanding of simultaneous processing capabilities. Stove pipe, command, and control mentality.	JIT, Pull System
6) Defects	Production faults and service mistakes waste resources in four ways. First, excessive amounts of materials are mismanaged. Second, manpower required to produce the part or provide a service; time wasted cannot be recovered. Third, additional manpower is required to rework the product or render the service. Fourth, additional manpower is required to address any impending customer complaints.	Human error. Poorly designed input templates. No disciplined reviews, tests, verifications conducted. Data only rendered when user requests. Poor maintenance of testing equipment and machinery.	VSM, Kaizen
7) Excess motion	Poor workflow, layout, housekeeping, and inconsistent or undocumented work procedures can be caused by unnecessary motion.	Lack of distributed, direct access, on-line access, digital versions of heritage information. Teamsters not co-located. Lack of organisational structure inhibits formation of multiskilled teams.	VSM, Sort, Set in order, Shine, Standardize, Sustain (5S)

Types of waste	Definition	Causes	Lean tool/Technique
		Excessive amounts of unnecessary information to sort through	
8) Underutilised staff/Talent	Underutilisation of mental, creative, and physical skills and abilities are included, where non-lean environments only recognise underutilisation of physical attributes.	The main cause of this type of waste includes poor workflow, organisational culture, insufficient hiring practices, lack of training, and high employee turnover.	Kaizen, VSM

LM focuses on producing VA products, while identifying and eliminating NVA activities in the production environment. The core function of LM aims to reduce wasteful practices in the process of providing increased customer value. According to Womack and Jones (2003), value should primarily focus on offering products with particular capabilities at predetermined prices through predefined customer dialogues. In order to increase production and profits without adding more resources, lean organisations should concentrate on reducing NVA activities by shifting efforts to those operations that add value (Dwivedi 2013). Therefore, to demonstrate this idea, Alkher (2019), Dwivedi (2013), and Rathilall (2011), cite the following key implications of LM, compared to traditional batch manufacturing (Table 2.8).

Table 2.8: Key implications between LM and Traditional batch manufacturing

	Lean Manufacturing	Traditional Batch Manufacturing
Orientation	Customer driven - Production is made to order.	Supply driven - Production is based on a forecast.
Planning	Orders are pulled through factory based on customer/downstream demand. Manufacturing schedule is flexible and easy to adjust.	Orders are pushed through factory based on production plan/forecast. Manufacturing schedule is rigid and hard to adjust.
Production cycle time	Cycle times are in hours and days. Total production cycle shortened to approach	Cycle times are in weeks and months. Total production cycle takes longer

	Lean Manufacturing	Traditional Batch Manufacturing
	time spent actually processing the materials.	than actual time spent processing the materials.
Inventory	Inventory levels are based on one-piece flow. Little or no work in progress between each production stage.	Inventory levels are based on large batches. Buffer of work in progress between each production stage.
Handoff of works in progress	Stations are set up by product flow. Materials given directly from one production stage to the next.	Stations are set up by department function. After each stage materials accumulate in work in progress storage areas before being used by next production stage.
Quality inspection	Quality is tested at each station. In-line inspection by workers.	Quality is done through random sampling. Checking of samples by quality control inspectors.
Employee involvement	Employees are empowered to identify improvements.	Employees provide diminutive or no input.
Manufacturing costs	Manufacturing costs are controlled and decreasing.	Rising manufacturing costs are uncontrolled.

Since the Lean approach has been successful in the industrial manufacturing setting (Oberhausen and Plapper 2015), a similar approach has recently been introduced into the health care arena (Gellad and Day 2016). This has presented an opportunity to achieve efficiency, while improving the quality of operational performance of the laboratory (Michael *et al.* 2013). In this regard, it is necessary to focus on waste reduction, satisfying customer expectations, and continuous cost reductions, with continuous improvements also needed to survive competitively (Sharma and Suri 2017; Bhat *et al.* 2021; Tenera and Pinto 2014).

To attain quality, lower cost, reduce cycle time, and increase safety, as well as employee motivation, the lean management approach requires implementation of a set of principles and tools. Several tools can be effectively used to eliminate the various types of wastes within an organization. These tools include JIT, VSM, Kaizen, and material requirement planning, along with Kanban, 5s, the pull system, and PDCA, among others (Table 2.7) (Gupta and Jain 2013; Liker 2004). The above-mentioned tools perform various functions for lean management within an organization.

2.15 LEAN MANUFACTURING (LM) TOOLS/TECHNIQUES

2.15.1 Pull system in LM

The pull production system is one of the most fundamental principles within lean (Karlsson and Åhlström 1996; Womack and Jones 2003). Pull production systems are generally described as upstream processes that only produce when necessary for downstream processes. Customer demand is taken into account to start production, and the downstream process signals the upstream process to start producing.

Production quantity covers the renewal of stock between processes (Spearman and Zazanis 1992). By considering customer demand before production, the pull systems control the workload within the system. According to Womack and Jones (2003), in comparison to a push production system, jobs are pulled by subsequent workstations as needed in a pull system, rather than jobs being pushed from one workstation to the next, upon completion. In summary, the pull system simply means no one upstream should produce a good or service until requested by the downstream customer.

2.15.2 Kanban and paired-cell overlapping loops of cards with authorisation (POLCA) within the pull system

In the pull system, cards are used as production orders. “Kanban” is the Japanese word for tag, or signal. Material movement between workstations in a production line is based on cards in the Kanban system. It is a visual indicator used to display and track production throughout the factory/manufacturing plant; this improves the communication of information. Consequently, a supplier should only deliver parts to the production line as and when required. This will, in turn, prevent storage of parts in the production area, which is the basic need of the Kanban system (Gupta and Jain 2013; Sundar, Balaji and Kumar 2014; Powell, Riezebos and Strandhagen 2013). In addition, a Kanban system is developed to achieve JIT, with improved manufacturing efficiency. The use of a Kanban board is to display the inventory involved within the production line; it shows total work-in-process (WIP), input, output, and total machine breakdown, as well as target, and so on (Ukey, Deshmukh and Arora 2021).

According to Powell *et al.* (2013), Kanban can be classified into two types: production kanban, used to communicate and authorise production requirements on the shop floor,

and supplier kanban, used to communicate the requirement of raw materials and components to suppliers.

An alternate in a pull system to kanban is POLCA; an acronym for paired-cell overlapping loops of cards with authorisation. It is a card-based control system used to manage a high variety of parts or custom engineered products (Krishnamurthy and Suri 2009). Riezebos (2010) explains POLCA is a pull system pertinent in make-to-order (MTO) companies. This material control system manages the authorisation of order progress on the shop floor in a cellular manufacturing environment. The process is facilitated by strictly limiting WIP inventory between cells. The aim of the system is to increase the speed of job transfer and reduce the unbalances in the manufacturing system.

2.15.3 Just-in-Time (JIT) in lean manufacturing (LM)

According to Ohno (1982), JIT is defined as the company's ability to attain an appropriate amount of resources “just in time”, in other words, as needed, on time, at the last moment. Fullerton and McWatters (2002) define JIT as an excellence-based approach that is attained through ongoing improvement throughout all phases of the production cycle. The main objective of the JIT method is to reduce inventory holding costs and increase inventory turnover (Kesavan 2023).

JIT is a tool of LM, supported by pillars of successful planning and implementation of activities necessary to produce a final product. The primary goal of the system is to supply each process with a single part at a time, precisely when it is needed, in accordance with the JIT principle. Reducing lot and buffer sizes, as well as order lead times, is indicated as significant components of JIT by several authors (Alkher *et al.* 2017; Gupta and Jain 2013; Letelier *et al.* 2021). To facilitate JIT implementation, a transition from a ‘push’ (based on forecast demand) system to a ‘pull’ (based on actual demand) system is required, in order to ensure a smooth and synchronised workflow. This enables products to be produced at the right quantity, at the right time (Karlsson and Åhlström 1996). 2.15.4 Value stream mapping (VSM) in LM

Lean Management is used by the majority of prominent and prosperous businesses to cut costs, eliminate waste, and speed up deliveries (Rohac and Januska 2015). A focus

on reduction of wastage, satisfaction of customer expectations, continuous cost reductions and continuous improvements is required to survive in a highly competitive environment (Sharma and Suri 2017; Bhat *et al.* 2021; Tenera and Pinto 2014; Oberhausen and Plapper 2015).

As a tool of Lean Management, VSM helps define the steps in a process that brings the organization or unit closer to its goal (Gellad and Day 2016). VSM is known to be a visual representation of the flow of people, material, and information in a complex system (Toussaint and Berry 2013; Singh *et al.* 2010; Michael *et al.* 2013). This method was originally called “Material and Information Flowing Mapping” at Toyota and included material and information required within the process (Rother and Shook 2003). VSM is a useful tool of LM to reduce the wastage in any process, by segregating Value Added (VA) and NVA activities. In addition to identifying waste, VSM identifies its contributing factors and serves as a basis for process improvement implementation (Michael *et al.*2013).

Lean techniques focus on reducing lead time and eliminating wastes in all kinds of forms (Verma and Sharma 2016, Gellad and Day 2016). Multistage manufacturing processes can be methodically visualised, analysed, and optimised using VSM from a QA perspective. The technique allows quality control loops, quality key indicators, and inspection processes to be visualised within the process flow (Haefner *et al.* 2014; Michael *et al.* 2013). Developing a VSM, with the assistance of an outside coach and employees, essentially contributes to a deeper understanding of the process and the way in which it is performed, since it highlights the essential VA and the numerous NVA steps taken. In the absence of this understanding, any improvement tactics will fail. The goal of VSM is to identify solutions that are meaningful and lasting (Michael *et al*. 2013).

2.15.4 5S in LM

This tool is one of the simplest tools of LM. It is a systematic method of organising and standardising the workplace (Figure: 2.10). Implementation of this tool within the organization allows for immediate return on investment across all industry boundaries. In addition, it can be applied to every function within the organization. Due to this attribute, it is usually the first recommendation for a company implementing LM (Kilpatrick 2003;

Rathilall 2011). Five S in LM emanates from Japanese words, which are explained below, in order (Alkher 2019; Ukey 2021; Chandrayan, Solanki, and Sharma 2019):

1. Seiri (Sort) – This is the first step of 5S, which entails going through equipment, tools, materials, and so on, thoroughly. This assists with identifying necessary and unnecessary items in the workplace.

2. Seiton (Set in Order) – After items have been sorted through, they must be set in order. Each item should be allocated a respective place within the department. There must be a place for everything and everything in its place. A place should be allocated to an item, taking into account various factors such as its usability, necessity, frequency of use, and so on.

3. Seiso (Shine) – The shine stage refers to the cleaning up of the work area and maintenance of equipment and machinery. 5S encourages everyone to take responsibility for cleaning up his or her workstation. In industry, cleaning sessions must take place daily, preferably after every few hours.

4. Seiketsu (Standardise) – This stage focuses on standardising the process. Standardisation entails a set of SOPs of routine tasks. This SOP will assist with maintaining the quality of work conducted in the workplace.

5. Shitsuke (Sustain) – The sustain stage refers to maintaining, repeating, and improving the 5S system. This takes effort from everyone in the organization to ensure the system runs efficiently and effectively for a long period of time.

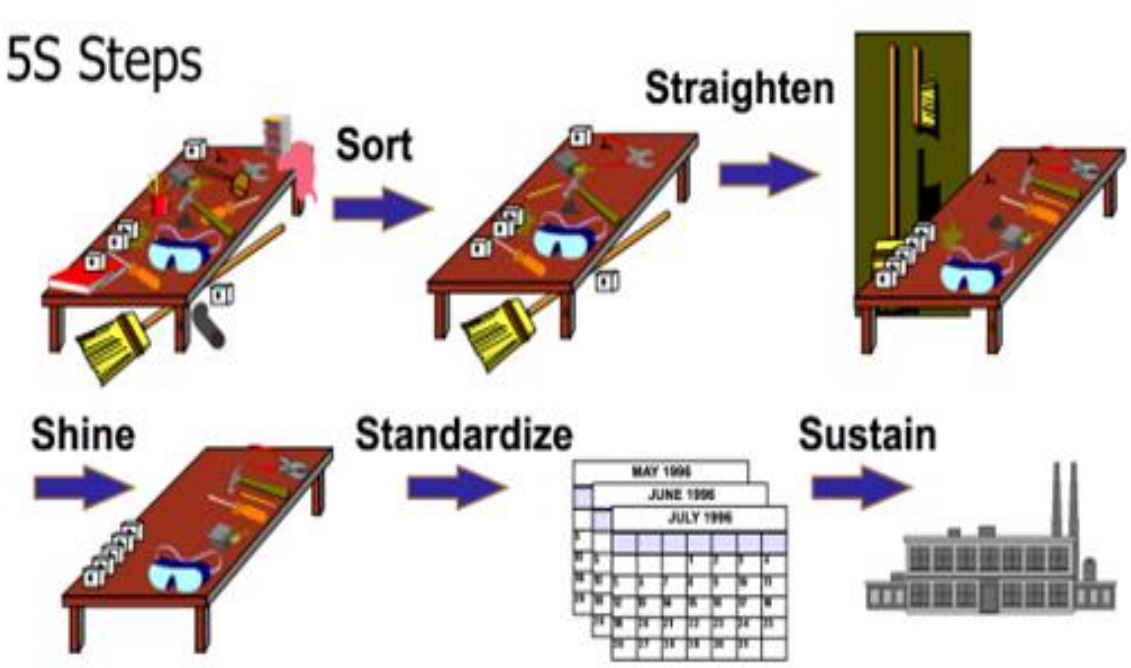

Figure 2.10: Illustration of the 5S tool in sequence

Source: Alkher (2019)

2.15.5 Kaizen in LM

The word Kaizen was first introduced by author Masaaki Imai in his book “Kaizen: The Key to Japan's Competitive Success in 1986”. The term Kaizen is composed of two words of the Japanese language, KAI (which means *change*) and ZEN (which means *good*). Together, illustrative of *good change* or *better change*, however, universally accepted as continuous improvement. On a daily basis, the smallest possible process improvement, or work improvements, is considered Kaizen.

According to Liker (2004), Kaizen is the process of continuously eliminating waste by making small, continuous improvements to quality and processes; hence reducing costs and improving worker safety. This does not mean Kaizen is only representative of small changes, however, it is sometimes impossible to make large changes that will result in continuous improvement and good results. Often, it is necessary to implement small steps to facilitate improvement on a large scale (Imai 1997). The author further explains each improvement can be divided into two parts: Kaizen and Innovation (Imai 1997). Unlike Kaizen, an innovation involves significant investment in equipment and technology, with

an ultimate goal of achieving drastic changes and improvements. In addition, the successful implementation of Kaizen involves the collective efforts of employees at every level of the organization (Bhuiyan and Baghel 2005; Forza 1996), illustrated below (Figure 2.11).

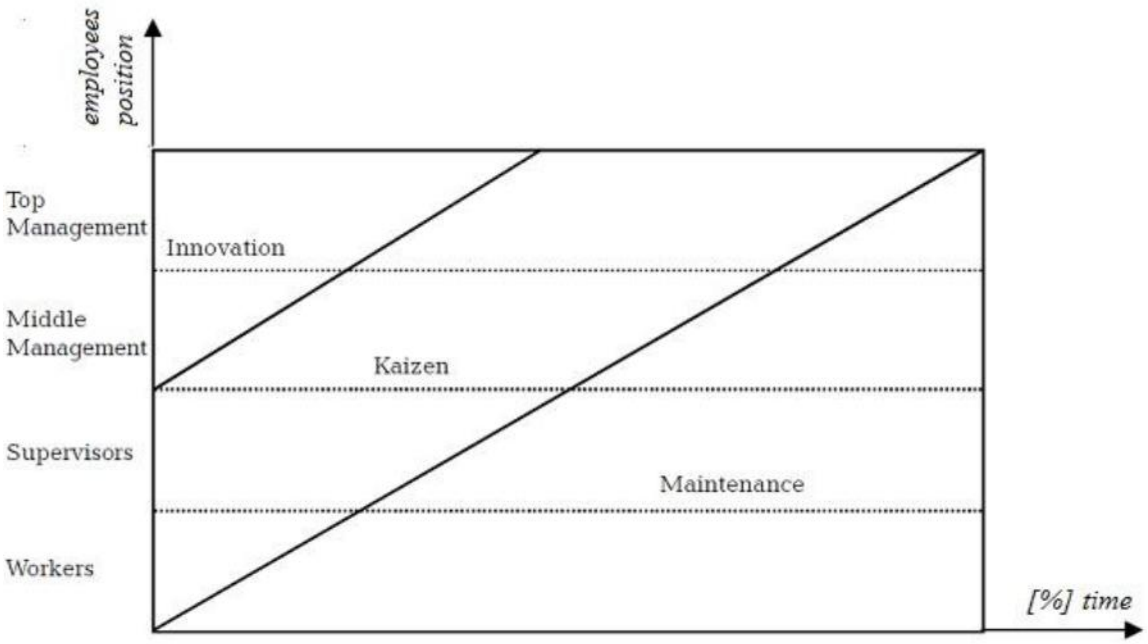

Figure 2.11: Improvement divided into innovation and Kaizen with all members involved

Source: Adapted from Bhuiyan and Baghel (2005) and Forza (1996)

According to Suárez-Barraza, Ramis-Pujol, and Kerbache (2011), there are currently three perspectives or umbrellas under which kaizen can be envisioned, each containing a set of guidelines and methods. In addition, Kaizen can take at least three forms (Imai 1986), namely;

1) Kaizen management – innovation and improvement fall under the purview of senior management, while maintaining work standards and guaranteeing that workers and middle managers carry out moderate improvements.

2) Group Kaizen - focuses on improvement of team and/or quality circles and the solution of daily problems.

3) Individual Kaizen - focusing on bottom-up organisational design, that is, staff suggestions from shop floor workers. Since the floor workers are most familiar with work processes, they are well-placed to generate solutions to problems.

According to various authors (Suárez-Barraza *et al.* 2011; Imai 1986; Ismyrlis 2021), the three perspectives of Kaizen are:

1) Kaizen as a “management philosophy”,
2) Kaizen as a component of TQM; and
3) Kaizen as a theoretical principle for improvement methodologies and techniques.

Perspective 1: Kaizen as an umbrella term for management philosophy (Figure 2.12).

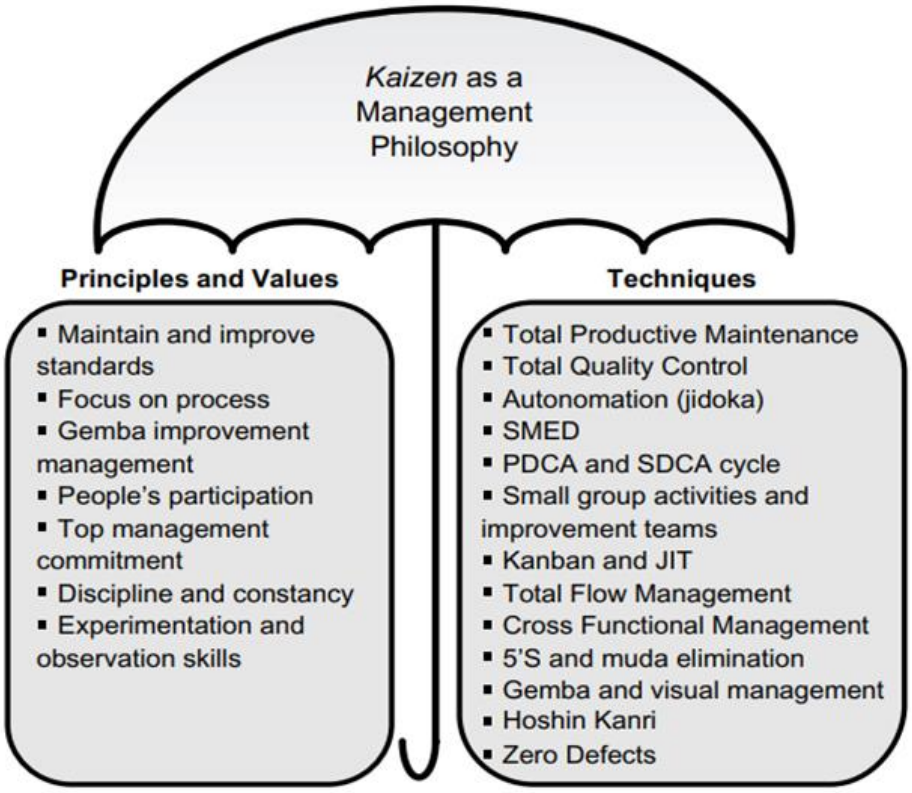

Figure 2.12: Perspective 1 – Kaizen as an umbrella term for management philosophy

Source: Suárez-Barraza et al. (2011)

According to Imai (1986) and Ismyrlis (2021), the first perspective of Kaizen as a "management philosophy" that consists of a set of values and tenets that guide business management. The first perspective embraces all Japanese inspired management practices, techniques and tools (Figure 2.12). Literature suggests Kaizen is a way of interpreting work discipline. From this perspective, standardisation, order and cutting of waste are fundamental features of Kaizen (Imai 1986), 1997; Bhuiyan and Baghel 2005; Ismyrlis 2021). The two other fundamental tenets of this management philosophy viewpoint are standard improvement and maintenance, which are accomplished with the participation of all employees. Businesses that implement this strategy make use of suggestion schemes (individual Kaizen) and improvement groups (group Kaizen) (Suárez-Barraza *et al.* 2011; Jayantha 2021).

Perspective 2: Kaizen as an element of TQM (Figure 2.13),

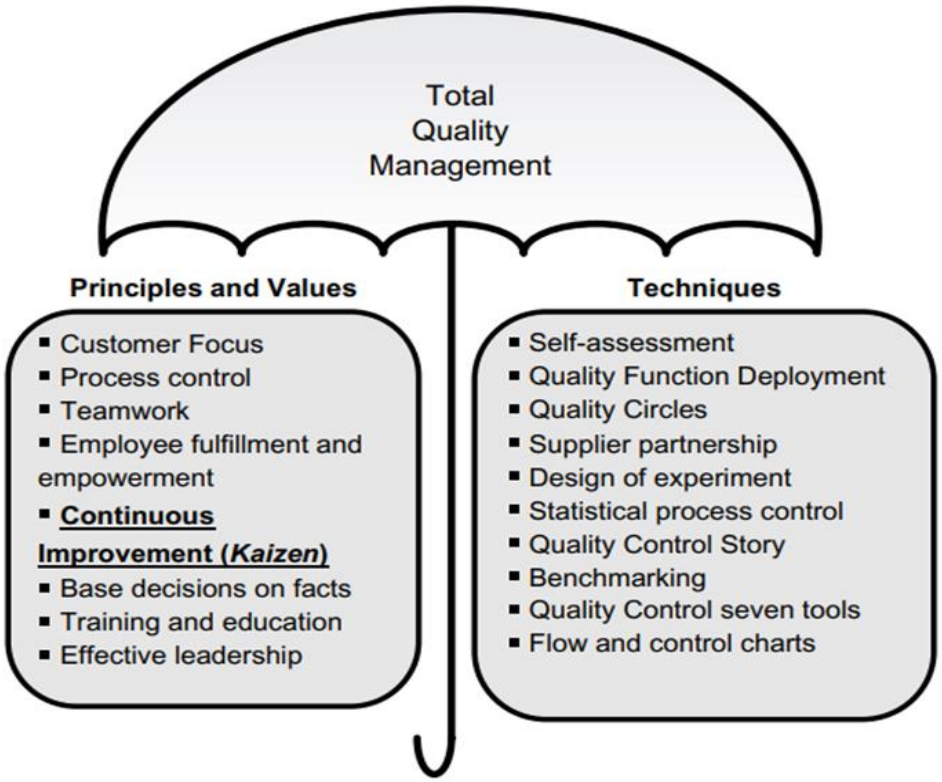

Figure 2.13: Perspective 2 - Kaizen as an element of TQM

Source: Suárez-Barraza et al. (2011)

The second perspective sees Kaizen as one of the key elements in TQM (Suárez-Barraza *et al.* 2011). Furthermore, the literature indicates the roots of improvement programs in the west can be traced back to World War II (Jayantha 2021). According to Webley (1996), the programme included training and education of supervisors, employing statistical control and continuously improving processes. In the 1950's, the TQM program was introduced in Japan by various experts in the field, such as Deming and Juran (Ismyrlis 2021; Bathaei, Awang and Ahmad 2021).

According to published research, teamwork and client orientation are the other two components of TQM, along with kaizen. As a component of TQM, continuous improvement refers to the company's ongoing dedication to analysing its technical and administrative procedures in order to identify more efficient methods of operation. Statistical control of processes and flow diagrams that link to TQM are two of the strategies used to accomplish this goal (Figure 2.13) (Suárez-Barraza *et al.* 2011; Bathaei *et al.*2021).

Perspective 3: Kaizen as a theoretical principle for improvement methodologies and techniques

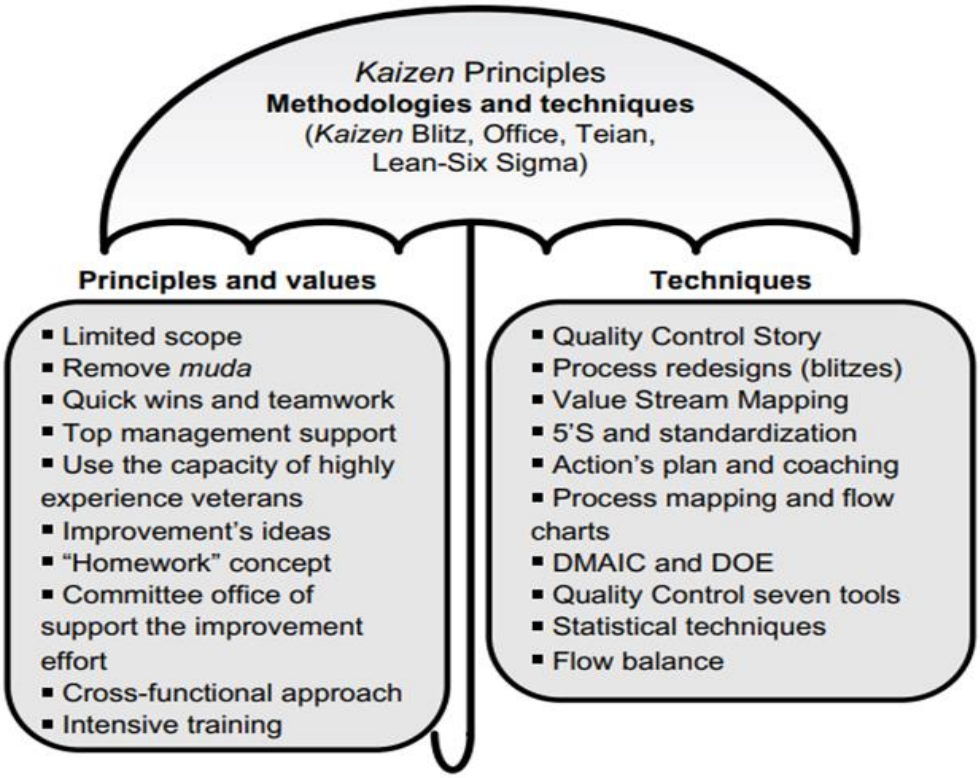

Figure 2.14: Perspective 3 - Kaizen as a theoretical principle for improvement methodologies and techniques

Source: Suárez-Barraza et al. (2011)

The final viewpoint derived from the literature regards Kaizen as the theoretical foundation for implementing waste reduction strategies and/or procedures (Figure 13). Reducing waste will improve lead times, boost profitability, optimize JIT delivery of goods, and increase process and product quality (Ismyrlis 2021; Yigit 2022). According to Ismyrlis (2021) and Suárez-Barraza *et al.* (2011), there are at least five methodologies and/or techniques under this umbrella: Kaizen Blitz, Gemba-Kaizen, Office Kaizen and Kaizen Teian, as well as Lean-Kaizen Six Sigma (Figure 2.14). Literature reveals this perspective of Kaizen, where all associated methodologies and techniques embody the main working principles of Kaizen, as a "management philosophy" (Figure 2.12), which is supported through the techniques and tools shown in both Figures 2.12 and 2.14.

2.15.6 Overall guiding principles “cornerstones” attained for Kaizen from all three perspectives

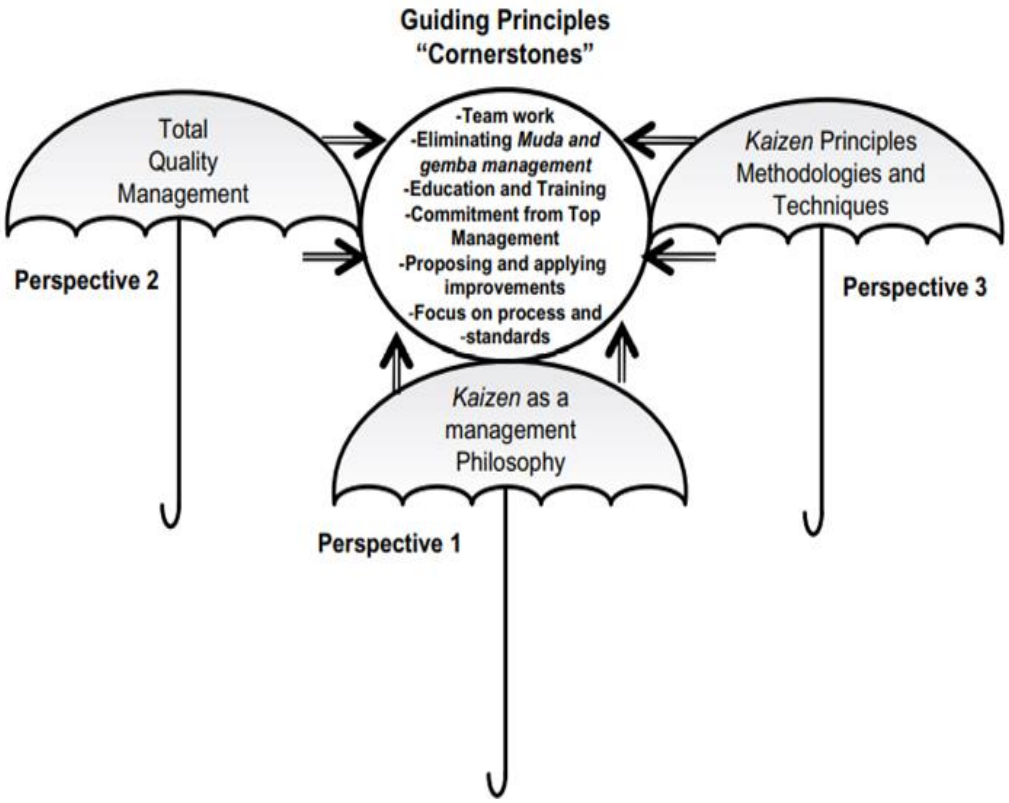

Figure 2.15: Guiding principles “cornerstones” attained from all three perspectives
Source: Suárez-Barraza et al. (2011)

Kaizen can be viewed as a collection of tenets that guide learning and improvement; these tenets are especially important when considering the three views that comprise the framework, which are referred to as "cornerstones" (Figure 2.15) (Suárez-Barraza *et al.*2011). Jayantha (2021) suggests there is a need for further research in the field of the hybrid continuous improvement methodologies that have been developed and to determine their applicability to various industries. Figure 2.15 indicates the common findings observed using the different perspectives. In summary, Kaizen is considered not merely an isolated concept but an umbrella concept, forming an umbrella that covers several techniques, including Kanban, total productive maintenance, six sigma, and automation, as well as JIT, suggestion systems, process mapping and flow charts.

2.15.7 Plan-Do-Check-Act (PDCA) cycle in LM

The PDCA cycle illustrated in Figure 2.16, is a cornerstone of continuous improvement. According to Liker (2004), the cycle of waste elimination relates to creating a one-piece flow, surface problems, counter measures and evaluating results.

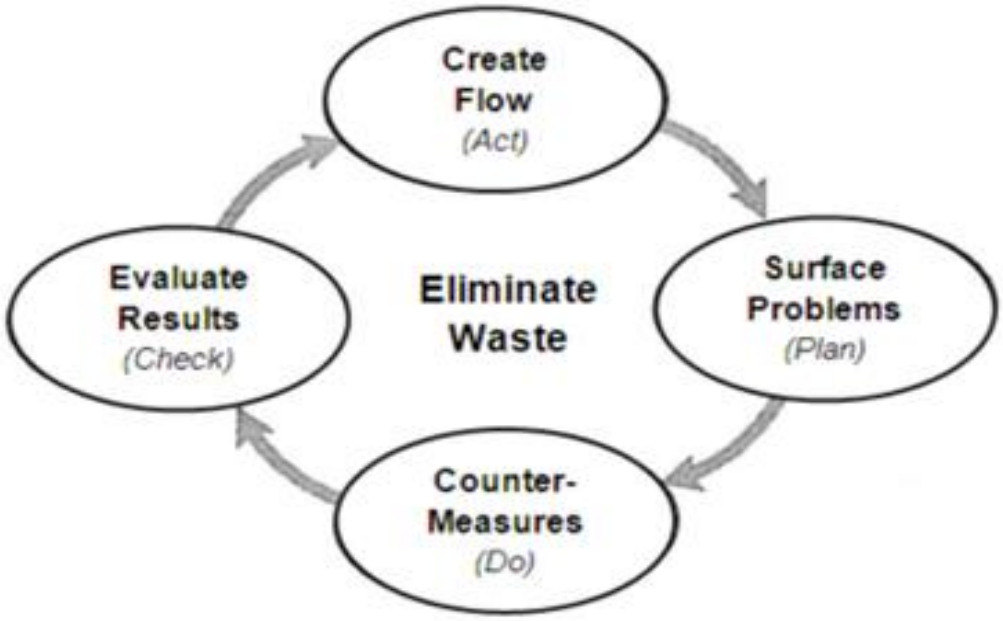

Figure 2.16: The PDCA cycle

Source: Liker (2004)

Sharing a similar view as Liker (2004) and from a more fundamental perspective, Kholif *et al*. (2018) state the PDCA methodology was used to reduce error occurrence and increase process capability to enhance laboratory efficiency and effectiveness. For the PDCA cycle to be effective, the problem situation should follow an investigation process (Figure 2.17). According to Al-Bakoosh, Ahmad and Idris (2020), the planning phase identified the root cause of the problem and where it occurred. In addition, the planning phase considered and analysed preliminary data in an attempt to set current objectives (Kholif *et al.* 2018). The next step involved implementing the improvement, after which the check phase ascertained whether the objectives were met. The act phase entails adopting new standards and identifying further improvements.

A fundamental point to note is that the PDCA cycle has recently been adopted into the ISO 9001:2015 standards (Lai 2017; Valdivieso-Gómez and Aguilar-Quesada 2018). Habibie and Kresiani (2019), assert calibration and testing laboratories have already started implementing ISO/IEC 17025:2017, in conjunction with the implementation of the ISO 9001:2015 standard, which contains the PDCA cycle. The processed-based PDCA cycle is responsible for improving quality of services aligned with the objective of ISO/IEC 17025:2017 implementation.

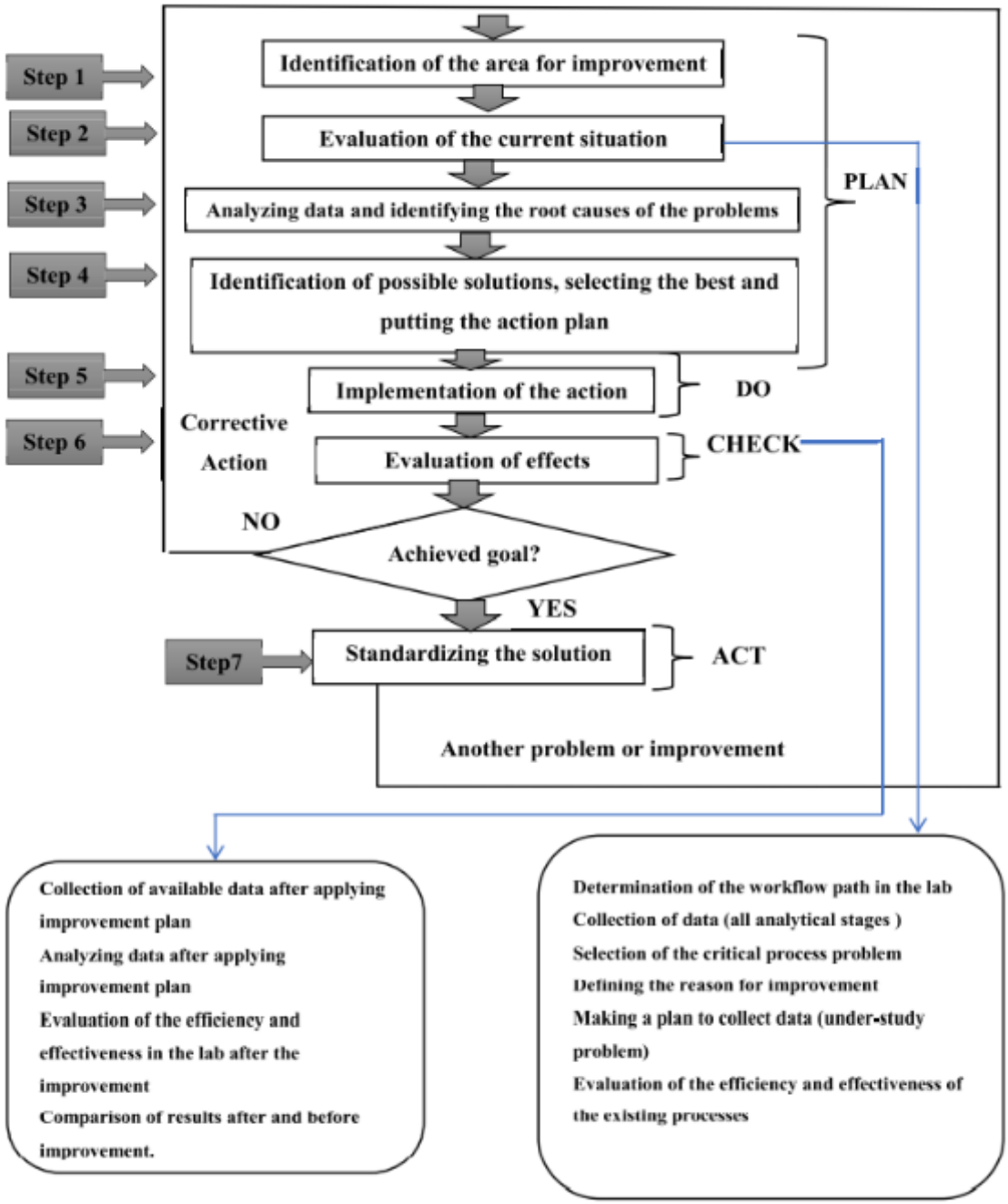

Figure 2.17: Systematic methodology of the PDCA cycle

Source: Kholif et al. (2018)

2.16. BENEFITS OF LEAN MANUFACTURING (LM) IN LABORATORIES

According to Ukey *et al.* (2021), the pull system has enabled the CAD laboratory within the apparel industry to reduce the amount of material or inventory between operations. Kanban converts any 'Push' system into a 'pull system' for production, which inherently

helped increase productivity by approximately eight percent. It has been noted by several authors that the use of Kanban within the pull system facilitates, JIT process implementation which inherently improves the flow of materials and inventory in both the laboratories and small to medium manufacturing enterprises (Powell *et al.* 2013; Driouach, Zarbane and Beidouri 2019; Ukey *et al.* 2021).

The overall objective of JIT is to obtain a smooth and synchronised system, by reducing excessive quantities of material/parts within the process and encouraging one part at a time, using the pull system (based on actual demand). This will assist with reducing waste of excess inventory, which inherently limits space required to store excessive materials/parts. Excessive parts or material within the working area lead to poor housekeeping and, ultimately, a safety concern within the workplace, since incidents are prone to take place due to poor housekeeping and may result in an accident. According to Dagdeviren, Durak and Sadat (2020), there has been a reduction of chemical consumption by 41 percent between 2018 and 2019, with material consumption reduced by 52 percent, using a combination of Jit and 5S methodology within the media lab situated at MIT.

White *et al.* (2015) discovered, while using lean methodologies, primarily VSM, JIT and 5s, a reduction was attained in troponin T TAT by 33 minutes (86 minutes to 53 minutes) and urine sedimentation TAT by 88 minutes (117 to 29 Minutes) within the laboratory at a teaching hospital emergency department. Sugianto *et al.* (2015) used a combination of lean tools such as Kaizen, VSM, and Kanban that resulted in a total process time reduction of 29 percent within the pathology laboratory at a medical centre for children. Implementation of a revised-state value stream resulted in a total process time of 238 minutes, of which 89 minutes were NVA, and an improved process cycle efficiency of 63 percent. Furthermore, according to Michael *et al.* (2013), there has been an improvement of TAT in a medical laboratory for the Papanicolaou cervical screening test through the use of lean management tools such as VSM.

A pathology laboratory situated in a public hospital in Ankara, Turkey, noted 73.6 percent time spent on a gastric biopsy sample, in the pathology laboratory, was wasted (Durur and Akbulut 2019). The most common causes of waste were identified as problems with

cleaning, equipment supply problems, lack of clinical information, and equipment malfunction and errors. To simplify the process and streamline information, gastric biopsy was selected as a product/service family for VSM. A current state map and setting a future state map were followed in creating the VSM in the pathology laboratory. In addition, a current value stream plan was prepared, in order to achieve the goals set in the future state map. The causes of wastage as a result of the VSM, observations and meetings were visualised by means of the fishbone diagram, as a result of brainstorming with pathology laboratory employees.

According to Muiambo, Joao and Navas (2021), a training laboratory within the pharmaceutical industry has employed lean management successfully; to identify the main types of waste daily and the lean maturity of the laboratory, in order to establish priority areas of intervention; to make the laboratory the leanest. Brainstorming sessions / group focus discussions, pareto analysis and a fishbone diagram were used to identify the different types of wastes that contributed to 51.4 percent of the problems.

VSM in a chemical textile laboratory for the azo dye test helped identify NVA activities in every step (Natakusuma *et al.* 2018). In addition, it has identified the largest source of waste within the laboratory system. This has effectively assisted the laboratory to manage NVA activities to improve the system and ultimately achieve the goal of decreased TAT of the testing laboratory. Similarly, VSM will be applied to the ageing kinetics, viscose production and application tests to visually inspect the processes, with key quality indicators and control loops noted. It will also assist the COE laboratories to visually identify the main contributors to repeat work and waste generated. Existing measures in place can then be reviewed and improved. In addition, new measures can be developed and potentially implemented.

According to the National Quality infrastructure in Indonesia (Habibie and Kresiani 2019), there are generally four steps in one PDCA cycle, namely, the plan, the do, the check and the act step. By implementing ISO 9001:2015, a PDCA model was created based on the requirements of the ISO/IEC 17025:2017 standard in a calibration and testing laboratory. In the "PLAN" step, a foundation and ethical code was formulated, in order to operate calibration/testing activities that can produce valid results. The "DO" step was regarded

as the main activity of the laboratory, starting from the upstream process, namely the calibration/testing request, up to the downstream process such as issuing a calibration/testing certificate, which are products from the calibration/testing laboratory. The "CHECK" step was conducted to assess the suitability, adequacy and effectiveness of the laboratory management system. The final "ACT" step was regarded as the actions taken to eliminate/minimise risk, eliminate non-conformities and realise opportunities, so as to generate an increase in laboratory performance (Habibie and Kresiani 2019).

Al-Bakoosh *et al.* (2020) experienced positive results with continuous improvement within the laboratory to achieve quality iron alloy. The cause-and-effect diagram (Fishbone-Diagram) was used to identify the root cause of the defects within a system. In conjunction with a PDCA cycle, defects were effectively minimised. Kholif *et al.* (2018) noted the PDCA cycle implementation continuously improved quality of a dairy laboratory. In addition, a reduction was further noted in the number of contaminated milk samples (68.02 to 74.06 percent) and an increased capability index (88.95 to 96.85 percent).

2.16.1. Enablers and barriers of lean management

To effectively implement lean management, in a laboratory environment, it is crucial to understand what enables implementation and what appears to a barrier. Table 2.9 illustrates the enablers and barriers experienced in the medical laboratory. By understanding these crucial factors, a smooth transition into lean management can be attained in any laboratory environment. Enablers and barriers of Lean management implementation within the medical laboratory industry (Drotz 2014; Isack *et al.* 2018; Mallick, Ahmad and Bisht 2012; Mutingi *et al.* 2017; Ismyrlis 2021) are set out in Table 2.9 below:

Table 2.9: Lean management implementation enablers and barriers within the medical laboratory industry

Enablers	Barriers
Top management needed to be involved.	Staff resistant to change.
Employee enablement.	Leadership inadequacies.

Enablers	Barriers
Flow orientation.	Weak links between improvement programme and the strategy.
Ability to learn and accept changes.	Inadequate planning.
Proper planning.	Inadequate training provided.
Quality workshops organised regularly/Adequate training.	Lack of democratic talk.
Free to talk about all wastes.	Lack of attention rendered to customers (internal and external customers).
All (internal and external) customer satisfaction is tracked and reviewed.	

