



**Investigating Challenges of Near Infrared Spectroscopy In
The Cane Testing Services At South African Sugar
Association**

Nozibusiso Pretty Chiliza
Student number: 200201201

**A dissertation submitted in partial fulfilment of the requirements for the degree of
MASTER OF COMMERCE IN LEADERSHIP**

**College of Law and Management Studies
Graduate School of Business and Leadership**

Supervisor: Dr Bibi Zaheenah Chummun


August 2023

SUPERVISORS' PERMISSION TO SUBMIT



College of Law and Management Studies

Supervisors Report of Revised and Corrected Thesis/ Dissertation

Name: Nozibusiso Pretty Chiliza	No: 200201201	
Dissertation title: Investigating Challenges of Near Infrared Spectroscopy in The Cane Testing Services At South African Sugar Association		
Qualification: MCLS	School: GSB&L	
	Yes	No
I certify that the following student has made the changes/corrections to his/her dissertation/thesis as requested in the examiner's report/s.	x	
Comments if necessary:		
Supervisors Name: Prof Bibi Zaheenah Chummun		
Signature: 		
Date: 02/08/2023		
Head of Masters Research:		
Signature:		
Date:		

DECLARATION

I, Nozibusiso Chiliza, declare that:

- The research reported in this thesis, except where otherwise indicated, is my original work.
- This thesis has not been submitted for any degree or examination at any other university.
- This thesis does not contain another person's data, pictures, graphs, or other information, unless specifically acknowledged as being sourced from another person.
- This thesis does not contain another person's writing, unless specifically acknowledged as being sourced from other researchers. Where other written sources have been quoted:
 - a) Their words have been rewritten, but the general information attributed to them has been referenced.
 - b) Where their exact words have been used, their writing has been placed inside quotation marks, and referenced.
- Where I have reproduced a publication of which I am author, co-author, or editor, I have indicated in detail which part of the publication was actually written by myself alone and I have fully referenced such publications.
- This thesis does not contain text, graphics, or tables copied and pasted from the Internet, unless specifically acknowledged, and the source being detailed in the thesis and in the reference list.

Signed: N. Chiliza 

ACKNOWLEDGEMENTS

I would like to thank God Almighty for giving me strength and courage to attempt my master's degree and the Holy Spirit for encouraging me all the way thorough. Without Jesus, I am as good as dead.

I would like to express my sincere appreciation and gratitude to the following individuals, without whose assistance this study would not have been possible:

- My employer, the South African Sugar Association; with special thanks to the late Ms Judith Wilson, Mr Brendon Penn, and Mr Seelan Naidoo for their support, guidance, and allowing me to conduct research within the industry.
- My supervisor, Prof. Bibi Zaheenah Chummun, for pushing and guiding me to do this research.
- Cane testing managers and supervisors who agreed to participate in this study.
- My loving husband, Wiseman, for his prayers and support throughout my studies.
- My children, Malwande, Qhawekazi, and Mqhele, whom I love very much.

ABSTRACT

The primary routine laboratory analysis of measuring sugar content is conducted using standard refractometry and polarimetry. A secondary method, near infrared (NIR) spectroscopy, offers various benefits and limitations and is well established to monitor the quality of raw sugarcane received by sugar mills for pricing. The perceived problem is that Cane Testing Services has been testing using traditional analytical chemistry methods performed by different individuals utilising various instruments and chemicals. NIR spectroscopy means analysis is performed by one individual in a short time and no chemicals are needed, which causes potential redundancies in some existing positions. An investigation of the challenges that accompany NIR spectroscopy implementation is required to understand its impact and consequences for the organisation. This study is descriptive in nature; a qualitative research approach using structured interviews therefore gathered data on the challenges of implementing NIR spectroscopy, to provide a description of the technology function, and to make recommendations regarding solutions to the challenges. Five managers and five supervisors at Cane Testing Services were interviewed to collect data. Thematic analysis was conducted to code the data into categories and themes. The study findings identified challenges such as poor communication, NIR spectroscopy being a secondary method, organisational structure, and fear of change. The conclusions of this study are that the significant benefits of NIR spectroscopy are environmental safety benefits, cost efficiency, and time saving. Implementation management and personnel reskilling are essential to offset potential job losses.

TABLE OF CONTENTS

SUPERVISORS' PERMISSION TO SUBMIT.....	i
DECLARATION.....	ii
ACKNOWLEDGEMENTS.....	iii
ABSTRACT	iv
LIST OF TABLES	xi
LIST OF FIGURES	xii
LIST OF ABBREVIATIONS.....	xiii
CHAPTER ONE: INTRODUCTION	1
1.1 Introduction	1
1.2 Background of the study	2
1.2.1 Sugar industry.....	2
1.2.2 The South African Sugar Association (SASA).....	3
1.3 Problem statement	4
1.4 Research objectives	4
1.5 Research questions.....	5
1.6 Rationale of the study	5
1.7 Research methodology synopsis.....	5
1.8 Delimitations and limitations of the study.....	6
1.9 Outline of chapters.....	6
1.10 Summary.....	7
CHAPTER TWO: LITERATURE REVIEW	8
2.1 Introduction	8
2.2 Origin and distribution of sugarcane	8
2.2.1 Classification of sugarcane	9
2.2.2 International production of sugarcane	9
2.2.3 South African production of sugarcane	10
2.3 Precision agriculture in the sugarcane industry	13

2.3.1	The need to measure sugarcane quality in the field.....	13
2.3.2	Laboratory techniques to assess sugarcane quality and their limitations for field use.....	13
2.3.3	Procedure for sugarcane testing payments at Cane Testing Services (CTS).....	14
2.4	Introduction of new technology.....	15
2.5	Transformation of jobs and skills.....	16
2.5.1	Technology in the South African sugar industry.....	17
2.5.2	Near infrared (NIR) spectroscopy.....	18
2.5.3	Chemometrics.....	18
2.5.4	NIR spectroscopy application in the sugarcane industry.....	20
2.5.5	Benefits and limitations of NIR spectroscopy.....	22
2.5.6	Hurdles to acceptance.....	23
2.6	The use of NIR spectroscopy by other sugar industries.....	23
2.6.1	The case of Indonesia.....	23
2.6.2	Poor market regulation.....	24
2.6.3	The case of Brazil.....	25
	The measurement of sugarcane quality indicators used to determine the payment given to producers in Brazil includes brix and polarisation analysis of extracted juice as well as brix, polarisation, and prepared sugarcane fibre determinations (Da Silva Melo et al., 2022). This technique has been used to investigate important aspects of several factory samples, including the sugarcane, intermediate process streams, and raw sugar. For instance, this technique has been used to accurately measure a variety of quality indicators in diluted molasses samples, with positive outcomes for fructose, glucose, conductivity ash, and dry matter. Additionally, the technique has been used to analyze sugarcane juice in order to identify characteristics like brix, polarization, and reducing sugars (fructose and glucose).....	25
2.7	Various challenges faced by sugarcane farmers.....	25
2.8	Theoretical framework.....	26
2.8.1	Technology Adoption Models.....	26
2.8.2	Theory of Diffusion of Innovation.....	27
2.8.3	Technology, organisation, and environment (TOE) framework.....	30

2.8.4	Technological context.....	30
2.8.5	Organisational context.....	30
2.8.6	Environmental context.....	31
2.9	Summary.....	32
CHAPTER THREE: RESEARCH METHODOLOGY.....		34
3.1	Introduction	34
3.2	Research approach.....	34
3.3	Research design	35
3.4	Research objectives	35
3.5	Research questions.....	36
3.6	Study site	36
3.7	Population and target population.....	36
3.8	Sampling technique	36
3.8.1	Criteria to select respondents.....	37
3.9	Data-collection method.....	37
3.9.1	Data-collection tools.....	37
3.9.2	Structured interviews.....	38
3.10	Data analysis.....	38
3.11	Inductive and deductive approach	39
3.12	Data quality control	39
3.12.1	Validity and reliability.....	39
3.12.2	Trustworthiness issues.....	40
3.13	Truth value.....	40
3.14	Representativeness.....	40
3.15	Consistency.....	40
3.16	Applicability	40
3.17	Ethical considerations.....	41
3.18	Limitations of the study.....	41

3.19	Summary.....	41
CHAPTER FOUR: FINDINGS AND DISCUSSION.....		42
4.1	Introduction	42
4.2	Participant demographics.....	42
4.3	Section A: Biographical and demographic information	42
4.3.1	Gender of the respondents	42
4.3.1.1	<i>Aim of the question</i>	42
4.3.1.2	<i>Results and Discussion</i>	42
4.3.2	Age of the participants.....	43
4.3.2.1	<i>Aim of the question</i>	43
4.3.2.2	<i>Results and Discussion</i>	43
4.3.3	Number of years working at SASA	43
4.3.3.1	<i>Aim of the question</i>	43
4.3.3.2	<i>Results and Discussion</i>	44
4.3.4	Current position	44
4.3.4.1	<i>Aim of the question</i>	44
4.3.4.2	<i>Results and Discussion</i>	44
4.4	Section B: Challenges related to adopting the NIR spectrophotometer at CTS	45
4.4.1	What was your experience when adopting the NIR spectrophotometer on your site?.....	45
4.4.1.1	<i>Aim of the question</i>	45
4.4.1.2	<i>Results and Discussion</i>	45
4.4.2	What were the challenges?	46
4.4.2.1	<i>Aim of the question</i>	46
4.4.2.2	<i>Results and Discussion</i>	46
4.4.3	Did these challenges affect plant or employee productivity?	48
4.4.3.1	<i>Aim of the question</i>	48
4.4.3.2	<i>Results and Discussion</i>	48
4.4.4	What are you doing or have done about those challenges?	49

4.4.4.1	<i>Aim of the question</i>	49
4.4.4.2	<i>Results and Discussion</i>	50
4.5	Section C: Understanding the functioning of NIR spectroscopy	50
4.5.1	What is your overall understanding of the functioning of NIR spectroscopy?....	50
4.5.1.1	<i>Aim of the question</i>	50
4.5.1.2	<i>Results and Discussion</i>	51
4.5.2	Has the NIR spectrophotometer changed the way you do things in the plant?	52
4.5.2.1	<i>Aim of the question</i>	52
4.5.2.2	<i>Results and Discussion</i>	52
4.5.3	What are the significant benefits of using an NIR spectrophotometer?	53
4.5.3.1	<i>Aim of the question</i>	53
4.5.3.2	<i>Results and Discussion</i>	53
4.5.4	Based on your experience when adopting an NIR spectrophotometer, would you recommend this technology to someone else?.....	54
4.5.4.1	<i>Aim of the question</i>	54
4.5.4.2	<i>Results and Discussion</i>	54
4.6	Section D: Future improvements	55
4.6.1	Are there any improvements relating to NIR spectroscopy that you would like to see happening in the future?	55
4.6.1.1	<i>Aim of the question</i>	55
4.6.1.2	<i>Results and Discussion</i>	55
4.6.2	In your opinion, should SASA consider workshops about NIR spectroscopy?....	56
4.6.2.1	<i>Aim of the question</i>	56
4.6.2.2	<i>Results and Discussion</i>	56
4.7	Summary	57
CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS.....		58
5.1	Introduction	58
5.2	Conclusions	58
5.3	Recommendations.....	58

5.3.1	Demographics of the research participants	58
5.3.2	How does NIR spectroscopy work?	59
5.3.3	What are the challenges faced by CTS management in the introduction of NIR spectroscopy?.....	59
5.3.4	To what extent do these challenges affect the implementation of NIR spectroscopy?.....	60
5.4	Implications for further research.....	61
REFERENCES.....		62
APPENDICES		71
Appendix A: Ethical clearance from University of KwaZulu-Natal		71
Appendix B: South African Sugar Association (SASA) gatekeeper letter		72
Appendix C: Research interview schedule		73
Appendix D: Informed Consent form		75
Appendix E: Participant biographic data.....		77
Appendix F: Originality report.....		78
Appendix G: Proofread letter confirmation.....		79
Appendix G: Proof reading and academic editing letter.....		79

LIST OF TABLES

Table 2-1:	Top sugar-producing countries.....	10
Table 2-2:	Comparison of common methods for sugarcane quality determination.....	14
Table 2-3:	Recoverable value (RV) calculation.....	14
Table 2-4:	Typical application of laboratory NIR spectroscopy methods in the sugarcane industry.....	21
Table 2-5:	Advantages and disadvantages associated with NIR spectroscopy.....	23
Table 4-1:	What was your experience when adopting the NIR spectrophotometer?.....	45
Table 4-2:	Challenges experienced.....	46
Table 4-3:	Did these challenges affect plant and employee productivity?.....	48
Table 4-4:	What are you doing or have done about those challenges?.....	50
Table 4-5:	What is your overall understanding of the functioning of NIR spectroscopy?.....	51
Table 4-6:	Has NIR spectroscopy changed how you do things in the plant?.....	52
Table 4-7:	What are the significant benefits of using NIR spectroscopy?.....	53
Table 4-8:	Based on your experience when adopting NIR spectroscopy, would you recommend this technology to someone else?.....	54
Table 4-9:	Are there any improvements relating to NIR spectroscopy that you would like to see happen in the future?.....	55
Table 4-10:	In your opinion, should SASA consider workshops about NIR spectroscopy?.....	56

LIST OF FIGURES

Figure 2-1:	A map of the South African sugar industry	11
Figure 2-2:	South Africa's sugarcane production between 2014/2015 and 2020/2021	12
Figure 4-1:	Participants' gender	43
Figure 4-2:	Participants' years of experience in the sugar industry	44

LIST OF ABBREVIATIONS

CTS	Cane Testing Services
DAC	Direct analysis of cane
GIS	Geographic Information System
GPS	Global Positioning System
NIR	Near infrared
nm	Nanometre
PDA	Photo diode array
Rp	Indonesian rupiah
R	South African rand
RV	Recoverable value
SASA	South African Sugar Association
SASRI	South African Sugarcane Research Institute
SAST	South African Sugar Terminal
SMRI	Sugar Milling Research Institute
TCD	Tonnes of cane per day
TOE	Technology, organisation and environment [framework]
UCL	Union Co-operative Limited
USA	United States of America

CHAPTER ONE: INTRODUCTION

1.1 Introduction

Sugarcane is one of the important crops in many economies (Da Silva Melo et al., 2022). Sugarcane is the primary component used in the production of sugar worldwide. South Africa has an extensive history of sugarcane production.