2.17. CHAPTER SUMMARY

It is evident from literature as to which quality management standards can be adapted to a laboratory environment. Nevertheless, A clear need exists for standards tailored to a research testing laboratory. The advantages are numerous, notwithstanding a few prevailing disadvantages. It is evident from literature the disadvantages can be remedied through an IQMS. In addition, it is important to note the positive impacts of quality management standards on: customer satisfaction; leadership; engagement and continuous improvements.

This chapter also outlined the main determinants of LM, followed by critical success factors for lean transformation within a laboratory, reviewing the contributions of various authors in the development of LM. There are numerous advantages and disadvantages of lean implementation within a laboratory setting. The benefits of LM in a laboratory were clearly examined. Literature indicates a clear relationship between quality management standards and lean. An integration of the two frameworks will prove to be a fruitful exercise, which will improve the overall quality of any laboratory. The next chapter will provide the design of the research and the methodology employed during this investigation.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1 INTRODUCTION

This chapter describes the research tools, design and methodology followed in this study, with the aid of a flow diagram. In addition, the chapter highlights the available techniques for conducting research and discusses the research framework used during the course of this study. It will provide details of the questionnaire design, data collection techniques, target population group, and sample size, as well as credibility. The preliminary pilot study and findings will be discussed, followed by the introduction of the main study.

3.2 RESEARCH DESIGN

According to Abbott and McKinney (2013), the definition of research design is the modes of observation that allow scientists to collect data. This can be achieved using systematic and structured ways. Under specific circumstances, the research question may require an observational study. However, in other circumstances the research question may require an experimental procedure. In all circumstances there are several options in planning the final study (Myers, Well and Lorch 2010).

Differences of exploratory research arise when investigating a specific research question or phenomenon in an uncontrolled environment. The nature of the object under investigation prevents the researcher from manipulating any of the variables. A study that closely follows a scientific research plan is called an experimental research study. It consists of a hypothesis, a variable that the researcher can change, and variables that are calculable, measurable, and comparable (Singh 2021).

Descriptive designs are predominantly used to collect information regarding variables without changing the environment or manipulating any variable; hence, they do not consider the possible cause and effect (Baker 2017). Furthermore, it appears a research design is required to lay out a plan or structured framework intended to guide the research. Researchers Myers *et al.* (2010) share similar views, namely, the design for research is a plan for data collection. Viewed in this light, the researcher must fully

analyse the set of circumstances at the organisation before designing the intended study (Rathilall 2011). In this light, the outline of this project is presented in Figure 3.1.

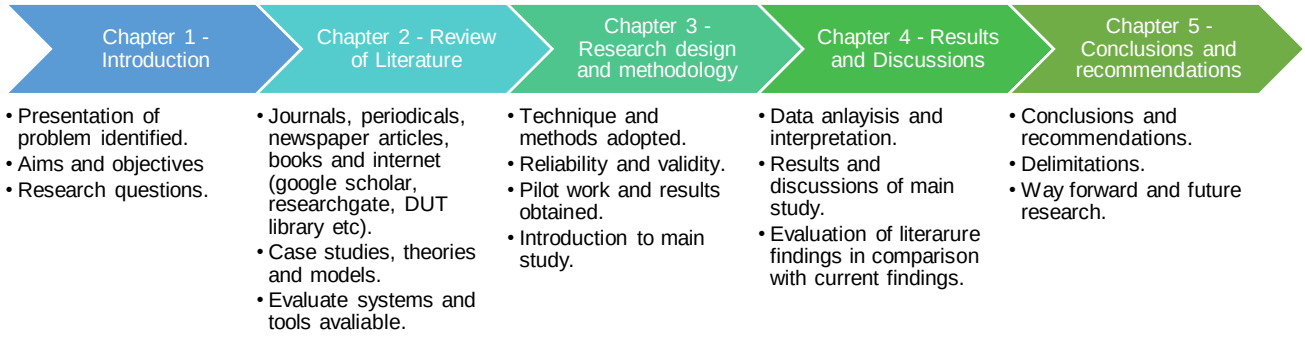

Figure 3.1: Graphical representation of research design

As indicated by the graphical representation above (Figure 3.1), the research design begins with establishing the problem within the organisation, followed by a tailored literature review. Thereafter, a structured methodology is constructed, after which an investigation is undertaken, and the results and discussions presented, culminating in the conclusions and recommendations at the end of the study.

3.3 RESEARCH APPROACH

A pragmatic paradigm assists the researcher to optimally frame, examine and provide tentative answers to the research questions by mixing approaches and methods. The method adopted for this study relies on qualitative and quantitative viewpoints, data collection, analysis and inference techniques being combined, according to the logic of mixed methods research, to address the research question(s) (Onwuegbuzie *et al.* 2009). The pragmatic approach assists with collecting data with a combination of objective and subjective components (Abusabha and Woelfel 2003).

According to Hussein (2009), there have been mixed views regarding the use of triangulation in research. Some authors have argued triangulation is used to increase the depth of understanding a specific phenomenon, while others have argued it is actually used to increase the study accuracy; triangulation can, thus, be associated with validity measures. Furthermore, triangulation can be defined as the use of multiple methods; mainly qualitative and quantitative methods used to study the same phenomenon;

resulting in increased study credibility. In light of the above, quantitative and qualitative methods will be explored further.

3.3.1 Quantitative methods

Fryer, Larson-Hall and Stewart (2018) hold the view that fundamental components of a quantitative approach to research entail measuring items that one can count (quantity) and collection of sufficient data to accomplish statistical analysis (using test scores, numerical results from questionnaires, counts of various classroom behaviours, and more). Several authors share similar views, that the fundamental objective of quantitative methods is to apply the scientific method through methodical, empirical research, even though this objective is occasionally obscured by the intricate statistical techniques they commonly deploy (Brown 2014; Jang, Wagner and Park 2014).

According to Brown (2008), quantitative research places emphasis on generalisability, reliability, and validity, while qualitative research emphasises dependability, credibility, and confirmability. Once the research questions have been decided upon, with the measurement of variables operationalised and the relevant groups sorted, the researcher must consider how to analyse the data (Fryer *et al.* 2018). Anticipating every aspect in advance will highlight areas that could need additional attention during the study. In light of this, it's critical to assess which variables will be independent and dependent in a cause-and-effect study, or which variables may be associated in a correlational or regression study design (Phakiti 2015; Larson-Hall 2015).

Quantitative research, as Phakiti (2015) explains, uses two types of statistical analyses namely; descriptive and inferential statistics. Nonetheless, where quantitative research aims to investigate the characteristics of a population (for example, census survey) or opinions, perceptions and attitudes of individuals that simply aim to report an average score, a percentage, or a rank of something of all participants, will use descriptive statistics. Quantitative research, which requires more than merely an average score, ranked score or a percentage to, for instance, examine a casual-like or linear relationship between two or more variables, uses inferential statistics.

3.3.2 Qualitative methods

The underlying concept of qualitative research is stated to focus on the meanings, traits and defining characteristics of events, people, interactions, settings/cultures and experience (Richard 2013; Mohajan 2018). Lune and Berg (2017) re-iterate that quality refers to what, how, when, and where its essence and ambience lie. Qualitative research thus refers to the meanings, concepts, definitions, and characteristics, as well as metaphors, symbols, and descriptions of things. Richard (2013) emphasises qualitative methods comprise approaches that centralise and place primary value on complete understandings, and how people (the social aspect of our discipline) think, experience, and operate within environments that are active, and social in their foundation and structure.

Data used in qualitative research can be collected by means of a range of collection methods. These include interviews with individuals, observations of people, places, and actions/interactions. In addition, analysis of media content, whether written, spoken, or drawn, among others, along with guided conversions with groups of individuals (focus groups) can be used. Interviews are typically planned conversations conducted by researchers with individuals. One of the most productive ways to acquire knowledge regarding a person, place, or set of activities, is to ask questions of people who have knowledge on the topic. Interviews can be used to acquire information from people, just as quantitative researchers ask questions using surveys.

Both qualitative and quantitative methods have significant benefits to the research, as illustrated above. Mixed research methods, which incorporate both qualitative and quantitative aspects, can be used to answer more complex types of research questions (Brown 2014; Jang *et al.* 2014).

A pragmatic (mixed methods) paradigm will be employed for the purpose of this study, with the research approach consisting of both qualitative and quantitative techniques. In view of the definitions above for qualitative and quantitative methods of analysis, pre- and post-study questionnaires will be used as a data collection tool. In addition, interactive focus groups/brainstorming sessions will be held with employees on the floor, in order to

acquire in-depth information required for the purpose of this research, as a qualitative method of data collection.

3.4 RESEARCH FRAMEWORK

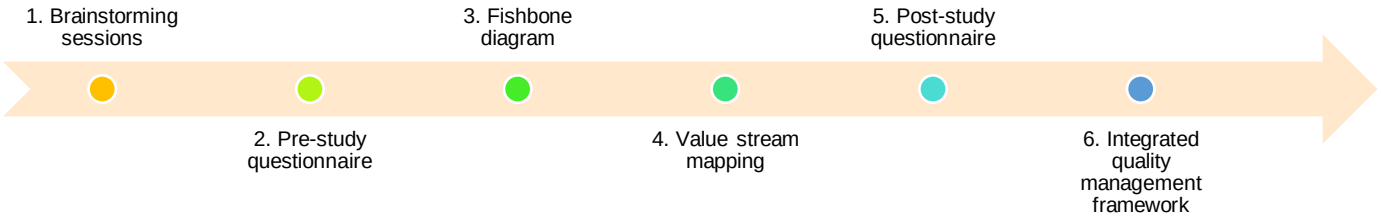

Figure 3.2: Overview of research framework undertaken for present study

Brainstorming sessions will be held with employees of Sappi's COE Technical department to understand the causes/challenges behind the repeat work of ageing kinetics, viscose production and application tests within a project. More details on the facilitation of the sessions are presented below.

A pre-study questionnaire (Appendix B) will be used as a primary source for data collection. The questionnaire design is explained in-depth, below. Simple bar charts will be used to highlight the most frequently occurring causes of repeat work and waste production that contribute to the delay in results during ageing kinetics, viscose production and application tests. Numerical values are represented by height or length of lines or rectangles of equal width, to compare numerical data by size or importance (Dando 2014). According to Helouvry, Strohl and Williams (2015), bar charts can also be used to illustrate ranking, part to whole percentages, deviation or distribution between categories or groups.

Information obtained on ageing kinetics, viscose process and application tests from the questionnaire and brainstorming sessions held will be visualised using a fishbone diagram. This diagram is an appropriate and general technique of graphical representation to explore and clearly and simply categorise the potential root causes of the evolution of technological innovations for an appropriate management of technology (Coccia 2018). The benefits of using a fishbone diagram to graphically represent findings was highlighted in Chapter 2.

VSM will be applied to the ageing kinetics, viscose production, and application tests to visualise processes with key quality indicators and control loops noted. VSM is an effective tool of LM to reduce the wastage in any process by segregating VA and NVA activities (Verma and Sharma 2016; Durur and Akbulut 2019), in addition to assisting with visualisation and rationalisation of processes and its use in the context of a real enterprise (Rohac and Januska 2015). The extensive benefits of VSM used in a process were described in Chapter two. The following steps will be undertaken to gather information required to complete the VSM of the process at Sappi COE (Figure 3.3).

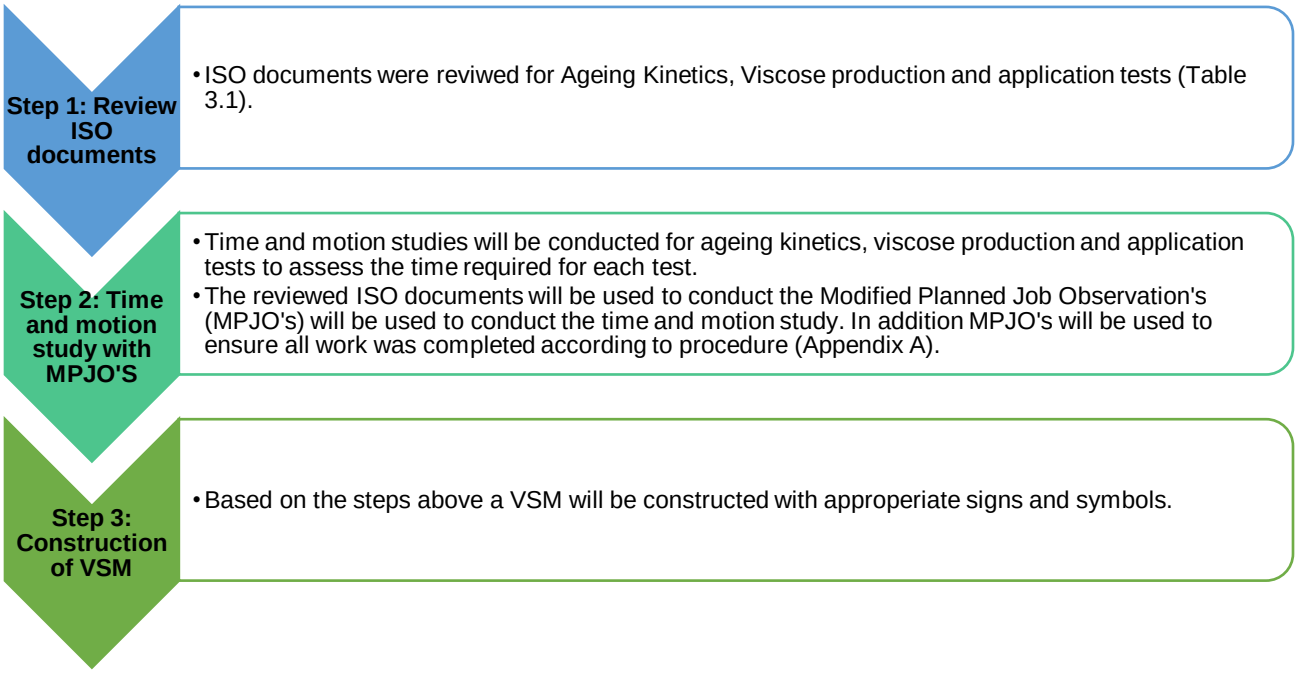

Figure 3.3: Steps used to gather information required for VSM

Table 3.1: Reviewed ISO documents for ageing kinetics, viscose production and application tests

Documents		Document numbers	First Revision	Second Revision	Accepted	Updated on the intranet
1	Steeping Small Scale	VISC 001	05/05/2022	16/05/2022	18/05/2022	X
2	Pressing Small Scale	VISC 002	22/06/2022	23/06/2022	18/07/2022	X
3	Shredding Small Scale	VISC 003	19/05/2022	07/06/2022	13/06/2022	X

Documents		Document numbers	First Revision	Second Revision	Accepted	Updated on the intranet
4	Viscose Ageing	VISC 013	09/03/2022	04/05/2022	18/05/2022	X
5	Alkcell Ageing Curves	VISC 014	06/07/2022	23/08/2022	07/09/2022	X
6	Sampling of Viscose Dope	VISC 026	18/08/2022	20/08/2022	07/09/2022	X
7	Cellulose In Viscose (CIV)	VISC TEST 013	13/07/2022	26/07/2022	03/08/2022	X
8	Alkali Cellulose Analysis - CiA and SiA	VISC TEST 014	18/08/2022	24/08/2022	07/09/2022	X
9	Hottenroth	VISC TEST 016	18/08/2022	24/08/2022	07/09/2022	X
10	Soda In Viscose (SIV)	VISC TEST 017	07/07/2022	23/08/2022	07/09/2022	X
11	Filterability (Kw)	VISC TEST 019	20/09/2022	27/09/2022	28/09/2022	X
12	Xanthation of Alkcell	VISC PREP 001	20/09/2022	27/09/2022	28/09/2022	X
13	Dissolving and Ripening	VISC PREP 002	20/09/2022	27/09/2022	28/09/2022	X
14	Ball fall	VISC TEST 009	20/09/2022	27/09/2022	28/09/2022	X

After possible causes are identified, an IQMS will be developed and implemented. In order to evaluate the effectiveness of the IQMF, a post-study questionnaire (Appendix C) will be self-administered to employees of Sappi's COE Technical department and Technical teams that have participated in the pre-study.

3.5 DATA COLLECTION METHODS

3.5.1 Target population and sample size

Depending on the type of research undertaken, an appropriate method of sampling is required to ascertain crucial information to satisfy research questions and study objectives. Sampling may be defined as the process through which individuals or sampling units are selected from the target population (Martínez-Mesa *et al.* 2016). Sampling techniques provide a range of methods that enable the researcher to minimise the amount of data required; by considering data collected from a representative subgroup, instead of the entire larger population.

Sampling techniques can be divided broadly into two categories: probability/representative sampling and non-probability/judgemental sampling. In addition, unique cases may allow data to be collected from the entire sample or smaller populations (Acharya *et al.* 2013; Saunders *et al.*2009). This type of sampling is termed census sampling (Martínez-Mesa *et al.* 2016; Saunders *et al.* 2009). Figure 3.4 depicts sampling types used by researchers in scientific studies.

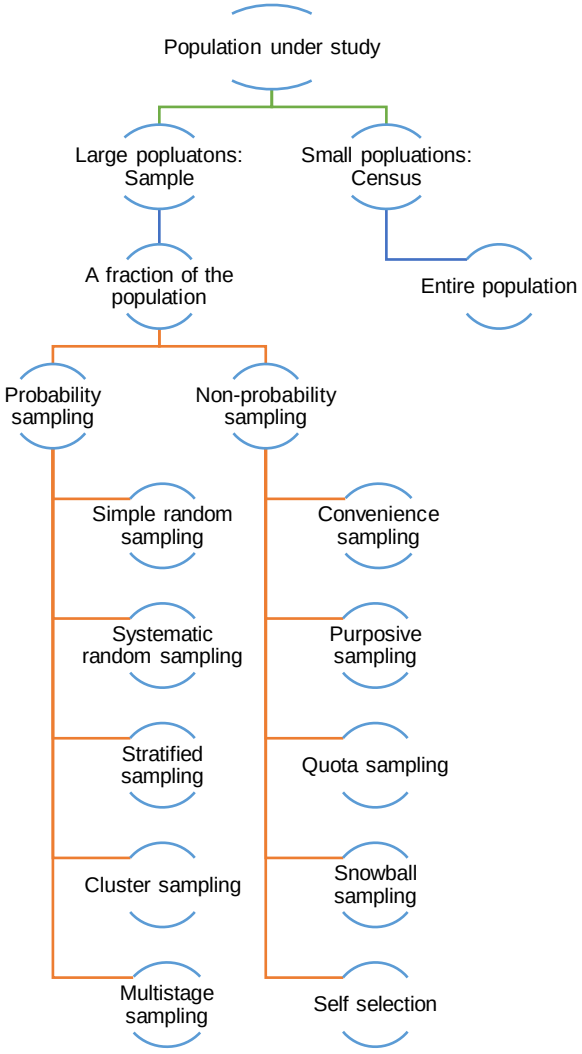

Figure 3.4: Sampling types used by researchers in scientific studies

Source: Adapted from Saunders et al. (2009) and Martínez-Mesa et al. (2016)

3.5.2 Probability sampling

Probability sampling ensures the chance or probability of each individual being selected from the population is known and is usually equal for all cases (Acharya *et al.* 2013; Saunders *et al.* 2009). It is then possible to answer research questions and achieve objectives that require one to estimate, statistically, the characteristics of the population from the sample. Consequently, probability sampling is often associated with survey and experimental research strategies (Saunders *et al.* 2009). Table 3.2, describes and discusses the different types of probability sampling (Acharya *et al.* 2013; Saunders *et al.* 2009; Martínez-Mesa *et al.* 2016).

Table 3.2: Types of probability sampling

Probability sampling type	Definition
Simple random	Simple random sampling, sometimes called random sampling, is the process of choosing a sample at random from the target population. Random number tables or an online random number generator, like Research Randomiser, are used in this kind of sampling. If the researcher has access to a precise and easily readable sample frame that includes a list of every member of the population ideally saved on a computer then simple random sampling may be a good option.
Systematic random sampling	Selecting participants from a ranked list of participants at predetermined intervals is known as systematic random sampling. Either a small or big number of cases can be successfully handled with this form of sampling. If in-person interaction is not necessary for the purpose of data collection, it works effectively for situations that are geographically scattered.
Stratified sampling	The process of stratified sampling entails segmenting the target population into several groups. Next, within each stratum, the samples are chosen using either systematic random selection or basic random selection. Furthermore, the total number of candidates for each stratum may be constant or directly related to the stratum's size. Each person has an equal chance of being chosen to take part in the research.
Cluster sampling	Stratified sampling and cluster sampling share several characteristics. Prior to the start of the sampling process, the population needs to be split into distinct groups. The groups referred to as clusters are based on naturally occurring groupings, such as the kind of manufacturing company, the location, the availability of schools and health services, and so forth. Instead of the entire list of people in a population, the sample frame in cluster sampling is the entire list of clusters. Next, a few clusters are chosen via basic random sampling from the sample frame. Subsequently, information will be gathered from every person in the chosen cluster.

Probability sampling type	Definition
Multi-stage sampling	Multi-stage cluster sampling is a substitute term for multi-stage sampling. It is frequently used to get around issues with a geographically separated population when in-person communication is necessary or when it would be too costly and time-consuming over a wide geographic area. This method can be applied to any discrete group, just as cluster sampling. Taking a sequence of cluster samples, each utiling some kind of random sampling, is known as multi-stage sampling. Multi-stage sampling is seen to depend on a number of distinct sampling frames. Basically, it is the researcher's responsibility to make sure the various sampling frames are all suitable and accessible. Stratified sampling approaches can be employed to guarantee suitable representation of the sample and minimise the effects of picking progressively smaller sub-groups.

3.5.3 Non-probability sampling

The concept of non-probability sampling can be defined as a deviation from the principles of probability sampling. In most cases, this means units with unknown probabilities are included, or some probabilities are known to be zero (Vehovar, Toepoel and Steinmetz 2016). According to Etikan and Bala (2017), non-probability sampling can be defined as a sampling technique that does not assume the probability that elements in the universe will be included in the study sample. Non-probability sampling can be observed using five different methods of sampling techniques: convenience, purposive, quota, and snowball, as well as self-selection sampling. Table 3.3 describes and discusses the different types of non-probability sampling (Acharya *et al.* 2013; Etikan and Bala 2017; Saunders *et al.* 2009).

Table 3.3: Types of non-probability sampling,

Non-probability sampling type	Definition
Accidental or convenience sampling	Selecting the examples that are simplest to collect, like people who are randomly interviewed at a shopping centre, is the aim of this sampling technique. The sample selection procedure will be carried out until the necessary sample size is attained. Because cases are only included in the sample because they are easy to get, this sampling strategy, although widely used, is vulnerable to bias and influence outside the researcher's control.
Purposive sampling	Another name for purposeful sampling is judgmental sampling. Using this kind of sampling, the researcher can choose participants based on their judgment. This makes it possible for the researcher to address particular research questions and accomplish the study's goals. This sampling

Non-probability sampling type	Definition
	strategy is frequently applied in case study research when working with relatively small samples, specifically when the researcher wants to gather exceptionally instructive cases.
Quota sampling	Since quota sampling is completely non-random, it is highly valued for use in surveys that involve interviews. Since the sample variability for quota variables is equal to that of the entire population, this method makes the assumption that the sample will accurately represent the population. The selection of cases within a stratum is completely non-random, quota sampling can be thought of as a sort of stratified sample.
Snowball sampling	When it is difficult to identify the desired member of the population, the snowball sampling approach is frequently used. Creating the first contact is one of the challenges of snowball sampling. When this is overcome, these people will find more people in the population, who will find more people, and so on, and the sample keeps growing. Because respondents are more likely to recognize possible respondents who are similar to themselves, this kind of sampling introduces certain concerns, such as bias, resulting in a homogeneous sample.
Self-selection sampling	The researcher gives everyone the opportunity to express their interest to participate in the study, self selection sampling takes place. As a result, the researcher needs to inform the public about the need for the cases, either by requesting them to participate or by advertising in the relevant media. From those who reply, information will be gathered.

3.5.4 Census sampling

Census sampling appeals as a sampling method for small populations, because it eliminates sampling errors and provides valuable data on all individuals in the population. In addition, the expenses for designing the questionnaire and creating the sample frame are "fixed," which means they won't change whether the sample size is 50 or 200. To reach a desired degree of precision, the entired population must be sampled using smaller populations (Singh and Masuku 2014).

According to Saunders *et al.* (2009), sampling strategies rely on the viability and sensibility of data collection to address the objectives to the full population and to address the research issue or questions. In general, it makes more sense to get data from every member of a population under fifty. Saunders *et al.* (2009) and Kasiulevičius, Šapoka and

Filipavičiūtė (2006) highlighted statistical analysis usually requires a minimum sample size of 30 elements for investigation.

The census method for data collection was used in this project, since the population size of Sappi COE is smaller than 50; therefore, the sample size for this study is 40. Since the questionnaire is based on practical experience and knowledge, as opposed to general perceptions, the target population includes Sappi employees from the COE laboratories and Technical teams employed for a minimum period of one year. The target population comprised Senior Scientists, Scientists, Technologists, and Senior Analysts, as well as Analysts, who are knowledgeable and familiar with the laboratory tests and processes and have been a part of a project within the section.

The sample size is based on the number of individuals available within COE laboratories and Technical teams with adequate experience and knowledge that meet the study inclusion criteria. The questionnaire will take approximately 30 minutes to complete. Brainstorming sessions with Technologists and Senior analysts/Analysts were held separately, using interview guidelines stipulated below. Each session lasted for approximately 1.5 to two hours.

3.5.5 Inclusion and exclusion criteria

Inclusion criteria for eligible participants:

- Educational background and experience: A suitable participant should have Chemistry/Chemical Engineering or Pulp and paper background or at least one year of working experience in a laboratory facility, with an understanding of viscose production, ageing kinetics and application testing.
- Types of occupations: Lead Scientist, Senior Scientists, Scientists, and Technologists, as well as Senior Analysts and Analysts.

Exclusion criteria for participants:

- No educational background in Chemistry/Chemical Engineering or Pulp and paper background.

- Less than one year of working experience in a laboratory facility with no experience in viscose production, ageing kinetics, and applications tests.

3.5.6 Questionnaire design

According to Saunders *et al.* (2009), the greatest use of questionnaires is made within the survey strategy of business and management research. It can be used for both experimental and case study research strategies. There are, nevertheless, several definitions of what a questionnaire means. Some authors reserve it exclusively for respondents answering questions, recording their own answers, while others use it as an umbrella term to include interviews that are administered either face-to-face or telephonically (Oppenheim 2000).

As per the definition of Sun (2015), a questionnaire can be used as a general term to include all techniques of data collection, in which each respondent is asked to respond to the same set of questions in a predetermined order. This type will be used for the purpose of this study. It is imperative that the questions chosen to take into account the subject matter, how each question is worded, and the intended response. In order to guarantee that the replies are legitimate for assessing the things they are intended to test, each question needs to be carefully considered in terms of its appropriateness for the study. To ensure that the participants do not misunderstand the abstract, the questions chosen need to be carefully considered in the context of the whole document. It was noted questionnaires are not particularly good to extract information for exploratory research or other research that requires a large number of open-ended questions (Saunders *et al.* 2009).

Questionnaires tend to be used for explanatory or descriptive research. Descriptive research will allow the researcher to recognize and characterise the variability in various occurrences. Examples of this type of study include questionnaires on attitudes and opinions as well as organisational procedures. Furthermore, the researcher will be able to investigate and clarify correlations between variables particularly cause-and-effect relationships through explanatory or analytical study (Atmowardoyo 2018; Saunders *et al.* 2009). Table 3.4 depicts several advantages and disadvantages of using a questionnaire to gain insight into an investigation (Sukdeo 2009).

Table 3.4: Advantages and disadvantages of using a questionnaire

Advantages	Disadvantages
Less expensive and a researcher can send questionnaires to a wide geographical area.	Questionnaires prevent probing, prompting and clarification of questions.
Can produce quick responses and results.	The identity of the respondent and the conditions under which the questionnaire was answered remains unknown. Possibility of anyone answering the questionnaire, other than the intended respondent, is amplified.
Respondents can complete the questionnaire at their convenience.	No opportunity to collect additional information.
Respondents can choose to remain anonymous.	A partial response is a possibility due to lack of supervision.
The opportunity for bias or errors caused by an interviewer are minimal.	Opportunity for low response rates when questionnaires are not returned on time.

3.5.7 Likert scale

According to Oppenheim (2000), the Likert Scale is commonly used, because it provides a less cumbersome procedure when compared to other types. A Likert-type scale attempts to quantify a person's attitude towards various statements, where in this study, a scale from 1 to 5, with 3 being a neutral midpoint, was used. The scale is often tailored from strongly disagree to strongly agree. The participant would be required to rank an item on a scale from 1 (strongly disagree) to 5 (strongly agree) (Hurst and Bird 2018). Likert plots will be used to manage multi-dimensional presentation of the categorical data.

Questionnaires can be a useful tool to gather data on a specific subject (Hurst and Bird 2018). In light of the reviewed literature, the advantages and disadvantages will be taken into consideration when designing the pre- and post-study questionnaires. The questionnaire will adopt both open- and closed-ended questions, with the questions highlighting key variables that affect and contribute to repeat work within the organisation.

3.5.8 Pre-study Questionnaire

The pre-study questionnaire (Appendix B) will be used as the primary data collection instrument from the pre- and post-study questionnaires. It will be self-administered during individual sessions, to understand the possible factors that necessitate repeat work; hence, delays within a project from a team perspective. It will identify key areas for improvement within the process/tests.

3.5.9 Post-study questionnaire

A post-study questionnaire (Appendix C) will be used to check whether the findings from the pre-study questionnaire were closed out after the IQMF implementation or persisted as a reoccurrence. If the results were to be positive, this would allow Sappi to implement a similar framework in laboratories at various sites, to address similar issues that may occur within the laboratory setting. Should the post-study questionnaire reveal the findings from the pre-study questionnaire have not been closed out, more effective solutions would be investigated and employed to solve the reoccurring issues.

3.5.10 Statistical data analysis

The statistical data analysis for the quantitative data will be conducted using R Statistical computing software of the R Core Team, 2020, version 3.6.3. Results will be presented in the form of descriptive and inferential statistics. Where applicable, the descriptive statistics of numerical measurements will be summarised as the minimum, maximum, quartiles and interquartile range. On the one hand, the means, standard deviation and the coefficient of variation were not applicable, due to the asymmetrical distribution. On the other hand, the categorical variables were described as counts and percentage frequencies. Furthermore, Likert plots were used for handling multi-dimensional presentation of the categorical data, while thematic analysis identified key points using NVIVO 12.

A Fisher's exact test was performed when the distribution of the cross tabulations contained an expected value of less than five, and a Chi-Square test was utilised to ascertain the relationship between categorical variables. Following the omnibus testing (Chi-Square or Fisher exact test), a row-wise paired z-test was employed as a post hoc analysis in the event that there was a significant difference between the two tests. The Chi-square test of homogeneity can be used to evaluate a sample's goodness of fit its ability to fit the distribution of a known population or to examine the independence between two categorical variables. The Chi square test is frequently used to compare two or more conditions or groups on a categorical outcome (Turhan 2020). A threshold of 0.05 is used to decide whether the differences are considered significant. P-values below 0.05

are expected in the case where differences between rows and columns are so great they are not the consequence of randomness (Barceló 2018; Samuels 2020).

3.6 RELIABILITY AND VALIDITY OF INSTRUMENT

3.6.1 Reliability

Reliability of instruments such as questionnaires indicates accuracy or precision of the questionnaire and whether it performs consistently (Hurst and Bird 2018). According to Surucu and Maslakci (2020), reliability can be defined as the stability of the measuring instrument used and its consistency over time. In other words, will the instrument have the ability to measure similar results when applied at different times.

Table 3.5: The most common forms of reliability measures

Types of reliability	Requirements to measure reliability
Cronbach's alpha	Calculating Cronbach's alpha is the first and possibly most popular method of assessing reliability in the creation of questionnaires. The degree to which each questionnaire question measures the same construct is determined by this computation, which yields an estimate of internal consistency. Cronbach's alpha can be calculated using most statistical software and is generally expressed as a number between 0 and 1 (Hurst and Bird 2018). It appears that the internal consistency increases with the number's proximity to 1. On the other hand, a weak correlation indicates that items can be assessing a variety of different attributes, whereas a perfect correlation of 1.0 indicates that questions are measuring a virtually same construct, leading to item redundancy (Taber 2018; Hurst and Bird 2018). It has been suggested coefficients above 0.70 and close to 0.90 suggest good internal consistency. It is important to note alpha scores reported on a questionnaire on one set of participants may differ to that of a second set of participants. Therefore, Cronbach's alpha should be calculated each time the test is administered (Kelleher *et al.* 1997; Hurst and Bird 2018, Taber 2018; Croasmun and Ostrom 2011).
Test–retest	This particular type of reliability gauges how consistently responses change over time. If given to the same individual twice and no interventions, activities, or other events could have affected the responses between the two testing sessions, it has been shown that a questionnaire with strong test-retest reliability would yield results that are identical. The researcher can compute the correlation coefficient between the two questionnaire administrations to evaluate the test-retest reliability (Hertzog 2008; Hurst and Bird 2018).
Spilt-half	This type of reliability assesses how consistently a questionnaire measures a given construct when its questions are comparable. The questionnaire's questions are divided into two equal halves, typically by first and second half or odd and even numbers, and the correlation between the two halves is evaluated. The dependability increases with the correlation between the two halves. Researchers should be aware that when a questionnaire evaluates

Types of reliability	Requirements to measure reliability
	more than one construct (such as vigour and self-esteem), they cannot employ the split-half method (Hurst and Bird 2018).
Henrysson's item–rest correlation	The conventional estimators of item-score connection that are most frequently employed are item-rest correlation, item-total correlation, and item-test correlation. It is incorporated as the weighting factor between the item and score variables in the most widely used reliability estimators (Metsämuuronen 2022). Item-to-total correlations, in general, quantify the connection between each item and the overall scale. Item-to-total correlations are computed to produce a correlation for every item on the scale. Items unable to achieve high correlation can be deleted from the instrument (LoBiondo-Wood and Haber 2013). Literature indicates item-rest correlations above 0.4 are considered acceptable as all questions are seen as relatable to the construct (Tapsir *et al.*2018; Metsämuuronen 2022).

Cronbach's alpha reliability analysis is commonly used to test the internal consistency of the measurement scale. Thus, achieving a value within the range of 0.7 to 0.9 indicates a high level of reliability. In addition, the item rest correlation is widely used as a classic estimator of item– score association and is embedded in the most often used estimators of reliability as the weighting factor between item and score variables, as indicated by the above literature (Table 3.5). The use of statistical tests, such as Pearson's correlation and item rest correlation, can be used to make the study more objective (Obilor and Amadi 2018; Saunders *et al.* 2009).

For this study, the internal consistency of a set of items was assessed using Cronbach's alpha and item-rest correlation. To improve the Cronbach's alpha, items with opposite scale direction were reversed and those suppressing the Cronbach alpha dropped. All the inferential statistical analysis tests were conducted at a five percent level of significance. Cronbach's alpha and item rest correlation were calculated on categories 1 to 7 from the pre-study questionnaires received from Sappi COE and Technical team participants. The questionnaire for this study contains eight categories and 78 questions, related to ageing kinetics, viscose production, and application tests. Cronbach's alpha was calculated on seven categories, consisting of 75 questions in total.

3.6.2 Validity

The validity of a questionnaire design reveals the degree to which an instrument measures the concept it is intended to measure and to aid the researcher in solving the

research problem (Saunders *et al.* 2009). Table 3.6, indicates the most common forms of validity measures (Hurst and Bird 2018; Surucu and Maslakci 2020).

Table 3.6: The most common forms of validity measures

Types of validity	Requirements to measure validity
Content validity	On completion of the questionnaire, the researcher must determine whether the questionnaire actually measures what it is intended to measure. The most effective way of examining content validity is through expert opinion. Experts within the field should examine the content validity of the items and ensure the questionnaire measures exactly what it is intended to measure.
Criterion validity	The ability of a new questionnaire to measure what it is supposed to measure is referred to as criterion validity. A clear and impartial indicator of what the new questionnaire is intended to measure should be used to evaluate it. For instance, if a participant's level of physical activity is being evaluated by the questionnaire, its criterion validity can be evaluated based on the actual quantity of physical activity they engage in, which can be detected using an accelerometer.
Construct validity (Convergent and Discriminant validity)	The degree to which a questionnaire relates to an established construct that is being measured is known as construct validity. One of the biggest obstacles to creating a questionnaire is this kind of validity. The two types of construct validity that can be utilised to prove a questionnaire's validity are discriminant and convergent validity. The degree of relationship between two measures of theoretical constructs is a sign of convergent validity. As an illustration, consider the correlation between a clinical depression questionnaire and other depression surveys. Convergent validity can be evaluated by calculating the correlation coefficient between two questionnaires. To determine whether the questionnaire can reveal differences between two or more population categories, discriminant validity is used. For instance, a questionnaire may be used to test the premise that those who exercise have a more positive attitude about exercise than those who do not. The questionnaire has discriminant validity since it shows that there are differences in views between those who exercise and those who don't.
Face validity	Face validity generally refers to the appearance and how easy the questionnaire is to read and understand. This type of questionnaire should avoid the use of technical language or terms that may not be easily understood by a person who does not have extensive knowledge in a specific field of study. Therefore, this format determines how easy it is for participants to read and understand the questions.

When a measuring instrument has a high level of validity, it implies the measuring instrument would achieve the desired outcomes of the research findings with a high level of confidence (Karlsson 2016; Saunders *et al.* 2009). Table 3.6 above indicates how content validity is used to determine whether the questionnaire covers the content of the

intended research by measuring the underlying construct. Content validity is considered a subjective form of measurement, because it still relies on people's perception for measuring constructs that would, otherwise, be difficult to measure. However it can be useful to attain discerning information from a target population (Abu-Bader 2021).

For the purpose of this study, content validity was established by sharing the instrument with professionals and experts who assessed and rated whether the instrument contained items that covered all facets of the construct under study. The professionals and subject matter experts selected included the COE General Manager, Operations Manager, Technical Manager Saiccor, and Lead Scientist, as well as Senior Research Scientists, Research Scientists and Technologists, who are subject-matter experts in viscose processes and applications tests. Figure 3.5 depicts the steps that can be taken to assess content validity of a questionnaire. According to Zamanzadeh et al. 2014, there are 3 critical steps that are required during content validation namely, development, judgment, and revision of the instrument. During the developmental stage the specific domain/s are identified in relation to the objective/s of the study. Items are then created under each domain to satisfy the research questions of the chosen study. Once the domain and items are established the research instrument is constructed (Figure 3.5). During the judgement stage the research instrument is sent out to lay experts for evaluation. The content validity ratio (CVR); item content validity index (I-CVI); scale content validity index (S-CVI) is calculated. In essence the comprehensiveness of the instrument is evaluated. During the revision of the instrument, feedback from the lay experts is taken into consideration as well as all item impact scores mentioned above to evaluate the effectiveness of the instrument to achieve the set-out objectives of the study. A similar procedure was adopted and followed during the course of this study (Figure 3.6). The content validity questionnaire can be viewed in Appendix D.

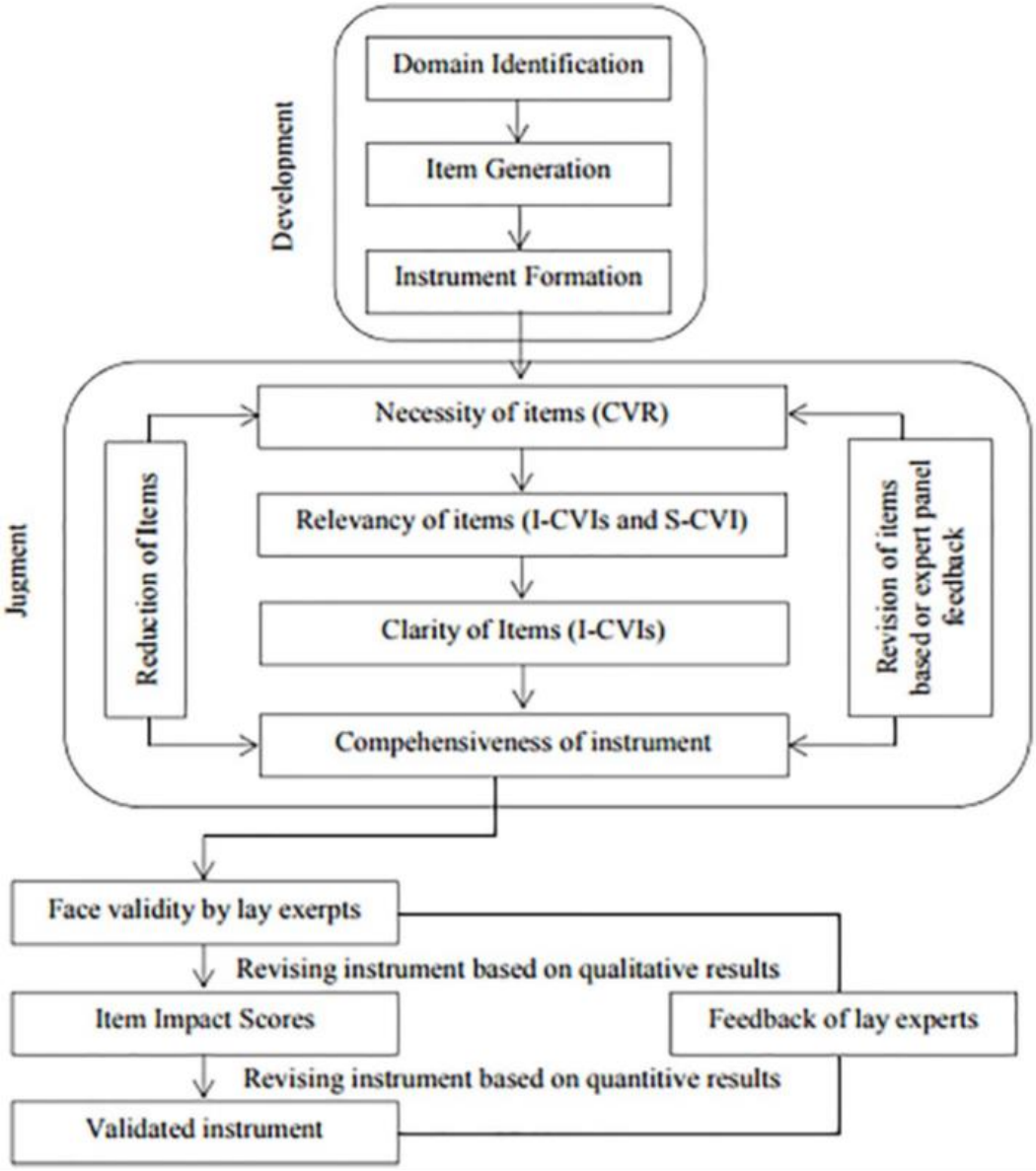

Figure 3.5: Steps involved in content validity

Source: Zamanzadeh et al. (2014).

Note. CVR = content validity ratio; I-CVI = item content validity index; S-CVI = scale content validity index.

Figure 3.6 outlines the steps involved in content validation for this study. During the development stage 8 domains were identified with 78 items generated in total to satisfy the objectives of this study. A content validation questionnaire was then constructed. During the judgement stage the necessity of items (CVR), relevance of items (I-CVIs and S-CVI) were calculated. Items were either retained or removed based on data collected to satisfy the research questions of this study. During the revision of the instrument,

feedback from Technical experts were taken into consideration as well as all item impact scores to evaluate the effectiveness of the instrument to achieve the set-out objectives of the study.