In the South Africa sugarcane was introduced as an experimental crop during the colonial era which proved to be suitable for the land. Currently, the South African sugar industry is consistently being ranked in the top 15 out of about 120 sugarcane producing nations worldwide (Lemmer, 2017). Consequently, the South African sugar industry contributes immensely to the national economy. Annually it averages an estimated R14 billion from direct income and provides direct employment for 85 000 people and indirect employment for 350 000 people (South African Sugar Association [SASA], 2021).

The industry has approximately 21 926 registered sugarcane growers who produce an average of 20 million tonnes of sugarcane, and six milling companies. These milling companies are Illovo Sugar Limited, Tongaat-Hulett Sugar, Rainbow Chicken Limited, Union Co-operative Limited (UCL), Umfolozi Sugar Mill, and Gledhow Sugar Company (SASA, 2021).

The large-scale or commercial sugarcane growers (approximately 1 800) produce nearly 83% of the total sugarcane crop. The milling companies produce at most 7% of the sugarcane crop. Most of the sugarcane plantations receive sufficient rainfall to grow sugarcane without irrigation, but in some parts of the country, such as the northern KwaZulu-Natal and Mpumalanga regions, sugarcane production occurs under irrigation and accounts for approximately 30% of the total production (Zulu et al., 2019).

The South African Cane Growers Association and the South African Farmers Development Association are the two groups that represent the sugarcane growers. The South African Sugar Millers' Association is the organisation for millers. Growers and millers collaborate to share their profits. SASA is the curator of this partnership and was founded in 1935 (SASA, 2021).

The Sugar Act of 1978, the Sugar Industry Agreement (SASA, 2000), and the SASA Constitution (2018) provide the rules for SASA. It is a non-governmental organization that has internal and industry-supporting divisions that offer a range of specialized services to improve the effectiveness, global competitiveness, and sustainability of the industry (SASA, 2021).

It is also essential to identify the cane blocks with the greatest in-field commercial cane sugar to maximize the sugar value during harvest using commercial cane sugar, an in-field assessment of

sugarcane quality. Furthermore, in-field commercial cane sugar values facilitate the optimum scheduling of harvests and crop inputs (Pitakaso & Sethanan, 2019).

Cane Testing Services (CTS) is a division of SASA that contracts with certain mill group boards to provide a professional service. It establishes the standard of each delivery made to the mill to calculate payment (SASA, 2021).

Brix (concentration of total dissolved sugar) and polarisation (sucrose content) are key quality parameters that are routinely analysed in sugarcane (Da Silva Melo et al., 2022). Furthermore, these parameters are monitored during multiple stages of the process as the laboratory uses traditional methods to collect and analyse samples. This process delays information, control, and decision making in the factories (Da Silva Melo et al., 2022).

The conventional analysis method is being replaced by near infrared (NIR) spectroscopy technology, which is regarded as the solution for the delays. Various countries have explored the application of this technology and opted to use NIR spectroscopy for sugarcane payment analysis.

Walford (2019) suggests that NIR spectroscopy offers the industry a rapid analysis method and additional analytes that are not measured in the factory environment, such as sucrose, glucose, and fructose. This study investigated challenges in CTS's management of the introduction of NIR spectroscopy as an alternative testing method.

1.2 Background of the study

1.2.1 Sugar industry

Several changes have been made to sugarcane industry throughout history, which is today well-known on a global scale for its high productivity, involvement in high-tech processes, high-quality raw material, and, particularly, for its capacity to produce both sugar and ethanol (De Matos et al., 2020)

The South African sugar industry is considered a cost-competitive producer of excellent-quality sugar, and is consistently ranked in the top 15 of 120 countries worldwide. The industry contributes immensely to the national economy through its “agricultural and industrial investments, foreign exchange earnings, high employment, and linkages with major suppliers, support industries, and customers” (SASA, 2021).

The anticipated average yearly direct income for the South African sugar industry is R14 billion. It provides direct and indirect employment for 435 000 people. It is also estimated that close to one million people in South Africa depend on the sugar industry for a living, which is more than 2% of the South African population (SASA, 2021).

Sugarcane production and processing result in direct employment, while numerous support industries result in indirect employment, such as chemical, fertiliser, fuel, transport, food, and services (SASA, 2021).

The sugar industry's future is centered on technology and cost reduction. To maintain worldwide competency, technical advancement in the sugar business is consequently crucial and must be a constant process (Kumari et al., 2017).

SASA is considered as the industry's primary decision-making body on matters of importance to millers and producers of sugarcane. The duty of investigating sugarcane varieties, pests, diseases, and crop protection fall within the preview of the South African Sugar Research Institute (SASRI). In addition, SASRI offers metrological and extension services to business stakeholders (Noyakaza, 2019). The South African sugar milling and refining sectors are additionally served by the Sugar Milling Research Institute (SMRI), which conducts research and provides technical assistance.

The South African sugar industry has 13 sugar mills owned by six milling companies. Of the 13 sugar mills, 12 are in KwaZulu-Natal, and the remaining one are in Mpumalanga (SASA, 2021).

1.2.2 The South African Sugar Association (SASA)

The collaboration between the South African Cane Growers Association and the South African Sugar Millers' Association is managed by SASA, a non-governmental organization. Equal numbers of representatives from the farmers' and millers' groups are on the SASA council. Every two years, a miller and a grower take turns serving as chair and vice chair. The council's role is to manage SASA's affair (SASA, 2021).

SASA is divided into sections that support its internal divisions, the industry partnership, and key industry operations. SASA's CTS division provides expert services that improve the industry's profitability, global competitiveness, and sustainability.

According to the Laboratory Manual for South African Sugar Factories (South African Sugar Technologists Association, 1985:117), CTS's operations at the mill are set up to sample and analyse individual sugarcane consignments utilising the direct analysis of cane (DAC) technique. The analytical processes offer the cane percentage values for sucrose, non-sucrose, and fibre that are required for each individual consignment's recoverable value (RV) computation. However, In addition to the individual consignment analysis, CTS determines the overall amount of sucrose, non-sucrose, and fiber contained in the combined juice and final bagasse (the so-called mill balance measure), which is the master measure of the entire input into the mill.

CTS "provides a specialist service under contract to individual Mill Group Boards to determine the quality of individual grower cane deliveries to the mill for cane payment" (SASA, 2021). RV content in

sugarcane supplied to the sugar mill by growers is assessed through analytical chemistry services provided by CTS. Moreover, CTS provides a neutral and objective foundation on which to calculate the RV paid by the miller to the grower.

The analytical assessment is conducted through the conventional analytical method with sample preparation for each individual analysis. That is where the need for NIR spectroscopy comes in since it requires little or no preparation of samples and can measure multiple parameters in a single scan.

1.3 Problem statement

Over the years, there has been an increase in worldwide interest shown by sugar industries in the possible utilisation of NIR spectroscopy analysis as a research and management tool in the fields of soil fertility, sugarcane nutrition, sugarcane quality testing, pest control, and disease resistance (Price et al., 2011). Some organisations utilise several advanced technologies (Mlekus et al., 2020). It is organisations' responsibility to address technology design, change management, and technology acceptance.

CTS has been using traditional analytical chemistry methods for testing, which means that various individuals perform various analyses utilising various instruments and chemicals (Walford, 2019:17). Introducing new NIR spectroscopy technology means one person can perform analyses quickly, and no chemicals are needed.

The factory personnel expected the results from the NIR spectroscopy to be the same as the results from the conventional method, as they disregarded the concept of repeatability and reproducibility (Walford, 2019:17). Furthermore, there was resistance to change as factory personnel thought that the traditional method was adequate. This may cause redundancies in some existing positions. It is thus important to investigate the challenges accompanying NIR spectroscopy implementation to understand its impact and dynamics in the organisation. This will benefit CTS and SASA in terms of planning and understanding the future of NIR spectroscopy in the organisation.

The aim of the study was to investigate management challenges related to the introduction of NIR spectroscopy at CTS. The study results will allow the researcher to make recommendations that will enable CTS and SASA to understand and overcome any challenges accompanying NIR spectroscopy adoption.

1.4 Research objectives

The study's objectives are as follows:

- To provide an overview of NIR spectroscopy functioning;
- To investigate the challenges related to introducing NIR spectroscopy at CTS;
- To measure the extent of the effects of these challenges on NIR spectroscopy at CTS; and

- To recommend how the challenges can be addressed.

1.5 Research questions

The study sought to address the following research questions:

- How does NIR spectroscopy work?
- What are the challenges faced by CTS' management in the introduction of NIR spectroscopy?
- To what extent do these challenges affect the implementation of NIR spectroscopy?
- What recommendations can be offered to address the challenges?

1.6 Rationale of the study

The researcher is an employee of the South African Sugar Terminal (SAST), a division of SASA, and has realised that there are possible challenges in the introduction of NIR spectroscopy. The SAST laboratory is currently evaluating the suitability of NIR spectroscopy for raw sugar analysis as NIR spectroscopy can perform six raw sugar analyses in less than a second. These analyses were traditionally completed in an eight-hour shift by six analysts, using six instruments, and large quantities of chemicals.

CTS has pilot sites at three mills where NIR spectroscopy is applied to sugarcane analysis and has investigated NIR spectroscopy for juices, but the method was not approved. This study will benefit SASA management, as it will provide an understanding of the challenges in the introduction of the use of NIR spectroscopy.

1.7 Research methodology synopsis

Thomas et al. (2022) define methodology as the process of research that explains the research procedure from planning to the stage where results are reported. They further mention that the methods, techniques, and procedures used in research methodology provide methods, techniques, and procedures to be used in the research design process.

A quota sampling method was employed in this study. In quota sampling, judgement and probability sampling are based on the researcher's judgement or previous knowledge. The amount of the population that falls into each classification is decided (Pandey & Pandey, 2021). Using quota sampling, the researcher located managers and supervisors directly involved in adapting NIR spectroscopy. Primary data for this research were collected using online meeting interviews. This research method was selected to enhance the analysis of the data and the study's trustworthiness.

The thematic analysis method was used for this study. The thematic analysis method is a useful technique when examining data as it is a potent yet adaptable technique that can be applied from a range

of paradigmatic perspectives (Castleberry & Nolen, 2018). Thematic analysis is a way to identify, analyse, organise, explain, and report on the topics found in the data collected (Nowell et al., 2017). Firstly, the researcher analysed the data. This was achieved by ensuring that the collected data were suitable for analysis. The interview schedule was divided into four groups for easy tracing of errors. Secondly, the interviews were recorded for easy reference and categorising information. Thirdly, the information was transcribed precisely to a readable version. The researcher read the transcripts until the content was understood. Fourthly, patterns were identified through the use of content analysis. The patterns were then identified, including the participants' challenges related to adopting NIR spectroscopy. Thereafter themes were identified, and quotations from the interviews assisted in supporting the research findings.

1.8 Delimitations and limitations of the study

The investigation was hindered by time constraints, which required the completion of the study in a short period of time. The research solely focused on the challenges experienced by managers and supervisors when implementing NIR spectroscopy. Furthermore, the study had a limited number of sites that are implementing the NIR spectroscopy technology, and not all SASA branches have implemented this technology. The study's goal is to investigate challenges of NIR spectroscopy in the CTS. The researcher employed quota sampling that included as study participants managers and supervisors directly involved in implementing NIR spectroscopy at CTS.

1.9 Outline of chapters

This research study investigated challenges in the introduction of NIR spectroscopy at CTS at SASA. The challenges are presented in the five chapters as outlined below.

Chapter One: Introduction

The first chapter is an introductory chapter that discusses the research problem, background, problem statement, and the aim of the research.

Chapter Two: Literature review

The literature review focuses on defining NIR spectroscopy, technology introduction, employee engagement regarding new technology, and a model to assess challenges within CTS.

Chapter Three: Research methodology

This chapter covers the research methodology used in the study, as well as the problem statement and objectives of the study.