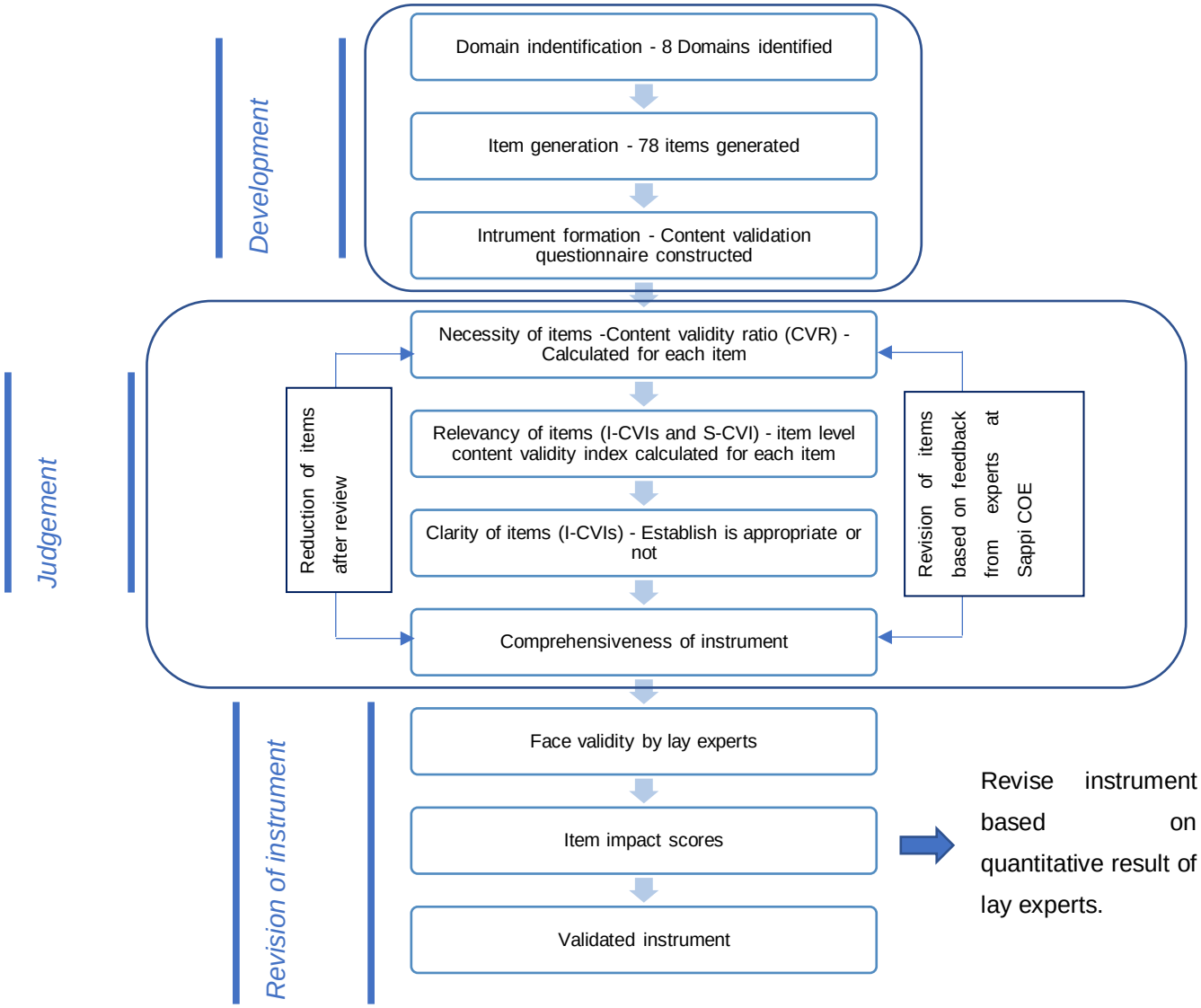

Figure 3.6: Steps involved in content validation at Sappi COE

3.6.3 Outline of content validation process at Sappi COE

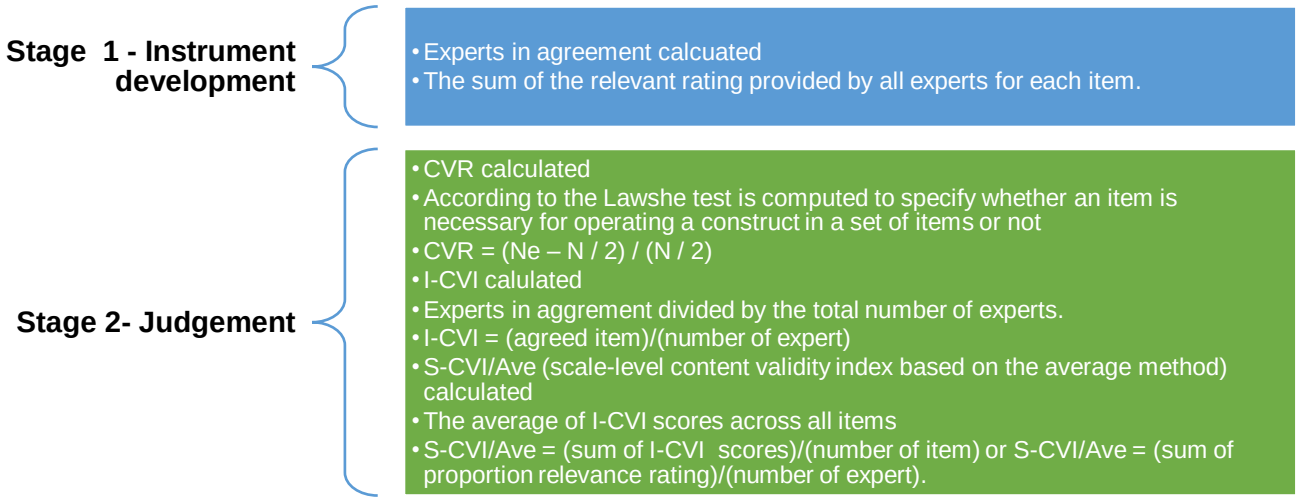

Figure 3.7: Content validation process undertaken at Sappi COE

The first stage of instrument development includes three steps; identifying the content domain, generating the sample items and constructing the instrument (Zamanzadeh *et al.* 2014). A content validation form was created (Appendix D), taking the above into consideration, while the content domain of the construct was obtained from literature reviewed, content analysis and focus groups (Figure 3.6). Figure 3.8 illustrates the instruction rating scale used for the content validation questionnaire. Prior to the statistical calculations, the relevance rating must be recoded as 1 (relevance scale of 3 or 4) or 0 (relevance scale of 1 or 2) (Yusoff 2019; Shrotryia and Dhanda 2019).

CONTENT VALIDATION QUESTIONNAIRE
Title: An integrated quality management framework to improve project throughput rate in a selected laboratory environment

Dear Experts,

Quality plays a crucial role in the business process within an organisation to improve efficiency and to be more effective in the global market. Improving quality and customer loyalty has a significant bearing on market share. A focus to reduce wastage, but also to satisfy customer's expectations, continuous cost reductions and continuous improvements are necessary to survive in a highly competitive environment. A significant amount of research has been carried out; which indicates that the application of quality management framework will assist to increase quality, reduce variability, and eliminate any waste produced. Therefore, the aim of this study, is to construct a quality management framework in Sappi COE laboratories; to improve project performance by reducing repeat work and eliminating waste to deliver results within the expected timelines. I would like to take this opportunity to thank you in advance for your willingness and time to participate in this questionnaire.

This questionnaire contains 8 domains (categories) and 78 items (questions) related to ageing kinetics, viscose production, and application tests. I require your expert judgement on the degree of relevance on each item to the measured domains. **Your review should be based on the relevant terminologies that are provided to you. Please be as objective and constructive as possible in your review and use the following rating scale:**

Degree of relevance:

1 = The item is not relevant to the measured domain
2 = The item is somewhat relevant to the measured domain
3 = The item is quite relevant to the measured domain
4 = The item is highly relevant to the measured domain

Dolyn Govender
Researcher
Student

Figure 3.8: Instruction rating scale used for the content validation questionnaire

In stage two, the selection of individuals to review and critique the instrument was undertaken, based on individual expertise on viscose, applications testing and processes. Experts were asked to rate the items on the basis of their relevance and necessity. Several researchers recommend the number of experts required for content validation should be at least six and should not exceed 10 (Polit and Beck 2006; Yusoff 2019; Shrotryia and Dhanda 2019).

The Content validity ratio (CVR) was calculated for each item. The CVR is an item statistic useful in the rejection or retention of specific items. Experts are requested to specify whether an item is necessary for operating a construct in a set of items (Zamanzadeh *et*

al. 2014; Gilbert and Prion 2016). Researchers Ayre and Scally (2014) undertook an investigation that encompassed validating the original critical values reported in Lawshe's paper. The use of the originally calculated CVR values from Lawshe (1975) yielded an equal value for the critical number of experts required, as shown in the exact calculations (Table 3.7). The findings suggest questionnaires and checklists developed using the CVR critical values originally reported by Lawshe (1975) remain valid. Items are either retained or eliminated, according to critical values from Table 3.7.

The formula for calculation of CVR = (Ne – N / 2) / (N / 2), in which Ne is the number of experts indicating "essential" and N is the total number of experts. The numeric value of CVR ranges from -1 to 1 (Lawshe 1975; Gilbert and Prion 2016). Once items have been identified for inclusion in the final form, the content validity index (CVI) is computed for the entire test (Zamanzadeh *et al.* 2014). Items with an item content validity index (I-CVI) of 0.78 or higher for three or more experts, indicates evidence of good content validity (Polit, Beck, and Owen 2007; Shrotryia and Dhanda 2019; Gilbert and Prion 2016). In addition, S-CVI/Ave based on I-CVI: the average of I-CVI scores across all items were calculated.

A simplified table (Table 3.7) shows CVRcritical, including how many experts are needed for an item to be considered essential (Ayre and Scally 2014; Lawshe 1975).

Table 3.7: Simplified table of CVRcritical with number of experts needed to deem an item essential

Panel size	Ncritical (minimum number of experts required to agree an item essential for inclusion)	Proportion agreeing essential	CVRcritical
5	5	1	1.00
6	6	1	1.00
7	7	1	1.00
8	7	0.875	0.750
9	8	0.889	0.778
10	9	0.900	0.800
11	9	0.818	0.636
12	10	0.833	0.667
13	10	0.769	0.538

Panel size	Ncritical (minimum number of experts required to agree an item essential for inclusion)	Proportion agreeing essential	CVRcritical
14	11	0.786	0.571
15	12	0.800	0.600
16	12	0.750	0.500
17	13	0.765	0.529
18	13	0.722	0.444
19	14	0.737	0.474
20	15	0.750	0.500
21	15	0.714	0.429
22	16	0.727	0.455
23	16	0.696	0.391
24	17	0.708	0.417
25	18	0.720	0.440
26	18	0.692	0.385
27	19	0.704	0.407
28	19	0.679	0.357
29	20	0.690	0.379
30	20	0.667	0.333
31	21	0.677	0.355
32	22	0.688	0.375
33	22	0.667	0.333
34	23	0.676	0.353
35	23	0.657	0.314
36	24	0.667	0.333
37	24	0.649	0.297
38	25	0.658	0.316
39	26	0.667	0.333
40	26	0.650	0.300

During the course of the study, content validation will be carried out on the questionnaire to verify whether the questionnaire was effective in measuring the study construct. The content validation results of the instrument will be explained in chapter 4.

3.7 BRAINSTORMING/FOCUS GROUP SESSIONS

It has been noted many researchers use a questionnaire to collect data, without consideration of other methods, such as examination of a secondary source. Although questionnaires may be used as the only data collection method in some instances, it may be beneficial to the researcher to couple this with other methods. These include, but are

not limited to observation, semi structured or unstructured interviews and brainstorming sessions (Geer *et al.* 2006; Saunders *et al*. 2009; Sukdeo 2009). According to Ramos (2003), brainstorming sessions are an intuitive and spontaneous process. There is no hierarchy. The world of ideas does not recognise rank, experience, or compensation levels. An environment of comfort must be created were senior members share information; facilitating a discussion where junior members feel safe in contributing their own ideas.

A secondary method of data collection comprised brainstorming sessions held with two different focus groups. Brainstorming sessions were initially held with Analysts and Senior Analysts. The second brainstorming session was with Technicians and Scientists. these sessions were carried out to understand the causes/challenges behind the repeat work of ageing kinetics, viscose production, and application tests within a project, supplementary to the questionnaires provided. An interview guide was prepared to facilitate healthy discussions between employees and the researcher (Table 3.8).

Table 3.8: Interview guide used to facilitate brainstorming sessions

Interview guide:
Preamble: Permission to record
1. General project concerns:
1.1 What are your difficulties during a project (time management, project deadlines inadequate and other issues you may encounter)?
1.2 Do you feel your tasks and objectives are clearly defined?
2. Project communications:
2.1 What are your general perceptions on communication within a project?
2.2 How can communication be improved within a project?
3. Scheduling and estimating:
3.1 Do you feel the time allocated for tasks within a project is fair?
3.2 How can time management be improved?
3.3 How can allocation of tasks be improved?
4. Ageing Kinetics:
4.1 What are the critical steps in ageing kinetics?
4.2 Which of the above-mentioned steps should be reviewed to improve the test?
5. Viscose production:

Interview guide:
5.1 What are the critical steps in viscose production?
5.2 Which of the above-mentioned steps should be reviewed to improve the test?
6. Application tests (SIV, CIV, Ball fall, KW filtration, Particle counts, Rheology):
6.1 Which of the above tests frequently results in repeats? In your opinion why does this occur?
6.2 From all the application tests which is the most difficult and time consuming to perform?
6.3 How can this test be improved?
7. Training and documentation:
7.1 How can training be improved?
7.2 Is the time allocated for training realistic?
8. General questions and concerns to be noted.

3.8 PILOT WORK

The pilot study assists to refine the measuring instrument, such that participants can easily answer questions and provide data without difficulty (Van Teijlingen and Hundley 2010; Hertzog 2008). According to Brooks, Reed, and Savage (2016), the benefit of pre-testing questionnaires includes identification of ambiguous questions and problems commonly encountered with wording or measurements. The target population for the pilot study consisted of Lead Scientists, Senior Scientists, Scientists, and Technologists as well as Senior Analysts from the Sappi COE Technical department. Ten participants were required to voluntarily complete the questionnaire.

The target population chosen for the pilot study had ample experience in ageing kinetics, viscose production and application tests; hence, their feedback will be used to streamline questions towards the study objectives. Data from the pilot study indicated the questions were easy to comprehend and free from ambiguity. However, minor grammatical errors were noted, with appropriate changes made to the main study questionnaires. It must be noted participants for the pilot study did not form a part of the main study.

3.9 SUMMARY OF THE CHAPTER

The focus of this chapter was to outline the research design of the present study, through detailed information sources and explanations of existing research philosophies and methodologies. The research design adopted a mixed methods approach, using both quantitative and qualitative methods of data collection. Pre- and post-questionnaires were

used to gain insight into the challenges experienced in Sappi COE laboratories. Brainstorming sessions held were a secondary method of data collection. In addition, a pilot study was conducted to verify the data collection instrument. Results indicate the instrument will be successful in ascertaining relevant information required to satisfy the study objectives. Planned job observations included collecting information required for completion of VSM of the processes in question. A detailed analysis of the main study is presented in the following chapter.

CHAPTER 4

ANALYSIS OF RESULTS AND DISCUSSION OF FINDINGS

4.1. INTRODUCTION

This chapter will discuss the results obtained from the pilot study as well as the main study. The breakdown of this chapter is depicted in the diagram below (Figure 4.1).

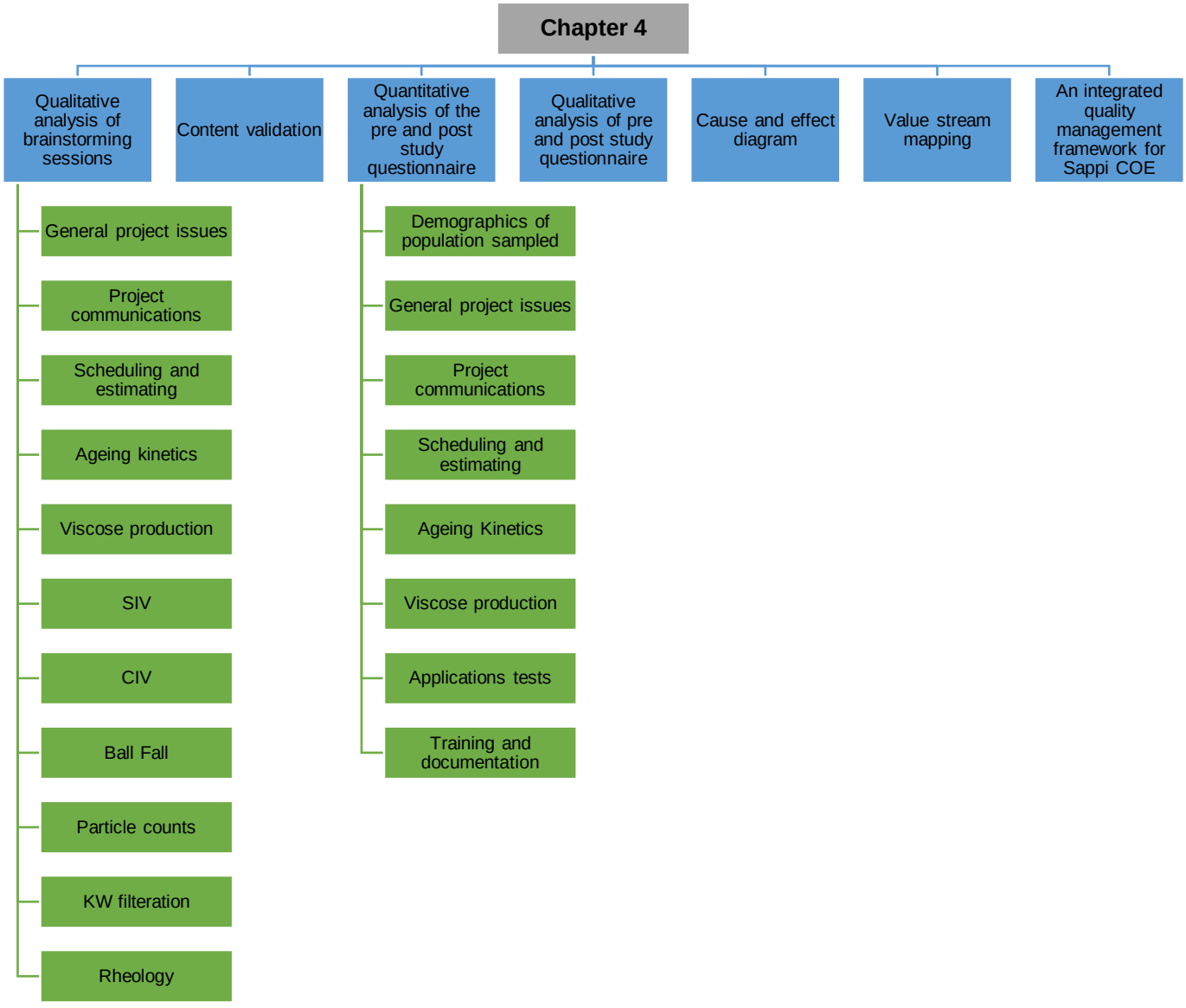

Figure 4.1: Schematic breakdown of Chapter 4

The findings from the brainstorming sessions will be discussed in detail in this chapter. Content validation will be analysed to establish the suitability of the questionnaire to achieve the objectives set out in this study. The statistical methods used to analyse the data presented by the pre and post questionnaire such as, Item-rest correlation, Cronbach's alpha and Nvivo 12, will be discussed in this chapter. In addition, P–values were used to distinguish degree of relevance from the pre- and post-studies. A cause-and-effect diagram will be used to analyse the overall findings of the brainstorming session and the pre-study questionnaire.

The findings from VSM conducted in Sappi COE will be deliberated in detail. The findings from the post study will be presented and discussed, together with the findings of the pre-study questionnaire, with finally, an analysis and detailed examination of the integrated quality framework.

4.2. QUALITATIVE ANALYSIS OF BRAINSTORMING SESSIONS

Brainstorming sessions are an effective mechanism to generate understanding and gain insight into the research participant's world. In addition, the aim of the brainstorming session was to gather the opinions from the research participants (Greenwood *et al.* 2017). Brainstorming sessions were initiated with two focus groups independently, that is, with the Analysts/Senior Analysts and Technicians/Scientists. Prior to commencement of the sessions a request was made to record the session. However, the request was declined by the participants. Instead, minutes were taken to ensure traceability (Appendix E). Each session took approximately two hours. An interview guide (Table 3.8) was prepared to steer the session in a particular direction to attain information that will assist with answering the research questions posed in Chapter 1. The section below represents a summary of the responses attained during brainstorming sessions held with the various focus groups around key aspects of ageing kinetics, viscose production and applications tests.

Technologists, at Sappi's COE department forms an integral part of the hierarchy within the department. They serve as the link between the Management sponsor (MS) and the Analysts/Senior Analysts. They are responsible for managing projects within the laboratory assigned to them via the project pipeline system. Projects are assigned based

on the availability of a Technologist, at the time. Therefore, a Technologist serves as a project manager (PM). Projects are ranked according to priority and then resource availability. Each Technologist has ample knowledge of ageing kinetics, the viscose process and application tests. In addition, each Technologist has managed several projects, therefore they were able to provide valuable input during the brainstorming session held. Figure 4.2 to 4.4 illustrates information gathered through the brainstorming session held with the Technologists on the various aspects around ageing kinetics, the viscose process and application tests.

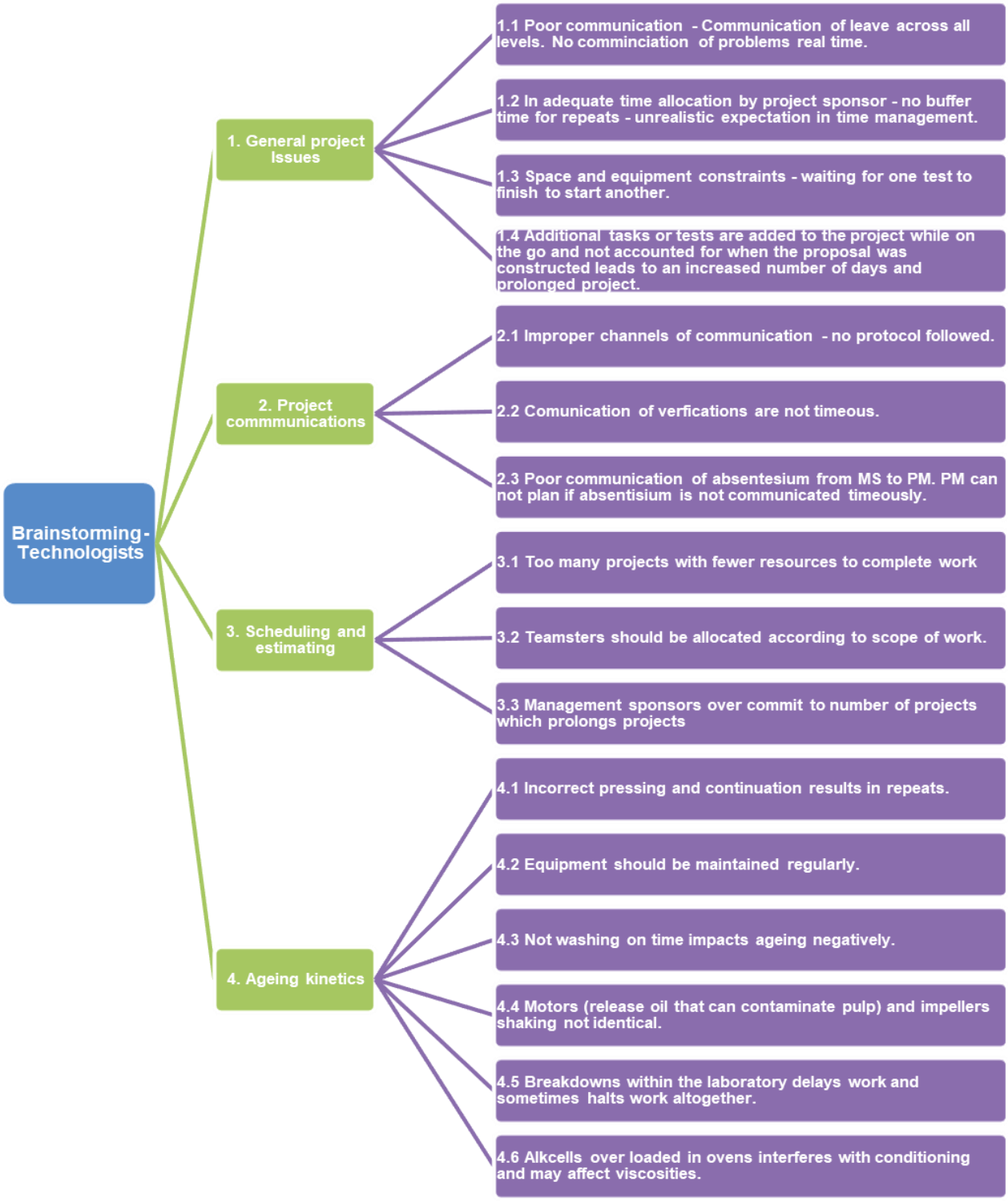

Figure 4.2: Findings from brainstorming session held with Technologists

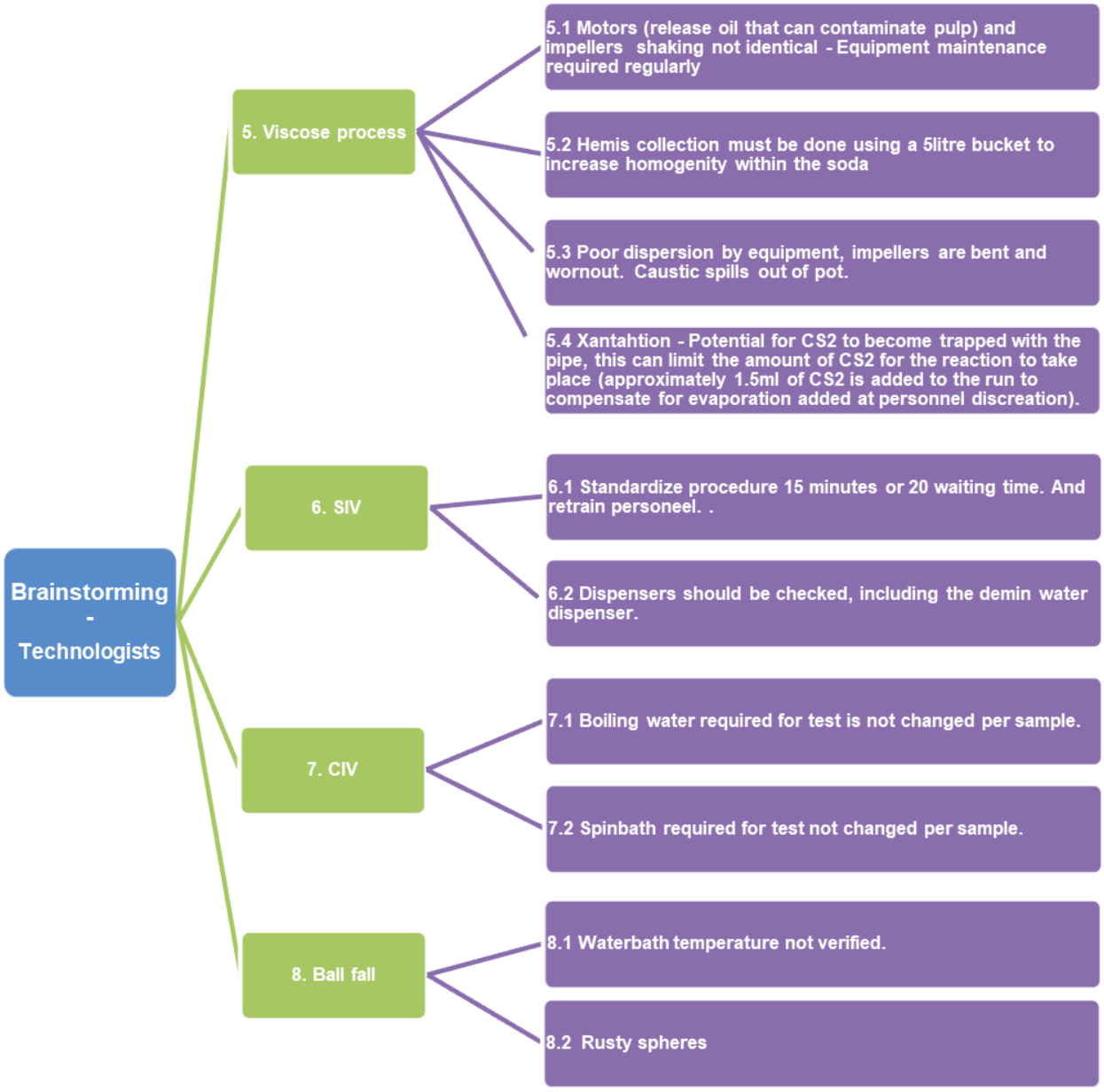

Figure 4.3: Findings from brainstorming session held with technologists (continued)

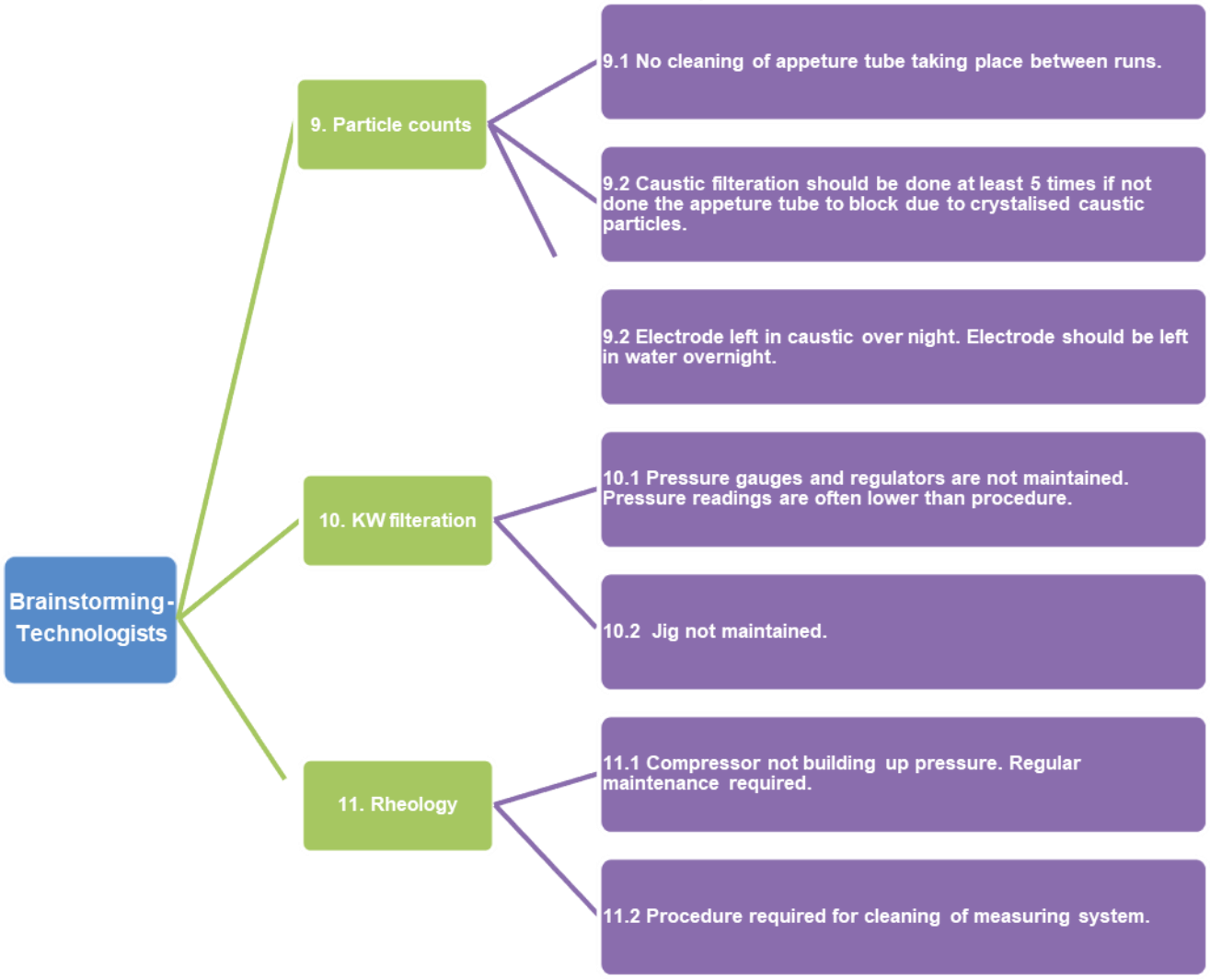

Figure 4.4: Findings from brainstorming session held with technologists (continued)

At Sappi COE Analysts and Senior Analysts play a vital role in conducting all critical tests within the laboratory such as ageing kinetics, viscose production and application tests. Each Analyst/Senior Analyst forms part of a team within the project. They have ample knowledge of the equipment used for each test as well as the critical parameters associated with each test. This allows the Analyst/Senior Analyst to easily identify areas of improvement. Figures 4.5 to 4.7 illustrate information gathered through a brainstorming session held with Analysts and Senior Analysts.

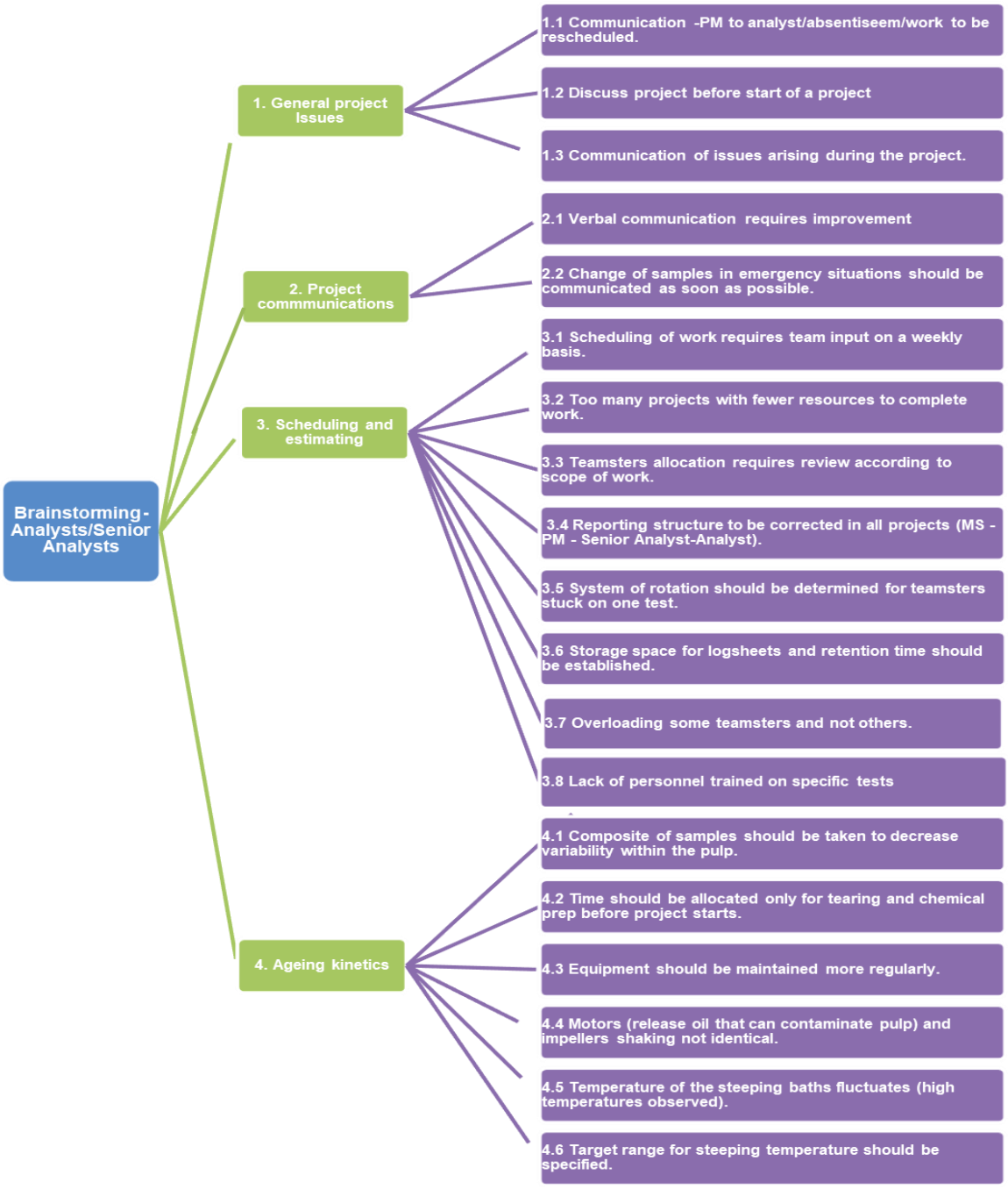

Figure 4.5: Findings from brainstorming session held with Analysts and Senior Analysts

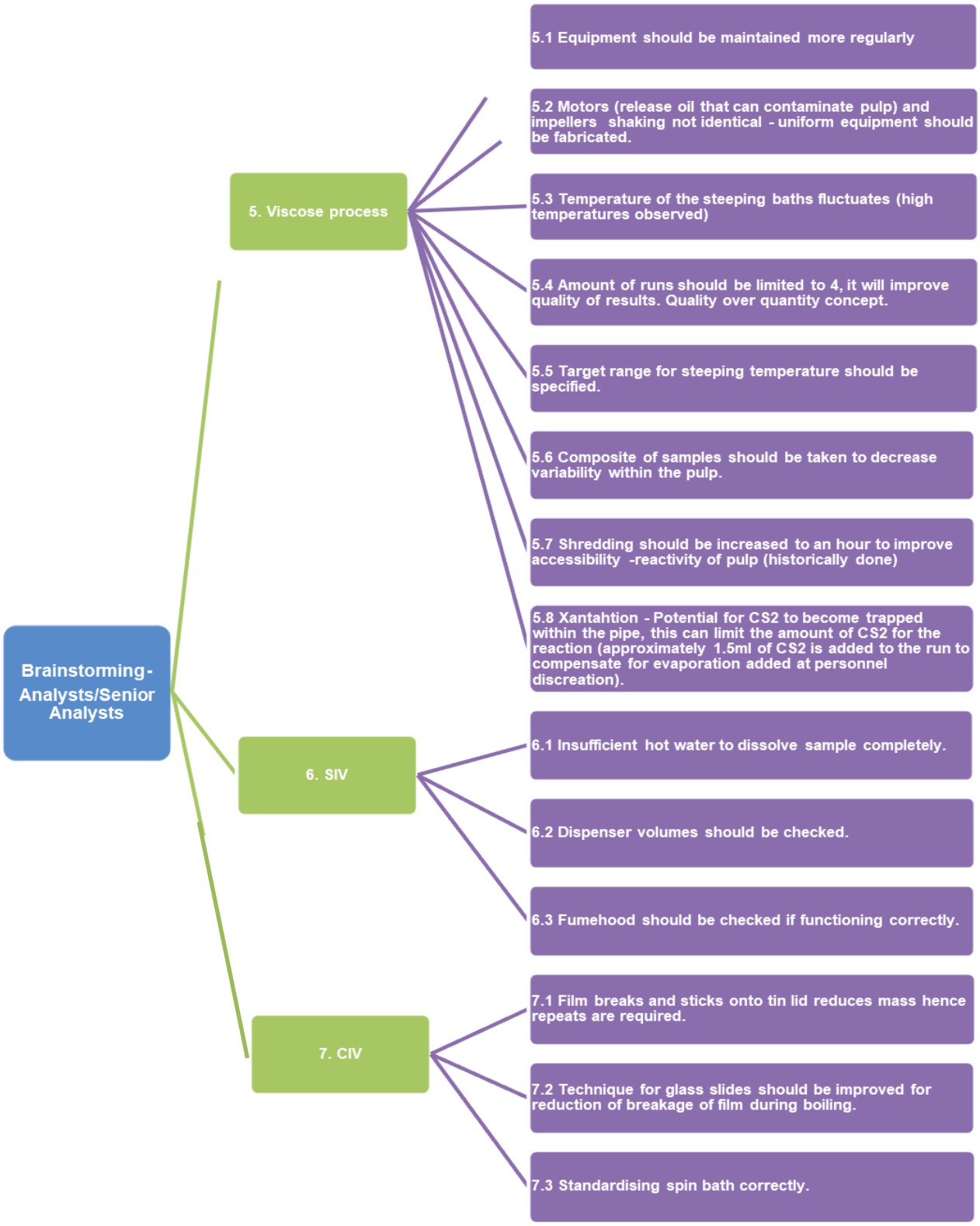

Figure 4.6: Findings from brainstorming session held with Analysts and Senior Analysts (continued)

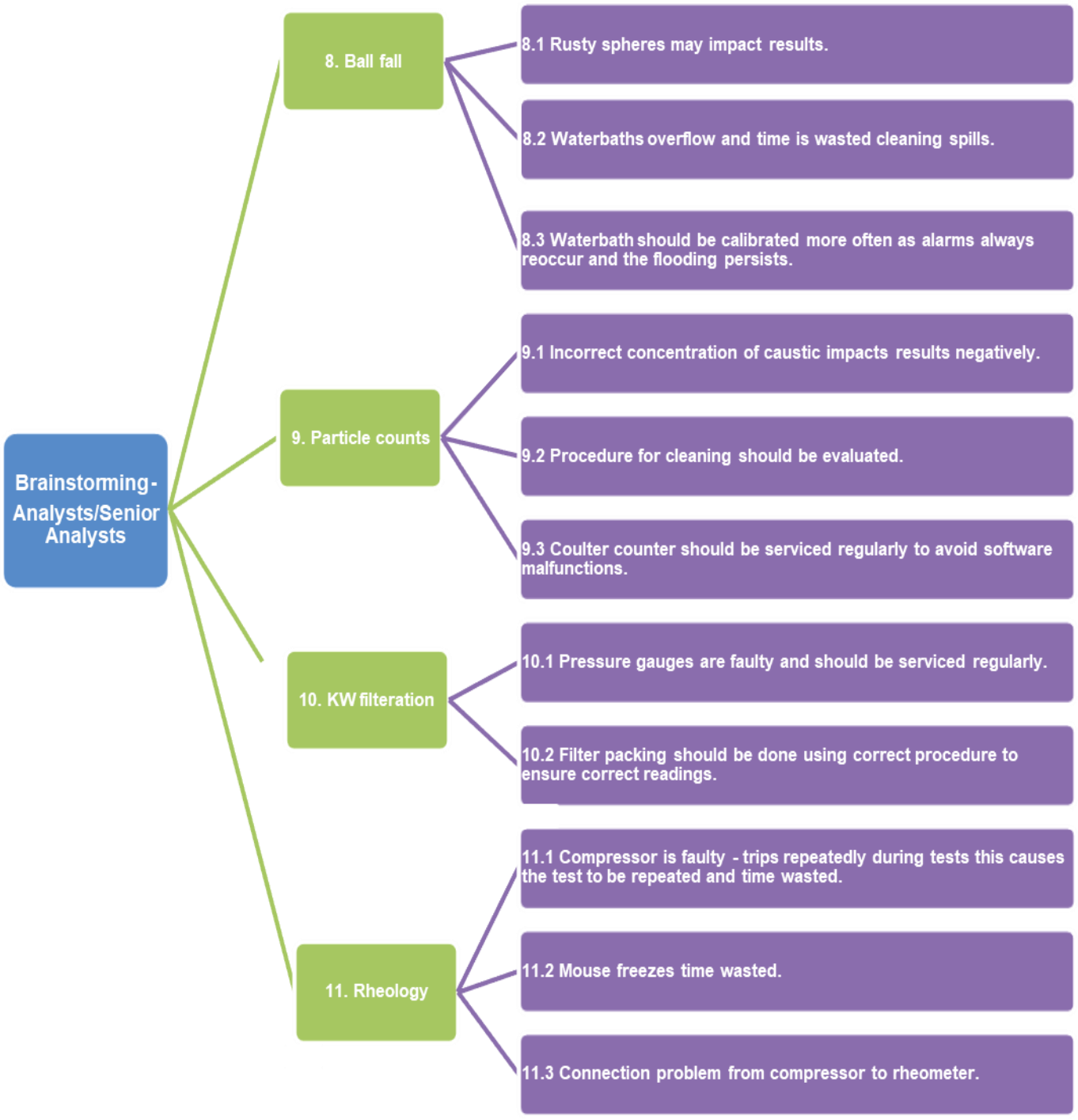

Figure 4.7: Findings from brainstorming session held with Analysts and Senior Analysts (continued)

Common findings of the constructs analysed from brainstorming sessions held with the Technologists and Analysts/Senior Analysts are listed below.

4.2.1 General projects issues

Space and equipment constraints are a common issue for example, the Fock test must be stopped or completed before the start of the Pentosan test. Additional tasks or tests are added to the project by the MS, while the project is on and not accounted for when the proposal was constructed. This leads to an increased number of days and a prolonged project.

4.2.2 Projects communications

Improper channels of communication are used and protocol/s are not followed. Results also imply poor communication of absenteeism, which affects project schedules negatively. Furthermore, communication of verifications is not timeously carried out.

4.2.3 Scheduling and estimating

The MS may commit to several projects with fewer resources available that can prolong each project. Teamsters are, furthermore, not allocated according to scope of work. In addition, results imply uneven work distribution.

4.2.4 Ageing Kinetics

It has been noted during steeping, motors leak oil into samples. The impellers are bent, resulting in excessive vibrations that displace caustic from the steeping pot. Teamsters have mentioned the temperature of steeping baths fluctuate, resulting in incorrect temperature while steeping. Teamsters further indicated the target range for steeping temperature should be specified. In addition, alkcell cakes are overloaded in ovens resulting in poor conditioning; this may affect the ageing curves negatively.

4.2.5 Viscose process

Due to the same equipment being used for steeping of samples for viscose production similar issues have surfaced such as the motors leak oil into samples being steeped as well as damaged impellers used results in excessive vibrations. Similarly, the temperature of steeping baths fluctuates resulting in incorrect temperature while steeping. During xanthation CS_2 is added using the discretion of the team member dosing CS_2, as residual

CS_2 is trapped within the pipe to sample. This may impact the results negatively as it is based on perception.

4.2.6 SIV (Soda in Viscose)

It has been noted that there is insufficient hot water to dissolve sample completely. The dispenser volumes are not checked before commencement of the test. Incorrectly dispensed volumes may lead to variable result.

4.2.7 CIV (Cellulose in Viscose)

The boiling water required to remove sulphates during washing is not changed per sample. In addition, the spinbath required to regenerate sample is not changed per sample. It has also been noted that the spinbath is not standardised correctly.

4.2.8 Ball Fall

Teamster have noted that the spheres used for ball fall are rusty and may impact results. The water bath overflows, and time is wasted cleaning spills.

4.2.9 Particle counts

Teamsters have indicated that incorrect concentration of caustic soda used during sample preparation. In addition, the caustic is not filtered 5 times which may cause crystallisation and blockage of aperture tube. It has been observed that the electrode is left in caustic overnight causing crystallisation around electrode.

4.2.10 KW filtration

Pressure gauges and regulators are not maintained resulting in the gauges reading lower than what is stated in the procedure.

4.2.11 Rheology

The compressor does not build up adequate pressure required to lift up the measuring cone. The rheometer program freezes continuously. There seems to be a software connection problem between compressor and rheometer, possibly attributed to irregular maintenance.

At COE laboratories, the common findings noted by the team members from the brainstorming sessions surround project communications at all levels within the

organisation, scheduling and estimating project timelines and resources. General maintenance of equipment has been highlighted as a crucial area of improvement. In addition, general project issues pertaining to space and equipment constraints have also been highlighted. The issues highlighted above may result in delayed results within a project; hence, a prolonged project duration. Similarly, several authors noted similar issues within the laboratory environment, in their institutions, with several measures employed to overcome these challenges (Durak and Sadat 2020; Sugianto *et al.* 2015; Durur and Akbulut 2019; Muiambo *et al.* 2021; Kholif *et al.* 2018; Habibie and Kresiani 2019; Al-Bakoosh *et al.* 2020).

4.3. CONTENT VALIDATION

If a measuring instrument has a high level of validity, it implies that the measuring instrument would achieve the desired outcomes of the research findings with a high level of confidence (Karlsson 2016; Saunders, Lewis and Thornhill, 2009). This study utilised content validity to assess whether the questionnaire achieved a high level of validity, which was established by sharing the instrument with professionals and experts who assessed and checked whether the instrument contained items that covered all facets of the construct under study (Table 4.1). The panel of experts chosen is regarded as subject matter experts and have vast knowledge on viscose processes and tests on applications (Raw data available in Appendix F). The process of content validation undertaken at Sappi COE can be viewed in Chapter 3 (Figure 3.6).

Table 4.1: Content validation of instrument used at Sappi COE

Category	Questions	Experts in agreement	I-CVI	Interpretation (Appropriate or need for revision)	CVR	Interpretation (Remained/Eliminated)
	Question 1	9	1,00	Appropriate	1,00	Remained
	Question 2	9	1,00	Appropriate	1,00	Remained
Category 1	Question 3	9	1,00	Appropriate	1,00	Remained
	Question 1	9	1,00	Appropriate	1,00	Remained
	Question 2	9	1,00	Appropriate	1,00	Remained
	Question 3	9	1,00	Appropriate	1,00	Remained
	Question 4	9	1,00	Appropriate	1,00	Remained
	Question 5	8	0,89	Appropriate	0,78	Remained
Category 2	Question 6	8	0,89	Appropriate	0,78	Remained

Category	Questions	Experts in agreement	I-CVI	Interpretation (Appropriate or need for revision)	CVR	Interpretation (Remained/Eliminated)
	Question 7	9	1,00	Appropriate	1,00	Remained
	Question 1	9	1,00	Appropriate	1,00	Remained
	Question 2	9	1,00	Appropriate	1,00	Remained
	Question 3	9	1,00	Appropriate	1,00	Remained
	Question 4	9	1,00	Appropriate	1,00	Remained
	Question 5	9	1,00	Appropriate	1,00	Remained
Category 3	Question 6	8	0,89	Appropriate	0,78	Remained
	Question 1	9	1,00	Appropriate	1,00	Remained
	Question 2	9	1,00	Appropriate	1,00	Remained
	Question 3	9	1,00	Appropriate	1,00	Remained
	Question 4	9	1,00	Appropriate	1,00	Remained
	Question 5	9	1,00	Appropriate	1,00	Remained
	Question 6	9	1,00	Appropriate	1,00	Remained
	Question 7	9	1,00	Appropriate	1,00	Remained
	Question 8	9	1,00	Appropriate	1,00	Remained
	Question 9	9	1,00	Appropriate	1,00	Remained
	Question 10	9	1,00	Appropriate	1,00	Remained
	Question 11	9	1,00	Appropriate	1,00	Remained
	Question 12	9	1,00	Appropriate	1,00	Remained
	Question 13	9	1,00	Appropriate	1,00	Remained
	Question 14	9	1,00	Appropriate	1,00	Remained
Category 4	Question 15	9	1,00	Appropriate	1,00	Remained
	Question 1	9	1,00	Appropriate	1,00	Remained
	Question 2	9	1,00	Appropriate	1,00	Remained
	Question 3	9	1,00	Appropriate	1,00	Remained
	Question 4	9	1,00	Appropriate	1,00	Remained
	Question 5	9	1,00	Appropriate	1,00	Remained
	Question 6	8	0,89	Appropriate	0,78	Remained
	Question 7	9	1,00	Appropriate	1,00	Remained
	Question 8	9	1,00	Appropriate	1,00	Remained
	Question 9	9	1,00	Appropriate	1,00	Remained
	Question 10	9	1,00	Appropriate	1,00	Remained
	Question 11	9	1,00	Appropriate	1,00	Remained
Category 5	Question 12	9	1,00	Appropriate	1,00	Remained
	Question 1	9	1,00	Appropriate	1,00	Remained
	Question 2	9	1,00	Appropriate	1,00	Remained
	Question 3	9	1,00	Appropriate	1,00	Remained
	Question 4	9	1,00	Appropriate	1,00	Remained
	Question 5	9	1,00	Appropriate	1,00	Remained
Category 6	Question 6	9	1,00	Appropriate	1,00	Remained

Category	Questions	Experts in agreement	I-CVI	Interpretation (Appropriate or need for revision)	CVR	Interpretation (Remained/Eliminated)
	Question 1	9	1,00	Appropriate	1,00	Remained
	Question 2	9	1,00	Appropriate	1,00	Remained
	Question 3	9	1,00	Appropriate	1,00	Remained
	Question 4	9	1,00	Appropriate	1,00	Remained
	Question 5	9	1,00	Appropriate	1,00	Remained
	Question 6	9	1,00	Appropriate	1,00	Remained
	Question 1	9	1,00	Appropriate	1,00	Remained
	Question 2	9	1,00	Appropriate	1,00	Remained
	Question 3	9	1,00	Appropriate	1,00	Remained
	Question 1	9	1,00	Appropriate	1,00	Remained
	Question 2	9	1,00	Appropriate	1,00	Remained
	Question 3	9	1,00	Appropriate	1,00	Remained
	Question 4	9	1,00	Appropriate	1,00	Remained
	Question 1	9	1,00	Appropriate	1,00	Remained
	Question 2	9	1,00	Appropriate	1,00	Remained
	Question 3	9	1,00	Appropriate	1,00	Remained
	Question 1	9	1,00	Appropriate	1,00	Remained
	Question 2	9	1,00	Appropriate	1,00	Remained
	Question 3	9	1,00	Appropriate	1,00	Remained
	Question 4	9	1,00	Appropriate	1,00	Remained
	Question 1	9	1,00	Appropriate	1,00	Remained
	Question 2	9	1,00	Appropriate	1,00	Remained
	Question 3	9	1,00	Appropriate	1,00	Remained
	Question 4	9	1,00	Appropriate	1,00	Remained
	Question 5	9	1,00	Appropriate	1,00	Remained
Category 7	Question 6	9	1,00	Appropriate	1,00	Remained
	Question 1	9	1,00	Appropriate	1,00	Remained
	Question 2	9	1,00	Appropriate	1,00	Remained
Category 8	Question 3	9	1,00	Appropriate	1,00	Remained
S-CVI/Ave = (sum of I-CVI scores)/ (number of item)			0,99			
Average proportion of items judged as relevance across the nine experts S-CVI/Ave = (sum of proportion relevance rating)/ (number of expert) = 0.99						

During the course of the study, content validation was carried out on the questionnaire to verify whether it was effective in measuring the constructs under study (Table 3.9). The CVR for each item ranged between 0.78 and 1. According to several researchers, this indicates all items are essential and will be retained in the instrument (Ayre and Scally

2014; Lawshe 1975; Gilbert and Prion 2016). I-CVI was calculated for all items and ranged between 0.89 and 1, reflecting good evidence of content validity for each item measuring the construct (Polit *et al.* 2007; Shrotryia and Dhanda 2019; Gilbert and Prion 2016). In addition, the average proportion of items judged as relevant across the nine experts (S-CVI/Ave) was calculated as 0.99. Overall, the content validity of the entire instrument was good, considering the CVR, I-CVI and S-CIV/Ave values; this indicates the instrument will be useful in obtaining the necessary information required from participants to satisfy the research objectives.

4.4. QUANTITATIVE ANALYSIS OF THE PRE AND POST STUDY QUESTIONNAIRE

4.4.1 Demographics of population sampled

Table 4.2 describes the details of the population sampled. It provides information regarding the participants, chosen for this study, such as department, position held by participant, duration in current position and their education level.

Table 4.2: Demographics of population sampled

Participant information	**Overall pre and post study (N=51)**
Department	
COE Technical	45 (88.2%)
Process	3 (5.9%)
Mill Technical	2 (3.9%)
Quality	1 (2.0%)
Position	
Senior Analyst/Analyst	27 (52.9%)
Analytical Chemistry Intern	1 (2.0%)
Technologist	13 (25.5%)
Scientist	10 (19.6%)
Duration in current position	

Participant information	**Overall pre and post study (N=51)**
Median(Q1-Q3)	5.00(2.13-8.50)
n(Min-Max)	51(0.583-15.0)
Education	
Matric	4 (7.8%)
N courses	6 (11.8%)
Diploma	14 (27.5%)
BSc	4 (7.8%)
Honours	1 (2.0%)
B-Tech	14 (27.5%)
Post Grad	6 (11.8%)
Other	2 (3.9%)

Most participants were from the COE Technical group, as indicated by Table 4.2. The remaining participants were from the Mill Technical department, Process and Quality department. During the pre-study, 30 questionnaires were sent out, with 29 questionnaires voluntarily answered and returned. Similarly, during the post-study, 30 questionnaires were sent out, with 22 returned. Ideally, a sample size of 30 is required for statistical analysis (Saunders *et al.* 2009; Kasiulevičius *et al.* 2006), which is, unfortunately, difficult to achieve within a smaller department.

Sappi COE laboratories have been specifically tailored to mimic the viscose manufacturing process of their customers, hence due to confidentiality agreements set up by Sappi and the customer, this study could not be shared with other laboratories to increase the sample size. Therefore, the study was limited to Sappi employees. The majority participants were Senior Analysts and Analysts, followed by Technologists, Scientists and an Analytical Intern. Most participants were in the position for a minimum of two years. In addition, the majority participants held Diplomas or higher qualifications.

All participants allowed to participate in the study were accepted based on criteria explained in detail in Chapter 3.

4.4.2 General Project Issues

Table 4.3: Item-rest correlation and Cronbach's alpha for General project issues

Items	Item-rest correlation	Alpha-if-deleted
Objectives clearly defined	0.81	0.88
Work tasks clearly defined	0.81	0.83
Role was clear	0.84	0.87
Overall	-	0.90

Literature suggests an alpha content ≥ 0.7 is acceptable (Kelleher *et al*. 1997; Hurst and Bird 2019). The Cronbach's alpha for this category was 0.90, indicating acceptable reliability (Table 4.3). This shows all questions related to the construct being measured and maintains a high reliability for the established scales. Furthermore, item-rest correlations above 0.40 are considered acceptable, since all questions are seen as relatable to each other (Tapsir *et al.* 2018; Metsämuuronen 2022). The item-rest correlation for general project issues were all above 0.4, which indicates good internal consistency between the questions relating to general project issues (Table 4.3).

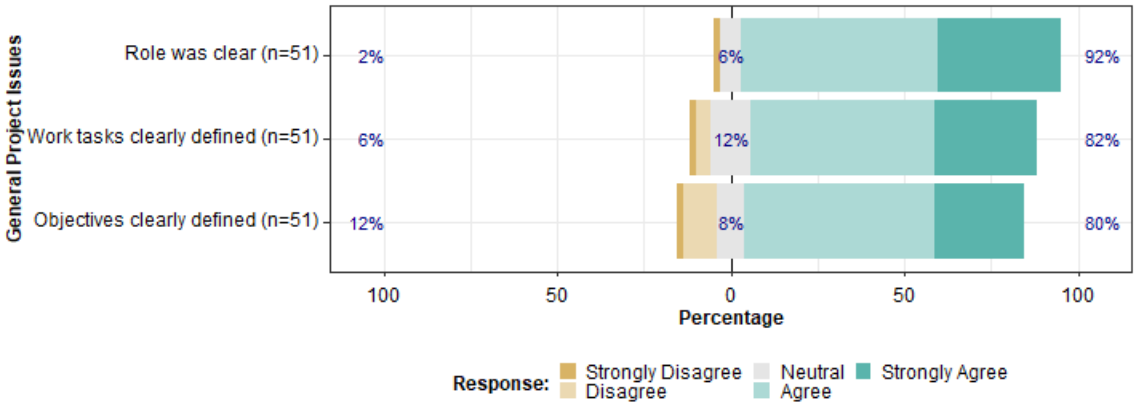

Figure 4.8: Graphical representation of responses to General project issues

Table 4.4: Analysis of responses to pre- and post-questionnaires on general project issues

Time	Pre (N=29)	Post (N=22)	p-value	Overall (N=51)
Objectives clearly defined			1.000	
Disagree	6 (21%)	4 (18%)		10 (20%)
Agree	23 (79%)	18 (82%)		41 (80%)
Work tasks clearly defined			1.000	
Disagree	5 (17%)	4 (18%)		9 (18%)
Agree	24 (83%)	18 (82%)		42 (82%)
Role was clear			1.000	
Disagree	2 (7%)	2 (9%)		4 (8%)
Agree	27 (93%)	20 (91%)		47 (92%)

The aim of this category was to investigate any challenges the team may face before the project commences. Overall, the responses from the team were positive (Figure 4.8). The team reported that the objectives of the project were clearly defined, with the work allocated and roles understood by team members within the project. A threshold of 0.05 is used to decide whether the differences are considered significant or not. P-values below 0.05 are expected in the case where differences between rows and columns are so great they are not the consequence of randomness (Barceló 2018; Samuels 2020). The p-values were greater than 0.05 for each question, indicating that there has not been a significant difference in opinion from the pre- to the post-study (Table 4.4).

According to similar studies conducted by several researchers, it is extremely important for personnel to understand the company's strategic goals and objectives, in order to improve business efficiency (Dirnagl *et al.* 2018; Krapp 2001; Valdivieso-Gómez and Aguilar-Quesada 2018).

4.4.3 Project Communications

Table 4.5: Item-rest correlation and Cronbach's alpha for project communications

Items	Item-rest correlation	Alpha-if-deleted
Team meetings efficient and effective	0.68	0.84
Closeout meetings efficient and effective	0.56	0.86
Management sponsor provided needed guidance and support	0.55	0.86
Manager provided needed guidance and support	0.44	0.87
Team had good understanding of my contributions	0.74	0.83
My responsibilities tasks and deliverables achievable	0.78	0.83
Clear Roles and responsibilities of the team members	0.74	0.83
Overall	-	0.87

A perfect correlation of 1.0 for Cronbach's alpha suggests questions are measuring an almost identical construct, resulting in item redundancy (Taber 2018). Therefore, it has been suggested coefficients above 0.70 and close to 0.90 suggest good internal consistency (Hurst and Bird 2018). The Cronbach's alpha for project communication was 0.87; indicative of good reliability for the instrument (Table 4.5). In addition, the item-rest correlation was above 0.4 for all questions, indicating good internal consistency among questions (Table 4.5).

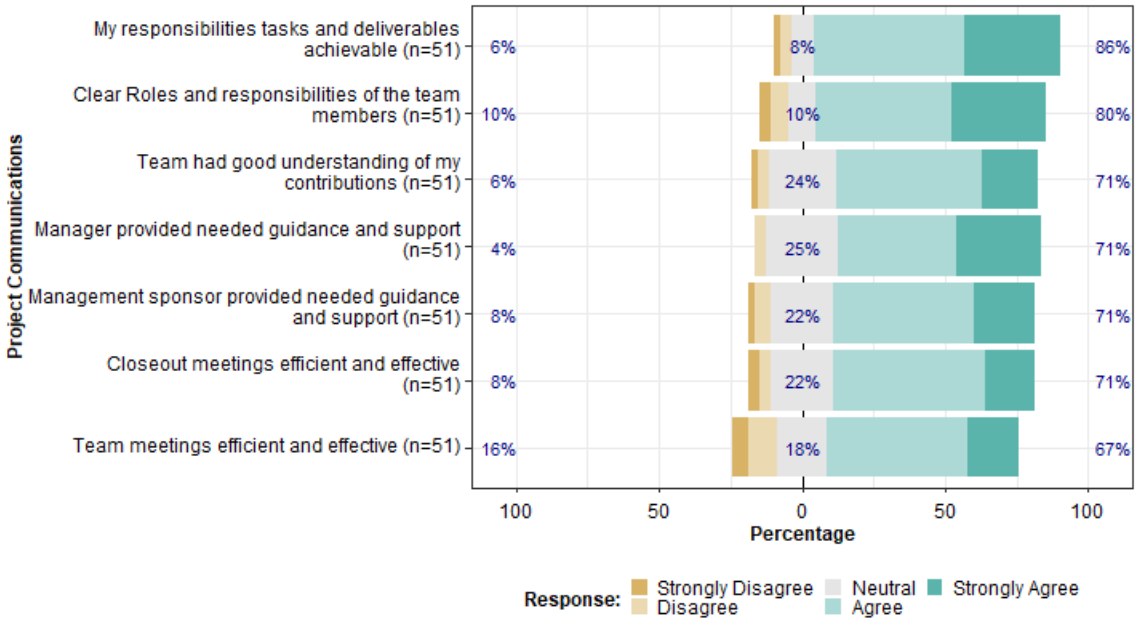

Figure 4.9: Graphical representation of response to project communications

Table 4.6: Analysis of responses to pre- and post-questionnaires on project communications

Time	Pre (N=29)	Post (N=22)	p-value	Overall (N=51)
Team meetings efficient and effective			0.162	
Disagree	12 (41%)	5 (23%)		17 (33%)
Agree	17 (59%)	17 (77%)		34 (67%)
Closeout meetings efficient and effective			0.770	
Disagree	9 (31%)	6 (27%)		15 (29%)
Agree	20 (69%)	16 (72%)		36 (71%)
Management sponsor provided needed guidance and support			0.770	
Disagree	9 (31%)	6 (27%)		15 (29%)
Agree	20 (69%)	16 (73%)		36 (71%)
Project manager provided needed guidance and support			0.361	
Disagree	10 (35%)	5 (23%)		15 (29%)
Agree	19 (66%)	17 (77%)		36 (71%)
Team had good understanding of my contributions			0.361	
Disagree	10 (35%)	5 (23%)		15 (29%)
Agree	19 (66%)	17 (77%)		36 (71%)
My responsibilities tasks and deliverables achievable			0.684	
Disagree	5 (17%)	2 (9%)		7 (14%)
Agree	24 (83%)	20 (91%)		44 (86%)
Clear Roles and responsibilities of the team members			1.000	
Disagree	6 (21%)	4 (18%)		10 (20%)
Agree	23 (79%)	18 (82%)		41 (80%)

Overall, teamsters agreed general project communications are good. The team indicated a good understanding of their contributions and responsibilities within the project. Teamsters were in agreement there is adequate support from the project sponsor and the

PM within a project. The team further indicated team meetings and project closeout meetings are an effective way of communication (Figure 4.9). The p-values for items under project communications were above 0.05; indicative of no significant shift in opinion from the pre- and post-study (Table 4.6).

Studies have shown increased service quality will result from enhanced communication of knowledge, and devices, as well as a more sophisticated culture of dealing with error mechanisms for continuous improvement (Dirnagl *et al.* 2018; Lee 2004; Emiliani 2006; Valdivieso-Gómez and Aguilar-Quesada 2018; Vianna *et al.* 2022).

4.4.4 Scheduling and Estimating

Table 4.7: Item-rest correlation and Cronbach's alpha for project communications

Items	Item-rest correlation	Alpha-if-deleted
Entire team committed to project schedule	0.41	0.80
Adequate time was allocated (overall for project)	0.62	0.76
Decisions about schedule changes discussed ahead	0.61	0.75
Appropriate time allocated (daily for each test)	0.52	0.78
Balanced work distribution among teamsters	0.65	0.75
System for sample management adequate	0.55	0.77
Overall	-	0.80

The item-rest correlation for each item was above 0.4 (Table 4.7), which suggests good internal consistency; indicative of items relating to each other. Overall, the Cronbach's alpha of 0.80 suggests good internal consistency among the items relating to the construct, scheduling and estimating (Table 4.7).

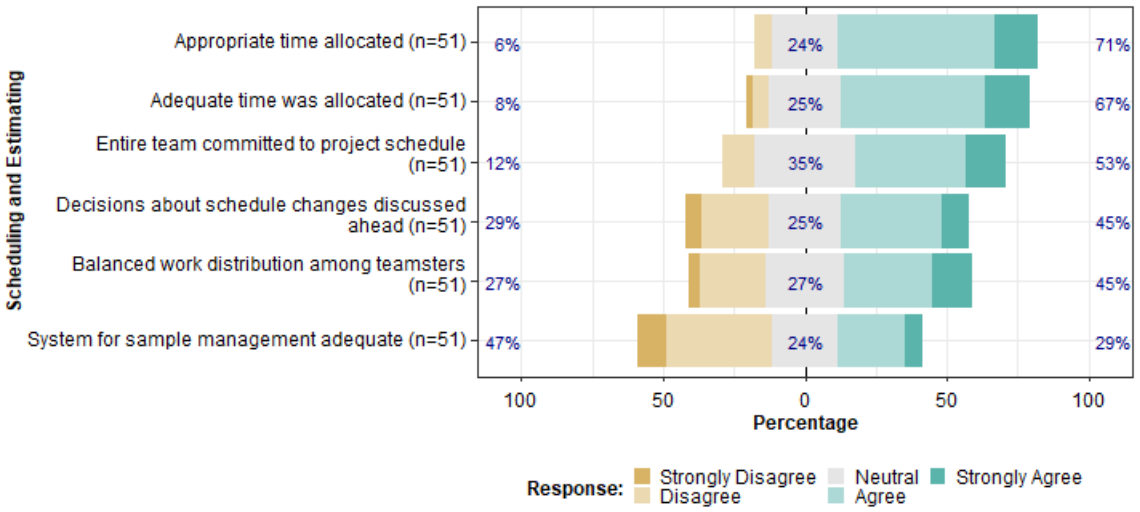

Figure 4.10: Graphical representation of response to scheduling and estimating

Table 4.8: Analysis of responses pre and post questionnaires including mean and p-value – scheduling and estimating

Time	Pre (N=29)	Post (N=22)	p-value	Overall (N=51)
Entire team committed to project schedule			0.443	
Disagree	15 (52%)	9 (41%)		24 (47%)
Agree	14 (48%)	13 (59%)		27 (53%)
Adequate time was allocated (overall for project)			0.162	
Disagree	12 (41%)	5 (23%)		17 (33%)
Agree	17 (59%)	17 (77%)		34 (67%)
Decisions about schedule changes discussed ahead			0.080	
Disagree	19 (66%)	9 (41%)		28 (55%)
Agree	10 (35%)	13 (59%)		23 (45%)
Appropriate time allocated (daily for each test)			0.361	
Disagree	10 (35%)	5 (23%)		15 (29%)

Time	Pre (N=29)	Post (N=22)	p-value	Overall (N=51)
Agree	19 (66%)	17 (77%)		36 (71%)
Balanced work distribution among teamsters			0.020	
Disagree	20 (69%)	8 (36%)		28 (55%)
Agree	9 (31%)	14 (64%)		23 (45%)
System for sample management adequate			0.005	
Disagree	25 (86%)	11 (50%)	0.023	36 (71%)
Agree	4 (14%)	11 (50%)	0.023	15 (29%)

It was agreed by the team there is adequate time allocated to each project, overall. In addition, the team was also in agreement there is adequate time allocation to each task daily. The entire team, furthermore, feels committed to the project schedule. Nonetheless, the majority of the team feels any changes within the schedule are not discussed ahead of time (Figure 4.10). The p-values indicates there has been a change with regard to the distribution of work among teamsters within the project (Table 4.8). They feel work is not distributed fairly among team members. Overall, teamsters indicate a need to improve the sample management system. However, there has been a significant improvement in the system for sample management, as indicated by the p-values from the pre- to post-study (Table 4.8).

Similarly, studies have shown unnecessary motion is one of the eight types of wastes noted under LM, where unnecessary motion is primarily caused by poor workflow, poor layout, housekeeping, and inconsistent or undocumented work methods (Dennis 2017; Kilpatrick 2003; Sugianto *et al.* 2015; Durur and Akbulut 2019; Graban and Padgett 2008; McManus 2005). It is, therefore, important for Sappi COE to work on the issues associated with scheduling and estimating within a project.

4.4.5 Ageing Kinetics

Table 4.9: Item-rest correlation and Cronbach's alpha for ageing kinetics

Items	Item-rest correlation	Alpha-if-deleted
Samples labelled neatly	0.38	0.81
Samples can be easily mixed up	0.30	0.82
Appropriate storage area	0.33	0.82
ISO document for sample preparation	0.56	0.80
Steeping pots and impellers maintained	0.59	0.79
Steeping motors regularly serviced	0.44	0.81
Steeping waterbaths maintained	0.53	0.80
Daily verifications for waterbath	0.61	0.79
Waterbaths cleaned frequently	0.53	0.80
Trained adequately for ageing kinetics	0.27	0.82
Trained adequately for CIAs and SIAs	0.29	0.82
Appropriate ISO document for Cia and Sia	0.34	0.81
Chemicals required for Cia and Sia	0.40	0.81
Oven temperatures verified	0.50	0.80
Ovens calibrated timeously	0.53	0.80
Overall	-	0.82

Most questions share a good internal consistency relating to each other under the construct ageing kinetics, indicated by the item rest correlation for each item (Table 4.9). The overall Cronbach's alpha of 0.82 for ageing kinetics indicates good internal consistency between items and the construct measured (Table 4.9). A graphical presentation (Figure 4.11) of response to ageing kinetics is offered below.

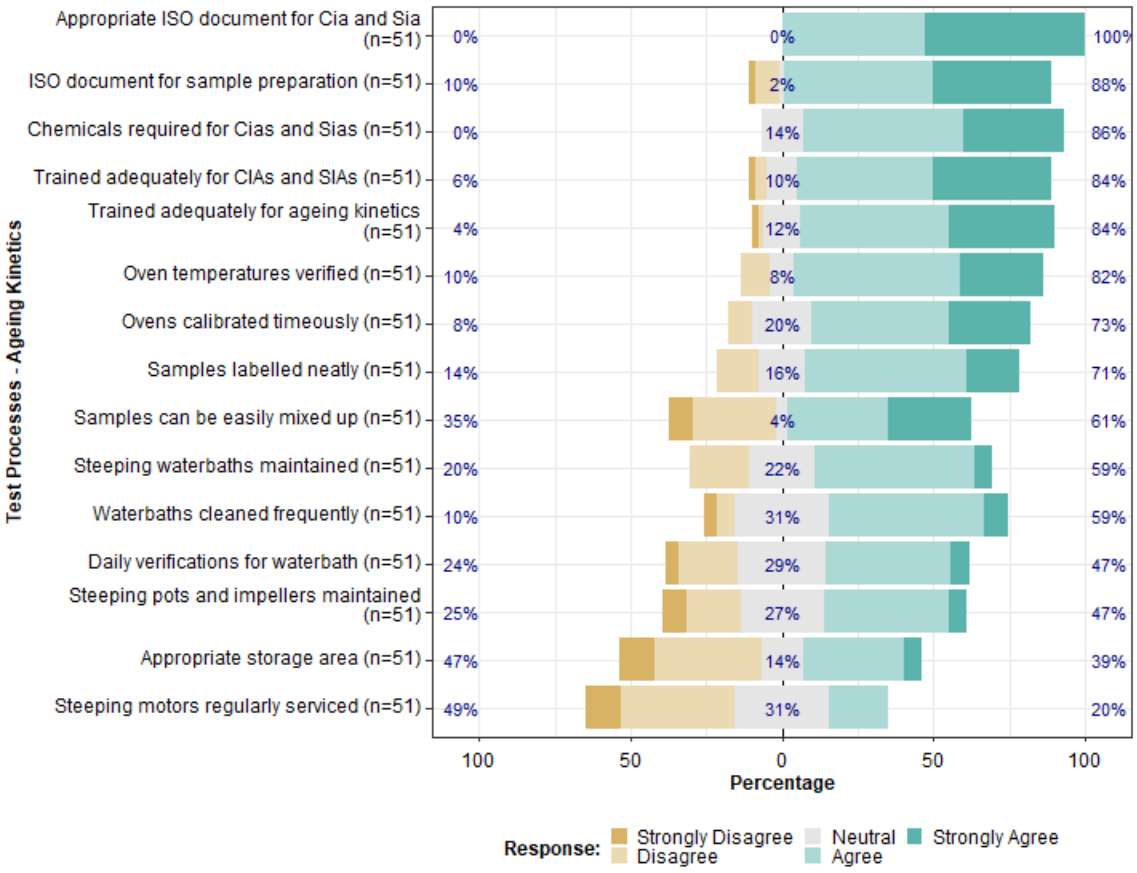

Figure 4.11: Graphical representation of response to ageing kinetics

Table 4.10: Analysis of pre- and post-study questionnaire responses to ageing kinetics

Time	Pre (N=29)	Post (N=22)	p-value	Overall (N=51)
Samples labelled neatly			0.125	
Disagree	11 (38%)	4 (18%)		15 (29%)
Agree	18 (62%)	18 (82%)		36 (71%)
Samples can be easily mixed up			<0.001	
Disagree	5 (17%)	15 (68%)	<0.001	20 (39%)
Agree	24 (83%)	7 (32%)	<0.001	31 (61%)
Appropriate storage area (for alkcell)			0.169	
Disagree	20 (69%)	11 (50%)		31 (61%)
Agree	9 (31%)	11 (50%)		20 (39%)

Time	Pre (N=29)	Post (N=22)	p-value	Overall (N=51)
ISO document for sample preparation			0.688	
Disagree	4 (14%)	2 (9%)		6 (12%)
Agree	25 (86%)	20 (91%)		45 (88%)
Steeping pots and impellers maintained			0.134	
Disagree	18 (62%)	9 (41%)		27 (53%)
Agree	11 (38%)	13 (59%)		24 (47%)
Steeping motors regularly serviced			0.295	
Disagree	25 (86%)	16 (73%)		41 (80%)
Agree	4 (14%)	6 (27%)		10 (20%)
Steeping waterbaths maintained			0.973	
Disagree	12 (41%)	9 (41%)		21 (41%)
Agree	17 (59%)	13 (59%)		30 (59%)
Daily verifications for waterbath			0.134	
Disagree	18 (62%)	9 (41%)		27 (53%)
Agree	11 (38%)	13 (59%)		24 (47%)
Waterbaths cleaned frequently			0.543	
Disagree	13 (45%)	8 (36%)		21 (41%)
Agree	16 (55%)	14 (64%)		30 (59%)
Trained adequately for ageing kinetics			1.000	
Disagree	5 (17%)	3 (14%)		8 (16%)
Agree	24 (83%)	19 (86%)		43 (84%)
Trained adequately for CIAs and SIAs			0.440	
Disagree	6 (21%)	2 (9%)		8 (16%)
Agree	23 (79%)	20 (91%)		43 (84%)
Appropriate ISO document for Cia and Sia			0.327	
Agree	29 (100.0%)	22 (100.0%)		51 (100.0%)
Chemicals required for Cia and Sia			0.684	
Disagree	5 (17%)	2 (9%)		7 (14%)
Agree	24 (83%)	20 (91%)		44 (86%)
Oven temperatures verified			1.000	

Time	Pre (N=29)	Post (N=22)	p-value	Overall (N=51)
Disagree	5 (17%)	4 (18%)		9 (18%)
Agree	24 (83%)	18 (82%)		42 (82%)
Ovens calibrated timeously			0.543	
Disagree	7 (24%)	7 (32%)		14 (28%)
Agree	22 (76%)	15 (68%)		37 (72%)

It is noted that teamsters agree the ISO document outlines all necessary steps required for ageing kinetics and sample preparation for the test. Teamsters further agree there is an adequate amount of training for personnel. In addition, teamsters agree all ovens used for the test have been verified on a daily basis and calibrated as per schedule (Figure 4.11). The p-values indicate there has been no change in terms of ISO documentation, training, verification and calibration for ageing kinetics from the pre- to the post-study (Table 4.10). Several authors have noted it is indispensably important to ensure clear ISO procedures, training and calibration of equipment, as this is used to achieve smooth operations within the laboratory (WHO 2011; Valdivieso-Gómez and Aguilar-Quesada 2018; Wadhwa *et al.* 2012).

It is worthy of note that teamsters feel that steeping pots, impellers and motors still require frequent maintenance, however, as indicated by the p-values, there is no significant change from the pre- to the post-study (Table 4.10). It must be noted there is currently a schedule for routine maintenance. However, this is proving to be inadequate according to teamsters. In addition, it was highlighted the need for daily verifications of steeping waterbaths remains (Figure 4.11). According to reports, similar challenges are faced by several authors regarding maintenance of equipment due to various factors (Dennis 2017; Kilpatrick 2003; Sugianto *et al.* 2015; Durur and Akbulut 2019; Graban and Padgett 2008; McManus 2005).

Teamsters agree there has been an improvement in sample management, suggested by the corresponding p values ($p<0.05$). However, samples can still be mixed up during storage, which needs further attention (Table 4.10). These results suggest that a sample

management system which functions correctly can significantly improve the flow of materials within the process (Powell *et al.* 2013; Driouach *et al.* 2019; Ukey *et al.* 2021).

4.4.6 Viscose production

Table 4.11: Item-rest correlation and Cronbach's alpha for viscose production

Items	Item-rest correlation	Alpha-if-deleted
Samples neatly labelled eligibly	0.57	0.84
Samples can be mixed up in storage	0.33	0.87
Steeping pots and impellers maintained adequately	0.62	0.84
Waterbath temperatures maintained correctly	0.69	0.83
Daily verifications of waterbath temperatures	0.61	0.84
Waterbaths descaled as frequently	0.56	0.84
Xanthation bottles labelled correctly	0.26	0.86
Temperatures for xanthation ovens verified	0.62	0.84
Xanthation ovens calibrated timeously	0.50	0.85
ISO document for xanthation clear	0.60	0.84
Waterbaths for ripening verified daily	0.64	0.84
Dissolving and ripening ISO document precise	0.54	0.85
Overall	-	0.86

The item rest correlation for most items under viscose production was indicative of good internal consistency among each item relative to the other (Table 4.11). The overall Cronbach's alpha of 0.86 indicated good internal consistency between items and the construct measured, namely, viscose production (Table 4.11).

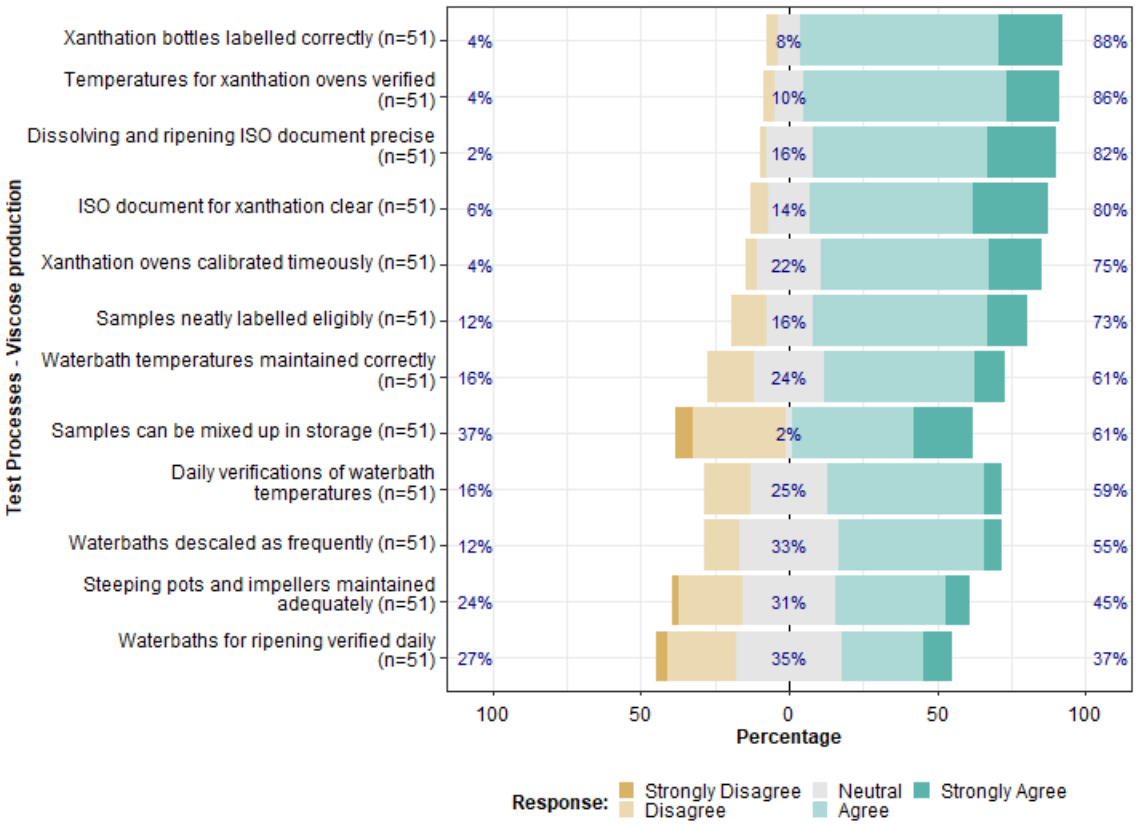

Figure 4.12: Graphical representation of response to viscose production

Table 4.12: Analysis of pre- and post-questionnaire responses for viscose production

Time	Pre (N=29)	Post (N=22)	p-value	Overall (N=51)
Samples neatly labelled eligibly			0.980	
Disagree	8 (28%)	6 (27%)		14 (27%)
Agree	21 (72%)	16 (73%)		37 (73%)
Samples can be mixed up in storage			0.002	
Disagree	6 (21%)	14 (64%)	0.007	20 (39%)
Agree	23 (79%)	8 (36%)	0.007	31 (61%)
Steeping pots and impellers maintained adequately			0.540	
Disagree	17 (59%)	11 (50%)		28 (55%)
Agree	12 (41%)	11 (50%)		23 (45%)
Waterbath temperatures maintained correctly			0.829	

Time	Pre (N=29)	Post (N=22)	p-value	Overall (N=51)
Disagree	11 (38%)	9 (41%)		20 (39%)
Agree	18 (62%)	13 (59%)		31 (61%)
Daily verifications of water bath temperatures			0.237	
Disagree	14 (48%)	7 (32%)		21 (41%)
Agree	15 (52%)	15 (68%)		30 (59%)
Waterbaths descaled as frequently			0.964	
Disagree	13 (45%)	10 (45%)		23 (45%)
Agree	16 (55%)	12 (55%)		28 (55%)
Xanthation bottles labelled correctly			1.000	
Disagree	3 (10%)	3 (14%)		6 (12%)
Agree	26 (90%)	19 (86%)		45 (88%)
Temperatures for xanthation ovens verified			0.684	
Disagree	5 (17%)	2 (9%)		7 (14%)
Agree	24 (83%)	20 (91%)		44 (86%)
Xanthation ovens calibrated timeously			0.693	
Disagree	8 (28%)	5 (23%)		13 (25%)
Agree	21 (72%)	17 (77%)		38 (75%)
ISO document for xanthation clear			0.295	
Disagree	4 (14%)	6 (27%)		10 (20%)
Agree	25 (86%)	16 (73%)		41 (80%)
Waterbaths for ripening verified daily			0.291	
Disagree	20 (69%)	12 (55%)		32 (63%)
Agree	9 (31%)	10 (45%)		19 (37%)
Dissolving and ripening ISO document precise			0.474	
Disagree	4 (14%)	5 (23%)		9 (18%)
Agree	25 (86%)	17 (77%)		42 (82%)

Teamsters are in agreement the ISO document, for xanthation, dissolving and ripening that explains the steps required to be performed, in a comprehendible way. In addition, it was noted the temperature of the xanthation oven is verified daily (Figure 4.12).

Teamsters agree the ovens are calibrated timeously, and the steeping waterbaths have been frequently descaled in both the pre-and post- study, with no significant change in opinion; as indicated by the p-values. As stated above, several authors suggests clear ISO procedures, training and calibration of equipment is required for the smooth operation of a laboratory (WHO 2011; Valdivieso-Gómez and Aguilar-Quesada 2018; Wadhwa *et al.* 2012).

Overall, teamsters disagreed the steeping pots and impellers are regularly maintained, since a p-value > 0.05 was obtained (Table 4.12). This indicates no change from the pre- and post-study. Teamsters also disagreed daily verification of ripening waterbaths takes place (Figure 4.12). As indicated by several authors above, similar issues around maintenance prevails within the laboratory environment and manufacturing industry (Dennis 2017; Kilpatrick 2003; Sugianto *et al.* 2015; Durur and Akbulut 2019; Graban and Padgett 2008; McManus 2005).

Teamsters are in agreement there is an improvement in sample management. P-values below 0.05 indicate a change in the sample management system (Table 4.12). However, samples can still be mixed up during storage, which requires further attention. As stated by several authors above, it has been observed a sample management system that functions correctly can significantly improve the flow of materials within the process (Powell *et al.* 2013; Driouach *et al.* 2019; Ukey *et al.* 2021).

4.4.7 Application tests (SIV, CIV, Ball fall, KW filtration, Particle counts, Rheology)

Table 4.13: Item-rest correlation and Cronbach's alpha for application tests

Items	Item-rest correlation	Alpha-if-deleted
Glassware for SIV in good condition	0.49	0.92
Ample glassware available for SIV	0.59	0.92
SIV reagents within expiration period	0.52	0.92
SIV ISO document precise	0.48	0.92
Trained adequately for SIV	0.23	0.92
Adequate system to sample viscose dope for SIV	0.42	0.92
CIV for glassware readily available	0.57	0.92
Ample glassware available for CIV	0.58	0.92
Hot plates for CIV readily available	0.54	0.92

Items	Item-rest correlation	Alpha-if-deleted
Ovens required for CIV verified	0.55	0.92
Analytical balances for CIV verified	0.44	0.92
Analytical balances for CIV calibrated timeously	0.48	0.92
Ball fall for glassware readily available	0.67	0.92
Water bath temperature for ball fall verified	0.64	0.92
Ball fall ISO document precise	0.54	0.92
Pressure gauges working correctly	0.61	0.92
ISO procedure explains KW precisely	0.55	0.92
KW apparatus easy to set up	0.55	0.92
Proper sampling techniques for KW	0.59	0.92
Particle counts procedure easy to follow	0.46	0.92
Coulter counter calibrated timeously	0.73	0.91
Chemicals available within expiration period	0.72	0.91
Rheology procedure easy to follow	0.38	0.92
Programme is user friendly	0.40	0.92
Rheometer is maintained frequently	0.60	0.92
Compressor is maintained frequently	0.62	0.92
Overall	-	0.92

As seen in table 4.13, the item rest correlation for items under viscose application tests indicates a good internal consistency (item rest correlation>0.4) between items. The overall Cronbach's alpha of 0.92 maintains high reliability for the established scales (Table 4.13). The questionnaire, therefore, measures good internal consistency between items and the construct measured.