Chapter Four: Data analysis

This chapter presents and discusses the results of the interviews conducted with management at CTS. The results are presented through data reduction, display, and drawing conclusions.

Chapter Five: Conclusions and recommendations

In Chapter Five the interview results are highlighted conclusion is made and provides recommendations to address identified shortcomings in terms of challenges with NIR spectroscopy at CTS. Suggestions are made for further research.

1.10 Summary

Chapter One introduced the study by presenting its background and rationale. This chapter outlined the aim of the study, the research objectives, and the study's research questions. Also discussed briefly were the research paradigm and approach, sampling, research style, data-generation methods, and analysis. Chapter Two presents the literature review of this study, where the impact of new technology and the effect on job redundancies were also reviewed. The process of sugarcane payment for CTS was discussed. The theory of diffusion of innovation and the technology, organisation, and environment (TOE) framework were reviewed to assess the study's theoretical basis.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter outlines the literature review of the study. The researcher reviewed various previously published literature that was found to be relevant to the research study. This chapter discusses the worldwide origin and distribution of sugarcane and the classification of sugarcane according to its species.

This chapter also discusses the cultivation of sugarcane at an international and national level. Sugarcane is produced in various parts of the world, including South Africa. Moreover, the chapter discusses precision agriculture in the sugarcane industry, various tools to achieve precision agriculture, and NIR spectroscopy as the tool to analyse sugarcane quality, its application in the sugarcane industry, and calibration. Various challenges that sugarcane farmers face are discussed in relation to technology acceptance models.

2.2 Origin and distribution of sugarcane

Sugarcane is a domestic crop in tropical South and Southeast Asia. While various sugarcane classes are most likely to have originated in several places – for instance, *Saccharum spontaneum* is found in East and North Africa, the Middle East, India, Malaysia, Taiwan, China, as well as in the Pacific to New Guinea (De Camargo et al., 2019) – northern India is the centre of sugarcane origin as it is where sugarcane with the smallest chromosome numbers is found (Tadesse, Bishaw & Assefa, 2018).

The *S. robustum* sugarcane species is found along the riverbanks in New Guinea and on islands around it. The species is an indigenous plant in the area. Another sugarcane species that is thought to be from New Guinea is *S. officinarum*, also known as “the noble cane” and is only found in tropical regions that have both favourable climate and soil (De Camargo et al., 2019). In contrast to *S. sinense*, which is mostly found in India, China, Indonesia, and Taiwan, the other sugarcane species, *S. barberi*, is assumed to have originated in India. *S. edule*, which is believed to be the sterile variety of *S. robustum*, is found only in New Guinea and the nearby islands (Braithwaite et al., 2019).

Sugarcane is regarded as America’s first cash crop as it has been there for the longest time. The southern states experienced plentiful growth, and sugarcane in the region was the main source of income for numerous plantations (Moodley, 2018). As a result, sugarcane is readily grown in places such as Hawaii, Louisiana, and Florida in the United States of America (USA) and Puerto Rico. However, over the years, the countries that have proven to be the largest producers of sugarcane are Brazil, India, China, Mexico, Thailand, and Pakistan (Moodley, 2018).

Currently, sugarcane is mainly grown tropical regions. KwaZulu-Natal is the highest latitudes for growing sugarcane in South Africa, while in Argentina and in the southernmost points of the Australian industry sugarcane is grown at approximately 30 degrees south, whereas in north-western Pakistan it is grown at 34 degrees north and in southern Spain it is grown at 37 degrees north (Moodley, 2018). Evans and Joshi (2020:4) state that

[t]he sugarcane production led to the first New World sugarcane mill grinding in about 1516 in Hispaniola. Sugar production spread to Cuba, Jamaica, Puerto Rico, and the other Greater Antilles by the end of the 1500s.

2.2.1 Classification of sugarcane

Evans and Joshi (2020) describe sugarcane as any of the several species of tall perennial true grasses within the genus *Saccharum* and tribe Andropogoneae. Sugarcane belongs to the grass family Poaceae, and it is officially classified as *S. officinarum*. This plant is commonly found in tropical and subtropical regions worldwide. There are various horticultural varieties of sugarcane and their characteristic differences are widely known, including variations in stem colour and length (Ndinya, 2019).

Approximately six species of perennial grasses belonging to the tribe Andropogoneae of the Poaceae's genus *Saccharum* L. make up sugarcane (Welker et al., 2019). Singh and Tiwari (2018) indicate that

[t]here are two wild species (*S. spontaneum* and *S. robustum*) and four cultivated species, *S. officinarum*, *S. barberi*, *S. sinense* and *S. edule*. The four cultivated species are complicated hybrids, and all intercrop readily. All commercial canes grown today are inter-specific hybrids.

2.2.2 International production of sugarcane

Sugarcane is one of the world's largest crops by production quantity (Singh & Tiwari, 2018). This claim is supported by sugar production in over 120 countries worldwide. Its global production is massive and is said to exceed 165 million tonnes a year.

Approximately 80% of sugar consumption is from sugarcane (Meza-Palacios et al., 2019). The remaining 20% is from sugar beet produced in the temperate region of the Northern Hemisphere. Of 125 nations producing sugar, 70 nations use sugarcane and 40 use sugar beet (Marzo et al., 2019). The remaining 10 nations produce sugar from both sugarcane and sugar beet. Only 10 of the largest sugar-producing countries are responsible for producing approximately 75% of world's sugar (Cherubin et al., 2021).

Brazil is a major producer of sugar, with the country accounting for approximately 25% of the world’s production and is regarded as the largest sugarcane producer (see Table 2-1). In 2012/2013,

Brazil produced 588 million tonnes of sugarcane while the world’s production is close to 2.6 billion tonnes yearly and is largely concentrated in tropical regions in developing nations in Latin America, Africa, and Asia (Cherubin et al., 2021).

Table 2-1: Top sugar-producing countries

Country	Tons
Brazil	721,077,287
India	347,870,000
China	124,038,017
Thailand	96,500,000
Pakistan	58,397,000
Mexico	50,946,483
Colombia	38,000,000
Philippines	30,000,000
United States	27,900,000
Indonesia	26,341,600
World	1,832,541,194

Source: Tembon (2021)

Brazil’s sugarcane plantations cover 9.5 million hectares or 1% of Brazil’s land area. The crop is mostly produced in the south-central and north-eastern parts of the country (Cherubin et al., 2021). Almost 90% of Brazil’s sugarcane is produced in the central part of the country, where the season lasts from April to December. By contrast, the north-season lasts from September to March, and the state of São Paulo produces 60% of all sugarcane produced in Brazil. In Brazil, sugarcane is used to make various goods, including ethanol for gasohol, a popular gasoline-ethanol combination.

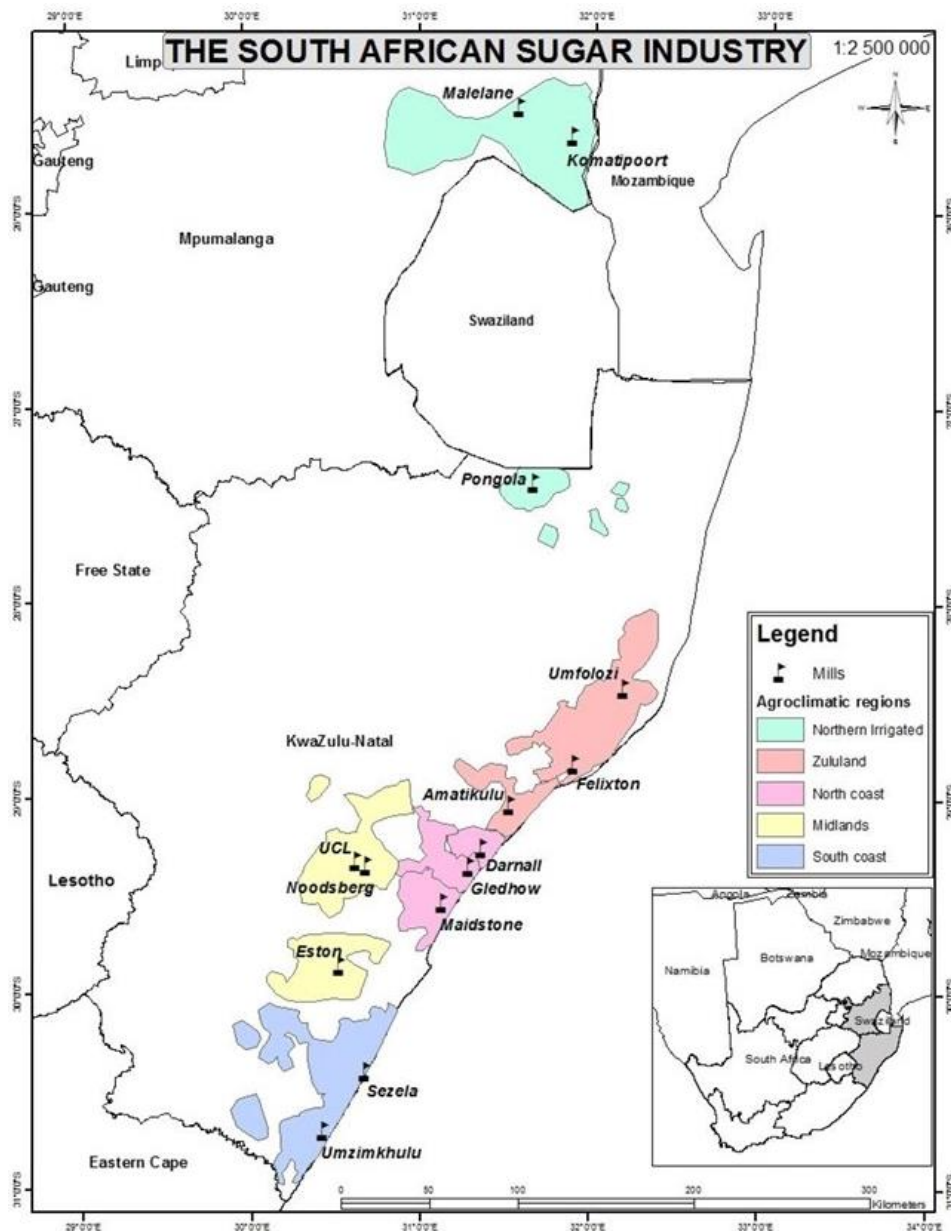
Gasoline-ethanol is the most widely used form of transportation fuel in Brazil and contrasts India, where sugarcane is used to make alcoholic drinks, sugar, and jaggery. In the USA, sugarcane is cultivated commercially in Florida, Hawaii, Louisiana, and Texas (Singh & Tiwari, 2018).

2.2.3 South African production of sugarcane

South Africa has an extensive history of sugarcane production. Sugarcane was introduced as an experimental crop during the colonial era and proved suitable for the land. Currently, the South African sugar industry is consistently ranked in the top 15 of 120 sugarcane-producing nations worldwide (Moodley, 2018). The country has roughly 26 400 registered sugarcane producers in three provinces: KwaZulu-Natal, the Eastern Cape, and Mpumalanga (see Figure 2-1). Of these 26 400 sugarcane growers, over 25 000 are considered small-scale growers and are responsible for 10% of the sugarcane production in South Africa (SASA, 2013).

The large-scale or commercial sugarcane growers (approximately 1 800) produce nearly 83% of the total sugarcane crop. The milling companies produce at most 7% of the sugarcane crop. Most of the sugarcane plantations receive enough rainfall to grow sugarcane without irrigation, but in some parts of the country, such as the northern KwaZulu-Natal and Mpumalanga regions, sugarcane production occurs under irrigation and accounts for approximately 30% of total production (Zulu et al., 2019). South African sugarcane growers are represented by the South African Cane Growers Association. There are 13 sugar mills. Illovo Sugar Ltd controls four and Tongaat-Hulett Sugar Ltd controls another four mills. Tsb Sugar RSA Ltd is the owner of the other two. Umfolozi Sugar Mill (Pty) Ltd, UCL, and Gledhow Sugar Company (Pty) Ltd each own one mill (Zulu et al., 2019). Only one mill is in the province of Mpumalanga, while the remaining mills are in KwaZulu-Natal.