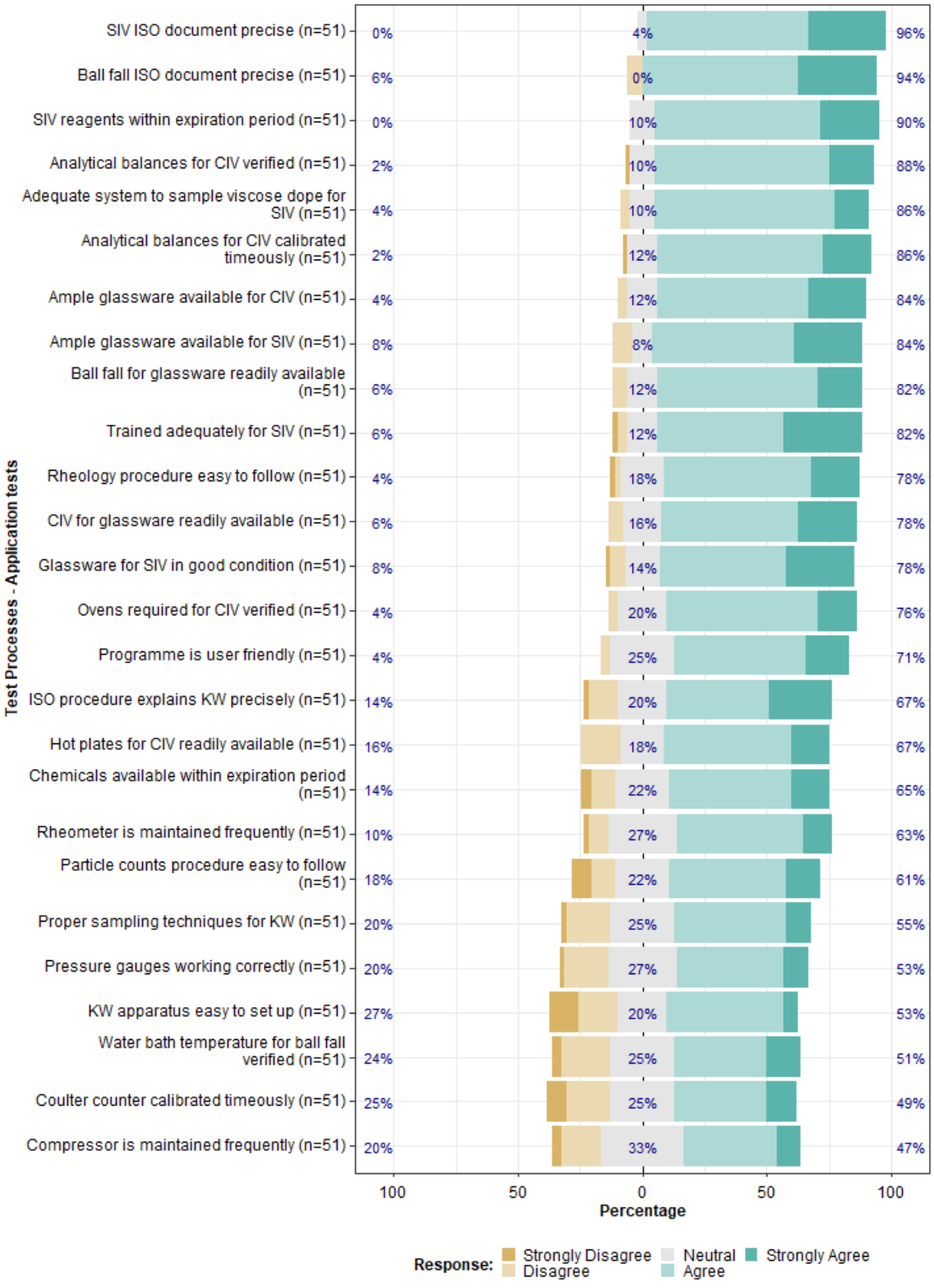

Figure 4.13: Graphical representation of response to application tests

Table 4.14: Analysis of pre- and post-questionnaire responses for application tests

Time	Pre (N=29)	Post (N=22)	p-value	Overall (N=51)
Glassware for SIV in good condition			0.498	
Disagree	5 (17%)	6 (27%)		11 (22%)
Agree	24 (83%)	16 (73%)		40 (78%)
Ample glassware available for SIV			0.440	
Disagree	6 (21%)	2 (9%)		8 (16%)
Agree	23 (79%)	20 (91%)		43 (84%)
SIV reagents within expiration period			0.375	
Disagree	4 (14%)	1 (5%)		5 (10%)
Agree	25 (86%)	21 (96%)		46 (90%)
SIV ISO document precise			0.500	
Disagree	2 (7%)	0 (0%)		2 (4%)
Agree	27 (93%)	22 (100%)		49 (96%)
Trained adequately for SIV			0.714	
Disagree	6 (21%)	3 (14%)		9 (18%)
Agree	23 (79%)	19 (86%)		42 (82%)
Adequate system to sample viscose dope for SIV			1.000	
Disagree	4 (14%)	3 (14%)		7 (14%)
Agree	25 (86%)	19 (86%)		44 (86%)
CIV for glassware readily available			0.737	
Disagree	7 (24%)	4 (18%)		11 (22%)
Agree	22 (76%)	18 (82%)		40 (78%)
Ample glassware available for CIV			1.000	
Disagree	5 (17%)	3 (14%)		8 (16%)
Agree	24 (83%)	19 (86%)		43 (84%)
Hot plates for CIV readily available			0.110	
Disagree	7 (24%)	10 (45%)		17 (33%)
Agree	22 (76%)	12 (55%)		34 (67%)
Ovens required for CIV verified			0.147	
Disagree	9 (31%)	3 (14%)		12 (24%)
Agree	20 (69%)	19 (86%)		39 (76%)

Time	Pre (N=29)	Post (N=22)	p-value	Overall (N=51)
Analytical balances for CIV verified			0.218	
Disagree	5 (17%)	1 (5%)		6 (12%)
Agree	24 (83%)	21 (95%)		45 (88%)
Analytical balances for CIV calibrated timeously			0.684	
Disagree	5 (17%)	2 (9%)		7 (14%)
Agree	24 (83%)	20 (91%)		44 (86%)
Ball fall for glassware readily available			0.060	
Disagree	8 (28%)	1 (5%)		9 (18%)
Agree	21 (72%)	21 (95%)		42 (82%)
Water bath temperature for ball fall verified			0.313	
Disagree	16 (55%)	9 (41%)		25 (49%)
Agree	13 (45%)	13 (59%)		26 (51%)
Ball fall ISO document precise			0.249	
Disagree	3 (10%)	0 (0%)		3 (6%)
Agree	26 (90%)	22 (100%)		48 (94%)
Pressure gauges working correctly			0.842	
Disagree	14 (48%)	10 (45%)		24 (47%)
Agree	15 (52%)	12 (55%)		27 (53%)
ISO procedure explains KW precisely			0.162	
Disagree	12 (41%)	5 (23%)		17 (33%)
Agree	17 (59%)	17 (77%)		34 (67%)
KW apparatus easy to set up			0.443	
Disagree	15 (52%)	9 (41%)		24 (47%)
Agree	14 (48%)	13 (59%)		27 (53%)
Proper sampling techniques for KW			0.275	
Disagree	15 (52%)	8 (36%)		23 (45%)
Agree	14 (48%)	14 (64%)		28 (55%)
Particle counts procedure easy to follow			0.346	
Disagree	13 (45%)	7 (32%)		20 (39%)
Agree	16 (55%)	15 (68%)		31 (61%)
Coulter counter calibrated timeously			0.210	

Time	Pre (N=29)	Post (N=22)	p-value	Overall (N=51)
Disagree	17 (59%)	9 (41%)		26 (51%)
Agree	12 (41%)	13 (59%)		25 (49%)
Chemicals available within expiration period			0.296	
Disagree	12 (41%)	6 (27%)		18 (35%)
Agree	17 (59%)	16 (73%)		33 (65%)
Rheology procedure easy to follow			0.737	
Disagree	7 (24%)	4 (18%)		11 (22%)
Agree	22 (76%)	18 (82%)		40 (78%)
Programme is user friendly			0.770	
Disagree	9 (31%)	6 (27%)		15 (29%)
Agree	20 (69%)	16 (73%)		36 (71%)
Rheometer is maintained frequently			0.062	
Disagree	14 (48%)	5 (23%)		19 (37%)
Agree	15 (52%)	17 (77%)		32 (63%)
Compressor is maintained frequently			0.039	
Disagree	19 (66%)	8 (36%)		27 (53%)
Agree	10 (34%)	14 (64%)		24 (47%)

Overall, teamsters are in agreement there are no major concerns with regard to the procedure contained within the ISO document for SIV. The team also agrees no major concerns exist regarding the condition and availability of glassware required; for SIV. It was been noted the chemicals used for SIV were within the expiration date. All teamsters agree training for SIV is adequate. No major concerns for sampling of the viscose dope for the SIV test were found (Figure 4.13). The p-value for each question posed was greater than 0.05, indicative of no change in response from pre- to post-study (Table 4.14).

The response from teamsters indicates there are no major concerns in terms of glassware condition and availability for CIV. In addition, hot plates are available for use. Teamsters are also in agreement the ovens and analytical balances used for the CIV test are verified

and calibrated timeously (Figure 4.13). The p-value indicates no significant shift in opinions from the pre- to the post-study for each question (Table 4.14).

In terms of the ball fall test, it is evident from the responses of teamsters, there are no major issues in terms of availability of glassware and water bath verification. The team agrees the procedure for ball fall outlines each step adequately (Figure 4.13). The p-value indicates no change in opinion from the pre- and post-study (Table 4.14).

It was noted teamsters agree the pressure gauges work efficiently and the setup is easy to use. The team agrees the ISO document explains the KW test precisely (Figure 4.13). No major shift is indicated by the p-values in opinion from the pre- to post-study (Table 4.14).

Also noted, is the teamsters agree the rheology procedure is easy to follow and the program is user friendly. Teamsters further agree the rheometer is maintained frequently (Figure 4.13). According to the p-value, an improvement has been highlighted with the maintenance of the compressor for the rheometer ($p<0.05$) (Table 4.14).

Similarly, several authors maintain it is essential that clear ISO procedures, training and calibration of equipment is attained for the smooth operation of a laboratory (WHO 2011; Valdivieso-Gómez and Aguilar-Quesada 2018; Wadhwa *et al.* 2012).

4.4.8 Training and Documentation

Table 4.15: Item-rest correlation and Cronbach's alpha for training and documentation

Items	Item-rest correlation	Alpha-if-deleted
Forms and templates effective	0.73	0.69
Forms and templates contain enough details	0.53	0.74
Training on lab tests completely effective	0.63	0.71
Recommend substantially more training	0.44	0.76
Training program need improvement	0.41	0.76
Team members are adequately trained	0.47	0.75
Overall	-	0.78

The item-rest correlation value greater than 0.4 is indicative of a good relationship between each of the items and the total scale (LoBiondo-Wood and Haber 2013). The item-rest correlation for all questions under training and documentation was above 0.4, indicating good internal consistency among items. The Cronbach's alpha was 0.78, which shows a good relationship between the items and the construct measured (Table 4.15).

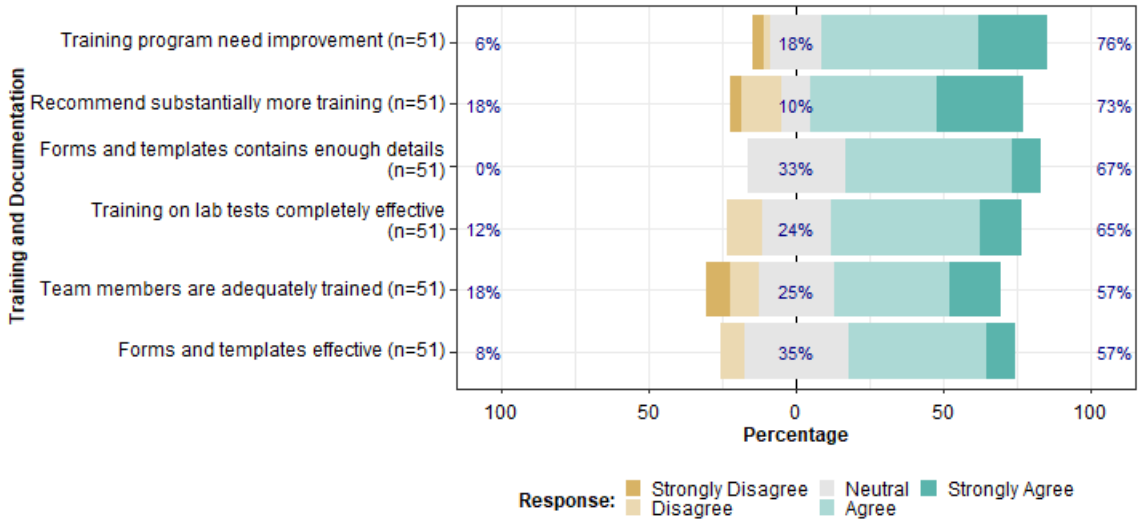

Figure 4.14: Graphical representation of response to scheduling and estimating

Table 4.16: Analysis of pre- and post-questionnaire responses including mean and p-value – scheduling and estimating

Time	Pre (N=29)	Post (N=22)	p-value	Overall (N=51)
Forms and templates effective			0.780	
Disagree	13 (45%)	9 (41%)		22 (43%)
Agree	16 (55%)	13 (59%)		29 (57%)
Forms and templates contain enough details			0.842	
Disagree	10 (35%)	7 (32%)		17 (33%)
Agree	19 (65%)	15 (68%)		34 (67%)
Training on lab tests completely effective			0.651	
Disagree	11 (38%)	7 (32%)		18 (35%)
Agree	18 (62%)	15 (68%)		33 (65%)
Recommend substantially more training			0.196	

Time	Pre (N=29)	Post (N=22)	p-value	Overall (N=51)
Disagree	10 (35%)	4 (18%)		14 (28%)
Agree	19 (65%)	18 (82%)		37 (72%)
Training program need improvement			0.583	
Disagree	6 (21%)	6 (27%)		12 (24%)
Agree	23 (79%)	16 (73%)		39 (76%)
Team members are adequately trained			0.780	
Disagree	13 (45%)	9 (41%)		22 (43%)
Agree	16 (55%)	13 (59%)		29 (57%)

Teamsters are in agreement the documentation, such as forms and templates, are effective and contain enough detail required for training. In addition, teamsters agree the training provided on lab tests are effective. However, it was identified the training programme requires improvement. In addition, teamsters recommended more training on various tests must be carried out (Figure 4.14). The p-values indicate no change of opinion from the pre- to the post-study (Table 4.16). Historically, it was noted key elements of continuous improvement included training and education of supervisors in employing statistical control. This is extremely important for smooth implementation of a QMS within an organisation (Suárez-Barraza *et al.* 2011; Bathaei *et al.* 2021; Webley 1996).

It is positive to note Sappi COE does not have major issues with regard to ISO documentation, training, and calibration of equipment within its processes/tests. Quantitative data collected through the questionnaires indicate common consensus of an existing problem with communication of changes within the schedule, as well as unfair work distribution. In addition, maintenance of equipment is noted as a pertinent issue. While daily verification of waterbaths seems to be a general concern, it has also been identified the training programme requires attention. These factors may hinder generation of timeous results which will, essentially, increase project duration.

4.5. QUALITATIVE ANALYSIS OF PRE AND POST STUDY QUESTIONNAIRE

4.5.1 Question 8.1 - In your opinion, what part of the ageing kinetics test can be improved?

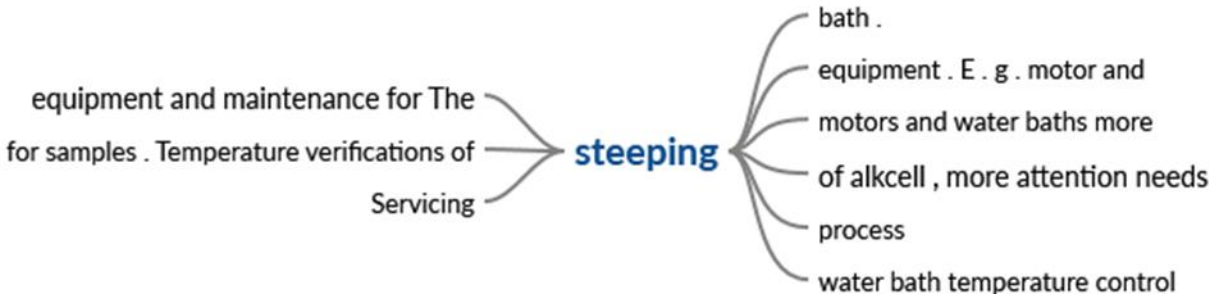

Figure 4.15: Word Tree supporting Steeping (Source: NVIVO 12, Date: 27.08.2023)

Figure 4.16: Word Tree supporting Steeping (Source: NVIVO 12, Date: 27.08.2023)

Figure 4.17: Word Tree supporting Steeping (Source: NVIVO 12, Date: 27.08.2023)

It was noted the general maintenance of the steeping bath, pots and impellers is poor and requires attention. Teamsters observed the steeping bath temperature is not verified before steeping commences. In addition, temperature control of steeping baths has been pointed out as an area of improvement (Figures 4.15-4.17). Maintenance schedules are pertinent to correct functioning of equipment.

Pressing is the second most critical step in ageing kinetics, which teamsters highlighted in need of review and improvement. It was further pointed out that accuracy during pressing of alkcell should be given more attention. In addition, tresses should be added onto a maintenance schedule, as it seems to be a pertinent issue (Appendix G).

Washing during ageing is a crucial step required to neutralise the sample to prevent further depolymerisation. It was noted washing procedures should be reviewed. In addition, there seems to be a shortage of boiling water, therefore, some team members

were using warm water, instead of boiling water, as the procedure indicates (Appendix G).

According to teamsters' general maintenance of steeping baths, motors, and impellers, airlines seem to be poor and require attention. Maintenance schedules, therefore, need to be revised to address these issues (Figure 4.17).

Similarly, several authors noted it is crucial ISO procedures, training and calibration of equipment is attained for the precise operation of a laboratory (WHO 2011; Valdivieso-Gómez and Aguilar-Quesada 2018; Wadhwa *et al.* 2012).

4.5.2 Question 8.2 - In your opinion, what part of viscose production can be improved?

Figure 4.18: Word Tree supporting Steeping (Source: NVIVO 12, Date: 27.08.2023)

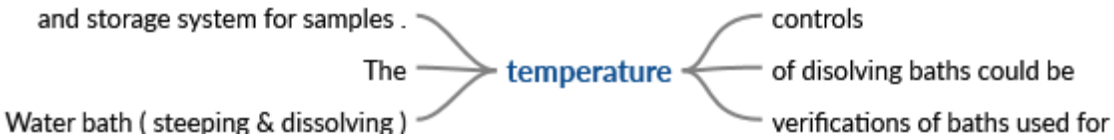

Figure 4.19: Word Tree supporting Steeping (Source: NVIVO 12, Date: 27.08.2023)

Since steeping, pressing, and shredding are required for both ageing kinetics and viscose production, similar issues have been noted, as above, for viscose production. In addition, these processes use the same pieces of equipment, such as steeping baths, pots and impellers for viscose production. It was highlighted by teamsters that steeping bath temperature is not verified before steeping commences. In addition, the ball fall, waterbath and the dissolving baths require daily verification (Figure 4.18 & 4.19).

Similar to ageing kinetics, pressing and washing are critical for production of good quality viscose and have again been highlighted by teamsters as an area for improvement.

4.5.3 Question 8.3 - In your opinion, which application tests do you feel need improvement?

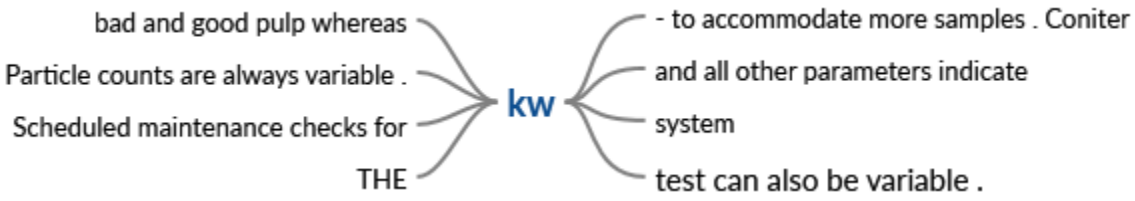

Figure 4.20: Word Tree supporting Steeping (Source: NVIVO 12, Date: 27.08.2023)

A common consensus is the KW filterability test is responsible for most repeats within the project, as it is one of the crucial indicators of viscose reactivity. It was observed that KW equipment is poorly maintained and requires scheduled maintenance checks (Figure 4.20). Teamsters indicated there is variability observed within the KW test and this results in repeat analysis.

Analyses of the qualitative data (Appendix G) indicate similar findings, that is, maintenance of equipment and verifications of waterbaths. In addition, it was highlighted the maintenance of the KW equipment is a problem. This may cause multiple repeats, thus increasing project duration.

4.6 CAUSE AND EFFECT DIAGRAM

A cause-and-effect diagram can be beneficial in a number of ways, as it can provide critical information for factors contributing to the root cause of a problem (Lilana 2016; Neyestani 2017). In addition, the cause-and-effect diagram identifies and groups together triggers that lead to a problem (Ilie and Ciocoiu 2010). Careful analyses and evaluation of each cause is then undertaken from the data supplied, after which the team involved decides which causes have the greatest impact on the process (Suárez-Barraza and Rodríguez-González 2019). Information required for the cause-and-effect diagram constructed for Sappi COE laboratories was gathered through brainstorming sessions and pre-study questionnaires sent out to the department (Figure 4.21).

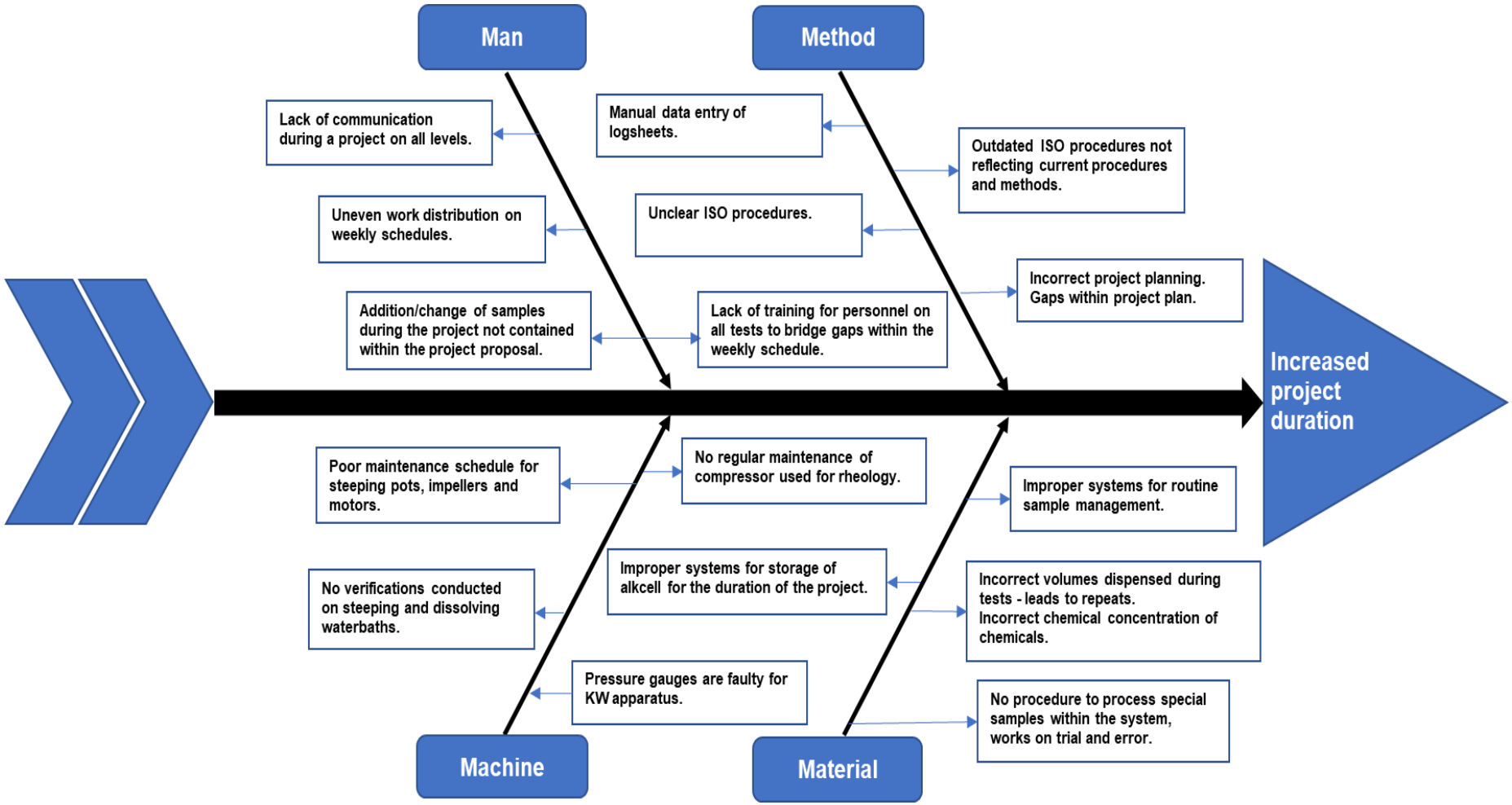

Figure 4.21: Cause and effect diagram for increased project duration within Sappi COE laboratories

The cause-and-effect diagram illustrates the most prominent causes that affect the duration of a project with Sappi COE (Figure 4.21), under the sub-headings, namely, man, method, machine and material (4M methodology). As researchers explained, Dr Karou Ishikawa found many employees were overwhelmed by confusion when exposed to the number of process associated activities. This presented an opportunity to develop a tool to assist employees in coping with these processes. Subsequently, the cause-and-effect diagram was industrialised to categorise possible causes of a problem and to take appropriate action in their solving (Neyestani 2017; Sharma and Suri 2017). Essentially, the cause-and-effect diagram was used effectively to categorise possible causes of increased project duration within a project at Sappi COE laboratories. This will assist management to attain a high-level overview of the possible causes and enable taking appropriate action to resolve the issues highlighted.

4.7 VALUE STREAM MAPPING (VSM)

VSM is known to be a visual representation of the flow of people, material, and information in a complex system (Toussaint and Berry 2013; Singh *et al.* 2010; Michael *et al.* 2013). VSM has been used in Sappi COE to illustrate the flow of people, material and information within “ageing kinetics” (Figure 4.23), “viscose production” (Figure 4.24) and “applications” (Figure 4.25). To facilitate VSM within COE laboratories all ISO documents were revised and corrected, as per Table 3.1. This will be used to conduct the modified job operations (MJOs) on all relevant steps within ageing kinetics, viscose production and application tests.

4.7.1 VSM – Ageing Kinetics

Tables 4.17–4.21 illustrate fundamental process knowledge collected from modified planned job observations (MPJOs), conducted on the ageing kinetics process within the Sappi COE laboratories. In addition, the MPJOs were able to obtain task times and waste generated (Appendix H). The data obtained from the MPJOs on the various tasks within the process have been exemplified using VSM symbols (Figure 4.22), data boxes and associated parameters. Figure 4.23 represents VSM of ageing kinetics using the above-mentioned data.

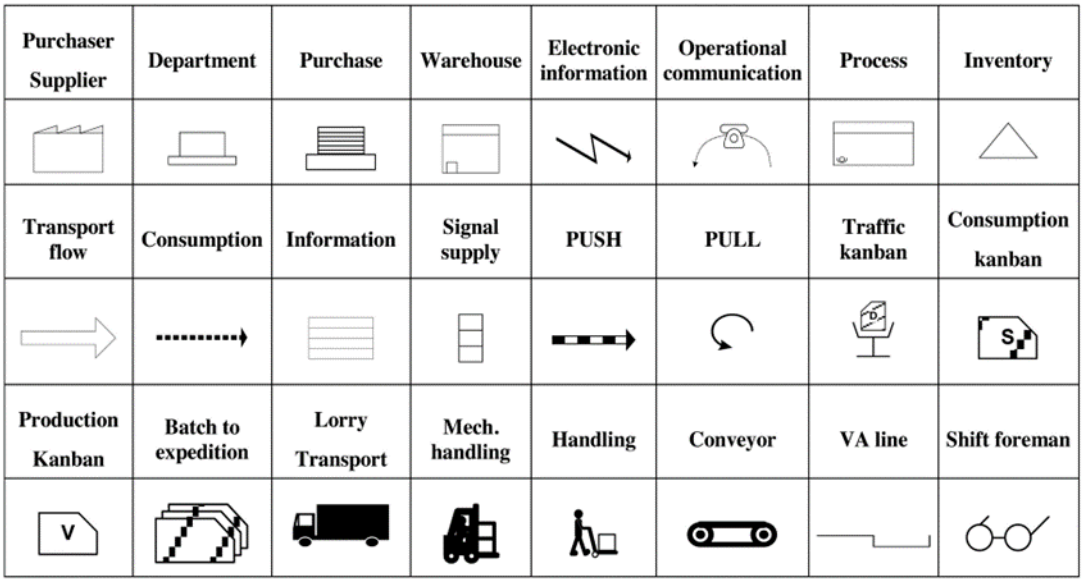

Figure 4.22: VSM symbols

Source: Rohac and Januska (2015) and Sugianto et al. (2015)

Tables 4.17–4.21 summarizes critical data exacted from MPJOs, conducted on the ageing kinetics process within the Sappi COE laboratories. The data collected will be explained below in relation to VSM constructed for ageing kinetics, Figure 4.23.

Table 4.17: Summary of VSM data collection – Steeping small scale

Job observed	Steeping small scale		Doc no:	VISC 001
Department:	Tech Centre (COE)		Revised date:	18/07/2022
Time required to perform one complete test (hour)	Type of waste identified if any for one complete test	Number of value adding (VA) steps identified	Number of non-value adding (NVA) steps identified	Comment
3.23	Time: 2hours of waiting	22	0	8.3.2. Either 8.3.1 or 8.3.2 can be used to get moisture of the sample

Table 4.18: Summary of VSM data collection – Pressing small scale

Planned job observation			
Job observed	Pressing of alkcell - small scale	Doc no:	VISC 002
Department:	Tech centre (COE)	Revised date:	23/06/2022

Time required to perform one complete test (hour)	Type of waste identified if any for one complete test	Number of value adding (VA) steps identified	Number of non-value adding (NVA) steps identified	Comment
1.02	Physical waste: Excess caustic soda containing hemicellulose expelled into the drain.	42	0	8.3.34. Can waste total time of pressing and sample if the target is out of range

Table 4.19: Summary of VSM data collection – Shredding small scale

Planned job observation			
Job observed	Shredding small scale	Doc no:	VISC 003
Department:	Tech centre (COE)	Revised date:	23/06/2022

Time required to perform one complete test (hour)	Type of waste identified if any for one complete test	Number of value adding (VA) steps identified	Number of non-value adding (NVA) steps identified	Comment
0.46	None	12	0	

Table 4.20: Summary of VSM data collection – Alkcell ageing curves

Planned job observation			
Job observed	Procedure for alkcell ageing curves	Doc no:	VISC 014
Department:	Tech centre (COE)	Revised date:	31/08/2022

Time required to perform one complete test (hour)	Type of waste identified if any for one complete test	Number of value adding (VA) steps identified	Number of non-value adding (NVA) steps identified	Comment
1.15	Physical waste: Excess shredded alkcell. Time: Waiting time of 7 hours for samples to dry in oven	17	1	8.2.3. Bottles are not labelled, note made in oven. 8.2.4. Available tray used on the day. 8.2.5. Statement not instruction. 8.2.9. Only done when catalyst is added to ageing, study is based on a control sample. 8.2.12. Only done when catalyst is added to ageing, study is based on a control sample. 8.2.13. Based on ideal conditions and done right the first time. 8.2.17. Statement not instruction.

Table 4.21: Summary of VSM data collection – CED viscosity of pulp, alkcell and cellulose products

Planned job observation

Job observed	CED Viscosity of pulp, alkcell, and cellulose products	Doc no:	VISC TEST 013
Department:	Tech centre (COE)	Revised date:	04/08/2022

Time required to perform one complete test (hour)	Type of waste identified if any for one complete test	Number of value adding (VA) steps identified	Number of non-value adding (NVA) steps identified	Comment
3.11	Time: 1 hour waiting time, samples placed in the oven. 1 hour waiting time, samples placed in the desiccator. 0.5 hours waiting time while samples shake. 0.5 hours waiting time while samples shake. 0.5 hours waiting time while samples reach temperature in the bath. 0.5 hours waiting time while samples reach temperature in the bath. Physical waste: CED solution and contaminated paper towels.	24	0	None

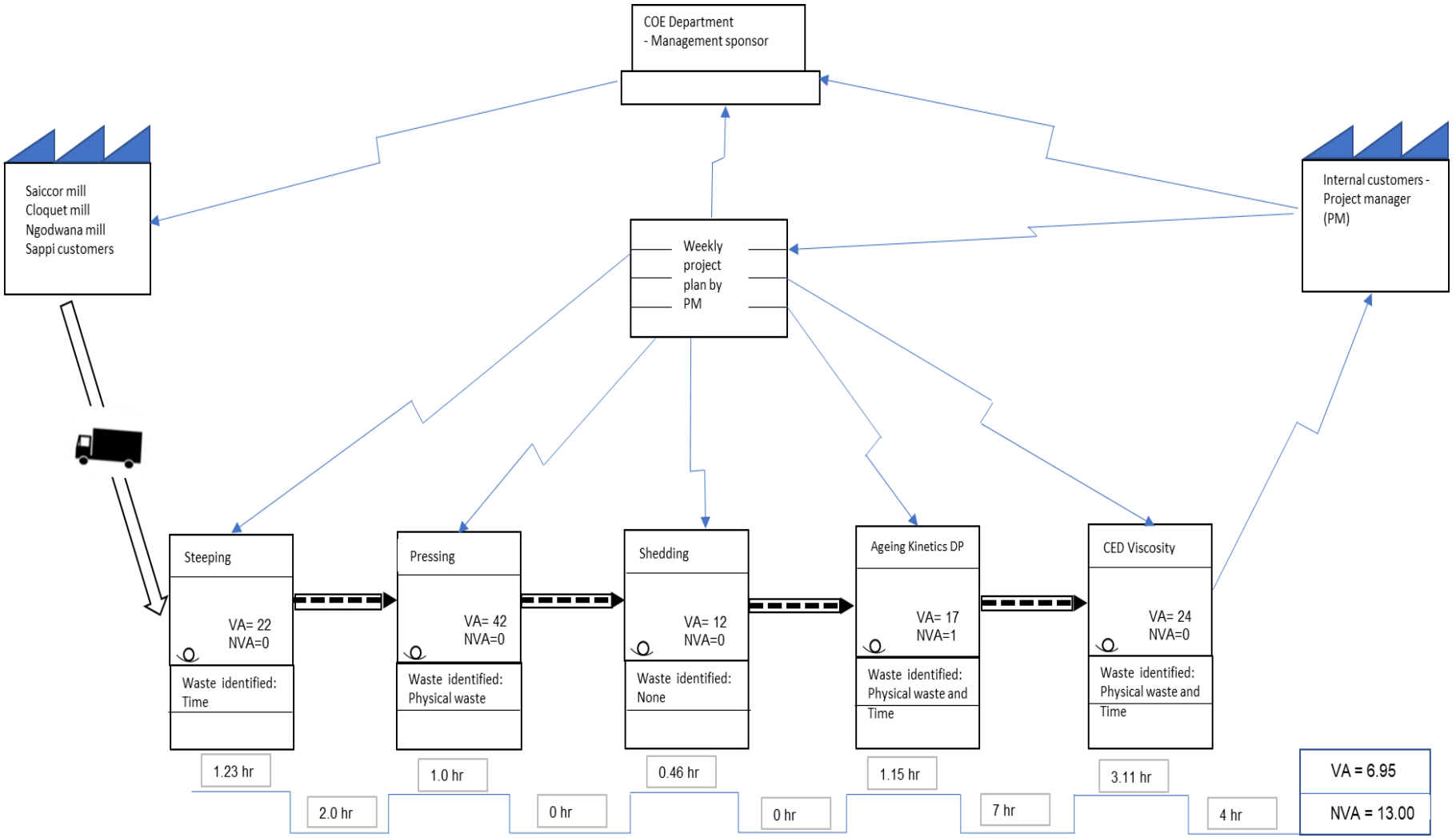

Figure 4.23: VSM constructed for ageing kinetics at Sappi COE laboratories

Figure 4.23 illustrates VSM of ageing kinetics that includes five fundamental tasks, steeping, pressing, shredding, and ageing kinetics for DP, as well as CED viscosity. During steeping, 22 value added (VA) steps were identified, with (non-value adding)NVA steps noted. The time taken for the actual task was 1.23 hours. The waste identified was waiting time during the steeping, this occurs while caustic is heating, and the sample is steeping. In addition, time is wasted while the sample is in the oven for moisture analysis. The NVA time was approximately two hours (Table 4.17).

It was observed there are 42 VA steps during pressing and no NVA steps. The type of waste identified was physical waste such as, caustic soda expressed during pressing, as well as paper towels used for wiping the press basket. The time taken for all activities during pressing was one hour (Table 4.18).

During shredding of the alkcell there are 12 VA steps and no NVA steps. The time of the VA steps amounted to 0.46 hours, with no waste noted during this task (Table 4.19).

It was noted, during ageing kinetics to obtain a degree of depolymerisation (DP), there are 17 VA steps and one NVA step. The time taken to perform all VA steps was 1.15 hours, with the types of waste identified as physical waste and time. Time allocated to waste amounted to even hours, due to waiting for samples to be retrieved and washed every hour. Physical waste identified was excess shredded alkcell (Table 4.20).

The CED viscosity test contains 24 VA steps and no NVA steps. The time taken to perform this task was 3.11 hours. The types of wastes were physical waste and time. The amount of time wasted amounted to approximately 4 hours, as a result of waiting for samples to regulate in waterbaths, as well as shaking and conditioning of samples (Table 4.21).

Overall, the total time allocated to the ageing kinetics process amounted to 6.95 hours. The most prominent wastes identified were physical waste and time. It was noted 13 hours of time is available for use on other tasks within the department. In addition, it must be noted some of the free time observed was allocated to filler work within the department. However, time management can be further improved.

VSM has been employed by several laboratories to reduce TAT and improve cycle efficiencies (Dagdeviren *et al.* 2020; White *et al.* 2015; Sugianto *et al.* 2015). In addition, VSM has been known to identify areas for improvement and the types of waste generated. It has been used in laboratories to identify value adding activities and NVA activities. This has effectively assisted the laboratories to manage NVA activities to improve the system and, ultimately, achieve the goal of decreased TAT by the testing laboratory (Natakusuma *et al.* 2018). The implementation of VSM for ageing kinetics is able to achieve similar results, as reported by the researchers mentioned above.

4.7.2 VSM – viscose production

Tables 4.22–4.24, illustrate the fundamental process knowledge collected from MPJOs conducted on the viscose production process within the Sappi COE laboratories. In addition, as stated above, the MPJOs were able obtain task times and waste generated (Appendix H). The data obtained from the MPJOs on the various tasks within the process are represented using VSM symbols (Figure 4.22 above), data boxes and associated parameters for viscose production. It must be noted the three initial steps, steeping, pressing, and shredding, are identical to that for ageing kinetics process. Therefore, the data for the initial steps will be obtained from Tables 4.17-4.19 for the creation of VSM for viscose production (Figure 4.24).

Table 4.22: Summary of VSM data collection – Procedure for Viscose Ageing (viscose preparation)

Planned job observation				
Job observed	Procedure for Viscose ageing (Viscose preparation)	Doc no:	VISC 013	
Department:	Tech centre (COE)	Revised date:	21/09/2022	
Time required to perform one complete test (hour)	Type of waste identified if any for one complete test	Number of value adding (VA) steps identified	Number of non-value adding (NVA) steps identified	Comment
0.72	Time: 5 hours waiting time for ageing and 1 hour for cooling	14	0	None

Table 4.23: Summary of VSM data collection – Xanthation of Alkcell

Planned job observation

Job observed	Xanthation of Alkcell	Doc no:	VISC PREP 001
Department:	Tech centre (COE)	Revised date:	28/09/2022

Time required to perform one complete test (hour)	Type of waste identified if any for one complete test	Number of value adding (VA) steps identified	Number of non-value adding (NVA) steps identified	Comment
0.57	None	12	0	8.3.9. ISO doc to be amended, they do not shake the bottle anymore as it is a safety hazard.

Table 4.24: Summary of VSM data collection – Dissolving and ripening

Planned job observation			
Job observed	Dissolving and ripening	Doc no:	VISC PREP 002
Department:	Tech centre (COE)	Revised date:	28/09/2022

Time required to perform one complete test (hour)	Type of waste identified if any for one complete test	Number of value adding (VA) steps identified	Number of non-value adding (NVA) steps identified	Comment
0.20	None	9	0	8.3.1. Statement not instruction. 8.3.6. Statement not instruction, dissolving of 5.5hrs however after working hours. 8.3.7. Statement not instruction. 8.3.8. Statement not instruction. 9. Statement not instruction.

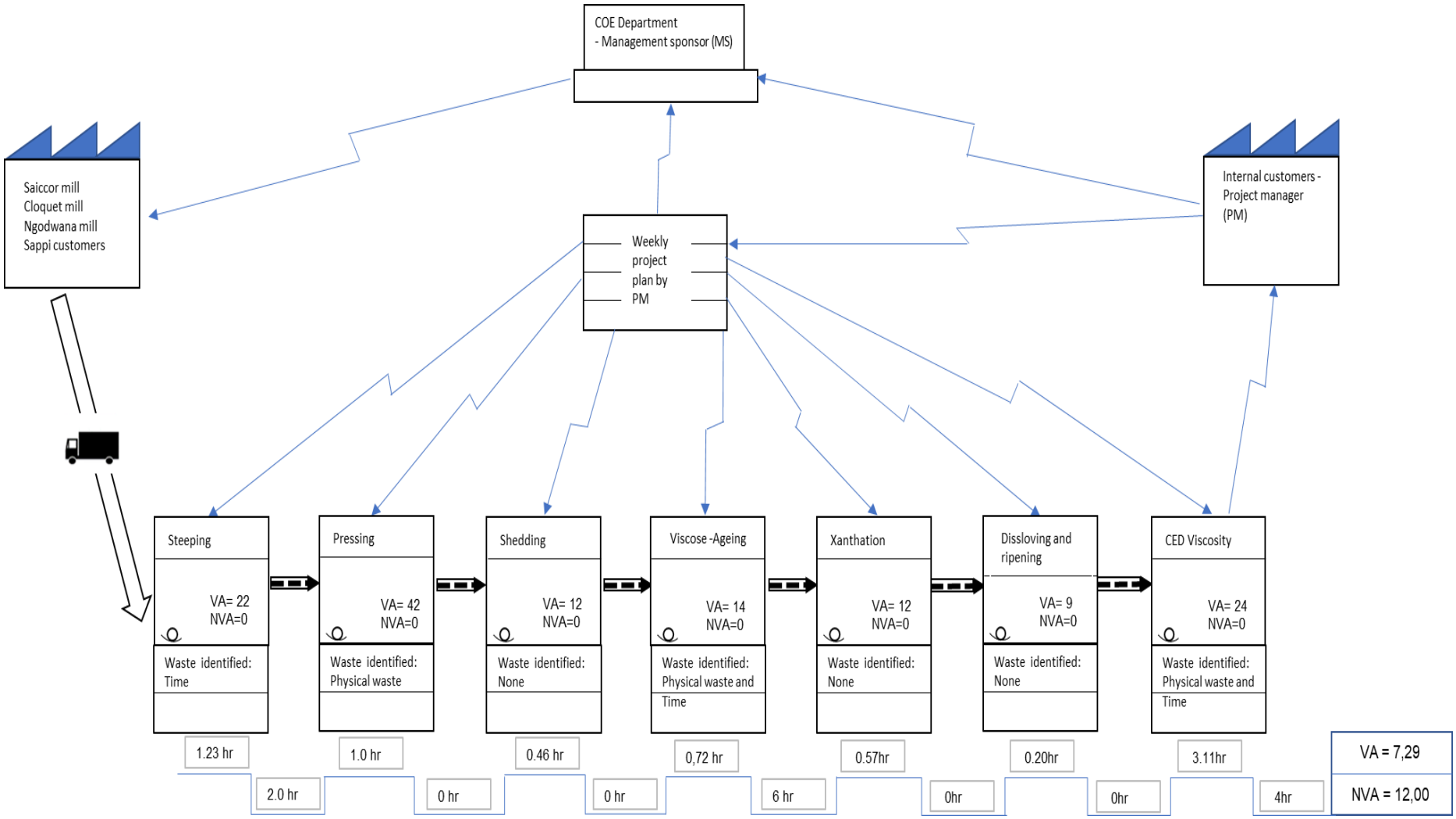

Figure 4.24: VSM constructed for viscose production at Sappi COE laboratories

Figure 4.24 illustrates VSM of viscose production, which includes seven fundamental tasks, namely, steeping, pressing, shredding, and viscose ageing, as well as xanthation, dissolving and ripening, along with CED viscosity. The first three initial steps are identical to ageing kinetics and were explained in detail above (Tables 4.17-4.19). Therefore, the explanation of VSM for viscose production will continue from viscose ageing, with data obtained from Tables 4.22-4.24.

It has been identified viscose ageing has 14 VA steps and no NVA steps, while the actual time spent on tasks amounts to 0.72 hours. Two types of wastes were identified, physical waste and Time. Time wasted amounted to six hours due to waiting for samples to reach the correct DP, as well as cooling time of the sample before xanthation (Table 4.22).

The xanthation process consists of 12 VA steps, with no NVA steps recorded. The time taken for the xanthation process amounted to 0.57 hours. There was no waste recorded for this process (Table 4.23) .

During dissolving and ripening, nine VA steps were recorded, with no NVA steps for dissolving and ripening. The process time recorded for dissolving and ripening was 0.20 hours (Table 4.24).

Elements around the CED have been explained in detail above and will apply for alkcell from viscose production.

The total time taken for viscose production amounted to 7.29 hours. It has been estimated that the total time available for additional tasks amounted to 12 hours. In addition, two types of wastes have been identified, physical waste and time. Once again it must be noted, while some of the free time observed was allocated to filler work within the department, time management can be further improved. VSM has been used to evaluate process times, VA and NVA activities, as well as waste generated. Similar findings have been noted by several researchers, as stated above (Dagdeviren *et al.* 2020; White *et al.* 2015; Sugianto *et al.* 2015; Natakusuma *et al.* 2018). It is positive to note there are no NVA activities within the viscose production process.

4.7.3 VSM – viscose application tests

Tables 4.25–4.30 illustrate the fundamental process knowledge collected from MPJOs conducted on viscose application tests within Sappi COE laboratories. In addition, as stated above, the MPJOs were able obtain task times and waste generated (Appendix H). The data obtained from the MPJOs on the various tasks within the process were demonstrated using VSM symbols (Figure 4.22), data boxes and associated parameters for viscose application tests. Figure 4.25 illustrates VSM of viscose application tests using the above-mentioned data.

Table 4.25: Summary of VSM data collection – SIV

Planned job observation				
Job observed	Soda in viscose (SIV)	Doc no:	VISC TEST 017	
Department:	Tech centre (COE)	Revised date:	31/08/2022	
Time required to perform one complete test (hour)	Type of waste identified if any for one complete test	Number of value adding (VA) steps identified	Number of non-value adding (NVA) steps identified	Comment
0.59	Time: Waiting time 15 minutes. Physical waste: SIV waste solution (viscose in acid/base solution).	9	0	None

Table 4.26: Summary of VSM data collection – CIV

Planned job observation				
Job observed	Cellulose in Viscose (CIV)	Doc no:	VISC TEST 013	
Department:	Tech centre (COE)	Revised date:	04/08/2022	
Time required to perform one complete test (hour)	Type of waste identified if any for one complete test	Number of value adding (VA) steps identified	Number of non-value adding (NVA) steps identified	Comment
0.73	Physical waste: Waste tissue paper contaminated with viscose dope. Spinbath solution after viscose regeneration. Boiling water. Regenerated film after drying. Time: 45 minutes waiting time	23	0	None

Table 4.27: Summary of VSM data collection – Ball fall

Planned job observation				
Job observed	Ball fall		Doc no:	VISC PREP 009
Department:	Tech centre (COE)		Revised date:	28/09/2022
Time required to perform one complete test (hour)	Type of waste identified if any for one complete test	Number of value adding (VA) steps identified	Number of non-value adding (NVA) steps identified	Comment
0.28	Time: 3 hours waiting time. Physical waste: Viscose dope from ball fall tubes.	8	0	8.3.3. Not done, either change ISO doc or start practice.

Table 4.28: Summary of VSM data collection – KW

Planned job observation				
Job observed	Filterability (Kw) viscose test		Doc no:	VISC TEST 019
Department:	Tech centre (COE)		Revised date:	28/09/2022
Time required to perform one complete test (hour)	Type of waste identified if any for one complete test	Number of value adding (VA) steps identified	Number of non-value adding (NVA) steps identified	Comment
0.46	Time: 30minutes waiting time. 60minutes waiting time at 10minute intervals. Physical waste: Filtered viscose dope.	13	0	None

Table 4.29: Summary of VSM data collection – Particle count, also known as Coulter counter analysis

Planned job observation				
Job observed	Coulter counter analysis - viscose test		Doc no:	VISC TEST 018
Department:	Tech centre (COE)		Revised date:	11/11/2019
Time required to perform one complete test (hour)	Type of waste identified if any for one complete test	Number of value adding (VA) steps identified	Number of non-value adding (NVA) steps identified	Comment
4.5	Physical waste: Contaminated viscose solution. 6% NaOH blank solution. Contaminated demineralised water. Excess viscose sample in solution after analyses. Cleanse solution after cleaning is complete.	56	0	None

	Contaminated demineralised water. Time: Waiting time of 15 minutes for stirring of sample. Waiting time of 30 minutes for settling of sample.			

Table 4.30: Summary of VSM data collection – Rheology

Planned job observation				
Job observed	Rheology of viscose dope		Doc no:	VISC TEST 012
Department:	Tech centre (COE)		Revised date:	03/08/2022
Time required to perform one complete test (hour)	Type of waste identified if any for one complete test	Number of value adding (VA) steps identified	Number of non-value adding (NVA) steps identified	Comment
0.66	Physical waste: Contaminated paper towel with viscose, water and acid solution. Time: Waiting time of 30 minutes to attain compressor pressure	41	0	None

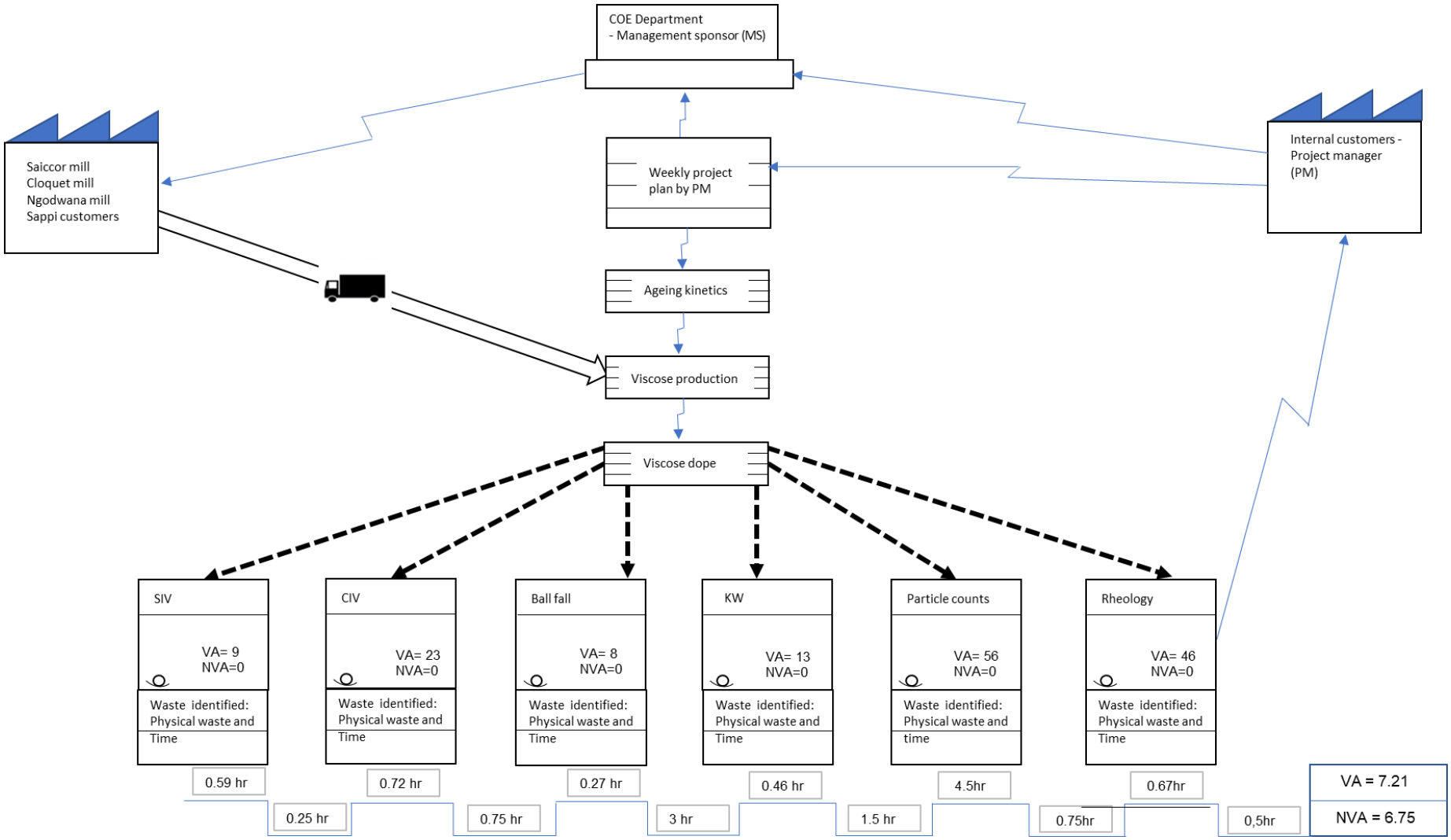

Figure 4.25: VSM constructed for viscose application tests at Sappi COE laboratories

Figure 4.25 establishes VSM for viscose application tests in Sappi COE laboratories. Six viscose application tests were analysed independently: SIV, CIV, ball fall, KW, particle counts and rheology.

The SIV test consisted of nine VA steps, with no NVA steps noted. Two types of wastes were noted, namely physical waste and time. While the total time spent on the SIV test was 0.5 hours, the time spent on waiting for sample reaction to take place amounted to 0.25 hours (Table 4.25).

During the CIV test, 23 VA steps were noted, with no NVA steps observed within the test. The CIV test generates two types of waste, physical waste and time. The time taken to perform the CIV test amounted to 0.72 hours, with a waiting time of 0.75 hours (Table 4.26).

The ball fall test has eight VA steps with no NVA steps observed. Two types of wastes are generated, physical waste and time. The total time required to perform ball fall was 0.27 hours, with a 3-hour waiting period (Table 4.27).

It was noted KW filtration consists of 13 VA steps, with no NVA steps within the test procedure. Physical waste and time were identified as the type of wastes generated during KW filtration. The time taken to perform the test was 0.46 hours, with 1.5 hours of waiting time (Table 4.28).

The particle count test was noted to contain 56 VA steps, with no NVA steps noted. Physical waste and time were also noted as the two types of wastes generated during the test. The actual running time for the test amounts to 4.5 hours, with a 0.75 hour waiting time (Table 4.29).

The rheology test contains 46 VA steps, with no NVA steps observed during the procedure. There are two types of wastes generated during rheology, physical waste and time. While the time taken to complete the test amounts to 0.67 hours, the waiting time is 0.5 hours (Table 4.30).

Overall, VA activities for viscose application tests amount to 7.21 hours, with a waiting time of 6.75 hours. As stated above, it must be noted some of this free time was allocated to filler work. However, time can be maximised to accommodate extra activities required within the department. Two types of wastes were predominantly

highlighted throughout viscose applications testing., physical waste and time. It is positive to note there are no NVA steps within the test procedures.

During ageing kinetics, viscose production and application tests, the time factor has been critically examined within each process or test. This was analysed critically, due to its potential to extend the time required within a project.

VSM conducted on ageing kinetics, viscose production and applications provided the following benefits to Sappi COE:

- The flow of people, material, and information within the process/tests.
- Value adding activities were noted.
- Nonvalue adding activities were noted.
- Process/test cycle times were established.
- Types of wastes according to LM were noted (Table 2.7).

It should be known that, VSM provided similar benefits to several laboratories, ranging from chemical textile laboratories to pathology laboratories (Dagdeviren *et al.* 2020; White *et al.* 2015; Sugianto *et al.* 2015; Natakusuma *et al.* 2018).

4.8 AN INTEGRATED QUALITY MANAGEMENT FRAMEWORK (IQMF) FOR SAPPI COE

It must be noted Sappi COE laboratories are governed by an internal Sappi standard known as Sappi 25. This standard was produced for the Sappi mill testing laboratories to demonstrate they operate a management system, are technically competent and able to generate impartial and technically valid results. Sappi uses this standard as the basis for internal certification of the technical competence of mill laboratories. Although Sappi mills are certified against ISO 9000, this certification does not, of itself, demonstrate the competency of the laboratory to produce technically valid data.

Sappi 25 is based on the ISO 17025:2017, which is the international standard for general requirements for the competency of testing and calibration laboratories. The standard has been specifically designed to address the needs of Sappi mill testing laboratories not sufficiently addressed by the ISO 9000 standard (Chula 2021). The standard is applicable only to Sappi's full batch analysis tests, such as, copper number, solubilities, brightness, and pentosans, as well as ash, CED viscosity final

sheet, and resins. The Sappi 25 standard does not apply to ageing kinetics, viscose production and application testing. Therefore, an IQMF will be beneficial in addressing some of the laboratories' existing quality issues.

Prior to the development of the framework, a pilot study was undertaken. In addition, analysis of data acquired from the pre-study questionnaire and the brainstorming sessions identified certain root causes of the prolonged project duration. These findings have been grouped together and visualised using a fishbone diagram. The core findings noted were considered in development of the IQMF.

Critical analysis of the above provided the necessary data that enabled recognition of potential issues within the ageing kinetics, viscose production and application tests, which could have significant consequences on project duration.

The major root causes identified in the study that affect project duration include:

1) Lack of communication on all levels within the COE.
2) Inadequate systems available for sample management.
3) Lack of maintenance schedules for critical pieces of equipment.
4) Unclear/outdated ISO procedures.
5) Poor time management.

The above root causes were considered, and a proposed solution designed and incorporated into the integrated framework. The proposed framework will be based on fundamental principles and tools adopted from ISO 17025: 2015 (eight clauses) and LM (3 LM tools).

Table 4.31 identifies the root causes of increased project duration and the corresponding ISO 17025:2017 principles that will be used to address these root causes (Ribeiro *et al*. 2020; Michem Dynamics 2018; Chula 2021). In addition, it will illustrate the possible LM tools that can be used to address the root causes (Al-Bakoosh *et al.* 2020; Kholif *et al.* 2018; Dennis 2017; Kilpatrick 2003; Sugianto *et al.* 2015; Durur and Akbulut 2019; Graban and Padgett 2008; McManus 2005).

Table 4.31: Fundamental ISO principles and LM tools used to address root causes of increased project duration

Root causes	ISO fundamental principles	Lean Manufacturing Tools
1) Lack of communication on all levels within the organisation.	Clause 6.2 – Personnel – 6.2.4 The management of the laboratory shall communicate to personnel their duties, responsibilities and authorities. 6.2.5 The laboratory shall have procedure(s) and retain records for: a) determining the competence requirements; b) selection of personnel; c) training of personnel; d) supervision of personnel; e) authorisation of personnel; f) monitoring competence of personnel.	
2) Inadequate systems available for sample management.	7.3 Sampling 7.3.1 The laboratory shall have a procedure for sampling materials for subsequent testing. The sampling procedure shall be based on an international/national standard or any reference with credible background. The sampling procedure shall include and address factors needed to be controlled to ensure the integrity of the sample is protected and that valid results will be obtained. 7.3.2 The sampling method shall describe: a) the selection of samples or sites; b) the sampling plan; c) the preparation and treatment of sample(s) from a substance, material or product to yield the required item for subsequent testing or calibration. 7.3.3 The laboratory shall retain records of sampling data that forms part of the testing or calibration that is undertaken. These records shall include, where relevant: a) sample description and reference to the sampling method used; b) date and time of sampling; c) data to identify and describe the sample (e.g. number, amount, name);	PDCA 5S

	d) identification of the personnel performing sampling; e) identification of the equipment used; f) environmental or transport conditions; g) diagrams or other equivalent means to identify the sampling location, when appropriate; h) deviations, additions to or exclusions from the sampling method and sampling plan.	
3) Lack of maintenance schedules for critical pieces of equipment.	6.4.3 The laboratory shall have a procedure for handling, transport, storage, use and planned maintenance of equipment in order to ensure proper functioning and to prevent contamination or deterioration. 6.4.4 The laboratory shall verify that equipment conforms to specified requirements before being placed or returned into service. 6.4.5 The equipment used for measurement shall be capable of achieving the measurement accuracy and/or measurement uncertainty required to provide a valid result.	
4) Unclear/outdated ISO procedures.	7.2.1.2 All methods, procedures and supporting documentation, such as instructions, standards, manuals and reference data relevant to the laboratory activities, shall be kept up to date and shall be made readily available to personnel.	VSM
5) Poor time management.		VSM

4.8.1 Existing measures in place to address above-mentioned root causes of prolonged project duration

- Lack of communication on all levels within the COE.

  An organogram is available to all personnel on the intranet. All employee documents are available within the department, as well as with the human resources department. A structured training program is currently in place at COE. All training documents are stored as hard copies within the department. In addition, soft copies are available on SharePoint. The department hosts monthly COE

meetings to keep all personnel informed of current events within the department. Annual engagement surveys are rendered to all Sappi employees.

- Inadequate systems available for sample management.
  COE had no sample management system available prior to this study.

- There is lack of maintenance schedules for some critical pieces of equipment.
  Existing maintenance schedule on SAP to notify operations manager of equipment to be serviced.

- Unclear/outdated ISO procedures.
  A yearly review of outdated ISO documents is undertaken within the financial year.

- Poor time management.
  Weekly schedules are collated to allocate work to each teamster on various projects. This is compiled by PMs of specific projects.

4.8.2 An integrated quality management framework (IQMF) tailored for Sappi COE

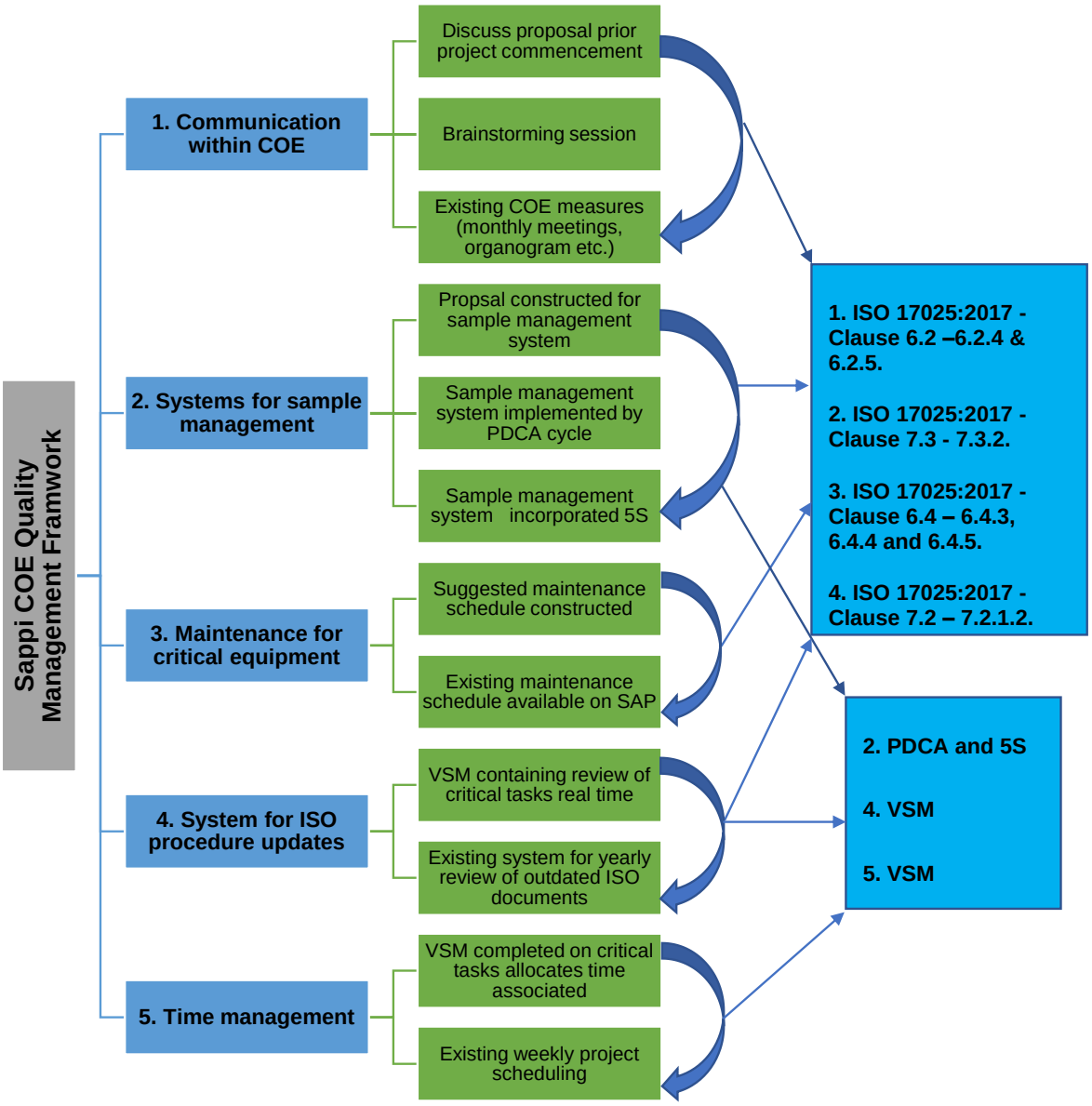

Figure 4.26: An IQMF based on the fundamental principles from Table 4.31

The IQMF (Figure 4.26) takes the following aspects into consideration to address the above-mentioned root causes.

- Lack of communication on all levels within the COE

Reinstated initial discussion of project prior to commencement of the project. Initiated brainstorming sessions with all members of the team during and after project completion.

- Inadequate systems available for sample management.

The following PDCA cycle was put into place to assist with sample management within the pulp store. In addition, the p-value from the post questionnaires reflected a positive change within the sample management system after implementation of the various improvement measures set out by the PDCA cycle shown below.

Plan

- Constructed proposal (Appendix I).
- Investigated possible QMS used in the various Sappi mills.
- Identified possible system that could be effective in the COE pulp store.
- Planned to implement a pilot system.

Do

- Procured appropriate items used for the tracking system.
- Reviewed findings from the pilot study and made possible changes.
- Implemented finalised system (Figure 4.27).

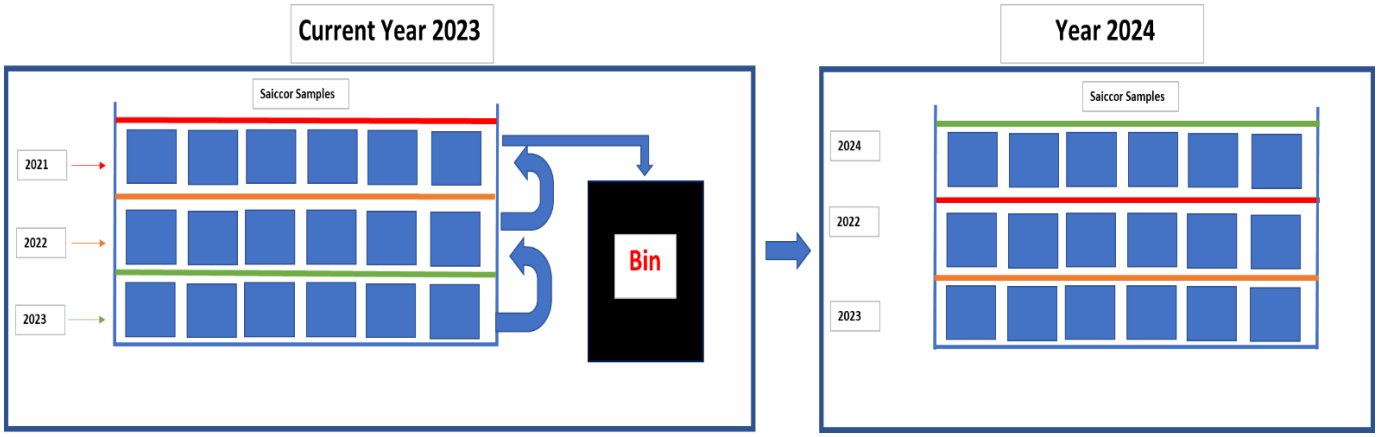

Figure 4.27: Schematic representation of COE pulp sample management system

- Implemented 5S to sort, straighten and shine, logbooks created (Appendix J) to sort and straighten samples. Teams were employed to sort samples according to Figure 4.27.

Check

- Trained personnel on how to use the system effectively. Completed closeout presentation on how to manage the pulp store effectively.
- Implemented 5S (Standardise) to evaluate system and improve through the use of a pulp store checklist (Appendix K) and, in essence, satisfy ISO standard.

Act

- A similar approach was implemented at the various labs for project analysis.
- The duration of samples stored was determined and rolled out.
- Implemented 5S (Sustain) to ensure the system is reviewed during housekeeping at the safety, health, environment and quality at monthly meetings, by using the checklist.

- Lack of maintenance schedules for critical pieces of equipment.

Suggested maintenance schedule for viscose laboratory equipment (Appendix L).

- Unclear/outdated ISO procedures.

Steps within VSM contained a review of current ISO documents that outlined test methods and procedures. It prompted real-time changes required within the process. This process simultaneously satisfied Clause 7.2.1.2 of ISO 17025:2017.

- Poor time management.

VSM was completed as shown above for ageing kinetics, viscose production, and application tests. This will assist each PM to identify the time required for each task scheduled. Hence, it will identify free time each teamster may or may not have. This will make it easier for the PM to allocate filler work and pair tasks together.

Several researchers have used IQMFs to address numerous quality-related issues within the laboratory environment (Sugianto *et al.* 2015; Michael *et al.* 2013; Durur and Akbulut 2019; Muiambo *et al.* 2021; Habibie and Kresiani 2019; Al-Bakoosh *et al.* 2020).

4.9 SUMMARY OF CHAPTER

Chapter four presented and analysed the results of the empirical study. Various avenues were explored through brainstorming sessions, pre- and post-questionnaires and visual data assembly using a cause-and-effect diagram. In addition, VSM proved a useful tool to extract data on the system and processes carried out within COE laboratories. The overall results indicated the key focus areas which required attention were within ageing kinetics, viscose production and application tests within COE laboratories. An integrated framework was developed, based on ISO 17025:2017 standards, integrated with lean tools, to assist in resolving some highlighted issues.

Based on the review and presentation of the collated results, the following chapter will present the study conclusion and recommendations.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1. INTRODUCTION

Chapter five will provide concluding remarks based on the results obtained in the empirical study. It will provide findings from the implemented IQMF. The first part of this chapter will summarise whether the aims and objectives posed in chapter 1 were satisfied. The chapter will highlight the restrictions and limitations which impinged on the investigation. Appropriate recommendations and the way forward will be presented, in line with the study objectives and the improvement in quality within Sappi COE laboratories.

5.2. ACHIEVEMENT OF RESEARCH AIMS AND OBJECTIVES

The aim of this research was to reduce or eliminate repeat work during projects; to improve throughput time for project deliverables through development and implementation of an IQMF within Sappi COE laboratories. The brainstorming sessions and pre-study questionnaire indicated sample management and maintenance as major components of delays within a project, apart from other significant findings, explained in chapter 4.

It was evident, based on the results obtained from the post questionnaire, there has been an improvement in sample management within the department, after implementation of the framework. An improvement in sample management alleviates unnecessary time wasted in searching for samples, as well as incorrect samples being analysed due to insufficient tracking and information. This will, in essence, reduce the duration of time taken to complete a project.

The post questionnaire revealed a slight improvement in maintenance. However, p-values indicated no change statistically. The integrated framework developed incorporates maintenance schedules as one of the components to minimise downtime. The use of VSM, as a component for the integrated framework, allowed the researcher to ascertain various aspects that affected project duration, such as NVA activities, resulting in time wasted. In addition, VSM allowed the researcher to identify the various types of physical wastes generated within the processing. The IQMF incorporated ISO 17025:2017 standards and LM tools to assist in minimising project duration, by

resolving issues that affect project duration. Overall, the empirical study satisfied the objectives set out in chapter 1.

5.3. RESTRICTIONS AND LIMITATIONS

The following limitations were noted that may present opportunities for future study. The first limitation noted is the study was based primarily on the core functions within Sappi COE laboratories, namely ageing kinetics, viscose production and application tests. However, the laboratory embarks on several other ad hoc tests within the department. Examples of the specific tests include, but are not limited to: hydrolysis, pentosan, optical properties and quick reactivity tests, and more. These tests are, sometimes, required to be conducted within the battery of tests for specific projects, with repeat analysis for these tests at times required due to anomalies within the results obtained. The factors around the repeat analysis may present a new set of challenges compared to those for ageing kinetics, viscose production and applications tests. Therefore, it will require a different set of tools to address the related issues.

The second limitation was that the timeframe for implementation of research work that was limited. It has been highlighted during the course of the study that maintenance is one of the major contributors of repeat analysis. Therefore, implementation of the maintenance schedules would have been pertinent in resolving many issues around the laboratory. However, due to the existing maintenance schedules available and authorisations required, it was not possible to implement and fully exercise appropriate maintenance schedules.

5.4. RECOMMENDATIONS

The implementation of IQMF assists with the continuous, incremental improvement of the quality of results rendered by Sappi COE laboratories. However, outstanding aspects of IQMF are still to be implemented to unlock the full potential of the IQMF; such as improved maintenance schedules and so on. To ensure adequate implementation of IQMF, it will require buy-in from management, and all the relevant role players. During the multiple brainstorming sessions held and the data collected from questionnaires, which rendered, the following recommendations that should be taken into account to fully adopt the IQMF:

- Re-institute group meetings before commencement of a project to unpack the project proposal.

- Remove redundant equipment to make space for new tests and existing tests that can be performed within COE laboratories.
- Set up a Microsoft team group per project for daily update, used by the team coordinator; primarily to communicate daily laboratory issues and for daily results updates (No MS on the group only PM to teamsters).
- All staff should be trained to be competent in all tests to ensure that the same teamsters start and end a project. This will eliminate “chopping and changing” teamsters within a project.
- Fewer projects undertaken; with the addition of more teamsters per project. This will ensure improved quality of results within a shorter timeframe.
- More than one external supplier should be sourced for maintenance issues, equipment, and fabrication. This will eliminate unnecessary waiting time for a specific supplier to attend to breakdowns.
- Make use of internal resources for work on breakdowns and fabrication of equipment.
- Xanthation should be an automated closed system to eliminate human error, as it is noted to be a crucial step for viscose production.
- Regeneration of viscose should be reinstated.
- Waterbaths should be calibrated more frequently to prevent reoccurring alarms.
- KW filtration has been observed the main test that causes repeats of the entire process. Workshops to analyse the test should be conducted to attain a deeper understanding of the test.

5.5. CONCLUDING REMARKS

Quality management, within the industry and service departments provides a continuous and infinite improvement in the quality of the product or service rendered. The investigation into the current operations and processes at Sappi COE laboratories provided a good review of the current status of quality management within the department. It discovered areas that may potentially delay project completion. A root cause of repeat analysis was conducted, and the potential causes were identified, with an IQMF developed and implemented to improve the functioning status of the laboratory. It is evident through the findings of this study that a IQMF can effective in improving the quality of work undertaken in a laboratory environment.

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Appendix A: Example of a planned job observation conducted for value stream mapping.

Table 1: Blank template

Planned job observation								
Job observed					Doc no:			
Department:					Revised date:			
Step no:	Correct		Time required to perform step (seconds) - Participant 1	Time required to perform step (seconds) - Participant 2	Waste identified if any	Step value adding (VA) or non-value adding (NVA)		Comment
	Yes	No						
		Sec	0	0				
		Min	0,00	0,00				
		Hour	0,00	0,00				

Table 2: Example of completed planned job observation: Ball fall

Planned job observation								
Job observed	Ball fall			Doc no:	VISC PREP 009			
Department:	Tech centre (COE)			Revised date:	28/09/2022			
Step no:	Correct		Time required to perform step (seconds) - Participant 1	Time required to perform step (seconds) - Participant 2	Waste identified if any	Step value adding (VA) or non-value adding (NVA)		Comment
	Yes	No	17/02/2023	17/02/2023		VA	NVA	
8.3.1	Yes		60	60	None	VA		
8.3.2	Yes		3	5	None	VA		
8.3.3	Yes		0	0	None	VA		Not done, either change ISO doc or start practice.
8.3.4	Yes		10800	10800	3 hours waiting time.	VA		
8.3.5	Yes		180	180	None	VA		
8.3.6	Yes		65	65	None	VA		
8.4	Yes		600	720	None	VA		
9.	Yes		10	7	None	VA		
		Sec	11718	11837				
		Min	195,30	197,28				
		Hour	3,26	3,29				

Appendix B: Pre-study questionnaire

PRE-STUDY QUESTIONNAIRE

Title: An integrated quality management framework to improve project throughput rate in a selected laboratory environment

Dear Respondent

Quality plays a crucial role in the business process within an organisation, to improve efficiency and to be more effective in the global market. Improving quality and customer loyalty has a significant bearing on market share. A focus to reduce wastage, but also to satisfy customer's expectations, continuous cost reductions and continuous improvements are necessary to survive in a highly competitive environment. A significant amount of research has been carried out, which indicates that the application of quality management framework will assist to increase quality, reduce variability, and eliminate any waste produced. Therefore, the aim if this study, is to construct a quality management framework in Sappi COE laboratories to improve project performance by reducing repeat work and eliminating waste to deliver results within the expected timelines. I would like to take this opportunity to thank you in advance for your willingness and time to participate in this questionnaire.

Dolyn Govender
Researcher
Student

Guidelines and Instructions for Completing the Questionnaire

Note to the participant

- I need your assistance to identify issues you are currently experiencing with regards to project management and co-ordination within your department.
- What you say in this questionnaire will remain private and confidential.
- Please note that there is no correct or incorrect answer.
- Please try to answer all questions to the best of your ability.
- Please answer all questions as honestly as you can.

How to complete the questionnaire

1)The questions are divided into two sections and eight categories.

- The sections are as follows:
  - ✓ Section A – Particulars of participant
  - ✓ Section B – Categories containing questions pertaining to project management.
- The categories are as follows:
  - ✓ Category 1: General project issues
  - ✓ Category 2: Project communications
  - ✓ Category 3: Scheduling and estimating
  - ✓ Category 4: Test Processes – Ageing Kinetics
  - ✓ Category 5: Test Processes – Viscose production
  - ✓ Category 6: Test Processes – Application tests (SIV, CIV, Ball fall, KW filtration, Particle counts, Rheology)
  - ✓ Category 7: Training and Documentation
  - ✓ Category 8: General Process Questions

2) Please mark the appropriate answer with a cross.
3) Please answer all questions according to the prescribed selection criteria.
4) The questionnaire will take approximately 30 minutes to complete.

Section A

Department: _____

Position: _____

Duration in current position: _____

Education: _____

Section B

Category 1: General Project Issues					
Questions	**Strongly Disagree**	**Disagree**	**Neither Agree nor Disagree**	**Agree**	**Strongly Agree**
Do you feel the objectives for the project was clearly defined?					
Do you feel your objectives for your work tasks were clearly defined?					
Do you feel your role in the project was clear?					

Category 2: Project Communications					
Questions	**Strongly Disagree**	**Disagree**	**Neither Agree nor Disagree**	**Agree**	**Strongly Agree**
Do you feel project team meetings were efficient and effective?					
Do you feel project closeout meetings are efficient and effective?					
The management sponsor provided needed guidance and support for the project?					
The project manager provided needed guidance and support for the project?					
The project team had a good understanding of my contributions to this project?					
My individual responsibilities, tasks, and deliverables were achievable?					
The roles and responsibilities of the team members were clear?					

Category 3: Scheduling and Estimating

Questions	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Do you feel the entire team was committed to the project schedule?					
Did you feel that adequate time was allocated to for ageing kinetics, viscose production and application tests?					
Decisions about schedule changes are discussed ahead of time before you start your test (either ageing kinetics or applications tests)?					
Do you feel the appropriate time are allocated to each test daily (either ageing kinetics, viscose production or applications test)?					
Do you feel work distribution among teamsters are balanced and achievable for the day?					
Do you feel the current system for sample management is adequate?					

Category 4: Test Processes - Ageing Kinetics

Questions	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Are samples labelled neatly?					
Do you agree samples can be easily mixed up due to poor sample management systems?					
Do you agree there is an appropriate storage area to keep samples prior to steeping for each project?					
Do you agree there is an appropriate ISO document that explains how to prepare the sample?					
Do you agree steeping pots and impellers maintained appropriately?					
Do you agree steeping motors are regularly serviced?					
Do you agree steeping waterbaths are maintained at the temperature required?					
Do you agree daily verifications for waterbath temperatures are completed prior to steeping?					
Do you agree waterbaths are cleaned as frequently as required?					
Do you agree you are trained adequately for steeping, pressing and shredding for ageing kinetics?					

Do you agree you are trained adequately for CIAs and SIAs?					
Do you agree there is an appropriate ISO doc that explains how to perform Cia and Sia?					
Do you agree chemicals required for Cias and Sias are within the expiry period of use?					
Do you agree oven temperatures are verified before samples for ageing kinetics are placed in?					
Do you agree ovens are calibrated timeously?					

Category 5: Test Processes – Viscose production

Questions	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Do you agree samples required for viscose preparation neatly labelled eligibly?					
Do you feel samples can be mixed up due to lack of proper storage facilities?					
Do you agree steeping pots and impellers are maintained adequately?					
Do you agree waterbath temperatures are maintained correctly before steeping?					
Do you agree daily verifications of waterbath temperatures are completed prior to steeping?					
Do you agree waterbaths are descaled as frequently as required?					
Do you agree xanthation bottles are labelled correctly before being placed in the oven?					
Do you agree temperatures for xanthation ovens are verified prior to sample being placed in?					
Do you agree xanthation ovens are calibrated timeously?					
Do you agree the ISO document for xanthation explains the procedure clearly?					
Do you agree the waterbaths used for ripening are verified daily?					
Do you agree the dissolving and ripening ISO document explain the procedure precisely?					

Category 6: Test Processes – Application tests (SIV, CIV, Ball fall, KW filtration, Particle counts, Rheology)					
Questions	**Strongly Disagree**	**Disagree**	**Neither Agree nor Disagree**	**Agree**	**Strongly Agree**
SIV					
Do you agree glassware used for SIV are in good condition?					
Do you agree there are ample glassware available for use when performing SIV?					
Do you agree the reagents used to perform SIV are within the expiration period?					
Do you agree the ISO document for SIV explains the procedure precisely?					
Do you feel you are trained adequately for SIV?					
Do you agree is there an adequate system to sample viscose dope for SIV?					
CIV					
Do you agree all necessary glassware used to perform CIV readily are available?					
Do you agree there are ample glassware available for use when performing CIV?					
Do you agree the hot plates required for CIV are readily available to use?					
Do you agree the ovens required for CIV are verified prior to work commencing?					
Do you agree the analytical balances required for CIV are verified daily prior to work?					
Do you agree the analytical balances required for CIV are calibrated timeously?					
Ball fall					
Do you agree the glassware required for ball fall is readily available?					
Do you agree the water bath temperature for ball fall is verified prior to work being carried out?					
Do you agree the ISO procedure explains ball fall precisely?					
KW filtration					
Do you agree all pressure gauges are working correctly?					
Do you agree the ISO procedure explains KW precisely?					

Do you agree the KW apparatus is easy to set up?					
Do you agree there are proper sampling techniques for KW?					
Particles counts					
Do you agree the procedure for particle counts is easy to follow?					
Do you agree the coulter counter is calibrated timeously?					
Do you agree chemicals are readily available and within the expiration date?					
Rheology					
Do agree the procedure for rheology is easy to follow?					
Do you agree the programme is user friendly?					
Do you agree the rheometer is maintained frequently?					
Do you agree the compressor is maintained frequently?					

Category 7: Training and Documentation

Questions	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Do you feel project management forms and templates are effective?					
Do you feel project management forms and templates contains enough details of the test?					
Are training on lab tests completely effective?					
Would you recommend substantially more training on lab tests for future projects?					
Does the training program need improvement?					
Do you feel all team members are adequately trained and can perform bulk of the tests required within the project?					

Category 8: General Process Questions	
Questions	**Your response**
In your opinion what part of the ageing kinetics test can be improved?	
In your opinion what part of viscose production can be improved?	
In your opinion which application tests do you feel needs improvement?	

Appendix C: Post-study questionnaire

POST-STUDY QUESTIONNAIRE

Title: An integrated quality management framework to improve project throughput rate in a selected laboratory environment

Dear Respondent

Quality plays a crucial role in the business process within an organisation, to improve efficiency and to be more effective in the global market. Improving quality and customer loyalty has a significant bearing on market share. A focus to reduce wastage, but also to satisfy customer's expectations, continuous cost reductions and continuous improvements are necessary to survive in a highly competitive environment. A significant amount of research has been carried out, which indicates that the application of quality management framework will assist to increase quality, reduce variability, and eliminate any waste produced. Therefore, the aim if this study, is to construct a quality management framework in Sappi COE laboratories to improve project performance by reducing repeat work and eliminating waste to deliver results within the expected timelines. I would like to take this opportunity to thank you in advance for your willingness and time to participate in this questionnaire.

Dolyn Govender
Researcher
Student

Guidelines and Instructions for Completing the Questionnaire

Note to the participant

- I need your assistance to identify issues you are currently experiencing with regards to project management and co-ordination within your department.
- What you say in this questionnaire will remain private and confidential.
- Please note that there is no correct or incorrect answer.
- Please try to answer all questions to the best of your ability.
- Please answer all questions as honestly as you can.

How to complete the questionnaire

1)The questions are divided into two sections and eight categories.

- The sections are as follows:
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  - ✓ Section B – Categories containing questions pertaining to project management.
- The categories are as follows:
  - ✓ Category 1: General project issues
  - ✓ Category 2: Project communications
  - ✓ Category 3: Scheduling and estimating
  - ✓ Category 4: Test Processes – Ageing Kinetics
  - ✓ Category 5: Test Processes – Viscose production
  - ✓ Category 6: Test Processes – Application tests (SIV, CIV, Ball fall, KW filtration, Particle counts, Rheology)
  - ✓ Category 7: Training and Documentation
  - ✓ Category 8: General Process Questions

2) Please mark the appropriate answer with a cross.
3) Please answer all questions according to the prescribed selection criteria.
4) The questionnaire will take approximately 30 minutes to complete.

Section A

Department: _____

Position: _____

Duration in current position: _____

Education: _____

Section B

Category 1: General Project Issues					
Questions	**Strongly Disagree**	**Disagree**	**Neither Agree nor Disagree**	**Agree**	**Strongly Agree**
Do you feel the objectives for the project was clearly defined?					
Do you feel your objectives for your work tasks were clearly defined?					
Do you feel your role in the project was clear?					

Category 2: Project Communications					
Questions	**Strongly Disagree**	**Disagree**	**Neither Agree nor Disagree**	**Agree**	**Strongly Agree**
Do you feel project team meetings were efficient and effective?					
Do you feel project closeout meetings are efficient and effective?					
The management sponsor provided needed guidance and support for the project?					
The project manager provided needed guidance and support for the project?					
The project team had a good understanding of my contributions to this project?					
My individual responsibilities, tasks, and deliverables were achievable?					
The roles and responsibilities of the team members were clear?					

Category 3: Scheduling and Estimating

Questions	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Do you feel the entire team was committed to the project schedule?					
Did you feel that adequate time was allocated to for ageing kinetics, viscose production and application tests?					
Decisions about schedule changes are discussed ahead of time before you start your test (either ageing kinetics or applications tests)?					
Do you feel the appropriate time are allocated to each test daily (either ageing kinetics, viscose production or applications test)?					
Do you feel work distribution among teamsters are balanced and achievable for the day?					
Do you feel the current system for sample management is adequate?					

Category 4: Test Processes - Ageing Kinetics

Questions	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Are samples labelled neatly?					
Do you agree samples can be easily mixed up due to poor sample management systems?					
Do you agree there is an appropriate storage area to keep samples prior to steeping for each project?					
Do you agree there is an appropriate ISO document that explains how to prepare the sample?					
Do you agree steeping pots and impellers maintained appropriately?					
Do you agree steeping motors are regularly serviced?					
Do you agree steeping waterbaths are maintained at the temperature required?					
Do you agree daily verifications for waterbath temperatures are completed prior to steeping?					
Do you agree waterbaths are cleaned as frequently as required?					
Do you agree you are trained adequately for steeping, pressing and shredding for ageing kinetics?					