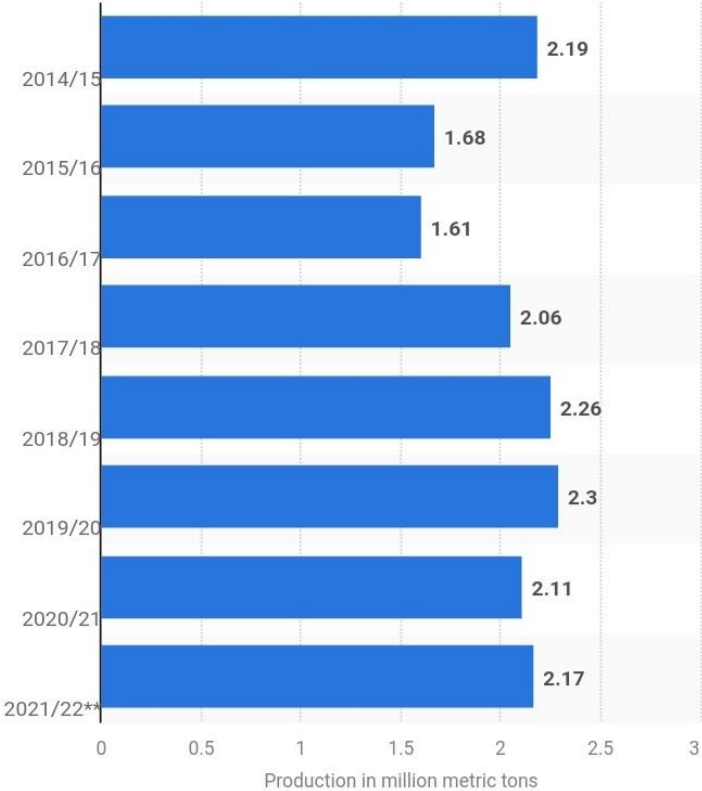
Figure 2-1: A map of the South African sugar industry



Source: Tembon (2021)

All these sugar mills are under the representation of the South African Sugar Millers’ Association. Four of these mills are regarded as the “white end” and produce their own refined sugar. South Africa’s lowest sugar production ever was 1.8 million tonnes, mainly due to climatic challenges such as drought. During the 2012/2013 season, South Africa produced two million tonnes of sugarcane. During the 2013/2014 planting season, South Africa produced 8% more sugarcane, which amounted to 2.1 million tonnes of sugar (Cardozo et al., 2018). Sugarcane production in South Africa has experienced exponential growth since then. In 2019/2020, South Africa produced over 19.3 million tonnes of sugarcane, which was considerably higher than in 2018/2019. Figure 2-2 shows the sugarcane production in South Africa from the period 2014/2015 and 2020/2021.

Figure 2-2: South Africa’s sugarcane production between 2014/2015 and 2020/2021



Source: Statista (2022)

In the 2014/2015 financial year, South Africa produced 2.19 million tonnes of sugarcane, declining in 2015/2016 to 1.68 million tonnes, and a further decline in 2016/2017 to 1.61 million tonnes. Production increased steadily from the 2017/2018 financial year, with a decline again in 2020/2021. However, in the past decade, it can be noted that the South African sugarcane industry has been struggling to break even. The industry survives on tight profit margins due to stagnation and declining yields, combined with a high rise in input and production costs. Cutting cycles have been shortened by the prevalence of Eldana 1 in the coastal regions, which results in poor yields and poor sugarcane quality delivered (Doorasamy, 2019).

2.3 Precision agriculture in the sugarcane industry

Monitoring of agricultural land is important and valuable for the industry. Precision agriculture is a useful management tool that is used to map yield and quantity variability and boost profit margins by applying crop inputs more effectively. The Global Positioning System (GPS), Geographic Information System (GIS), miniaturized computers, automatic control, in-field and remote sensing, information processing, and telecommunications are just a few examples of contemporary technological advancements that greatly benefit this tool (Finger et al., 2019). Precision agricultural techniques have been studied and adopted in various cropping systems, particularly grain crops. Precision agricultural methods have also been applied in the sugarcane industry (Kong et al., 2019).

Various precision agricultural technologies have been used largely for yield monitoring and mapping. Most of the technologies are limited to field monitoring and lack the ability to measure product quality. There is currently no accurate way to assess sugarcane quality in the field. An in-field monitoring system is required to estimate sugarcane output and quality during harvest.

2.3.1 The need to measure sugarcane quality in the field

Sugarcane plantations are vast, and it is practically impossible to assess the yield quality in the field. That is why technologies have become more relevant over the years; be it for monitoring or mapping purposes. The field of assessing sugarcane quality has seen an increase in interest. Sugarcane quality measurements made in the field are crucial because they affect payment and have the potential to enhance both the payment and data collection processes by removing consignment errors. For clonal evaluation, the ability to measure sugarcane quality values in the field would be helpful (Gonçalves et al., 2021).

Discovering the cane blocks with the highest in-field commercial cane sugar, which is a measure of sugarcane quality taken in the field, is essential for optimizing the sugar value at harvest. Furthermore, in-field commercial cane sugar values would facilitate the optimum scheduling of harvests and crop inputs (Pitakaso & Sethanan, 2019).

2.3.2 Laboratory techniques to assess sugarcane quality and their limitations for field use

Sugar content forms the basis of determining sugarcane quality. Refractometry and polarimetry are used as standard methods to routinely measure sugar content in the laboratory. Brix, polarisation, and fibre are measured as sugarcane quality (Perlo et al., 2020). Alternatively, sugar content can also be measured by chromatographic methods and “the spectroscopic method can also be used for both qualitative and quantitative measurements in the sugar industry” (Sexton et al., 2018). Table 2-2 provides a comparison of common methods for sugarcane quality determination.

Table 2-2: Comparison of common methods for sugarcane quality determination

Method	Sampling time (min)	Sample form	Amount of samples required	Approximate cost of equipment
Refractrometry	5 - 20	Juice (raw or clarified)	50 - 100 ml	Hand-held (A\$700) Laboratory (A\$5k)
Polarimetry	10 -20	Juice (clarified)	100-200 ml	A\$16k
Chromatography	30	Juice (clarified)	100-200 ml	A\$13-33k
Biosensor	5	Raw juice must be mixed with a mediator	50 up to 200 mmol L ⁻¹	A\$6k
Brix hydrometer	15-20	Juice (raw or clarified)	100-200 ml	A\$40
Wet chemical methods	20	Prepared juice	Each 0.0047g of sucrose to be mixed with 1 ml of Fehling's solution	No specific equipment is needed
Spectroscopy	0.2 to 1 (after calibration)	Raw or clarified juice or macerated cane samples, or possibly billet samples	50 - 100 ml	A\$10~18k (350 to 1075 nm) A\$100~140k (350 to 2500 nm)

Source: Taira et al. (2010)

2.3.3 Procedure for sugarcane testing payments at Cane Testing Services (CTS)

The sucrose concentration of sugarcane has historically been used as a quality indicator for sugarcane payment reasons in the South African sugar industry. Lately, payment for sugarcane has been based on its RV content (SASA, 2021) (see Table 2-3).

The worth of the sugar and molasses that will be collected from the sugarcane that each producer delivers is measured by the RV, which is determined as follows:

Table 2-3: Recoverable value (RV) calculation

RV % cane	=	$S - dN - cF$
where S	=	sucrose % cane
N	=	non-sucrose % cane
F	=	fibre % cane
And D	=	the relative value of sucrose which each unit of non-sucrose diverts from sugar production to molasses
C	=	the loss of sucrose from sugar production per unit of fibre

Source: SASA (2021)

For each season, the factors d and c are determined and are around 0.38 and 0.02 respectively. The RV basis of sugarcane payment provides the necessary incentives for enhancing the sugarcane delivered to the mill in light of regional agreements between growers and millers regarding issues that affect sugarcane quality. This will lead to improved efficiencies for everyone (SASA, 2021).

According to the Laboratory Manual for South African Sugar Factories (South African Sugar Technologists Association, 1985:117), CTS's operation at the mill is set up to sample and analyse individual sugarcane consignments utilising the DAC technique. The analytical processes offer the cane percentage values for sucrose, non-sucrose, and fibre that are required for each individual consignment's RV computation. However, In addition to the individual consignment analysis, CTS determines the total amount of sucrose, non-sucrose, and fiber present in the mixed juice and final bagasse (the so-called mill balance measure), which is the master measure of the entire input into the mill.

Over a week, the mixed juice and final bagasse streams from the mill balance, as well as the individual sugarcane consignment stream, which are both analysed in parallel. The individual consignment DACs for sucrose, non-sucrose, and fiber are all adjusted after the week in a reconciliation process so that the summations for each component match those found in the mill balance. The updated DAC statistics are then used to compute the RV percentage for each sugarcane consignment (SASA, 2021).

This parallel measurement of the total amount of sucrose, non-sucrose, and fibre (and hence RV) entering the mill over the week is an effective control measure since any change in the typical connection between the two measurements signals an instant divergence from the norm (DAC and mill balance). The miller measures the input to the factory using the mill balance measure, and from this input, the mill's recoveries and efficiency are computed. The South African sugar industry uses a relative payment system, like many other sectors that produce sugarcane (SASA, 2021).

2.4 Introduction of new technology

Technology is recognised as important for sustainable economic growth and development. Its evolution varies from country to country, and even domestically, depending on influencing variables. The introduction of new technology in an organisation strongly influences management and reduces manual labour, cost, and waste, which consequently increase income (Mohamed, 2018).

Kuswurdjanto and Wening (2019) mention that businesses must adapt to an ever-changing environment to suit the requirements of their customers and remain competitive in a global economy. Staying competitive requires a company to continue evolving and adjusting processes and technology to achieve a competitive advantage. An organisation must improve its ability to bring in new technology and manage it. Furthermore, to implement a technology change successfully, numerous areas must be addressed effectively to avoid internal conflict or staff resistance to change; both of which must be

managed. When choosing a new technology, examining, and planning must be implemented for employee training, communication, and a multi-generational workforce. These issues can be solved with a well-defined implementation strategy.

Higher pollution levels need more expensive pollution-control equipment, which greatly influences profitability and environmental performance. Many South African organisations do not use the latest technologies and innovations to reduce waste. South Africa is dedicated to cleaner manufacturing to secure a sustainable future and urges organisations to also dedicate themselves to a sustainable future (Maama, Doorasamy & Rajaram, 2021). Many companies are unaware that introducing cleaner production can lead to significant savings (Pathirana & Yarime, 2018). By using fewer resources to create the same amount of product, the organisation may reduce expenditure while advancing its objectives for a healthy environment. Over 11% of South Africa's agricultural workforce is employed in the sugar industry.

2.5 Transformation of jobs and skills

Currently, companies are undergoing enormous changes, largely because of significant technological advancements. These changes are necessary for organisations to address crucial concerns, including how businesses will produce value, where individuals will execute their work, and how they will interact and communicate (Erkutlu & Chafra, 2020). One of the topics that must therefore be carefully considered is how these developments will alter the dynamics of employment, people, and organisations.

Organisational structure and performance are influenced by how productively decisions are made and according to established procedures. Internal labour adaptability also affects performance via innovation. Considering the persuasive notion of competitive high-tech environments, internal labour adaptability is particularly intriguing. The latest research recognises new sources of adaptability and invention based on more in-depth logical information and tools that can guide knowledge capacity within the organisation. Several authors have highlighted the enormous role that innovative technologies, which include artificial intelligence, Web 2.0, and social media, play in enhancing operational superiority, first-hand products, services, business models, and client relationships (Zeebaree et al., 2020).

Employees are strategically important in the development of technology because They create the overall product strategy, keep track of how it is being implemented, and, when necessary, adjust the cyber-physical production system. But for this, specific abilities, knowledge, and a different paradigm of skills are required. Knowledge management, increasing production system automation, digital communication, and interactive management functions are factors that affect the demand for new skills and flexibility of staff (Erkutlu & Chafra, 2020). On the other hand, relatively few studies in the literature address the skills required and how to offer these skills so that new technology applications are spread

and employed successfully in businesses. Untrained and uneducated workers will have a negative impact on businesses.

Rapid technology progress affects workforce development in two ways (Ra et al., 2019). Firstly, the need for specialised abilities is probably changing faster, which results in a shorter shelf life for talents. It will be necessary to be able to unlearn old technologies and practices and relearn new ones to adapt to disruptions caused by technological breakthroughs properly. In other words, new technology itself can provide a remedy for the problems it brings. Creativity in the workplace is essential for adapting to changing needs and utilising technology to its fullest potential. Secondly, since employees now and in the future are impacted by exponential technology breakthroughs, learning must be ongoing and pursued by all participants. Furthermore, the current educational systems alone are insufficient for fostering continual learning. It is therefore necessary to establish a learning society.

There is no relationship between gender and acceptance of new technology (Chimento-Díaz, 2022:24). Age has an impact, as younger people and people with higher education have greater acceptance of using new technology.

2.5.1 Technology in the South African sugar industry

The industry's technological brilliance is one of its defining characteristics. The sector continues to be at the forefront of innovation because of two organisations, namely SASRI and the Sugar Milling Research Institute (SMRI). The leading sugarcane agricultural research institute in Africa, SASRI, conducts studies on the development of new sugarcane varieties as well as on crop management and farming methods to increase the profitability of the industry (SASA, 2021).

The efficient transfer of new information and the introduction of new technologies significantly contribute to the industry's sustainability. Four multi-disciplinary programmes are where research is grouped, namely systems design and optimisation, crop protection, crop performance and management, and variety enhancement. The SASA section offers more information. The SMRI is the primary scientific organisation that conducts research and provides technical assistance to the Southern African sugar milling and refining sectors. The central refinery and all 14 of South Africa's raw sugar plants are full members of the SMRI (SMRI, 2022).

According to the SMRI, the South African sugar industry is one of the lowest-cost producers in the world and is a strategically significant agro-processing sector in South Africa. The reasons for South Africa's positioning are increased production costs (sugarcane and factory), loss of expertise, tariffs on sugar-containing beverages, and dumped cheap imported sugar. The sugar business is mature and exhibits indications of decline. It contends with an evolving and increasingly competitive economy. It is obvious that disruptive and potentially game-changing technologies will be needed to bring about

the crucial shift for the sector to stay competitive and sustainable. The SMRI has embarked on introducing and researching NIR spectroscopy.