Do you agree you are trained adequately for CIAs and SIAs?					
Do you agree there is an appropriate ISO doc that explains how to perform Cia and Sia?					
Do you agree chemicals required for Cias and Sias are within the expiry period of use?					
Do you agree oven temperatures are verified before samples for ageing kinetics are placed in?					
Do you agree ovens are calibrated timeously?					

Category 5: Test Processes – Viscose production

Questions	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Do you agree samples required for viscose preparation neatly labelled eligibly?					
Do you feel samples can be mixed up due to lack of proper storage facilities?					
Do you agree steeping pots and impellers are maintained adequately?					
Do you agree waterbath temperatures are maintained correctly before steeping?					
Do you agree daily verifications of waterbath temperatures are completed prior to steeping?					
Do you agree waterbaths are descaled as frequently as required?					
Do you agree xanthation bottles are labelled correctly before being placed in the oven?					
Do you agree temperatures for xanthation ovens are verified prior to sample being placed in?					
Do you agree xanthation ovens are calibrated timeously?					
Do you agree the ISO document for xanthation explains the procedure clearly?					
Do you agree the waterbaths used for ripening are verified daily?					
Do you agree the dissolving and ripening ISO document explain the procedure precisely?					

Category 6: Test Processes – Application tests (SIV, CIV, Ball fall, KW filtration, Particle counts, Rheology)					
Questions	**Strongly Disagree**	**Disagree**	**Neither Agree nor Disagree**	**Agree**	**Strongly Agree**
SIV					
Do you agree glassware used for SIV are in good condition?					
Do you agree there are ample glassware available for use when performing SIV?					
Do you agree the reagents used to perform SIV are within the expiration period?					
Do you agree the ISO document for SIV explains the procedure precisely?					
Do you feel you are trained adequately for SIV?					
Do you agree is there an adequate system to sample viscose dope for SIV?					
CIV					
Do you agree all necessary glassware used to perform CIV readily are available?					
Do you agree there are ample glassware available for use when performing CIV?					
Do you agree the hot plates required for CIV are readily available to use?					
Do you agree the ovens required for CIV are verified prior to work commencing?					
Do you agree the analytical balances required for CIV are verified daily prior to work?					
Do you agree the analytical balances required for CIV are calibrated timeously?					
Ball fall					
Do you agree the glassware required for ball fall is readily available?					
Do you agree the water bath temperature for ball fall is verified prior to work being carried out?					
Do you agree the ISO procedure explains ball fall precisely?					
KW filtration					
Do you agree all pressure gauges are working correctly?					
Do you agree the ISO procedure explains KW precisely?					

Do you agree the KW apparatus is easy to set up?					
Do you agree there are proper sampling techniques for KW?					
Particles counts					
Do you agree the procedure for particle counts is easy to follow?					
Do you agree the coulter counter is calibrated timeously?					
Do you agree chemicals are readily available and within the expiration date?					
Rheology					
Do agree the procedure for rheology is easy to follow?					
Do you agree the programme is user friendly?					
Do you agree the rheometer is maintained frequently?					
Do you agree the compressor is maintained frequently?					

Category 7: Training and Documentation

Questions	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Do you feel project management forms and templates are effective?					
Do you feel project management forms and templates contains enough details of the test?					
Are training on lab tests completely effective?					
Would you recommend substantially more training on lab tests for future projects?					
Does the training program need improvement?					
Do you feel all team members are adequately trained and can perform bulk of the tests required within the project?					

Category 8: General Process Questions	
Questions	**Your response**
In your opinion what part of the ageing kinetics test can be improved?	
In your opinion what part of viscose production can be improved?	
In your opinion which application tests do you feel needs improvement?	

Appendix D: Content validation questionnaire

CONTENT VALIDATION QUESTIONNAIRE

Title: An integrated quality management framework to improve project throughput rate in a selected laboratory environment

Dear Experts,

Quality plays a crucial role in the business process within an organisation, to improve efficiency and to be more effective in the global market. Improving quality and customer loyalty has a significant bearing on market share. A focus to reduce wastage, but also to satisfy customer's expectations, continuous cost reductions and continuous improvements are necessary to survive in a highly competitive environment. A significant amount of research has been carried out, which indicates that the application of quality management framework will assist to increase quality, reduce variability, and eliminate any waste produced. Therefore, the aim if this study, is to construct a quality management framework in Sappi COE laboratories to improve project performance by reducing repeat work and eliminating waste to deliver results within the expected timelines. I would like to take this opportunity to thank you in advance for your willingness and time to participate in this questionnaire.

This questionnaire contains 8 domains (categories) and 78 items (questions) related to ageing kinetics, viscose production, and application tests. I require your expert judgement on the degree of relevance on each item to the measured domains. **Your review should be based on the relevant terminologies that are provided to you. Please be as objective and constructive as possible in your review and use the following rating scale:**

Degree of relevance:

1 = The item is not relevant to the measured domain
2 = The item is somewhat relevant to the measured domain
3 = The item is quite relevant to the measured domain
4 = The item is highly relevant to the measured domain

Dolyn Govender
Researcher
Student

Guidelines and Instructions for Completing the Questionnaire

Note to the participant

- I need your assistance to identify issues you are currently experiencing with regards to project management and co-ordination within your department.
- What you say in this questionnaire will remain private and confidential.
- Please note that there is no correct or incorrect answer.
- Please try to answer all questions to the best of your ability.
- Please answer all questions as honestly as you can.

How to complete the questionnaire

1)The questions are divided into two sections and eight categories.

- The sections are as follows:
  - ✓ Section A – Particulars of participant
  - ✓ Section B – Categories containing questions pertaining to project management.
- The categories are as follows:
  - ✓ Category 1: General project issues
  - ✓ Category 2: Project communications

- ✓ Category 3: Scheduling and estimating
- ✓ Category 4: Test Processes – Ageing Kinetics
- ✓ Category 5: Test Processes – Viscose production
- ✓ Category 6: Test Processes – Application tests (SIV, CIV, Ball fall, KW filtration, Particle counts, Rheology)
- ✓ Category 7: Training and Documentation
- ✓ Category 8: General Process Questions

2) Please mark the appropriate answer with a cross.
3) Please answer all questions according to the prescribed selection criteria.
4) The questionnaire will take approximately 30 minutes to complete.

Section A

Department: _____

Position: _____

Duration in current position: _____

Education: _____

Section B

Category 1: General Project Issues				
Questions	**1**	**2**	**3**	**4**
1. Do you feel the objectives for the project was clearly defined.				
2. Do you feel your objectives for your work tasks were clearly defined.				
3. Do you feel your role in the project was clear.				

Category 2: Project Communications				
Questions	**1**	**2**	**3**	**4**
1. Do you feel project team meetings were efficient and effective.				
2. Do you feel project closeout meetings are efficient and effective.				
3. The management sponsor provided needed guidance and support for the project.				
4. The project manager provided needed guidance and support for the project.				
5. The project team had a good understanding of my contributions to this project.				

6. My individual responsibilities, tasks, and deliverables were achievable.				
7. The roles and responsibilities of the team members were clear.				

Category 3: Scheduling and Estimating

Questions	1	2	3	4
1. Do you feel the entire team was committed to the project schedule.				
2. Did you feel that adequate time was allocated to for ageing kinetics, viscose production and application tests.				
3.Decisions about schedule changes are discussed ahead of time before you start your test (either ageing kinetics or applications tests).				
4. Do you feel the appropriate time are allocated to each test daily (either ageing kinetics, viscose production or applications test).				
5. Do you feel work distribution among teamsters are balanced and achievable for the day.				
6. Do you feel the current system for sample management is adequate.				

Category 4: Test Processes - Ageing Kinetics

Questions	1	2	3	4
1. Are samples labelled neatly.				
2. Do you agree samples can be easily mixed up due to poor sample management systems.				
3. Do you agree there is an appropriate storage area to keep samples prior to steeping for each project.				
4. Do you agree there is an appropriate ISO document that explains how to prepare the sample.				
5. Do you agree steeping pots and impellers maintained appropriately.				
6. Do you agree steeping motors are regularly serviced.				
7. Do you agree steeping waterbaths are maintained at the temperature required.				
8. Do you agree daily verifications for waterbath temperatures completed prior to steeping.				

9. Do you agree waterbaths are cleaned as frequently as required.				
10. Do you agree you trained adequately for steeping, pressing and shredding for ageing kinetics.				
11. Do you agree you are trained adequately for CIAs and SIAs.				
12. Do you agree there is an appropriate ISO doc that explains how to perform Cia and Sia?				
13. Do you agree chemicals required for Cias and Sias within the expiry period of use.				
14. Do you agree oven temperatures verified before samples for ageing kinetics are placed in.				
15. Do you agree ovens calibrated on timeously.				

Category 5: Test Processes – Viscose production				
Questions	**1**	**2**	**3**	**4**
1. Do you agree samples required for viscose preparation neatly labelled eligibly.				
2. Do you feel samples can be mixed up due to lack of proper storage facilities.				
3. Do you agree steeping pots and impellers maintained adequately.				
4. Do you agree waterbath temperatures maintained correctly before steeping.				
5. Do you agree daily verifications of waterbath temperatures completed prior to steeping.				
6. Do you agree waterbaths are descaled as frequently as required.				
7. Do you agree xanthation bottles labelled correctly before being placed in the oven.				
8. Do you agree temperatures for xanthation ovens verified prior to sample being placed in.				
9. Do you agree xanthation ovens calibrated timeously.				
10. Do you agree the ISO document for xanthation explain the procedure clearly.				
11. Do you agree the waterbaths used for ripening verified daily.				
12. Do you agree the dissolving and ripening ISO document explain the procedure precisely.				

Category 6: Test Processes – Application tests (SIV, CIV, Ball fall, KW filtration, Particle counts, Rheology)				
Questions	**1**	**2**	**3**	**4**
SIV				
1. Do you agree glassware used for SIV in good condition.				
2. Do you agree there are ample glassware available for use when performing SIV.				
3. Do you agree the reagents used to perform SIV within the expiration period.				
4. Do you agree the ISO document for SIV explain the procedure precisely.				
5. Do you feel you are trained adequately for SIV.				
6. Do you agree is there an adequate system to sample viscose dope for SIV.				
CIV				
1. Do you agree all necessary glassware used to perform CIV readily available.				
2. Do you agree there are ample glassware available for use when performing CIV.				
3. Do you agree the hot plates required for CIV readily available to use.				
4. Do you agree the ovens required for CIV verified prior to work commencing.				
5. Do you agree the analytical balances required for CIV verified daily prior to work.				
6. Do you agree the analytical balances required for CIV calibrated timeously.				
Ball fall				
1. Do you agree the glassware required for ball fall is readily available.				
2. Do you agree the water bath temperature for ball fall is verified prior to work being carried out.				
3. Do you agree the ISO procedure explains ball fall precisely.				
KW filtration				
1. Do you agree all pressure gauges are working correctly.				
2. Do you agree the ISO procedure explains KW precisely.				

3. Do you agree the KW apparatus is easy to set up.				
4. Do you agree there are proper sampling techniques for KW.				
Particles counts				
1. Do you agree the procedure for particle counts is easy to follow.				
2. Do you agree the coulter counter is calibrated timeously.				
3. Do you agree chemicals are readily available and within the expiration date.				
Rheology				
1. Do agree the procedure for rheology is easy to follow.				
2. Do you agree the programme is user friendly.				
3. Do you agree the rheometer is maintained frequently.				
4. Do you agree the compressor is maintained frequently.				

Category 7: Training and Documentation				
Questions	**1**	**2**	**3**	**4**
1. Do you feel project management forms and templates are effective.				
2. Do you feel project management forms and templates contains enough details of the test.				
3. Are training on lab tests completely effective.				
4. Would you recommend substantially more training on lab tests for future projects.				
5. Does the training program need improvement.				
6. Do you feel all team members are adequately trained and can perform bulk of the tests required within the project.				

Category 8: General Process Questions				
Questions	**1**	**2**	**3**	**4**
1. In your opinion what part of the ageing kinetics test can be improved.				
2. In your opinion what part of viscose production can be improved.				
3. In your opinion which application tests do you feel needs improvement.				

Appendix E: Minutes taken during brainstorming sessions

sappi

Sappi Pulp

Saiccor Mill

Minutes

Confidential

Meeting	**Brainstorming Session Minutes September 2022 – Analysts and Senior Analysts**
Date and time	30 August 2022, 14:00 – 15:30
Venue	Tech Centre Boardroom
Present	D Govender (Chairperson), S. Hlongwane, N. Ngcobo, S. Pershad, A. Khanyile, Z. Madikizela, E Mngoma, M. Sabela, T. Perumal, M Hlongwa, S. Qwabe, N Khanye, V Mazibuko, P Reddy, S Mthembu
By invitation	D. Govender
Apologies	None

Discussion and decision			**Action**
1.	**Welcome**		DG
	D Govender welcomed all to the meeting. An explanation was given of the purpose of the meeting held and the intended value of the session. Request to record – Declined.		
2.	**General project Issues**		DG
		2.1 Communication -PM to analyst/absenteeism/work to be rescheduled (a system to set up). 2.2 Discuss project before start of a project. 2.3 Communication of issues taking place in the background needs is a issue and needs improvement (step wise process - what's happening in every stage).	
3.	**Project communications**		DG
		3.1 Verbal communication should be improved. 3.2 Change of samples in emergency situations should be communicated as soon as possible.	

Discussion and decision		Action
4.	**Scheduling and estimating** 4.1 Weekly basis (whole team should be involved in scheduling of work and allocation). 4.2 Too many projects with fewer resources to complete work. 4.3 Teamsters should be allocated according to scope of work e.g. 12 samples allocated there should be at least x (4) teamsters. 4.4 Structure to be corrected (MS -PM - Analyst II-Analyst I) in all projects (Avoid project switch multiple seniors on one project and only analysts on one project). 4.5 System of rotation should be determined for teamsters stuck on one test (everyone should be trained on all tests - training plan required. 4.6 Storage space for log sheets and retention time should be established. 4.7 Overloading some teamsters and not others -work should be allocated evenly - Quantity over quality experienced. 4.8 Lack of personnel trained on specific tests.	DG
5.	**Ageing kinetics** 5.1 Composite of samples should be taken to decrease variability within the pulp. 5.2 Time should be allocated only for tearing and chemical prep before project starts. 5.3 Equipment should be maintained more regularly. 5.4 Motors (release oil that can contaminate pulp) and impellers shaking not identical - uniform equipment should be fabricated. 5.5 Temperature of the steeping baths fluctuates (high temperatures observed) 5.6 Target range for temperature should be specified.	DG
6. Viscose process		DG
	6.1 Recent longer ageing times require speed cooling -This may affect the quality of viscose negatively. 6.2 Equipment should be maintained more regularly. 6.3 Motors (release oil that can contaminate pulp) and impellers shaking not identical - uniform equipment should be fabricated. 6.4 Temperature of the steeping baths fluctuates (high temperatures observed). 6.5 Amount of runs should be limited to 4, it will improve quality of results, rushing work can compromise on quality of results. 6.6 Target range for temperature should be specified. 6.7 Composite of samples should be taken to decrease variability within the pulp. 6.8 Shredding should be increased to an hour to improve accessibility -reactivity of pulp (historically done).	

Discussion and decision		Action
	6.9 Xantahtion - CS2 gets stuck in pipe can limit the amount of CS2 for reaction (approximately 1.5ml of CS2 is added to the run to compensate for evaporation added at personnel discretion).	
7.	**SIV** 7.1 Hot water should be increased to 100ml at least to ensure sample dissolves. 7.2 Dispenser volumes should be checked. 7.3 Fumehood should be checked if functioning correctly.	DG
8.	**CIV** 8.1 Film breaks and sticks onto tin lid reduces mass hence repeats are required. 8.2 Technique for glass slides should be improved for reduction of breakage of film during boiling. 8.3 Standardizing spin bath correctly. 8.4 Find alternative to help reduce repeats**.**	DG
9.	**Ball fall** 9.1 Rusty spheres may impact results. 9.2 Water baths overflow and time is wasted cleaning spills. 9.3 Water bath should be calibrated more often as alarms always reoccur and the flooding persists.	DG
10.	**Particle counts** 10.1 Incorrect concentration of caustic impacts results negatively. 10.2 Procedure for cleaning should be evaluated. 10.3 Coulter counter should be serviced regularly to avoid software malfunctions.	DG
11.	**KW filtration** 11.1 KW is the main cause of repeats for viscose production. 11.2 Pressure gauges are faulty and should be serviced regularly. 11.3 Filter packing should be done using correct procedure to ensure correct readings.	DG
12.	**Rheology** 12.1 Compressor is faulty - trips repeatedly during tests this causes the test to be repeated and time wasted.	DG

Discussion and decision			Action
	12.2 Mouse freezes time wasted. 12.3 Connection problem from compressor to rheometer.		
13.	**Hottenroth** 13.1 Subjective test depends on personnel perform the test. 13.2 Too much variability because it's based-on perception. 13.3 Deeper technical understanding of test is required by personnel performing the test.		DG
14.	**Other concerns**		DG
	14.1	Drainage system should be looked at as the drains are always blocked.	
	14.2	Water baths should be calibrated more frequently alarms always coming on.	
	14.3	KW is the main test that causes repeats of the whole process.	
	14.4	Analysts requested feedback presentation of all findings. Invite all.	
15.	**Recommendations**		DG
	15.1	Regeneration of viscose should be reinstated.	
	15.2	The fumehood should be working correctly.	
16.	**Closing** D Govender thanked all for their valuable input and recommendations.		DG

sappi

Sappi Pulp

Saiccor Mill

Minutes

Confidential

Meeting	**Brainstorming Session Minutes September 2022 – Technologists**
Date and time	14 September 2022, 15:00 – 16:30
Venue	Tech Centre Boardroom
Present	D Govender (Chairperson), L Singh, O Matasva, T Shangase, S Njamela, S Harilal
By invitation	D.Govender
Apologies	None

Discussion and decision			**Action**
1.	**Welcome**		DG
	D Govender welcomed all to the meeting. An explanation was given of the purpose of the meeting held and the intended value of the session. Request to record – Declined.		
2.	**General project Issues**		DG
		2.1 Poor communication - Communication of leave from MS to PM to Snr analysts. No communication of problems real time, communication only happens at the end of shift/day. 2.2 In adequate time allocation by project sponsor - no buffer time for repeats - unrealistic expectation in time management. 2.3 Poor communication/cooperation of problems in the lab. 2.4 Space and equipment constraints - waiting for one test to finish to start another e.g., Pentosan has to be on hold to carry out fock test. 2.5 Additional tasks or tests are added to the project while on the go and not accounted for when the proposal was constructed leads to an increased number of days and prolonged project.	
3.	**Project communications**		DG
		3.1 Improper channels of communication - no protocol followed - Do not inform PM of the project but informs another PM. 3.2 Communication of verifications are not timeous.	

		3.3 Poor communication of absenteeism from MS to PM. PM cannot plan if absenteeism is not communicated timeously.	
4.	**Scheduling and estimating** 4.1 Too many projects with fewer resources to complete work. 4.2 Teamsters should be allocated according to scope of work e.g. 12 samples allocated there should be at least x (4) teamsters. 4.3 Management sponsors over commit to number of projects which prolongs projects.		DG
5.	**Ageing kinetics** 5.1 Incorrect pressing and continuation results in repeats. 5.2 Equipment should be maintained regularly. 5.3 Not washing on time impacts ageing negatively. 5.4 Motors (release oil that can contaminate pulp) and impellers shaking not identical - uniform equipment should be fabricated. 5.5 Breakdowns within the laboratory delays work and sometimes halts work altogether. 5.6 Alkcells overloaded in ovens interferes with conditioning and may affect viscosities.		DG
6. Viscose process			DG
	6.1 Equipment should be maintained more regularly. 6.2 Motors (release oil that can contaminate pulp) and impellers shaking not identical - uniform equipment should be fabricated. 6.3 Hemis collection must be done using a 5litre bucket to increase homogeneity within the soda. 6.4 Poor dispersion by equipment, impellers are bent and worn-out. Caustic spills out of pot. 6.5 Xanthation - CS2 gets stuck in pipe can limit the amount of CS2 for reaction (approximately 1.5ml of CS2 is added to the run to compensate for evaporation added at personnel discretion).		
7.	**SIV** 7.1 Standardize procedure 15 minutes or 20 waiting time. And retrain personnel. 7.2 Dispensers should be checked, including the demin water dispenser.		DG
8.	**CIV** 8.1 Boiling water required for test is not changed per sample. Water should be changed per sample. 8.2 Spinbath required for test not changed per sample - should be changed per sample.		DG

9.	**Ball fall** 9.1 Waterbath temperature not verified. 9.2 Rusty spheres.		DG
10.	**Particle counts** 10.1 No cleaning of aperture tube taking place between runs - should be done. 10.2 Caustic literature should be done at least 5 times - this causes aperture tube to block when caustic particles are not removed during filtering. 10.3 Electrode left in caustic overnight. - Electrode should be left in water overnight.		DG
11.	**KW filtration** 11.1 Pressure gauges and regulators are not maintained. Readings are sometimes lower than procedure. 11.2 Pot seals are not maintained. 11.3 Jig not maintained.		DG
12.	**Rheology** 12.1 Compressor not building up pressure - must be maintained or replaced. 12.2 Procedure required for cleaning of measuring system.		DG
13.	**Hottenroth** 13.1 No timers available for test - Timers to be mounted on fume hood. 13.2 Procedure is based on discretion, procedure should be revised. - Retraining.		DG
14.	**Other concerns**		DG
	14.1	Remove redundant equipment to make space for new tests and existing tests that can be done within COE labs (Sappi pentosan, Ash etc.).	
	14.2	There will be no chopping and changing of teamsters.	
15.	**Recommendations**		DG
	15.1	Set up teams' group per project for daily update, used by TC primarily to communicate daily lab issues and for daily updates of results (No MS on the group only PM to teamsters).	
	15.2	Everyone should be trained and competent of all to ensure same teamsters start and end a project.	
	15.3	Fewer projects committed with the addition of more teamsters per project, this will ensure quality results within a shorter timeframe.	

	15.4	More than one supplier should be sourced for maintenance issues, equipment, and fabrication.	
	15.5	Xanthation should be an automated closed system to eliminate human error as it is a crucial step for viscose production. OR xanthation procedure should be standardized and practiced in the laboratory.	
16.	**Closing** D Govender thanked all for their valuable input and recommendations.		DG

Appendix F: Raw data collected for content validation of instrument used.

Table 3: Raw data content validation

Category	Questions	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Expert 9	Experts in agreement	I-CVI	Interpretation (Appropriate or need for revision)	CVR	Interpretation (Remained/Eliminated)
	Question 1	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 2	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
Category 1	Question 3	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 1	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 2	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 3	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 4	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 5	0	1	1	1	1	1	1	1	1	8	0,89	Appropriate	0,78	Remained
	Question 6	0	1	1	1	1	1	1	1	1	8	0,89	Appropriate	0,78	Remained
Category 2	Question 7	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 1	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 2	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 3	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 4	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 5	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
Category 3	Question 6	0	1	1	1	1	1	1	1	1	8	0,89	Appropriate	0,78	Remained
	Question 1	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 2	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 3	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 4	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 5	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 6	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 7	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
Category 4	Question 8	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained

	Question 9	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 10	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 11	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 12	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 13	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 14	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 15	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 1	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 2	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 3	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 4	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 5	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 6	0	1	1	1	1	1	1	1	1	8	0,89	Appropriate	0,78	Remained
	Question 7	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 8	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 9	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 10	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 11	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
Category 5	Question 12	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 1	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 2	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 3	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 4	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 5	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 6	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 1	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 2	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 3	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 4	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 5	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
Category 6	Question 6	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained

	Question 1	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 2	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 3	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 1	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 2	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 3	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 4	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 1	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 2	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 3	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 1	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 2	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 3	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 4	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 1	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 2	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 3	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 4	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 5	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
Category 7	Question 6	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 1	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
	Question 2	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
Category 8	Question 3	1	1	1	1	1	1	1	1	1	9	1,00	Appropriate	1,00	Remained
Proportion relevance of each all items by each expert		0,95	1	1	1	1	1	1	1	1	S-CVI/Ave = (sum of I-CVI scores)/ (number of item)	0,99			
Average proportion of items judged as relevance across the nine experts S-CVI/Ave = (sum of proportion relevance rating)/ (number of expert)									0,99						

Appendix G: Obtained from qualitative raw aspect of the questionnaire data

Qn8.1 – In your opinion what part of the ageing kinetics test can be improved?

1. **Pressing (1)**

"*Accuracy in pressing alkcell*"

"Press's could be serviced more often to ensure that all are working and are in order."

"The pressing of alkcell"

"THE PRESSING OF ALKCELL."

2. **Washing (2&3)**

"PM and teamster communication can be improved. Analyst planning their work in advance can improve quality. Glassware washing."

"A maintenance schedule for the servicing of motors, airlines, hydraulics, etc. An improved labelling and storage system for samples. Temperature verifications of steeping bath."

"Steeping water bath temperature control"

"Servicing steeping motors and water baths more often."

"Washing during ageing needs to be standardised and proved. Impellers and pots need to all be the same dimensions. Motors need to be serviced more regularly. Shredders need to be serviced more regularly. Por funnels need to be cleaned more regularly."

"Washing during ageing needs to be standardised and proved. Impellers and pots need to all be the same dimensions. Motors need to be serviced more regularly. Shredders need to be serviced more regularly. Por funnels need to be cleaned more regularly."

"Only few teams must do the ageing in a day because there is a shortage of resources, urns for not water, some teams end up washing / neutralising with warm water. Mixing of samples in the ageing ovens."

3. **Shortage**

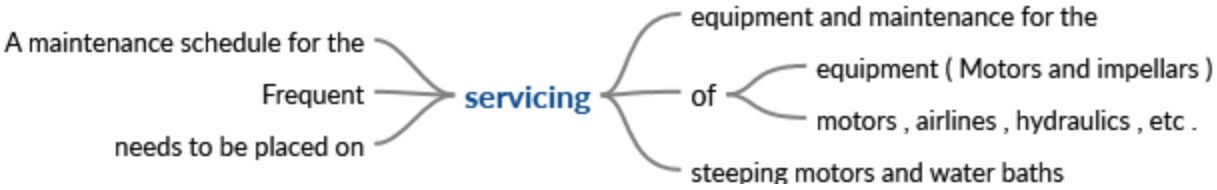
"Only few teams must do the ageing in a day because there is a shortage of resources, urns for not water, some teams end up washing / neutralising with warm water. Mixing of samples in the ageing ovens."

4. **Temperature (4)**

"A maintenance schedule for the servicing of motors, airlines, hydraulics, etc. An improved labelling and storage system for samples. Temperature verifications of steeping bath."

"Steeping water bath temperature control."

5. **Service (5)**



"A maintenance schedule for the servicing of motors, airlines, hydraulics, etc. An improved labelling and storage system for samples. Temperature verifications of steeping bath."

"Press's could be serviced more often to ensure that all are working and are in order."

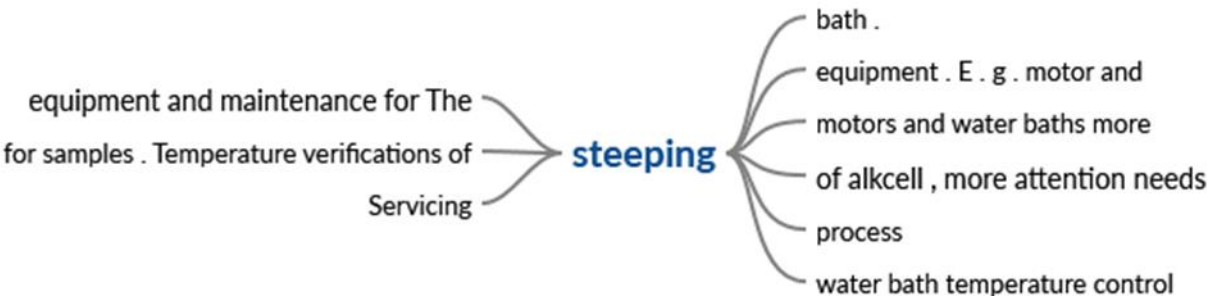
"Servicing steeping motors and water baths more often."

"The steeping of alkcell, more attention needs to be placed on servicing equipment and maintenance for the steeping equipment. E.g. motor and waterbaths need to be operating efficiently."

"Frequent servicing of equipment (Motors and impellers)."

"Washing during ageing needs to be standardised and proved. Impellers and pots need to all be the same dimensions. Motors need to be serviced more regularly. Shredders need to be serviced more regularly. Por funnels need to be cleaned more regularly."

6. **Steeping (6,7,8 &9)**



"A maintenance schedule for the servicing of motors, airlines, hydraulics, etc. An improved labelling and storage system for samples. Temperature verifications of steeping bath."

"Steeping water bath temperature control."

"Steeping of alkcell"

"Servicing steeping motors and water baths more often."

"The steeping of alkcell, more attention needs to be placed on servicing equipment and maintenance for the steeping equipment. E.g. motor and waterbaths need to be operating efficiently."

"Steeping process"

7. **Pots**

"We need light weight pots and polypropylene impellers"

"Washing during ageing needs to be standardised and proved. Impellers and pots need to all be the same dimensions. Motors need to be serviced more regularly. Shredders need to be serviced more regularly. Por funnels need to be cleaned more regularly."

"Only few teams must do the ageing in a day because there is a shortage of resources, urns for not water, some teams end up washing / neutralising with warm water. Mixing of samples in the ageing ovens."

8. **Impellers**

"We need light weight pots and polypropylene impellers."

"Washing during ageing needs to be standardised and proved. Impellers and pots need to all be the same dimensions. Motors need to be serviced more regularly.

Shredders need to be serviced more regularly. Por funnels need to be cleaned more regularly."

9. Storage

"A maintenance schedule for the servicing of motors, airlines, hydraulics, etc. An improved labelling and storage system for samples. Temperature verifications of steeping bath."

10. Viscosity

"Viscosity."

"Test the viscosity of your actual pulp sample instead of using pulp batch data viscosity"

11. Time

"More time can be put into sample preparation."

"The simultaneous usage of ovens by different personnel and opening at different times affects the ageing times."

12. Communication

"PM and teamster communication can be improved. Analyst planning their work in advance can improve quality. Glassware washing."

13. Planning

"PM and teamster communication can be improved. Analyst planning their work in advance can improve quality. Glassware washing."

"A maintenance schedule for the servicing of motors, airlines, hydraulics, etc. An improved labelling and storage system for samples. Temperature verifications of steeping bath."

14. Labelling

"A maintenance schedule for the servicing of motors, airlines, hydraulics, etc. An improved labelling and storage system for samples. Temperature verifications of steeping bath."

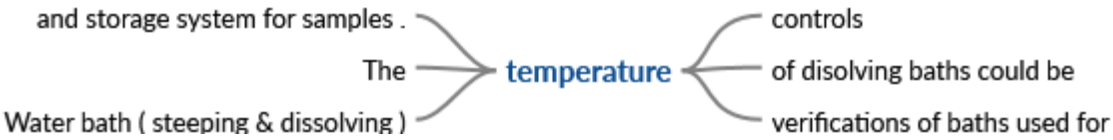
15. Dust

"When conditioning the samples in the instrument lab. I strongly feel they are exposed

too much to dust."

Qn8.2 – In your opinion what part of viscose production can be improved?

1. **Temperature**



"Water bath (steeping & dissolving) temperature controls."

"A maintenance schedule for the servicing of motors, airlines, hydraulics, etc for dissolving baths, kw apparatus and other equipment used in viscose testing. An improved labelling and storage system for samples. Temperature verifications of baths used for viscose applications testing like ball fall, dissolving baths, steeping baths, rheology water bath (those that are not included on the daily verification log sheets)."

"The temperature of dissolving baths could be verified."

2. **Labelling**

"Labelling of chemicals."

3. **Xanthation**

"Xanthation stage in viscose preparation."

"Xanthation."

4. **Dosage**

"CS2 dosage process can be improved."

5. **Steeping**

"Water bath (steeping & dissolving) temperature controls."

"A maintenance schedule for the servicing of motors, airlines, hydraulics, etc for dissolving baths, kw apparatus and other equipment used in viscose testing. An improved labelling and storage system for samples. Temperature verifications of baths used for viscose applications testing like ball fall, dissolving baths, steeping baths, rheology water bath (those that are not included on the daily verification log sheets)."

"Steeping of alkcell."

6. Planning

"As per aging kinetics additionally planning ahead can improve deliverables. Maximising free gaps during aging and viscose."

"A maintenance schedule for the servicing of motors, airlines, hydraulics, etc for dissolving baths, kw apparatus and other equipment used in viscose testing. An improved labelling and storage system for samples. Temperature verifications of baths used for viscose applications testing like ball fall, dissolving baths, steeping baths, rheology water bath (those that are not included on the daily verification log sheets)."

"Xanthation stage in viscose production."

7. Gaps

"As per aging kinetics additionally planning ahead can improve deliverables. Maximising free gaps during aging and viscose."

8. Maintenance

"Motor and impeller maintenance required more frequently."

"A maintenance schedule for the servicing of motors, airlines, hydraulics, etc for dissolving baths, kw apparatus and other equipment used in viscose testing. An improved labelling and storage system for samples. Temperature verifications of baths used for viscose applications testing like ball fall, dissolving baths, steeping baths, rheology water bath (those that are not included on the daily verification log sheets)."

"Impellers and pots need to all be the same dimensions. Motors need to be serviced more regularly. Dissolving baths need to be checked before dissolving. More digital thermometers required in labs."

9. Understanding

"Make viscose and precede to spinning. Understanding the whole trend of all the tests instead of focussing on certain ones."

10. Variables

"Acquire more controllable variables that have an effect on the production."

"Particle counts are always variable but may be an impact of viscose produced. Each viscose step needs to be followed meticulously."

11. Conditioning

"Shorten the conditioning period for alkcell."

12. Dimensions

"Impellers and pots need to all be the same dimensions. Motors need to be serviced more regularly. Dissolving baths need to be checked before dissolving. More digital thermometers required in labs."

13. Thermometers

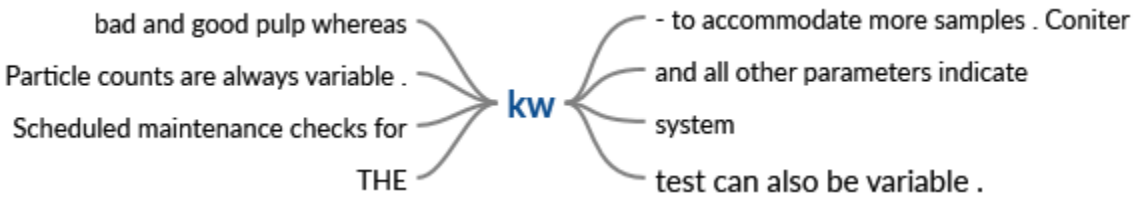
"Impellers and pots need to all be the same dimensions. Motors need to be serviced more regularly. Dissolving baths need to be checked before dissolving. More digital thermometers required in labs."

14. Step

"Particle counts are always variable but may be an impact of viscose produced. Each viscose step needs to be followed meticulously."

Qn8.3 – In your opinion which application tests do you feel needs improvement?

KW



"KW."- to accommodate more samples. Coulter counter and rheology training. Siv- to improve titration process. Additionally- Teamsters that have gaps should understand that filler work can be completed with allocated project work."

"Scheduled maintenance checks for Kw system."

"KW test."

"KW."

"KW."

"THE KW TEST."

"My understanding of siv and civ is limited because they should drop to increase to determine the quality of viscose they cannot be in target for bad and good pulp whereas kW and all other parameters indicate the quality of pulp."

"Particle counts are always variable. KW test can also be variable."

Samples

"KW- to accommodate more samples. Coulter counter and rheology training. Siv- to improve titration process. Additionally- Teamsters that have gaps should understand that filler work can be completed with allocated project work."

Training

"KW- to accommodate more samples. Coulter counter and rheology training. Siv- to improve titration process. Additionally- Teamsters that have gaps should understand that filler work can be completed with allocated project work."

Titration

"KW- to accommodate more samples. Coulter counter and rheology training. Siv- to improve titration process. Additionally- Teamsters that have gaps should understand that filler work can be completed with allocated project work."

Gaps

"KW- to accommodate more samples. Coulter counter and rheology training. Siv- to improve titration process. Additionally- Teamsters that have gaps should understand that filler work can be completed with allocated project work."

CiA, SiA, bulk density, CiV, SiV, Hottenroth, Xanthation, Ball Fall, Rheology.

Maintenance

"Scheduled maintenance checks for Kw system."

Alternative

"Research to be done on modern alternative test for ball fall."

Particle

"Particle counts are always variable. KW test can also be variable."

Appendix H: Raw data collected by using modified plan job observations for value stream mapping

Table 4: Steeping of sample

Planned job observation								
Job observed		Steeping small scale			Doc no:	VISC 001		
Department:		Tech Centre (COE)			Revised date:	18/07/2022		
Step no:	Correct		Time required to perform step (seconds) - Participant 1	Time required to perform step (seconds) - Participant 2	Waste identified if any	Step value adding (VA) or non-value adding (NVA)		Comment
	Yes	No	29/08/2022	29/08/2022		VA	NVA	
8.3.1	Yes		300	300	None	VA		
8.3.2	Yes		1800	1800	Waiting time in oven of 1,5hrs	VA		Either 8.3.1 or 8.3.2 can be used to get moisture of the sample
8.3.3.1	Yes		600	600	None	VA		
8.3.4.1	Yes		3600	3600	None	VA		
8.3.4.2	Yes		600	600	None	VA		
8.3.4.3	Yes		120	120	None	VA		
8.3.4.4	Yes		1800	1800	Waiting time of 0,5hrs for caustic to be heated	VA		
8.3.4.5	Yes		120	120	None	VA		
8.3.4.6	Yes		60	60	None	VA		
8.3.4.7	Yes		300	300	None	VA		
8.3.4.8	Yes		5	5	None	VA		
8.3.4.9	Yes		60	60	None	VA		
8.3.4.10	Yes		60	60	None	VA		
8.3.4.11	Yes		60	60	None	VA		
8.3.4.12	Yes		120	120	None	VA		
8.3.4.13	Yes		120	120	None	VA		
8.3.4.16	Yes		1800	1800	Waiting time of 0,5hrs for steeping to complete	VA		
8.3.4.18	Yes		1	1	None	VA		
8.3.4.19	Yes		60	60	None	VA		
8.3.4.20	Yes		10	10	None	VA		
8.3.4.21	Yes		10	10	None	VA		
8.3.4.22	Yes		10	10	None	VA		
		Sec	11616	11616				
		min	193,6	193,6				
		hour	3,23	3,23				

Table 5: Pressing of sample

Planned job observation

Job observed	Pressing of alkcell - small scale			Doc no:	VISC 002		
Department:	Tech centre (COE)			Revised date:	23/06/2022		
Step no:	Correct		Time required to perform step (seconds) - Participant 1	Time required to perform step (seconds) - Participant 2	Waste identified if any	Step value adding (VA) or non-value adding (NVA)		Comment
	Yes	No	18/07/2022	25/07/2022		VA	NVA	
8.3.1	Yes		60	300	None	VA		
8.3.2	Yes		30	120	None	VA		
8.3.3	Yes		60	60	None	VA		
8.3.4	Yes		60	60	None	VA		
8.3.5	Yes		60	60	None	VA		
8.3.6	Yes		120	120	None	VA		
8.3.7	Yes		60	60	None	VA		
8.3.8	Yes		30	60	None	VA		
8.3.9	Yes		60	30	None	VA		
8.3.10	Yes		5	30	None	VA		
8.3.11	Yes		360	270	None	VA		
8.3.12	Yes		120	120	None	VA		
8.3.13	Yes		30	60	None	VA		
8.3.14	Yes		5	5	None	VA		
8.3.15	Yes		10	60	None	VA		
8.3.16	Yes		2	30	None	VA		
8.3.17	Yes		2	2	None	VA		
8.3.18	Yes		3	10	None	VA		
8.3.19	Yes		5	10	None	VA		
8.3.20	Yes		2	2	None	VA		
8.3.21	Yes		2	2	None	VA		
8.3.22	Yes		25	20	None	VA		
8.3.23	Yes		2	2	None	VA		
8.3.24	Yes		120	120	None	VA		
8.3.26	Yes		900	720	Excess caustic soda expelled into the drain of the steeping area.	VA		
8.3.27	Yes		60	10	None	VA		
8.3.28	Yes		10	5	None	VA		
8.3.29	Yes		5	5	None	VA		
8.3.30	Yes		5	10	None	VA		
8.3.31	Yes		10	20	None	VA		
8.3.32	Yes		5	5	None	VA		
8.3.33	Yes		2	2	None	VA		
8.3.34	Yes		1	10	None	VA		Can waste total time of pressing and sample if the target is out of range
8.3.35	Yes		2	10	None	VA		

8.4.1	Yes		10	10	None	VA		
8.4.2	Yes		10	10	None	VA		
8.4.3	Yes		2	2	None	VA		
8.4.4	Yes		120	10	None	VA		
8.4.5	Yes		60	60	None	VA		
8.4.6	Yes		10	5	None	VA		
9.1	Yes		1200	1200	None	VA		
		Sec	3645	3707				
		Min	60,75	61,78333333				
		Hour	1,0125	1,029722222				

Table 6: Shredding of sample

Planned job observation								
Job observed	Shredding small scale				Doc no:	VISC 003		
Department:	Tech centre (COE)				Revised date:	23/06/2022		
Step no:	Correct		Time required to perform step (seconds) - Participant 1	Time required to perform step (seconds) - Participant 2	Waste identified if any	Step value adding (VA) or non-value adding (NVA)		Comment
	Yes	No	18/07/2022	25/07/2022		VA	NVA	
8.3.1	Yes		300	30	None	VA		
8.3.2	Yes		300	60	None	VA		
8.3.3	Yes		120	60	None	VA		
8.3.4	Yes		5	30	None	VA		
8.3.5	Yes		2	2	None	VA		
8.3.6	Yes		10	2	None	VA		
8.3.7	Yes		120	120	None	VA		
8.3.8	Yes		60	2	None	VA		
8.3.9	Yes		2	2	None	VA		
8.3.10	Yes		120	120	None	VA		
8.3.11	Yes		180	180	None	VA		
9.	Yes		600	900	None	VA		
		Sec	1819	1508				
		min	30,32	25,13				
		hour	0,51	0,42				

Table 7: Ageing of Alkcell

Planned job observation

Job observed	Procedure for alkcell ageing curves	Doc no:	VISC 014
Department:	Tech centre (COE)	Revised date:	31/08/2022

Step no:	Correct		Time required to perform step (seconds) - Participant 1	Time required to perform step (seconds) - Participant 2	Waste identified if any	Step value adding (VA) or non-value adding (NVA)		Comment
	Yes	No	15/02/2023	15/02/2023		VA	NVA	
8.2.1	Yes		120	300	None	VA		
8.2.2	Yes		480	180	None	VA		
8.2.3		No	0	0	None		NVA	Bottles are not labelled, note made in oven.
8.2.4	Yes		0	0	None	VA		Available tray used on the day.
8.2.5	Yes		0	0	None	VA		Statement not instruction.
8.2.6	Yes		600	300	Excess shredded alkcell.	VA		
8.2.7	Yes		30	120	None	VA		
8.2.8	Yes		60	300	None	VA		
8.2.9	Yes		0	0	None	VA		Only done when catalyst is added to ageing, study is based on a control sample.
8.2.10	Yes		2100	2940	None	VA		
8.2.11	Yes		2	2	None	VA		
8.2.12	Yes		0	0	None	VA		Only done when catalyst is added to ageing, study is based on a control sample.
8.2.13	Yes		2	2	None	VA		Based on ideal conditions and done right the first time.
8.2.14	Yes		10	60	None	VA		
8.2.15	Yes		60	60	Waiting time of 7 hours for samples to dry in oven	VA		
8.2.16	Yes		180	180	None	VA		
8.2.17	Yes		0	0	None	VA		Statement not instruction.
9.	Yes		60	120	None	VA		
		Sec	3704	4564				
		Min	61,73	76,07				
		Hour	1,03	1,27				

Table 8: CED Viscosities

Planned job observation			
Job observed	CED Viscosity of pulp, alkcell, and cellulose products	Doc no:	VISC TEST 013
Department:	Tech centre (COE)	Revised date:	04/08/2022

Step no:	Correct		Time required to perform step (seconds) - Participant 1	Time required to perform step (seconds) - Participant 2	Waste identified if any	Step value adding (VA) or non-value adding (NVA)		Comment
	Yes	No	16/08/2023	23/08/2023		VA	NVA	