2.5.2 *Near infrared (NIR) spectroscopy*

In order to price and trade with producers and growers while monitoring the quality of the raw sugarcane provided by sugar manufacturers, NIR spectroscopy is a well-established technology that can be used (Phetpan, Udompetaikul & Sirisomboon, 2018). The following physico-chemical factors that relate to physiological composition are used to estimate the quality of sugarcane: soluble solids content (brix), water-insoluble solids (fibre), and the apparent sucrose in the juice polarisation (Sexton et al., 2018). In addition, purity, sugarcane polarization, and total recoverable sugars are some of the additional criteria that are used to determine the pricing and trade of raw materials (Pasquini, 2018).

Over the years, there has been an increase in the worldwide interest shown by sugar industries in the use of NIR spectroscopy analysis. The introduction of NIR spectroscopy in the sugarcane industry has resulted in significant savings in fertiliser use and a significant reduction in the risk of environmental pollution and degradation (Phetpan et al., 2018). The use of NIR spectroscopy has proven effective in the management and monitoring of sugarcane plantations and informs producers of crop management, quality, and yield estimation. NIR spectroscopy application is cost effective and saves time.

In South Africa, the old technique of producing sugarcane depended heavily on soil and leaf value analysis to identify and address nutrient deficiency issues and to ensure that fertilisers were applied efficiently (Sexton et al., 2018). The determination of sugarcane is one of the most important tasks, according to the Fertiliser Advisory Service laboratory located at the Sugar Experiment Station. Of the 16 basic components, nitrogen is thought to be crucial for sugarcane development and juice quality. As a result, the importance of nitrogen to the sugarcane sector's economic growth may be assessed by the South African sugar business using over 30 000 tonnes of nitrogen annually. This nitrogen is worth \$25 million (SASA, 2021).

2.5.3 *Chemometrics*

The emergence of modern analytical chemistry changed in recent years with the introduction of the so-called chemometrics evaluation method. The term “chemometrics” describes the multivariate calibration method in analytical chemistry. This multivariate calibration method is in contrast to traditional univariate calibration. This technique uses the entire spectral structure for calibration, not just one spectral data point. The benefit of this type of calibration is the amount of spectral information used. The calibration also makes a slight difference in the sample spectrum so it can be identified. Although extensive literature on this topic exists, the predominantly mathematical language used in these publications is often difficult for analytical chemists to understand. Nevertheless, these NIR

spectroscopy evaluation measurements are usually absorption or emission spectra, and the determined system value is the concentration of the analyte. There are two approaches to creating a calibration model for such a system, namely univariate (single variable) calibration and the increasingly popular multivariate calibration method (Zhang et al., 2018).

A univariate calibration frequently results in inadequate prediction capacity due to the limitations of this approach that result from the concentration of the analyte being associated with only one spot in the spectrum. When analysing fresh, uncalibrated samples, it is impossible to detect outliers or the presence of unidentified interfering components. In other words, one cannot infer that the structure of the observed spectra fits the calibration data based just on peak height or peak area. The concentration data directly incorporate statistical signal variance, such as detector noise. The resultant uncertainty is often reduced by measuring many samples and then averaging the findings. Sufficient separation of the peak maxima is necessary for successfully calibrating multi-component systems (Zhang et al., 2018).

The analytical information contained in NIR spectroscopy is very complex, autocorrelated, and usually not readily available for analytical purposes (Zhang et al., 2018). In most cases, the information is scattered throughout the spectrum. This is because most of the components of the sample matrix contribute to some extent to the NIR spectroscopy absorbance or reflection spectrum, in addition to the spectral information from the analyte itself. In addition, physical properties such as the particle size distribution of the powder sample also have significant and usually undesired (non-informational or detrimental) effects on the entire NIR spectroscopy method. The first quantitative application of NIR spectroscopy was reported using the difference between two reflectance values obtained at two different wavelengths to correlate with the water content of grains and seeds. NIR spectroscopy thus originated as a multivariate analysis method.

A study utilising traditional univariate calibration techniques frequently produces worthless data for multi-component systems. Multivariate calibration techniques are one approach to tackling such issues. Calibration should account for all system-specific natural variations. The diversity of samples required to account for all variance increases with an application's complexity. Additionally, there are effects from varying temperatures, solids' particle sizes, and moisture content. Data collection of several hundred to thousands of samples may be needed for petrochemical applications or natural items such as wheat.

Simple applications, such as transparent organic liquid combinations, only require around 20 samples and more. In this situation, it is crucial to cover the whole spectrum of considerations evenly. Experience has shown that many users begin by gathering as much data as they can before they begin developing the model. There is a great deal of labour involved. Afterwards, it is understood that many spectra include duplicated data and do not offer anything useful to the model. The initial building of preparatory

techniques is therefore highly advised for subsequent samples to be measured more carefully (Zhang et al., 2018).

2.5.4 NIR spectroscopy application in the sugarcane industry

The NIR spectroscopy analysis study is not new in the sugar industry as it is highlighted that some conventional sugar methods can be replaced with NIR spectroscopy measurements to reduce cost (Dos Santos et al., 2013; Salgo, Nagy & Mikó, 1998).

NIR spectroscopy is a cost-effective and environmentally friendly tool as it uses the sample without pre-treatment or chemicals (Barra et al., 2021). It has been used in various disciplines, such as medical science, forensics, and biochemistry.

The process of NIR spectroscopy analysis involves an assortment of spectra using samples of known value, then sample properties are characterised to establish the validation model, and lastly targeting parameters of known samples over the targeted analyte (Sharabiani & Nazarloo, 2019). Chemometrics is used to build models. In chemometrics, statistics principles, computer statistics principles, computer science, and mathematics applications are used in processing chemical information to achieve an understanding and composition of the analyte (Otto, 2016).

The analyte is exposed to light in the region of the electromagnetic spectrum between 800 and 2 500 nanometres (nm). The wavelength of light absorbed by the sample is then measured by the NIR spectrometer. The chemistry bonds between hydrogen, carbon, oxygen, nitrogen, and sulphur atoms absorb the NIR light in various measures (Sharabiani & Nazarloo, 2019).

The substitution of conventional methods with NIR spectroscopy is limited. The introduction of NIR spectroscopy in the sugar industry requires proper investigation to select appropriate parameters that could be predicted by the spectra.

The application of NIR spectroscopy in the agricultural industry has been used to determine the chemical composition of various agricultural products (Phetpan et al., 2018). The application of spectrometry methods can be used for the measurement of quality through various wavelength regions, such as “visible (VIS: 350–700 nm); near-infrared (NIR: 700–2 500 nm), visible and shortwave NIR (VNIR: 350–1 100 nm), full range (FR: 350–2 500 nm) and mid-infrared (MIR: 2 500–25 000 nm)” (Rossel et al., 2006). Although these regions are very useful in measuring quality, the NIR wavebands are of great significance in measuring the quality of agricultural products (Nawi, Chen & Jensen, 2013).

NIR spectroscopy is one of the most important tools in the sugarcane industry. It is a compatible technique used to analyse the quality of sugar mills’ raw sugarcane yield. The use of NIR spectroscopy further extends to the pricing and trading between producers and growers of sugarcane since its quality

affects the pricing of sugarcane (Jensen et al., 2010). The capacity to analyse the sugarcane quality from juice and non-juice sample types is only one advantage that NIR spectroscopy offers (Phuphaphud et al., 2020), unlike other methods that are limited to measuring juice samples (see Table 2-4).

Table 2-4: Typical application of laboratory NIR spectroscopy methods in the sugarcane industry

Authors	Wavelength, nm	Measurement mode	Sample form	Prediction accuracy
Berding et al. (1991a)	NIR (1 445–2 348)	reflectance	Fibrated	°Brix ($R^2 = 0.91$) CCS ($R^2 = 0.91$) Fibre content ($R^2 = 0.89$) Pol ($R^2 = 0.96$)
Berding et al. (1991b)	NIR (1 445–2 348)	transflectance	Clarified juice	°Brix ($R^2 = 0.97$) CCS ($R^2 = 0.97$) Pol ($R^2 = 0.98$)
Cadet and Offman (1997)	MIR (8 000–12 500)	Reflectance	Raw juice	Pol ($R^2 = 0.98$)
Mehrotra and Siesler (2003)	NIR (1 111–2 222) NIR (1 111–2 500)	Transmittance Reflectance	Raw juice Fibrated	Pol ($R^2 = 0.96$) Pol (R^2 for the calibration model = 0.93) * Accuracy for prediction model was not reported
Madsen et al. (2003)	NIR (1 100–2 500)	Reflectance	Fibrated	Pol ($R^2 = 0.96$) °Brix ($R^2 = 0.97$) Fibre content ($R^2 = 0.90$)
Valderrama et al. (2007)	NIR (1 100–2 500)	Transmittance	Clarified juice	°Brix ($R^2 = 0.99$) Pol ($R^2 = 0.99$)
Taira et al. (2010)	NIR (1 100–2 498)	Reflectance	Fibrated	Pol (SEP = 0.21 %)

Source: Phuphaphud et al. (2020)

Phuphaphud et al. (2020) argue that obtaining sufficient juice samples during harvesting is difficult. However, NIR spectroscopy technologies could measure sugarcane quality through non-juice samples. This feature enables the elimination of the need to process raw juice into clarified juice. The importance of NIR spectroscopy and its application to sugarcane industry juice analysis were highlighted by Meyer and Wood (1988), and many qualitative and quantitative studies have been undertaken since then. Significant development has occurred in laboratory NIR spectroscopy systems for the analysis of molasses and mixed juice with the inclusion of massecuites (Da Silva Melo et al., 2022).

There have been further developments in the sugarcane industry concerning the use of NIR spectroscopy. Online NIR spectroscopy systems have been developed to determine sugarcane, bagasse, and sugar quality (Da Silva Melo et al., 2022). Additionally, online analysis systems for fibre analysis, sugarcane payment systems, and sugarcane quality schemes have all been established using the data from cane analysis systems. The literature on determining sugarcane quality characteristics using laboratory spectroscopic methods is summarised in Table 2-4. According to the table, several sample

types, including fibrated samples and clarified juices, have been utilised to test quality characteristics using spectroscopic techniques with varied wavelength bands and measurement modes.

2.5.5 Benefits and limitations of NIR spectroscopy

The NIR spectroscopy application in the laboratory environment is well recognised. However, there are still challenges regarding the application of these technologies in the field due to technical difficulties related to size constraints and power connectivity, including sensitivity to dust and vibration (Nawi, Chen & Jensen, 2014). The option to overcome the aforementioned limitations is by using an economical and easy-to-use photo diode array (PDA) detector spectrometer. Spectrometers offer various advantages, namely the ability to record a full spectrum at high speed, the absence of moving parts, lower price, repeatability of wavelength, and flexible process interfacing through flexible fibre optics (Nawi et al., 2014). PDA technologies are modern and advanced due to their speed of response and low price. Furthermore, these technologies are also most suitable for online applications, even under complex conditions.

The significant strength of NIR spectroscopy is that it can provide data in seconds. Besides its rapidity, NIR spectroscopy offers several other significant benefits over traditional chemical methods. NIR spectroscopy has high precision with both a physical and non-destructive method that requires minimal or no sample preparation (Lan et al., 2020). In addition, the strength of NIR spectroscopy is its provision of data in seconds with no sample preparation required (Afara et al., 2021:51). In contrast to conventional chemical analysis, NIR spectroscopy requires no chemicals and no chemical waste is produced. The other important advantage of NIR spectroscopy is the ability to analyse various methods simultaneously.

Table 2-5 lists the advantages and disadvantages associated with NIR spectrometer technologies. In NIR spectroscopy, proper calibration enables easy operation and use (Otto, 2016), as well as good accuracy. However, the primary drawback of NIR spectroscopy technologies is the requirement for precise spectroscopic equipment, which makes calibration difficult and time consuming. There is an inability to transfer calibrations between equipment owing to optical discrepancies. Other shortcomings are a lack of sensitivity for minor constituents and complexity in the choice of data treatment (Pasquini, 2018).

Table 2-5: Advantages and disadvantages associated with NIR spectroscopy

Advantages	Limitations
High continuous sampling rate enables automatic process control	Optical path must be kept clean
Non-destructive measurement	Not a primary method
High accuracy	Good sampling procedure is essential
Almost any liquid or solid sample can be used with sample presentation units	Estimation is made near the test surface area to determine constrained light entrance depth
Other components other than moisture can be measured, such as fat or oil, proteins, sugar, and fibre	For legitimate work, there must be a relationship between the surface and total moisture of the sample
Can be made insensitive to product temperature	Should first be calibrated against a conventional method
Simple to install and maintain	Indirect method; it relies on a calibration curve for prediction
No sample preparation is needed	In some cases, developing a calibration equation that covers all possible samples is impossible

2.5.6 Hurdles to acceptance

Two prominent factors emerged during the adoption of NIR spectroscopy at CTS, namely:

- Factory personnel expected the results from the NIR spectroscopy to be the same as the results from the conventional method, as they disregarded the concept of repeatability and reproducibility; and
- Factory personnel resisted change, as they thought that the traditional method was adequate (Walford, 2019).