8.3.1	Yes		1200	900	None	VA		
8.3.2	Yes		120	60	1 hour waiting time, samples placed in the oven.	VA		
8.3.3	Yes		240	120	1 hour waiting time, samples placed in the desiccator.	VA		
8.3.4	Yes		360	300	None	VA		
8.3.5	Yes		900	900	None	VA		
8.4.2	Yes		1200	900	None	VA		
8.4.3	Yes		420	300	None	VA		
8.4.4	Yes		420	300	None	VA		
8.4.5	Yes		480	120	None	VA		
8.4.6	Yes		0	0	0.5 hours waiting time while samples shake.	VA		
8.4.7	Yes		120	90	None	VA		
8.4.8	Yes		300	600	None	VA		
8.4.9	Yes		420	180	None	VA		
8.4.10	Yes		120	120	None	VA		
8.4.11	Yes		0	0	0.5 hours waiting time while samples shake.	VA		
8.4.12	Yes		300	120	0.5 hours waiting time while samples reach temperature in the bath.	VA		
8.4.14	Yes		14	14	None	VA		
8.4.15 to 8.4.18	Yes		2700	1800	None	VA		
8.4.19	Yes		900	300	None	VA		
8.4.20	Yes		6	14	None	VA		
8.4.21	Yes		60	90	None	VA		
8.4.22	Yes		2	2	0.5 hours waiting time while samples reach temperature in the bath.	VA		
8.4.23	Yes		300	300	None	VA		
8.5	Yes		1200	900	None	VA		
8.6	Yes		900	900	CED solution and contaminated paper towels.	VA		
9	Yes		60	300	None	VA		
		Sec	12742	9630				
		min	212.37	160.50				
		hour	3.54	2.68				

Table 9: Viscose ageing

Planned job observation			
Job observed	Procedure for Viscose ageing (Viscose preparation)	Doc no:	VISC 013
Department:	Tech centre (COE)	Revised date:	21/09/2022

Step no:	Correct	Time required to perform step (seconds) - Participant 1	Time required to perform step (seconds) - Participant 2	Waste identified if any	Step value adding (VA) or non-value adding (NVA)	Comment

	Yes	No	22/09/2023	22/09/2023		VA	NVA	
8.2.1	Yes		60	300	None	VA		
8.2.2	Yes		120	300	None	VA		
8.2.3	Yes		0	0	None	VA		
8.2.4	Yes		240	180	None	VA		
8.2.5	Yes		900	300	None	VA		
8.2.6	Yes		900	300	None	VA		
8.2.7	Yes		120	60	None	VA		
8.2.8	Yes		120	60	None	VA		
8.2.9	Yes		0	0	4-5 hours waiting for sample to age.	VA		
8.2.10	Yes		120	120	1 hour waiting time while samples cool down.	VA		
8.2.11	Yes		180	180	None	VA		
8.2.12	Yes		120	120	None	VA		
9.	Yes		0	0	None	VA		
10.	Yes		180	180	None	VA		
		Sec	3060	2100				
		min	51,00	35,00				
		hour	0,85	0,58				

Table 10: Xanthation of alkcell

Planned job observation								
Job observed	Xanthation of alkcell			Doc no:	VISC PREP 001			
Department:	Tech centre (COE)			Revised date:	28/09/2022			
Step no:	Correct		Time required to perform step (seconds) - Participant 1	Time required to perform step (seconds) - Participant 2	Waste identified if any	Step value adding (VA) or non-value adding (NVA)		Comment
	Yes	No	16/02/2023	16/02/2023		VA	NVA	
8.3.1	Yes		60	60	None	VA		
8.3.2	Yes		120	120	None	VA		
8.3.3	Yes		60	300	None	VA		
8.3.4	Yes		120	120	None	VA		
8.3.5	Yes		240	60	None	VA		
8.3.6	Yes		120	30	None	VA		
8.3.7	Yes		180	180	None	VA		
8.3.8	Yes		60	120	None	VA		
8.3.9	Yes		120	60	None	VA		ISO doc to be amended, they do not shake the bottle anymore as it is a safety hazard.
8.3.10	Yes		10	60	None	VA		
8.4	Yes		480	900	None	VA		

9.	Yes		420	120	None	VA		
		Sec	1990	2130				
		Min	33,17	35,5				
		Hour	0,55	0,59				

Table 11: Dissolving and ripening

Planned job observation								
Job observed	Dissolving and ripening				Doc no:	VISC PREP 002		
Department:	Tech centre (COE)				Revised date:	28/09/2022		
Step no:	Correct		Time required to perform step (seconds) - Participant 1	Time required to perform step (seconds) - Participant 2	Waste identified if any	Step value adding (VA) or non-value adding (NVA)		Comment
	Yes	No	16/02/2023	16/02/2023		VA	NVA	
8.3.1	Yes		0	0	None	VA		Statement not instruction
8.3.2	Yes		120	60	None	VA		
8.3.3	Yes		180	120	None	VA		
8.3.4	Yes		180	60	None	VA		
8.3.5	Yes		2	2	None	VA		
8.3.6	Yes		0	0	None	VA		Statement not instruction, dissolving of 5.5hrs however after working hours
8.3.7	Yes		0	0	None	VA		Statement not instruction
8.3.8	Yes		0	0	None	VA		Statement not instruction
9.	Yes		0	0	None	VA		Statement not instruction
		Sec	482	242				
		Min	8,03	4,03				
		Hour	0,13	0,07				

Table 12: Soda in Viscose (SIV)

Planned job observation								
Job observed	Soda in Viscose (SIV)				Doc no:	VISC TEST 017		
Department:	Tech centre (COE)				Revised date:	31/08/2022		
Step no:	Correct		Time required to perform step (seconds) - Participant 1	Time required to perform step (seconds) - Participant 2	Waste identified if any	Step value adding (VA) or non-value adding (NVA)		Comment
	Yes	No	21/09/2022	21/09/2022		VA	NVA	
8.3.1	Yes		300	300	None	VA		

8.3.2	Yes		5	5	None	VA		
8.3.3	Yes		300	300	None	VA		
8.3.4	Yes		5	5	None	VA		
8.3.5	Yes		5	5	None	VA		
8.3.6	Yes		900	900	Waiting time 15 minutes.	VA		
8.3.7	Yes		300	300	SIV waste solution (viscose in acid/base solution).	VA		
8.3.8	Yes		300	300	None	VA		
9.	Yes		10	10	None	VA		
		Sec	2125	2125				
		min	35,42	35,42				
		hour	0,59	0,59				

Table 13: CIV

Planned job observation			
Job observed	Cellulose in Viscose (CIV)	Doc no:	VISC TEST 013
Department:	Tech centre (COE)	Revised date:	04/08/2022

Step no:	Correct		Time required to perform step (seconds) - Participant 1	Time required to perform step (seconds) - Participant 2	Waste identified if any	Step value adding (VA) or non-value adding (NVA)		Comment
	Yes	No	21/09/2022	15/08/2023		VA	NVA	
8.2	Yes		5	300	None	VA		
8.3	Yes		60	300	None	VA		
8.4	Yes		1	5	None	VA		
8.5	Yes		1	5	None	VA		
8.6	Yes		60	180	Waste tissue paper contaminated with viscose dope.	VA		
8.7	Yes		1	5	None	VA		
8.8	Yes		60	30	None	VA		
8.9	Yes		30	10	None	VA		
8.10	Yes		5	5	None	VA		
8.11	Yes		300	30	None	VA		
8.12	Yes		1	60	None	VA		
8.13	Yes		1	180	None	VA		
8.14	Yes		180	10	Spinbath solution after viscose regeneration.	VA		
8.15	Yes		2	600	None	VA		
8.16	Yes		600	15	None	VA		
8.17	Yes		2	300	None	VA		
8.18	Yes		300	315	None	VA		

8.19	Yes		300	15	Boiling water.	VA		
8.20	Yes		2	60	45 minutes waiting time	VA		
8.21	Yes		120	60	None	VA		
8.22	Yes		2	30	Regenerated film after drying.	VA		
8.23	Yes		300	300	None	VA		
9.	Yes		30	30	None	VA		
		Sec	2363	2845				
		min	39.38	47.42				
		hour	0.66	0.79				

Table 14: Ball fall

Planned job observation			
Job observed	Ball fall	Doc no:	VISC PREP 009
Department:	Tech centre (COE)	Revised date:	28/09/2022

Step no:	Correct		Time required to perform step (seconds) - Participant 1	Time required to perform step (seconds) - Participant 2	Waste identified if any	Step value adding (VA) or non-value adding (NVA)		Comment
	Yes	No	17/02/2023	17/02/2023		VA	NVA	
8.3.1	Yes		60	60	None	VA		
8.3.2	Yes		3	5	None	VA		
8.3.3	Yes		0	0	None	VA		Not done, either change ISO doc or start practice.
8.3.4	Yes		0	0	3 hours waiting time.	VA		
8.3.5	Yes		180	180	None	VA		
8.3.6	Yes		65	65	None	VA		
8.4	Yes		600	720	Viscose dope.	VA		
9.	Yes		10	7	None	VA		
		Sec	918	1037				
		Min	15.3	17.28				
		Hour	0.26	0.29				

Table 15: KW filtration

Planned job observation			
Job observed	Filterabiity (Kw) viscose test	Doc no:	VISC TEST 019
Department:	Tech centre (COE)	Revised date:	2022/09/28

Step no:	Correct	Time required to perform step (seconds) - Participant 1	Time required to perform step (seconds) - Participant 2	Waste identified if any	Step value adding (VA) or non-value adding (NVA)	Comment

	Yes	No	2023/08/15	22/09/2023		VA	NVA	
8.3.1	Yes		300	180	None	VA		
8.3.2	Yes		300	300	None	VA		
8.3.3	Yes		780	684	None	VA		
8.3.4.1	Yes		3	15	None	VA		
8.3.4.2	Yes		0	2	30minutes waiting time.	VA		
8.3.4.3	Yes		2	60	None	VA		
8.3.4.4	Yes		2	5	None	VA		
8.3.4.5	Yes		21	5	None	VA		
8.3.4.6	Yes		2	5	None	VA		
8.3.4.7	Yes		21	5	60minutes waiting time at 10minute intervals.	VA		
8.3.4.8	Yes		0	0	Filtered viscose dope.	VA		
8,4	Yes		60	120	None	VA		
9	Yes		120	300		VA		
		Sec	1611	1681				
		min	26,85	28,02				
		hour	0,45	0,47				

Table 16: Particle counts

Planned job observation								
Job observed	Coulter counter analysis - viscose test				Doc no:	VISC TEST 018		
Department:	Tech centre (COE)				Revised date:	11/11/2019		
Step no:	Correct		Time required to perform step (seconds) - Participant 1	Time required to perform step (seconds) - Participant 2	Waste identified if any	Step value adding (VA) or non-value adding (NVA)		Comment
	Yes	No	25/10/2022	14/02/2023		VA	NVA	
6.3.1	Yes		60	60	None	VA		
6.3.2	Yes		60	60	None	VA		
6.3.3	Yes		60	120	None	VA		
6.3.4	Yes		60	120	None	VA		
6.3.5	Yes		60	10	None	VA		
6.3.6	Yes		60	10	None	VA		
6.4.1	Yes		60	60	None	VA		
6.4.2	Yes		10	60	None	VA		
6.4.3	Yes		2	2	None	VA		
6.4.4	Yes		60	61	None	VA		
6.4.5	Yes		60	61	None	VA		
6.4.6	Yes		60	61	None	VA		
6.4.7	Yes		1800	1830	None	VA		
6.4.8	Yes		120	180	None	VA		
6.4.9	Yes		120	60	Contaminated viscose solution.	VA		
6.4.10	Yes		2	10	None	VA		

6.4.11	Yes		30	2	None	VA		
6.4.12	Yes		2234	2325	None	VA		
6.4.13	Yes		10	120	None	VA		
6.7.1	Yes		60	30	None	VA		
6.7.2	Yes		2	2	None	VA		
6.7.3	Yes		2	1	None	VA		
6.7.4	Yes		2	1	None	VA		
6.7.5	Yes		2	1	None	VA		
6.7.6	Yes		2	1	None	VA		
6.7.7	Yes		2	1	None	VA		
6.7.8	Yes		2	2	None	VA		
6.7.9	Yes		2	2	None	VA		
6.8.1	Yes		10	2	6% NaOH blank solution.	VA		
6.8.2	Yes		10	2	None	VA		
6.8.3	Yes		900	915	None	VA		
6.8.4	Yes		5	3	None	VA		
6.8.5	Yes		2234	2325	Contaminated demin water.	VA		
6.9.1	Yes		120	120	None	VA		
6.9.2	Yes		120	30	None	VA		
6.9.3	Yes		0	0	None	VA		
6.9.4	Yes		2	1	None	VA		
6.9.5	Yes		900	902	Waiting time of 15 minutes for stirring of sample.	VA		
6.9.6	Yes		1800	1800	Waiting time of 30 minutes for settling of sample.	VA		
6.9.7	Yes		2	2	None	VA		
6.9.8	Yes		60	60	None	VA		
6.9.9	Yes		2	2	None	VA		
6.9.10	Yes		2	2	None	VA		
6.9.11	Yes		2	2	None	VA		
6.9.12	Yes		2	2	None	VA		
6.9.13	Yes		2	2	None	VA		
6.9.14	Yes		120	5	None	VA		
6.9.15	Yes		60	120	None	VA		
6.9.16	Yes		30	120	None	VA		
6.10.1	Yes		30	30	Excess viscose sample in solution after analyses.	VA		
6.10.2	Yes		1	30	None	VA		
6.10.3	Yes		1800	1830	None	VA		
6.10.4	Yes		10	30	Cleanse solution after cleaning is complete.	VA		
6.10.5	Yes		2234	2325	Contaminated demin water.	VA		
8.	Yes		60	60	None	VA		

9.	Yes		300	600	None	VA		
		Sec	15822	16575				
		Min	263,7	276,25				
		Hour	4,40	4,60				

Table 17: Rheology of viscose dope

Planned job observation								
Job observed	Rheology of viscose dope				Doc no:	VISC TEST 012		
Department:	Tech centre (COE)				Revised date:	03/08/2022		
Step no:	Correct		Time required to perform step (seconds) - Participant 1	Time required to perform step (seconds) - Participant 2	Waste identified if any	Step value adding (VA) or non-value adding (NVA)		Comment
	Yes	No	25/09/2022	2023/03/07		VA	NVA	
8.2.1.1	Yes		1800	1800	Waiting time of 30 minutes to attain compressor pressure	VA		
8.2.1.2	Yes		1	2	None	VA		
8.2.1.3	Yes		2	60	None	VA		
8.2.1.4	Yes		2	15	None	VA		
8.2.1.5	Yes		2	10	None	VA		
8.2.2.1	Yes		2	2	None	VA		
8.2.2.2	Yes		2	5	None	VA		
8.2.2.3	Yes		2	2,5	None	VA		
8.2.2.4	Yes		2	2	None	VA		
8.2.2.5	Yes		15	5	None	VA		
8.2.2.6	Yes		2	2	None	VA		
8.2.2.7	Yes		10	5	None	VA		
8.2.2.8	Yes		10	60	None	VA		
8.2.2.9	Yes		1	1	None	VA		
8.2.2.10	Yes		3	5	None	VA		
8.2.2.11	Yes		10	2	None	VA		
8.2.2.12	Yes		5	2	None	VA		
8.2.2.13	Yes		10	2	None	VA		
8.2.2.14	Yes		5	5	None	VA		
8.2.2.15	Yes		5	1	None	VA		
8.2.2.16	Yes		5	1	None	VA		
8.2.2.17	Yes		30	1	None	VA		
8.2.2.18	Yes		15	1	None	VA		
8.2.2.19	Yes		15	2	None	VA		
8.2.2.20	Yes		5	0	None	VA		
8.2.2.21	Yes		5	1	None	VA		
8.2.2.22	Yes		2	1	None	VA		
8.2.2.23	Yes		2	1	None	VA		

8.2.2.24	Yes		5	2	None	VA		
8.2.2.25	Yes		2	1	None	VA		
8.2.2.26	Yes		180	94	None	VA		
8.2.2.27	Yes		5	180	None	VA		
8.2.2.28	Yes		5	2	None	VA		
8.2.2.29	Yes		2	2	None	VA		
8.2.2.30	Yes		30	1	None	VA		
8.2.2.31	Yes		15	2	None	VA		
8.2.2.32	Yes		30	60	None	VA		
8.2.2.33	Yes		15	60	None	VA		
8.2.2.34	Yes		15	60	Contaminated paper towel with viscose, water and acid solution.	VA		
8.2.2.35	Yes		15	2	None	VA		
8.2.2.36	Yes		10	2	None	VA		
8.2.2.37	Yes		3	10	None	VA		
8.2.2.38	Yes		3	2	None	VA		
8.2.2.39	Yes		2	2	None	VA		
8.2.2.40	Yes		3	0	None	VA		
9.	Yes		5	5	None	VA		
		Sec	2315	2483,5				
		Min	38,58	41,39				
		Hour	0,64	0,69				

Appendix I: Technical proposal for pulp store management phase 2

sappi

Sappi Dissolving Pulp Centre of Excellence	**TECHNICAL PROPOSAL**
TITLE	Pulp store management phase 2
PROJECT NUMBER	TP 357/23
PROJECT VALUE	
PROJECT MANAGER	D Govender
AUTHOR	D Govender
MANAGEMENT SPONSOR	C Pillay
DATE ISSUED	15 February 2023 Approved: 28/02/2023
DISTRIBUTION	C. Yunnie M. Mathai S. Govender C. Pillay S. Njamela T. Shangase L. Singh N. Kerr P. Lekha O. Matasva T. Perumal S. Fataar
MANAGEMENT SPONSOR	C Pillay

Introduction

Since the establishment of Sappi COE laboratories in 2011, COE actively receives final sheet pulp samples from various mills namely, Sappi Saiccor, Ngodwana and Cloquet. In addition, Sappi COE conducts research and development in line with the companies sustainability and innovation goals. This entails sourcing and storing various samples (fabrics, waste cotton etc.). A pulp store has been allocated for storing all historical pulp samples and fabrics. The samples collected over the years have been stored without a proper tracking system and storage management procedure. It is imperative to keep recent samples in good condition as they may be required for future work and discard old samples taking up space. A tracking system has been put in place during the first phase of the pulp store management. This allows one to keep track of samples being added and removed from the pulp stores. The aim of the second phase of the project is to identify a quality management system to maintain samples kept in the pulp store.

Objectives

The aim of the study is to identify a quality management system to maintain samples kept in the pulp store.

Scope of Work

- Investigate possible quality management systems used in the various Sappi mills.
- Identify possible system that could be effective in the COE pulp store.
- Procure appropriate items used for the tracking system.
- Plan to implement a pilot system.
- Review findings from the pilot study and make possible changes.
- Implement finalized system.
- Train personnel on how to use system effectively.
- Evaluate system and improve.
- A similar approach will be implemented at the various labs for project analysis.
- The duration of samples stored will be determined.

Expected Benefit

The quality management system applied will ensure logical storage of the pulp samples at the COE pulp store.

Experimental Design

Sample List:

- All samples currently in pulp store.

Analysis

- No laboratory analysis required

Responsible Management and Project Schedule

Project Originator : C. Pillay
Project Manager : D. Govender
Team Co-Ordinator :
Teamsters :
Lab Manager : C. Pillay
Resources : Technical C.O.E.

Resources

Roles and Responsibilities Matrix:

Who?	**Collation of Results**	**Report**
COE Team		

Team Co-Ordinator		
Project Manager	R,A,D	R,A,D,X

Legend: **R**esponsible, **A**ccountable, **C**onsult, **I**nform, e**X**ecutes, takes functional **D**ecision, **a**vailable for advice

Project Timeline and Schedule:

Project Plan	**Duration**	**Start**	**Completion**
Draft and submit proposal	5 Days	10 February 2023	17 February 2023
PDCA cycle	20 Days	20 February 2023	17 March 2023
ISO Doc if required	5 Days	20 March 2023	24 March 2023
Report	14 days	27 March 2023	07 April 2023

Appendix J: Log books created using deposit slips below for tracking of samples

<table>
<tr><th colspan="5">Deposit Slip</th></tr>
<tr><td>Date entered:</td><td colspan="4"></td></tr>
<tr><td>Sample Description (Final sheet, shredded 2mm,4mm, lab bleached pulp PTC., etc):</td><td colspan="4"></td></tr>
<tr><td>Pulp grade (92 alpha VSF, 92 alpha lyocell, 91 alpha., etc)</td><td colspan="4"></td></tr>
<tr><td>Application (VSF, Speciality., etc):</td><td colspan="4"></td></tr>
<tr><td>Type of furnish (HW, SW, specific species name., etc)</td><td colspan="4"></td></tr>
<tr><td>Pulping process if available (PHK, Sulphite, Kraft., etc)</td><td colspan="4"></td></tr>
<tr><td>Project used for:</td><td colspan="4"></td></tr>
<tr><td rowspan="2">Origin eg., mill, customer, competitor sample (Please tick):</td><td>Saiccor mill</td><td>Ngodwana mill</td><td rowspan="2">Jumbo/batch number /competitor:</td><td rowspan="2"></td></tr>
<tr><td>Cloquet mill</td><td>Competitor</td></tr>
<tr><td>Name of personnel entering sample:</td><td colspan="2"></td><td>Weight Deposited:</td><td></td></tr>
<tr><td>Unique code (Assigned by pulp store manager)</td><td colspan="2"></td><td>Storage Location:</td><td></td></tr>
</table>

Withdrawal Slip			
Date of withdrawal:		**Unique code:**	
Project going to be used for:		**Jumbo/batch number /competitor:**	
Original weight:		**Weight of sample required for new project:**	
Name of personnel withdrawing sample:		**Additional info/comments:**	

Withdrawal Slip			
Date of withdrawal:		**Unique code:**	
Project going to be used for:		**Jumbo/batch number /competitor:**	
Original weight:		**Weight of sample required for new project:**	
Name of personnel withdrawing sample:		**Additional info/comments:**	

Appendix K: Pulp store checklist implemented to maintain standards within the pulp store

HOUSEKEEPING SCORES CHECKLIST

Scoring	Condition	Non-Conformances	Points
	1) Very Good	0	5
	2) Good	1 to 2	4
	3) Average	3 to 5	3
	4) Bad	6 to 8	2
	5) Very Bad	> 8	1

Date:
Location: **Pulp stores**

S	No	Check Item	Description	Findings	Score	%
SORT	1	General compliance: Pulp samples	All pulp samples are located in the correct shelve according to the label (e.g, Cloquet sample found on designated shelve)			
	2	General compliance: Pulp samples	Samples are correctly labelled (dated and description)			
	3	General compliance: Pulp samples	Sample boxes are in good condition			
	4	General compliance: Fabric samples	Fabrics are stored in the designated area			
	5	General compliance: Fabric samples	Fabrics are neatly trimmed and tidy			
	6	General compliance: Fabric samples	Fabrics are correctly labeled and can be clearly identified			
			Category subtotal		**0**	**0**
SAFETY	7	General compliance	Tripping electrical cables are removed from standing and walking areas			
	8	General compliance	Are shelves and racks clearly labeled			
	9	General compliance	Are shelves and racks structurally sound			
	10	General compliance	Is there adequate lighting available to read labels			
	11	General compliance	Is there adequate gloves available to prevent samples from becoming contaminated during handling			
	12	General compliance	Fire equipment has not been tampered with, seal intact			
	13	General compliance	Fire equipment unobstructed, walk ways are clear			
			Category subtotal		**0**	**0**
SHINE (CLEA	14	General compliance	Is the table used for sample preparation neat and tidy, free of dust			
	15	General compliance	Walls and cupboards are painted and kept clean			
	16	General compliance	Floors are free from dirt, parts and unidentified packaging materials			
			Category subtotal		**0**	**0**
STANDARDIZE	17	General compliance	Documents (pulp store list) is updated as to contents (Requested from Mannie)			
	18	General compliance	Labels are clear and free from ambiguity			
	19	General compliance	Labels are easily identifiable and representative of contents located on specific shelve			
	20	General compliance	Is the deposit and withdrawal logbook in good condition and easy to read			
			Category subtotal		**0**	**0**
SUSTAIN	21	Time and resources	Time and resources are allocated for housekeeping activities			
	22	Initiative	The team took an initiative to close out findings from the previous audit			
			Category subtotal		**0**	**0**
			GRAND TOTAL SCORE (%)		**0**	**0%**
			Previous score			
			% Change (+ / -)		0	

AREAS FOR IMPROVEMENT		

Appendix L: Proposed maintenance schedule

Maintenance schedule								
Equipment	Condition	Location	Assigned to	Last maintenance date	Maintenance frequency in days	New maintenance frequency in days proposed	Next Maintenance date	Notes/Comments
Steeping motors	Poor	Viscose lab	Dolyn	01/12/2023	365	182	01/12/2024	Should be moved to bi-annual maintenance schedule based on frequently occuring failures
Steeping pots	Poor	Viscose lab	Oswell	01/12/2023	365	182	01/12/2024	Should be moved to bi-annual maintenance schedule based on frequently occuring failures
Steeping impellers	Poor	Viscose lab	Thobe	01/12/2023	365	182	01/12/2024	Should be moved to bi-annual maintenance schedule based on frequently occuring failures
Steeping water baths	Fair	Viscose lab	Katlego	01/12/2023	365	182	01/12/2024	Should be moved to bi-annual maintenance schedule based on frequently occuring failures
Presses	Fair	Viscose lab	Palisha	01/12/2023	365	182	01/12/2024	Should be moved to bi-annual maintenance schedule based on frequently occuring failures
Shredders	Fair	Viscose lab	Theo	01/12/2023	365	182	01/12/2024	Should be moved to bi-annual maintenance schedule based on frequently occuring failures
Ageing ovens	Good	Viscose lab	Dolyn	01/01/2023	365	182	01/01/2024	
Xanthation ovens	Poor	Viscose lab	Oswell	01/01/2023	365	182	01/01/2024	Should be moved to bi-annual maintenance schedule based on frequently occuring failures
Drying ovens	Good	Viscose lab	Thobe	01/01/2023	365	182	01/01/2024	
Analytical balances	Good	Viscose lab	Katlego	01/12/2023	365	182	01/12/2024	
Top loading balances	Good	Viscose lab	Palisha	01/12/2023	365	182	01/12/2024	
Dissolving pots	Poor	Viscose lab	Theo	01/12/2023	365	182	01/12/2024	Should be moved to bi-annual maintenance schedule based on frequently occuring failures
Dissolving impellers	Poor	Viscose lab	Dolyn	01/12/2023	365	182	01/12/2024	Should be moved to bi-annual maintenance schedule based on frequently occuring failures
Dissolving waterbath	Poor	Viscose lab	Oswell	01/12/2023	365	182	01/12/2024	Should be moved to bi-annual maintenance schedule based on frequently occuring failures
Dissolving motors	Poor	Viscose lab	Thobe	01/12/2023	365	182	01/12/2024	Should be moved to bi-annual maintenance schedule based on frequently occuring failures
Dissolving Chillers	Fair	Viscose lab	Katlego	01/12/2023	365	182	01/12/2024	Should be moved to bi-annual maintenance schedule based on frequently occuring failures

Appendix M: Ethics certificate and clearance letter

TRREE

Zertifikat

Certificado

Certificat

Certificate

Promouvoir les plus hauts standards éthiques dans la protection des participants à la recherche biomédicale
Promoting the highest ethical standards in the protection of biomedical research participants

Clinical Trials Centre
The University of Hong Kong

Certificat de formation - Training Certificate

Ce document atteste que - this document certifies that

Dolyn Govender

a complété avec succès - has successfully completed

Introduction to Research Ethics

du programme de formation TRREE en évaluation éthique de la recherche
of the TRREE training programme in research ethics evaluation

Release Date: 2021/06/10

Professeur Dominique Sprumont
Coordinateur TRREE Coordinator

FMH

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Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
Email: lavishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

2 September 2022

Mrs D Govender
18 Salisbury Road
Widenham
Umkomaas
4170

Dear Mrs Govender

An integrated quality management framework to improve project throughput rate in a selected laboratory environment
Ethics Clearance Number: IREC 188/22

The DUT-Institutional Research Ethics Committee acknowledges receipt of your notification regarding the piloting of your data collection tool.

Kindly ensure that participants used for the pilot study are not part of the main study.

In addition, the DUT-IREC acknowledges receipt of your gatekeeper permission letter.

Please note that FULL APPROVAL is granted to your research proposal. You may proceed with data collection.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the DUT-IREC according to the DUT-IREC SOP's.

Please note that any deviations from the approved proposal require the approval of the DUT-IREC as outlined in the DUT-IREC SOP's.

Yours Sincerely

Professor J K Adam
Chairperson: DUT-IREC

Appendix N: Letter of information

LETTER OF INFORMATION

Title of the Research Study: An integrated quality management framework to improve project throughput rate in a selected laboratory environment

Principal Investigator/s/researcher: Dolyn Govender (Btech: Operations Management)

Co-Investigator/s/supervisor/s: Professor K G Moodley (PhD: Chemistry)

Brief Introduction and Purpose of the Study: Quality plays a crucial role in the business process within an organisation, to improve efficiency and to be more effective in the global market. Improving quality and customer loyalty has a significant bearing on market share. A focus to reduce wastage, but also to satisfy customer's expectations, continuous cost reductions and continuous improvements are necessary to survive in highly competitive environment. A significant amount of research has been carried out, that indicates the application of quality management frameworks assists with increased quality, reduced variability, and elimination of any waste produced. Therefore, the aim if this study, is to develop and implement an integrated management framework in Sappi COE laboratories to reduce repeat work, hence improving project performance.

Good Day

My name is Dolyn Govender. I am a 2nd year master's student at Durban University of Technology's in the department of Quality Management.

I am kindly requesting your participation in a master's research study that I am conducting titled: "An integrated quality management framework to improve project throughput rate in a selected laboratory environment", aimed at improving project performance. The study involves completing a pre and post study questionnaire to assess current project performance. The study is completely anonymous; therefore, it does not require you to provide your name or any other identifying information. Participation is completely voluntary, and you may withdraw from the study at any time.

Outline of the Procedures:

1.Value stream mapping will be applied to the ageing kinetics, viscose production and application tests to visualize processes with key quality indicators and control loops noted.

2. Brainstorming sessions will be held to with employees of Sappi COE technical department and technical teams to understand the causes/challenges behind the repeat work of ageing kinetics, viscose production and application tests within a project. In addition, a pre-study questionnaire (Appendix A) will be self-administered during individual sessions to understand the possible factors that cause of repeat work hence delays within a project from a team perspective. Brainstorming sessions will be held on site (Sappi Saiccor) during working hours (07:30am to 4:30pm), according to participants work schedules. The questionnaire will take approximately 30 minutes to complete during individual sessions. This will also be set up according to participants work schedules at Sappi Saiccor during working hours.

3. Information obtained on ageing kinetics, viscose process and application tests from the brainstorming sessions held will be visualized using a fishbone diagram.

4. A pareto chart will be used to highlight the most frequently occurring causes of repeat work and waste production that contributes to the delay in results in the ageing kinetics, viscose production and application tests.

5. After possible causes are identified an integrated quality management framework will be developed and implemented.

6. To evaluate the effectiveness of the integrated quality management framework a post study questionnaire (Appendix B) will be self-administered. The questionnaire will take approximately 30 minutes to complete during individual sessions. This will be set up according to participants work schedules at Sappi Saiccor during working hours.

Risks or Discomforts to the Participant: N/A

Explain to the participant the reasons he/she may be withdraw from the Study: N/A

Benefits: The participant will have an opportunity to voice their opinions on issues that affect them within a project.

Remuneration: N/A

Costs of the Study: N/A

Confidentiality: Any information you provide will be kept anonymous. The researcher will not use your personal information for any purposes outside of this research project. Also, the researcher will not include your name or anything else that could identify you in the study reports. Data will be kept secure by password protection and data encryption. Data will be kept for a period of at least 5 years, as required by the university.

Results: Findings of the proposed research will be relayed to participants upon request via, hardcopies or electronic copies.

Research-related Injury: N/A

Storage of all electronic and hard copies including tape recordings: Data collected from each participant will be collected stored in a locked cupboard. The confidentiality and personal data of each participant will be protected through signing of confidentiality documents. This data will be stored for a period of 5 years. All questionnaires will be shredded and disposed of. Electronic copies will be permanently deleted.

Persons to contact in the Event of Any Problems or Queries: Supervisor: Honorary Professor K. G Moodley. Please contact the researcher on 072 052 6647 or, my supervisor on 072 478 8242, or the Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the Director: Research and Postgraduate Support Dr L Linganiso on 031 373 2577 or researchdirector@dut.ac.za.

Appendix O: Participation Invitation Letter

Participation Invitation Letter

Dear Invitee,

My name is Dolyn Govender. I am a master's student at Durban University of Technology's in the department of Quality Management. I am kindly requesting your participation in a master's research study that I am conducting titled: "An integrated quality management framework to improve project throughput rate in a selected laboratory environment", aimed at improving project performance. The study involves completing a pre and post study questionnaire to assess current project performance. The study is completely anonymous; therefore, it does not require you to provide your name or any other identifying information. Participation is completely voluntary, and you may withdraw from the study at any time.

If you would like to participate in the study, please read the Informed Consent letter below. To accept you need to sign the consent letter below.

Your participation in the research will be of great importance to assist with project management gaps that currently exists at Sappi COE laboratories and how we can mitigate them.

Thank you for your time and participation

Sincerely,

Dolyn Govender, Masters Student, Durban University of Technology.

CONSENT

Full Title of the Study: "An integrated quality management framework to improve project throughput rate in a selected laboratory environment",

Names of Researcher/s: Dolyn Govender

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, Dolyn Govender, about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: ____,
- I have also received, read and understood the above written information (Participant Letter of

  Information) regarding the study.

- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

Full Name of Participant/	**Date**	**Time**	**Signature/Right**
Thumbprint			

I, Dolyn Govender herewith confirm that the above participant has been fully informed about the

nature, conduct and risks of the above study.

Full Name of Researcher	**Date**	**Signature**
Full Name of Witness (If applicable)	**Date**	**Signature**
Full Name of Legal Guardian (If applicable)	**Date**	**Signature**

Appendix P: Gatekeepers letter

08 June 2021
Dr Tracy Wessels
General Manager Group Sustainability and Research & Development
Work: 039 973 8420
Cell: 083 666 6589

Re: Request for Permission to Conduct Research

Dear: Dr Tracy Wessels

My name is Dolyn Govender, a Master of Philosophy in Quality Management student at the Durban University of Technology. The research I wish to conduct for my master's dissertation involves the management of chemical classification, compatibility, and storage facilities within a manufacturing plant.

I am hereby seeking your consent to use, data available from Sappi COE, interview Analysts and Senior analysts to gather relevant information needed for my study.

I have provided you with a copy of my proposal which includes copies of the data collection tools and consent and/or assent forms to be used in the research purposes, as well as a copy of the approval letter which I received from the Institutional Research Ethics committee (IREC).

If you require any further information, please do not hesitate to contact me on 072 052 6647 or dolyng@gmail.com. Thank you for your time and consideration in this matter.

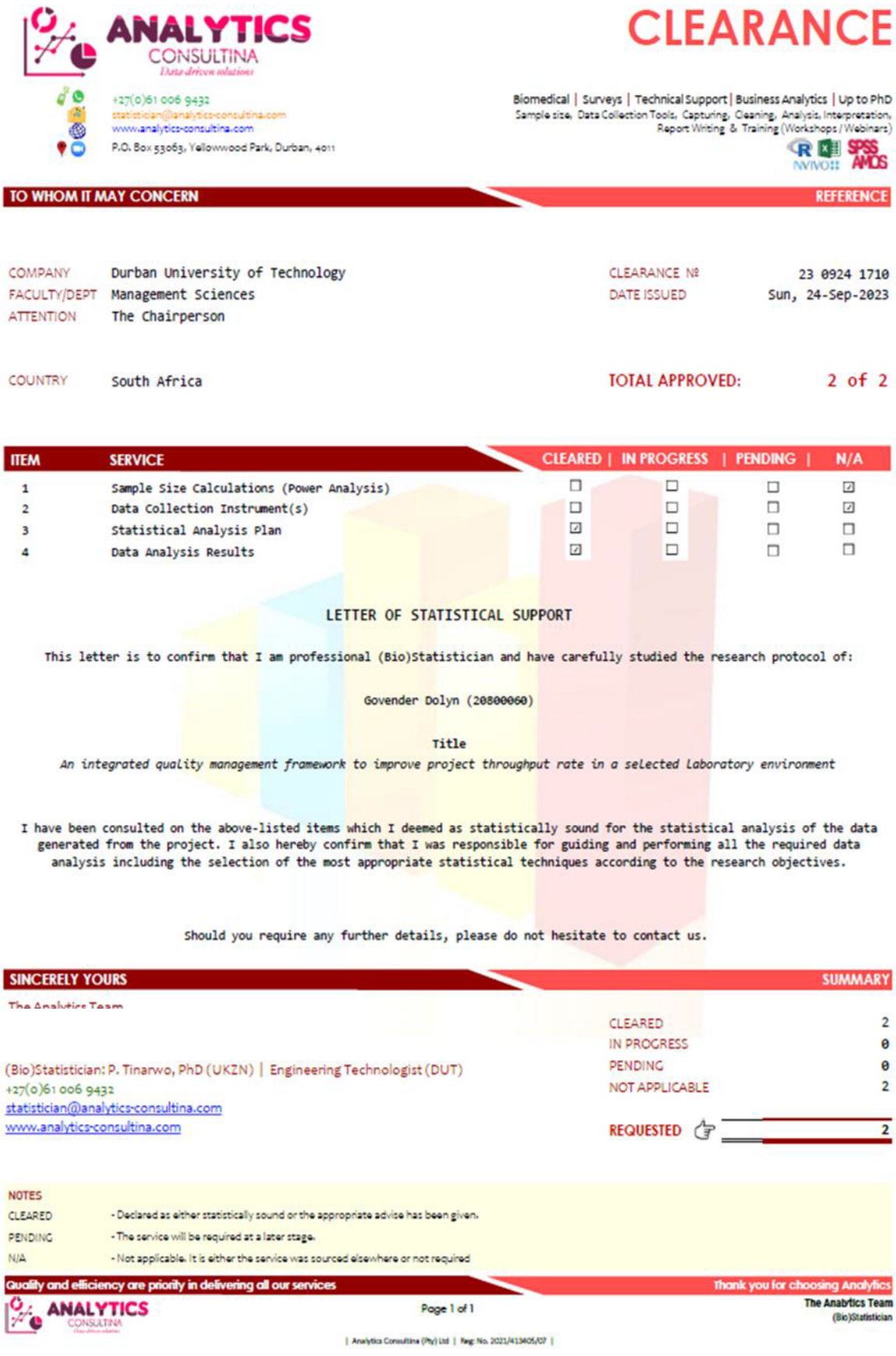
05/07/2021.

Dr Tracy Wessels

Yours sincerely,

Dolyn Govender
Durban University of Technology

Appendix Q: Statisticians clearance letter



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R Excel SPSS NVIVO AMOS

TO WHOM IT MAY CONCERN — **REFERENCE**

COMPANY	Durban University of Technology	CLEARANCE №	23 0924 1710
FACULTY/DEPT	Management Sciences	DATE ISSUED	Sun, 24-Sep-2023
ATTENTION	The Chairperson		
COUNTRY	South Africa	TOTAL APPROVED:	2 of 2

ITEM	SERVICE	CLEARED	IN PROGRESS	PENDING	N/A
1	Sample Size Calculations (Power Analysis)	☐	☐	☐	☑
2	Data Collection Instrument(s)	☐	☐	☐	☑
3	Statistical Analysis Plan	☑	☐	☐	☐
4	Data Analysis Results	☑	☐	☐	☐

LETTER OF STATISTICAL SUPPORT

This letter is to confirm that I am professional (Bio)Statistician and have carefully studied the research protocol of:

Govender Dolyn (20800060)

Title

An integrated quality management framework to improve project throughput rate in a selected Laboratory environment

I have been consulted on the above-listed items which I deemed as statistically sound for the statistical analysis of the data generated from the project. I also hereby confirm that I was responsible for guiding and performing all the required data analysis including the selection of the most appropriate statistical techniques according to the research objectives.

Should you require any further details, please do not hesitate to contact us.

SINCERELY YOURS — **SUMMARY**

The Analytics Team

CLEARED	2
IN PROGRESS	0
PENDING	0
NOT APPLICABLE	2
REQUESTED	2

(Bio)Statistician: P. Tinarwo, PhD (UKZN) | Engineering Technologist (DUT)
+27(0)61 006 9432
statistician@analytics-consultina.com
www.analytics-consultina.com

NOTES

CLEARED	- Declared as either statistically sound or the appropriate advise has been given.
PENDING	- The service will be required at a later stage.
N/A	- Not applicable. It is either the service was sourced elsewhere or not required

Quality and efficiency are priority in delivering all our services — Thank you for choosing Analytics

ANALYTICS CONSULTINA

Page 1 of 1

The Analytics Team
(Bio)Statistician

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Appendix R: Language editor clearance letter

Helen Richter
Advanced Editing, Proofreading
& Copy writing

editassist2023@gmail.com
072 9227221

14 November 2023

To whom it may concern:

CERTIFICATE OF EDITING & AUTHENTICATION

I have proofread and language edited the MPhil thesis titled:

"AN INTEGRATED QUALITY MANAGEMENT FRAMEWORK TO IMPROVE PROJECT THROUGHPUT RATE IN A SELECTED LABORATORY ENVIRONMENT"

by

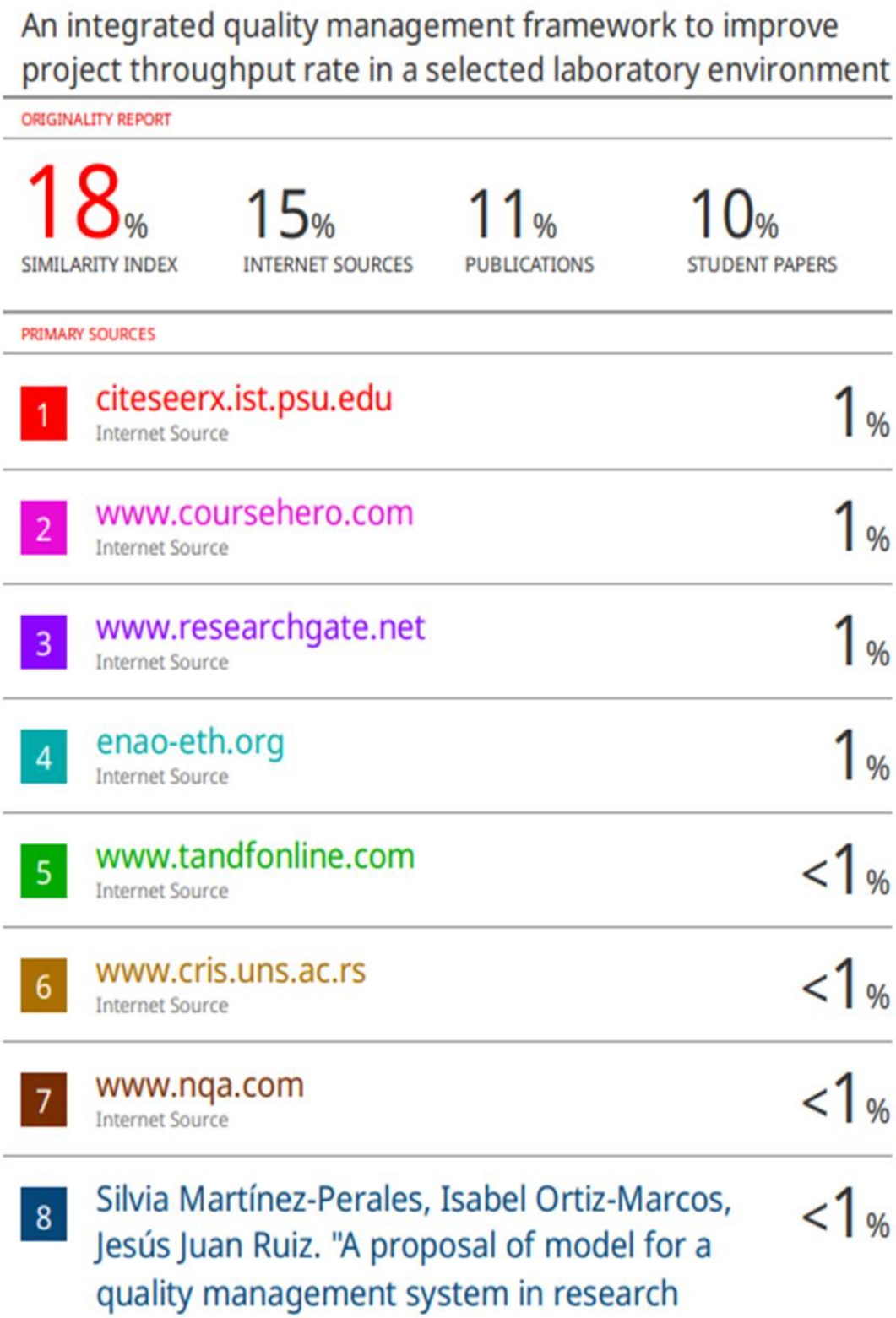
Dolyn Govender

The work is the author's own work, to the best of my knowledge, and is free of spelling, grammar, and structural and stylistic errors.

With thanks.

H. S. Richter (Ms)

Appendix S: Turnitin report



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