2.6 The use of NIR spectroscopy by other sugar industries

NIR spectroscopy is the best alternative to traditional analytical methods. Various NIR spectroscopy applications have been examined for usage in the sugar sector. NIR spectroscopy methods for assessing the fibre quality in shredded cane were established. NIR spectroscopy has been utilised to quantify the amounts of ash and fibre in sugarcane on a consignment-by-consignment basis. There have also been reports on online NIR spectroscopy systems for sugarcane, bagasse, and sugar analyses in sugar mills. NIR spectroscopy can potentially replace traditional analytical techniques (Kuswurjanto, 2019). In several nations, NIR spectroscopy is also used in place of sugarcane payment analysis.

2.6.1 The case of Indonesia

The sugar industry in Indonesia is significant to its national economy. The national sugar sector is projected to be worth Rp25 trillion, with annual production between 2.5 and 2.7 million tonnes. The nation's sugar business is divided into two sectors, namely industrial sugar and consumer sugar; the latter of which is only produced domestically. The industry is highly politicised and controversial due

to the local sugar lobbies' desire to defend their portion of the market from imports and because sugar is one of the commodities for which the government has consistently worked to achieve self-sufficiency (Toharisman, 2016).

Indonesia has 63 sugar mills that are controlled by 18 corporations. However, the bulk of these operations are outdated and have low production levels because of underinvestment. The capacity of the nation's sugar plants averages 3 900 tonnes of cane per day (TCD) and has a 7.1% sugar yield. This amount is low in comparison to Thailand, which has 50 sugar mills but a 940 000 TCD capacity and an 11.82% yield. As a result, Thailand produces 10.61 million tonnes of sugar annually; of which eight million tonnes are exported, whereas Indonesia produces only a quarter of that amount (Toharisman, 2016).

The ongoing loss in sugarcane fields hinders Indonesia's sugar sector. Almost all (95%) of the sugar fields in Java are owned by individual smallholder farmers, who control most of the sugarcane fields in Indonesia. Due to the significant degree of ownership fragmentation throughout the industry, the industry is especially vulnerable to land conversion as farmers look for higher-yielding crops, especially as land values continue to rise. Additionally, due to regional growth, vast tracts of agricultural land have been converted into industrial and residential districts across Java, which is the epicentre of sugarcane production in Indonesia (Toharisman, 2016).

2.6.2 Poor market regulation

The Indonesian government is trying to balance the demands of the local sugar sector and the demand from those industries that use it, which has resulted in substantial conflicts between the sugarcane industry and the government. According to the Ministry of Industry, in Indonesia consumed 5.7 million tonnes of sugar nationwide in 2015, with 2.8 million tonnes of plantation white sugar going to the local market for immediate consumption and 2.9 million tonnes of cheaper refined sugar from raw sugarcane going to the industrial sector (Toharisman, 2016).

The evaluation of sugarcane quality serves as the foundation for the sugarcane payment system for the Indonesian sugar industry (Kuswurjanto, 2019). The first mill sugarcane juice sample is obtained using a system with sensors. Juice quality is then assessed using a traditional analytical technique. Recent years have seen the use of core sampler systems in various sugar mills for sugarcane payment. The traditional analytical approach is labour and time intensive. The speed of the traditional analysis approach makes it impossible to analyse all the samples obtained from each truck for high milling capacity. It was thus essential to develop efficient and trustworthy techniques that could analyse all samples. The best alternative to the traditional analytical approach is NIR spectroscopy technology (Kuswurjanto, 2019).

2.6.3 *The case of Brazil*

Brazil is the largest producer of sugarcane in the world, contributing 38.6% of global production in 2019, an increase from the 25% of 2013. Brazilian sugarcane can be harvested in the south-central regions from April to December and in the northeast from September to April. Brazilian sugarcane's flexible bio-phenology and harvesting conditions make it challenging to pinpoint the harvest region from state to state. In Brazil, the south-central and north-eastern regions, particularly in the state of So Paulo, are where sugarcane is most commonly grown (Monteiro, Sentelhas & Pedra, 2018).

According to Monteiro et al. (2018), sugarcane is now a socioeconomically significant crop for other producers in Brazil, India, China, Thailand, Pakistan, the USA, and Australia. Recent years have seen a rapid expansion of sugarcane, taking over pastures, forests, and other croplands (Monteiro et al., 2018).

The measurement of sugarcane quality indicators used to determine the payment given to producers in Brazil includes brix and polarisation analysis of extracted juice as well as brix, polarisation, and prepared sugarcane fibre determinations (Da Silva Melo et al., 2022). This technique has been used to investigate important aspects of several factory samples, including the sugarcane, intermediate process streams, and raw sugar. For instance, this technique has been used to accurately measure a variety of quality indicators in diluted molasses samples, with positive outcomes for fructose, glucose, conductivity ash, and dry matter. Additionally, the technique has been used to analyze sugarcane juice in order to identify characteristics like brix, polarization, and reducing sugars (fructose and glucose).

2.7 Various challenges faced by sugarcane farmers

Sugarcane farmers face various challenges around the world, including in South Africa. These challenges are mostly linked to climatic and natural events, which include inconsistent rainfall and soil acidity, and factors such as lack of access to credit facilities. These are considered significant challenges facing the sugar industry's survival in African countries, including South Africa and Nigeria, among others. A study was undertaken by smallholder sugarcane farmers in Ethiopia who face challenges that include lack of access to credit, soil acidity, and natural disasters such as drought (Tena et al., 2016). These challenges are consistent with those found in other African countries. The challenges facing the sugarcane industry include drought stress, low soil fertility, pests and diseases, shortage of land, lack of improved pest-resistant varieties, and fluctuating prices (Tena et al., 2016). These issues negatively affect large-scale and small-scale growers, thereby causing a decrease in tonnage and resulting in lower income received. These issues affect both the level of productivity and the level of profitability. The level of productivity in the sugarcane industry is heavily affected by various issues that impact the sugarcane farmers' profit margins. This shows that both the South African and African sugarcane industries are facing serious challenges that have proven to have a significant impact on the entire

industry and its survival and success. Dubb (2017) further points out that the major issues facing the Kenyan sugarcane industry and farmers are not unique and are common in other African countries, including South Africa. These issues affect both the level of productivity as well as the level of profitability.

The level of productivity in the sugarcane industry is heavily affected by various issues that impact the sugarcane farmers' profit margins. However, it can also be argued that for small-scale sugarcane farmers, challenges also emanate from the farmer's abilities, such as lack of education and experience (Moodley, 2018). By considering the external difficulties that sugarcane growers experience, this may be resolved. The external challenges include climate change, one of the biggest problems for African farmers, as well as other problems like droughts and floods that negatively impact the production of sugarcane by both large- and small-scale growers, resulting in a decrease in tonnage and a reduction in income. In addition, recurrent droughts over the past ten years have reduced the amount of sugar produced per ton (Dubb, 2017). According to Dubb (2017), "aggregate production of sugar in South Africa has declined dramatically, from a peak of 2.75 million tonnes in 2003 to 1.82 million tonnes in 2012". Mekonnen et al. (2018) agree that 60% of the sugarcane produced in Brazil largely relies on rainfall. This means that there is a high reliance on rainfall by sugarcane farmers, which emphasises the significance of weather and climatic conditions. Sugarcane is a crop with moderately high water demand and is thus adversely impacted by water shortages (De Camargo et al., 2019).

The Impact of droughts extends further into sugarcane's various by-products, which include sugar, ethanol, and electricity sectors at various scales, on the local, national, and global levels. Moreover, another limitation facing sugarcane farmers in South Africa and the sugar industry is the inability to benefit from the production of by-products, namely ethanol and electricity.

Another issue is *Eldana saccharina*, which is a pest that feeds on crops and breeds on many crops, including sugarcane. South African sugarcane is also heavily affected by *E. saccharina*. Way and Goebel (2007) found that *E. saccharina* affects sugarcane by reducing its yield and bringing about inferior sugarcane crops.

2.8 Theoretical framework

2.8.1 Technology Adoption Models

Technology transfer is a powerful tool that can be used to promote industrial development in third-world countries (Rotimi, 2018). By relying on existing products, materials, or knowledge already acquired by technology-savvy countries, developing countries can gain access to a vast knowledge base for innovation. However, there must be sufficient local knowledge base to transfer the acquired technology; whether marketed or non-marketed. Technology acquisitions may be done by the government,

contractors, external agents (technology brokers), or a mixture of such agents. However, assimilation, adaptation, or imitation of acquired material, product, or knowledge marks the end of the method.

Through complementary efforts in research and development, creative imitation can be transformed into innovation. Governments play a central role in bringing together the various stakeholders involved in technology transfer and providing the vision, structure, resources, and necessary buffers to complement their actions. Each actor plays an important role in the success of the transfer process. Without this, the transfer will be significantly hindered (Rotimi, 2018).

There are several models that have been designed for product and process innovation characterisation. General concepts differentiate between the adoption perspectives on challenges regarding the adoption of NIR spectroscopy technology by CTS. The theory of diffusion of innovation (Napierkowski & Parsons, 1995; Martínez-Ros, 2019) and Martínez-Ros' (2019) TOE framework (as outlined by Eilu, 2018) assist in understanding the challenges faced in adopting NIR spectroscopy. The researcher deems the TOE framework appropriate for investigating the challenges faced in adopting NIR spectroscopy at CTS.

2.8.2 Theory of Diffusion of Innovation

Innovation adoption is the process through which certain people are more likely than others to embrace an invention, as opposed to everything happening at once in a social system. There are certain characteristics shared by people who adopt innovations earlier and those who do so later. When advertising technology to that group, it is essential to understand the characteristics of the target demography that will assist or impede the acceptance of the idea. Although the bulk of the public tends to fall towards the middle of the five recognised adopter groups, it is still important to comprehend the traits of the target demographic. Several tactics are used to promote innovations (Sartipi, 2020).

French sociologist Gabriel Tarde first discussed the diffusion of innovation theory in 1903, which was made popular by Everett Rogers in 1971. This theory states that the collaborative process is part of innovation, not technical competency (Sartipi, 2020). This suggests that for inventors to be successful in their marketing, they need to understand the individual characteristics of their audience. This theory focuses on the collaborative process as the method of diffusion. The theory also has a consumer-driven approach (Sartipi, 2020).

The theory of the diffusion of innovation describes how, why, and at what rate an innovation is accepted throughout the organisation. It depends on four pillars, namely ([Kawula, 2019](#)):

- a) Innovation is an idea, practice, or project that is perceived as new by an individual.
- b) Communication channels: a two-way process of passing information through verbal and nonverbal means.

- c) Time is a factor in the innovation-diffusion process, adopter classification, and adoption rate.
- d) Social system—the diffusion process is influenced by the social structure of the social system.

The theory suggests five distinct characterisations of adopters, namely innovator, early adopter, early majority, late majority, and laggards (Sartipi, 2020). These are discussed as follows:

- 1) **1) Innovators:** These are the ones who want to be the first to use an innovation. They are audacious and fascinated by cutting-edge ideas. These individuals typically come up with unique ideas initially and are very risk averse. If anything, not much has to be done to appeal to this group.
- 2) **2) Early adopters:** This group is made up of influential people. They like assuming leadership roles and accepting change. Since they are aware that change is necessary, they are comfortable implementing new ideas. How-to manuals and information sheets for implementation are two strategies to appeal to this group. Information won't sway them to make a change.
- 3) **Early majority:** Although these individuals do not often take the lead, they absorb new ideas. Before they are prepared to accept an innovation, they often want proof that it is effective. Success stories and proof of the innovation's efficacy are some strategies to appeal to this demographic.
- 4) **Late majority:** These people are resistive to change and won't accept an innovative concept until the majority has given it a go. One strategy to attract this audience is to provide information on how many other people have tried the innovation and successfully accepted it..
- 5) **Laggards:** These are exceedingly traditional and tradition-bound people. They are the hardest group to convince to accept change since they resist it.

Awareness of the need for an invention, choosing to embrace (or reject) the innovation, using the innovation first to test it, and ongoing usage are the processes by which a person adopts an innovation and whereby dissemination is accomplished. The adoption of an invention is influenced by five key elements, each of which is present in the five adopter groups to varying degrees (Sartipi, 2020):

- 1) **Relative advantage:** To what extent the innovation is considered superior to the idea, programme, or product it replaces.
- 2) **Compatibility:** How well the innovation matches the values, experiences, and needs of potential users.
- 3) **Complexity:** How difficult it is to understand and/or use the innovation.
- 4) **Trialability:** To what extent the innovation can be tested or experimented with before committing to adoption.
- 5) **Observability:** To what extent the innovation produces concrete results.

This theory has been successfully used in many areas, such as communication, agriculture, public health, criminal justice, social work, and marketing.

2.8.3 Technology, organisation, and environment (TOE) framework

The TOE framework has three important pillars that affect the adoption and implementation of technological innovation in an organisation (Schmitt et al., 2019). Application of the TOE framework can assist in identifying characteristics of the innovation that affect its implementation. The TOE framework is applicable to various disciplines because researchers can identify individual dimensions based on innovation and organisational characteristics (Borgman et al., 2013).

2.8.4 Technological context

The technological background alludes to important technologies in the organisation. This includes existing company-related tools and emerging technologies.

The technical context encompasses all the technologies pertinent to the company, including those presently in use and others that are marketed but not yet used. The adoption process is influenced by a firm's current technologies since they place restrictions on the amount and speed of technological change that may be made (Baker, 2011). Existing innovations that are not yet in use at the company have an impact on innovation by defining the boundaries of what is feasible and demonstrating to companies how technology can help them change and adapt. Innovations that produce incremental, synthetic, or discontinuous changes are three categories of innovations that exist outside of the company. New features or updated versions of current technology are introduced via innovations that bring about gradual change. For the adopting organisation, these incremental advances carry the least level of risk and disruption (Justino, Tengeh & Twum-Darko, 2022).

TOE framework advances, which have been labelled radical, involve substantial deviations from existing technology or procedures. A regulated rate of adoption is permitted in sectors where technological advancements result in gradual and even synthetic change. However, businesses must respond swiftly and decisively to adopt new technologies in discontinuous-change sectors if they want to preserve and improve their competitiveness. Firms must consider whether technology is competence enhancing or competence destroying when assessing its potential to bring about discontinuous change. While competence-destroying breakthroughs render many existing technologies and several forms of knowledge outdated, competence-enhancing innovations allow businesses to progressively transition as they build on their expertise (Justino et al., 2022).

2.8.5 Organisational context

The organisational context describes the characteristics of the organisation, including organisation size, formality, centralising degree, how complex the management structure is, and the quality of human

resources. Organisational characteristics may also reduce or encourage the adoption and implementation of technological innovations (Borgman et al., 2013).

The organisational context refers to the features and assets of the company, including personnel linkages, internal communication channels, firm size, and the amount of spare resources. This setting influences adoption and implementation choices in a variety of ways. First, methods that cross internal organisational barriers or connect internal subunits support innovation. Adoption is correlated with the presence of informal connecting agents, such as product champions, boundary spanners, and gatekeepers (Justino et al., 2022).

Examples of such systems are cross-functional teams and individuals with official or informal connections to other departments or value chain partners. The organisational structure has been researched more extensively to determine how it relates to the innovation adoption process. Adoption is correlated with organic and decentralised organisational structures. These kinds of organisations prioritise teams, provide flexibility in employee tasks, and encourage lateral contact, in addition to communication along reporting lines (Justino et al., 2022).

Other organizational structure research indicates that the implementation stage of the innovation process may be best suited to mechanical (rather than organic) structures, with an emphasis on formal reporting connections, centralized decision making, and well-defined responsibilities for personnel. Notably, the adoption phase could be best suited for organic and decentraalized organizations. The corporate context's communication procedures can also foster or stifle creativity. By establishing an organisational environment that embraces change and supports innovations that advance the company's basic goal and vision, top management may encourage innovation. Leadership should paint a compelling picture of the organisation's future, including assembling a capable executive team and highlighting top management's leadership behaviours and communication, techniques of outlining how innovation fits into the organisation's overall strategy, the strategy's significance for subordinates, rewards for innovation (formal and informal), and the firm's history of innovation. However, slack and size are two of the most-raised aspects of the organisational setting that influence creativity. It is also a topic of extensive research, although there is no clear evidence linking it to creativity. The relationship between size and innovation cannot be proved. Scholars suggest using more precise measurements of organisational characteristics rather than only generic measures (Justino et al., 2022).

2.8.6 *Environmental context*

This refers to the space where organisational activities are performed. This may include occupational associates, participants, and administration. It is beyond the organisation, which has restrictions on innovation.

The industry's organisational structure, the existence or lack of technical service providers, and the regulatory landscape are all examples of the environmental context. Several methods have been used to examine industry structure. For example, fierce rivalry encourages the use of innovation (Baker, 2011). Additionally, dominating companies within the value chain might encourage innovation among other value chain participants. It is said that enterprises in industries with significant economic development usually innovate more swiftly in terms of the industrial life cycle. However, innovative processes are not always straightforward in sectors that are mature or in decline. Some companies innovate by introducing efficiency improvements or expanding into other business sectors in response to the demise of an industry. To cut expenses, other businesses can forego innovation investment. Innovation is also impacted by the technical support infrastructure. Companies with high skilled labour costs are frequently forced to innovate through labour-saving technologies (Justino et al., 2022).

Innovation is also aided by the accessibility of consultants and other providers of technical services, as well as trained labour. Government regulation may influence innovation in a positive or negative way. Innovation is mandated for those businesses where governments place additional restrictions on industry, such as demanding pollution-control equipment from energy companies. In many businesses, strict safety and testing regulations can stifle innovation. Government regulation may therefore either promote or prevent innovation. In other words, the TOE framework and environments together create "both limits and possibilities for technological innovation". These variables impact the company's ability to innovate technologically (Justino et al., 2022).

2.9 Summary

One of the indigenous crops in tropical South and Southeast Asia is sugarcane. While various sugarcane types are most likely to have originated in several countries, for instance, the *S. spontaneum* occurs in East and North Africa, the Middle East, India, Malaysia, Taiwan, China, and in the Pacific to New Guinea, Brazil is the major producer of sugar, with the country accounting for 38.6% of the world's production, which makes it a major sugarcane producer in the world.

The South African sugar industry is consistently ranked in the top 15 of 120 sugarcane-producing nations worldwide. The country has an estimated 26 400 registered sugarcane producers in three provinces, namely KwaZulu-Natal, the Eastern Cape, and Mpumalanga.

Brix, polarisation, and fibre are content used to determine sugarcane quality. Refractometry and polarimetry methods are routinely used to analyse the measurement of sugar content in the laboratory, which is used for RV calculation. NIR spectroscopy is a well-established technology to analyse the quality of raw sugarcane received by sugar mills and subsequently for estimating prices and trading with growers. NIR spectroscopy offers various benefits and limitations.

The chapter discussed the implementation of NIR spectroscopy in the South African sugar industry by the SMRI. The impact of new technology and the effect on job redundancies were also reviewed. The process of sugarcane payment for CTS was disused. Technology adoption theories are very important when discussing the technology adoption in any context. They have proven to be very effective in understanding reasons and factors that influence adoption. The theory of diffusion of innovation is inseparable from the adoption process. The theory of diffusion and the TOE framework were selected to underpin this study because they are both in line with the aim of the study, which is to investigate challenges of NIR spectroscopy at CTS. The TOE framework is applicable to various disciplines because researchers can identify individual dimensions based on innovation and organisational characteristics.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

Research is an intellectual endeavour responsible for bringing fresh information to light (Pandey & Pandey, 2021). Research also corrects current mistakes, eliminates misunderstandings, and logically adds new learning.

A methodology is a process of research that explains the procedure(s) of the research from planning to the stage where results are reported (Thomas et al., 2022). Research methodologies provide the methods, techniques, and procedures used in the research design process (Thomas et al., 2022). When researchers research, it is important to clarify what they want to study and how they should do it.

Research methodology, research design, sampling techniques, and data-collection methods are discussed in this chapter. Data quality control, data-analysis methods, and various research approaches were applied to improve the trustworthiness of the study.

3.2 Research approach

Bougie and Sekaran (2019) cite three research approaches, namely qualitative, quantitative, and mixed-methods approaches. Qualitative research methods allow participants to understand their thoughts and experiences. Qualitative research techniques rely on opinions and perceptions. The opposite is quantitative research, which makes use of statistical analysis and numbers to produce quantitative information (Rutberg & Bouikidis, 2018). Furthermore, this type of research quantifies the problem by numerical data creation that can be further converted to practical statistics. Another prominent approach is the mixed-methods approach (Truong, Lui & Yu, 2020). This is where the researcher collects and analyses quantitative and qualitative data. This approach aims to draw strong points from both the qualitative and quantitative approaches to eliminate weaknesses that may be presented individually without replacing either method.

Qualitative research is best suited if the researcher seeks to measure a phenomenon by means of collecting data in a non-numerical form (Thomas et al., 2022). This study employed the qualitative research approach because the researcher sought to investigate challenges in adopting NIR spectroscopy at CTS at SASA. The primary use of the qualitative research method enables a researcher to collect relevant information through interviews (Thomas et al., 2022). Furthermore, qualitative research provides a holistic overview of people's views, opinions, and attitudes related to NIR spectroscopy adoption.

Qualitative analysis strategies were applied during this analysis, as they were applicable and relevant to the study undertaken. During this study, interviews served as a basic tool for data collection and were deemed efficient for the data-collection process. This study provides an in-depth description of challenges in the adoption of NIR spectroscopy through the exploration of managers' and supervisors' views.

3.3 Research design

Research design is a strategy that refers to how research is conducted (Rosenstein, 2019), which includes the enrolment and obligation of participants, data collection, data analysis, and data interpretation, which directly influence the validity of the study. There are three common research designs, namely descriptive, exploratory, and causal studies (Bougie & Sekaran, 2019). Descriptive studies collect data that depict individuals' attributes, occurrences, and circumstances. The objective is to describe. The researcher used interviews to explore the experiences, views, and beliefs of the participants.

Descriptive research aims to describe the characteristics of the phenomenon (Nassaji, 2015). This study utilised the descriptive research design. An exploratory study was conducted once additional, or certain, facts were recognised; however, additional proof is required to develop a possible theoretical framework (Bougie & Sekaran, 2019).

The descriptive research approach of this study was used to understand the challenges for the sugarcane industry related to adopting the NIR spectrophotometer at CTS. Significant facts are determined more completely in descriptive research than describing facts predicted by theory (Anastas, 2004). The insight into the testing of sugarcane at CTS was gained using a descriptive paradigm. The aim with the descriptive research selection was to attain a precise indication of management challenges related to adopting NIR spectroscopy. The study chose descriptive research to better understand the challenges in the introduction of NIR spectroscopy. The study aimed to investigate management challenges in the introduction of NIR spectroscopy at CTS. The researcher used interviews to explore the experiences, views, and beliefs of the participants. Insight into what is happening at CTS was gained using descriptive paradigm.

3.4 Research objectives

The perceived problem is that CTS has been using traditional analytical chemistry methods for testing. The traditional method results in various analyses performed by different individuals using various instruments and chemicals. The introduction of NIR spectroscopy means analysis will be performed by one person in a short period, with no chemicals needed. This may cause redundancies in some existing positions. NIR spectroscopy is a cost-effective and environmentally friendly tool as sample pre-treatment and the use of chemicals are not required (Yang et al., 2020).

The objectives of this study were as follows:

- 1) To provide an overview of NIR spectroscopy functioning;
- 2) To investigate the challenges related to introducing NIR spectroscopy at CTS;
- 3) To measure the extent of the effects of these challenges on NIR spectroscopy at CTS; and
- 4) To recommend how the challenges can be addressed.

3.5 Research questions

The researcher endeavoured to examine and address the research questions to achieve the study objectives. The questions were as follows:

- 1) How does NIR spectroscopy work?
- 2) What are the challenges faced by CTS' management in the introduction of NIR spectroscopy?
- 3) To what extent do these challenges affect the implementation of NIR spectroscopy?
- 4) What recommendations can be offered to address the challenges?

3.6 Study site

The study site is the physical place where desired data will be collected for a study (Humble & Radina, 2019). CTS's head office is located at Mount Edgecombe, north of Durban, KwaZulu-Natal. It provides a specialised service under contract to individual mill groups (SASA, 2021). CTS spreads quality analyses over the mill groups for payment purposes. For the purposes of this study, interviews were held with participants from the Komati, Eston, UCL, Sezela, and Felixton mills.

3.7 Population and target population

Bougie and Sekaran (2019) characterise a population as a complete cluster of individuals or things of interest that the investigator wishes to research. The study's target population was management at CTS, including managers and supervisors. CTS has 23 staff in management, which comprises 12 managers and 11 supervisors.

3.8 Sampling technique

Pandey and Pandey (2021) define sampling as selecting acceptable people, items, or events that are representative of the entire population. A small cluster is chosen to represent the whole group. Sampling aims to obtain correct and reliable data with a minimum time and energy investment. Pandey and Pandey (2021) further mention two types of sampling methods, namely probability and non-probability sampling. In the probability sampling method, every individual from the population is given an equal chance to be part of the sample.

On the contrary, in non-probability sampling, there is no known chance of selecting any individual participant (Pandey & Pandey, 2021). Non-probability sampling includes incidental, judgement, convenience, purposive, quota, and snowball sampling types (Pandey & Pandey, 2021). A quota sampling method was employed in this study. In quota sampling for judgement and probability sampling, the quantity of the population members in each category is decided based on judgement or previous knowledge (Pandey & Pandey, 2021). Using quota sampling, the researcher identified managers and supervisors directly involved in implementing NIR spectroscopy at CTS. The 10 participants in this study comprised five managers and five supervisors. Sample size in qualitative research is determined by saturation (Young & Casey, 2018). Saturation is the instrument employed to ensure adequate and quality data collection to support a study (Walker, 2012). The saturation point was reached after the researcher interviewed 10 participants.

3.8.1 Criteria to select respondents

It was important for the researcher that the respondents displayed certain attributes to participate in the study. The sampled respondents took part in the implementation phase of NIR spectroscopy at CTS, and they were all willing to be part of the study.

3.9 Data-collection method

Data sources vary from primary to secondary sources. When first-hand data are obtained in its original state by the researcher for the purposes of the study, those data are regarded as primary data (Bougie & Sekaran, 2019). Interviews, questionnaires, focus groups, and panels can be used to source primary data. The data collected previously beyond the problem at hand are regarded as secondary data. This research used primary data collected using online meeting interviews and secondary data that were collected from reliable sources (journals, books, and peer-reviewed papers). The primary research method was chosen to enhance the study's trustworthiness and to ease data analysis.

3.9.1 Data-collection tools

Data collection via interviews was used for this study. Individual online structured interviews were organised with 10 respondents. All 10 participants responded individually to structured online interview questions. A structured interview method was selected to promote standardisation, which minimises errors due to variations in the question asked (Rashidi et al., 2014:118). The advantage of this interview technique is that data can be gathered directly, and some confidential information can be obtained (Pandey & Pandey, 2021). The interviews were conducted in English, as all participants understood English.

3.9.2 Structured interviews

The interview schedule for this study contained four main sections: Section A (biographic information), Section B (challenges related to adopting NIR spectrophotometer), Section C (understanding the functioning of the NIR spectrophotometer), and Section D (future improvements and recommendations).

Participant selection was based on their involvement and experience throughout the implementation process of NIR spectroscopy. Pandey and Pandey (2021) emphasise that an interview can delve into unexpected factors, establish attitudes, and determine the source of a problem. Using interviews, the researcher gained insight into the participants' experiences, knowledge, attitudes, and views of the introduction of NIR spectroscopy at CTS. Section A of the questionnaire collected contextual data and the characteristics of the participants. Section B sought to uncover management challenges in the implementation of NIR spectroscopy. Section C sought to understand the overall functioning of NIR spectroscopy. Section D, which is the last section, aimed to uncover anticipated improvements.

The purpose of the research and the role of the participants were clearly explained before the commencement of the interviews. The participants were informed that the interview was voluntary and that their identity would be protected as the researcher assigned them pseudonyms.

The structured interview questions were administered to allow the participants to express themselves. This also allowed the researcher to mitigate potential bias, which led to fewer ambiguities in analysis. The selection of structured interviews increased the credibility, reliability, and validity of the study. The researcher took notes during the interviews and the sessions were recorded. The recording enabled the researcher to observe non-verbal actions. This assisted the researcher to observe what the participants thought about the issues, as some would smile and display other non-verbal cues. Permission to record the interview was granted by the participants to make reviewing the interview easy for the researcher during the transcription stage. The interview sessions were between 15 and 30 minutes long.

3.10 Data analysis

Data analysis in qualitative research entails systematically searching and organising interview transcripts, making observation notes, or gathering other non-textual information that researchers acquire to deepen their understanding of a phenomenon (Lester, Cho & Lochmiller, 2020). Furthermore, most of the time, categorising the collected data is involved in qualitative data analysis. Categorising entails minimising the amount of raw data, recognising noteworthy patterns, deriving meaning from the data, and thereafter constructing a logical chain of evidence to make sense of enormous volumes of data.

The thematic analysis method was used for this study. Thematic analysis is useful when examining data as it is a potent yet adaptable technique that can be applied from a range of paradigmatic perspectives (Castleberry & Nolen, 2018). Thematic analysis is a way to identify, analyse, organise, explain, and

report on the subjects found in the collected data (Nowell et al., 2017). Firstly, the researcher analysed the data. This was achieved by ensuring that the collected data were suitable. The interview schedule was firstly divided into four groups for easy tracing of errors. Secondly, all interviews were recorded for easy reference and categorising information. Thirdly, all information was transcribed precisely into a readable version. The researcher read the transcripts until the content was understood. Fourthly, patterns were identified through the use of content analysis. Then the patterns were identified, which included the participants' challenges related to adopting NIR spectroscopy. Thereafter themes were identified and direct quotations from the interviews were selected to assist in supporting the research findings.

3.11 Inductive and deductive approach

Qualitative analysis can be either inductive or deductive (Assarroudi et al., 2018). Both inductive and deductive approaches involve comparable content analysis processes. This process involves the preparation, organisation, and reporting of the results phase. Since this study was not quantitative and did not use scientific principles, the deductive methodology was unsuitable. Inductive reasoning was best suited for the study because data were needed to identify challenges related to implementing NIR spectroscopy at CTS at SASA.

3.12 Data quality control

Reliability and validity in qualitative research are debated among researchers (Hayashi, Abib & Hoppen, 2019). Quantitative research commonly uses reliability and validity, and of late the pair is reconsidered for the qualitative research model. The evaluation of qualitative content is determined by the data's trustworthiness. In order for researchers to establish their argument, the research findings made in qualitative research must be trustworthy (Hayashi et al., 2019).

3.12.1 Validity and reliability

To establish validity and reliability, qualitative researchers use statistical techniques (Daniel, 2019). Validity is defined by Bougie and Sekaran (2019) as the extent to which an instrument measures what it is supposed to measure. The ability of a measuring device to deliver repeatable findings over time is known as reliability. To establish credibility, qualitative researchers work to develop and use methodological procedures (Noble & Smith, 2015). Some techniques, such truth value, consistency or neutrality, and applicability, increase the credibility of a research.

This study's validity and reliability were increased by the nature of the interview questions administered. They were objective, and not biased or leading. It is not easy to measure reliability and validity in qualitative research since the study usually has no intention of generalising the findings to the larger group. Noble and Smith (2015) are of the view that qualitative research aims to design and incorporate

methodological strategies to ensure trustworthiness. There are strategies that enhance the credibility of the study such as truth value, and consistency, or neutrality and applicability.

3.12.2 Trustworthiness issues

Alternative criteria to demonstrate rigour within qualitative research are truth value, representativeness, consistency, and applicability (Noble & Smith, 2015).

3.13 Truth value

The goal of qualitative research is to define or comprehend the research interests from the participant's point of view (Napierkowski & Parsons, 1995). Truth value involves reflexivity and reflection on one's own perspective (Noble & Smith, 2015). The truth value of this study is as follows: firstly, the holistic approach through the data-collection method where structured online interviews were conducted; secondly, the precise transcription of the participants' words; and thirdly, all collected data were checked and compared for validity.

3.14 Representativeness

The sampled managers were able to share their in-depth experiences as they were directly involved in implementing NIR spectroscopy at CTS. The saturation point was reached at 10 interviews. All interviews were recorded, which allowed the researcher to repeatedly revisit the data to check emerging themes and the truth regarding NIR spectroscopy implementation at CTS. The issue of representativeness in this study was ensured by sufficient evidence to support data interpretations. No unsubstantiated statements were made and the analysis was based on the original data produced by the participants.

3.15 Consistency

Consistency of findings is attained through achieving auditability (Noble & Smith, 2015). This research is transparent and the research process is clearly described in this thesis, as outlined in Chapter One.

3.16 Applicability

Qualitative researchers can enhance applicability to determine whether the findings of the study can be used in other contexts, settings, or groups (Noble & Smith, 2015). The researcher interpreted the participants' responses objectively. The research is rich in detail of the context, as well as regarding the evaluation of the study conclusions and transferability to other SASA divisions.

3.17 Ethical considerations

Ethics is the collection of moral principles of an individual or a group of people, including expectations and guiding rules regarding conduct (Hagendorff, 2020). The researcher followed the ethical procedures recommended by the University of KwaZulu-Natal. Written permission was requested and granted by SASA to conduct the research. This permission was then sent as part of the application to collect data for ethical clearance to the University of KwaZulu-Natal's registrar. Ethical clearance was subsequently granted. The researcher sent all the participants emails to request their participation. They all confirmed their availability for an online interview. On the day of their individual interviews, all the participants signed consent letters. The participants were assured that the research findings would not be used for any purpose other than this master's dissertation.

3.18 Limitations of the study

Weaknesses that may be present in the research design are presented as study limitations (Ross & Bibler Zaidi, 2019). These influence the outcome and the conclusion of A research project. All research projects have limitations.

This research had the following limitations: NIR spectroscopy was only implemented at a few CTS sites and, as a result, the participants were few and only from the affected sites. Another limitation was the time factor, as the study was conducted over a short period of time. The study also did not include other parties involved, such as sugarcane growers.

Despite the limitations noted above, this study is the starting point for more research at CTS and SASA. The study provides valuable information about issues and research that SASA leadership should address when implementing new technology and innovation.

3.19 Summary

Chapter Three discussed the research methodology, design, and approach. The study's aim, research objectives, and questions were also outlined in this chapter. The chapter further discussed the population, sampling technique, and criteria for selecting respondents for the study. Finally, the online interview qualitative data-collection method and analysis using the thematic analysis method were described.

CHAPTER FOUR: FINDINGS AND DISCUSSION

4.1 Introduction

Chapter Four presents the research findings. The presentation is based on the methodology used for data collection, as discussed in the previous chapter. Data analysis is relative to three of the research objectives, namely to provide an overview of NIR spectroscopy functioning, to investigate the challenges related to introducing NIR spectroscopy at CTS, and to measure the extent of these challenges' effect on NIR spectroscopy at CTS. The research findings are logically arranged to allow the researcher's neutral and objective interpretation of the participants' views and experiences.

4.2 Participant demographics

This section discusses the background information of the research participants. The participants' attributes are provided in Annexure E.

4.3 Section A: Biographical and demographic information

4.3.1 Gender of the respondents

4.3.1.1 Aim of the question

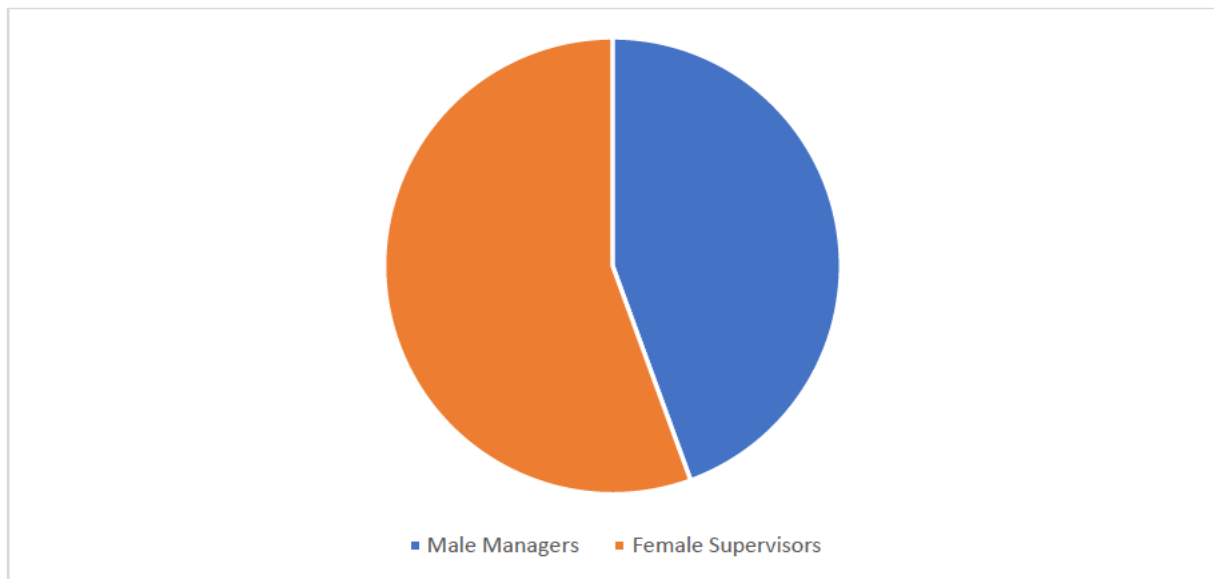
The first interview question explored gender equality among CTS's key-position managers and supervisors.

4.3.1.2 Results and Discussion

More than 80% of the managers were male, and 100% of the supervisors were female (see Annexure E and Figure 4-1). The 10 respondents consisted of four male and one female manager and five female supervisors.

There was no correlation with gender regarding the challenges of NIR spectroscopy implementation in CTS at SASA. Both female and male managers experienced challenges in the implementation of NIR spectroscopy. Most (80%) managers were male and all (100%) supervisors were female. This concurs with the literature that indicates that gender does not show any association with the acceptance of new technology (Chimento-Díaz et al., 2022).

Figure 4-1: Participants' gender



4.3.2 Age of the participants

4.3.2.1 Aim of the question

The question sought to establish the age group of the study participants.

4.3.2.2 Results and Discussion

Forty percent of the participants were in the 46 to 55 year age range, another third (30%) were between 36 and 45, and the last third (30%) were between 26 and 35. The results indicate that managers aged 46 to 55 accounted for 80% of the manager group, while the supervisors' ages were split evenly between 60% in the 36 to 45 year age range and 40% in the 26 to 35 year age range.

Age had no effect in this study on the challenges of NIR spectroscopy at CTS. There was a wide age range among the participants. The participants were all consistent in experiencing similar challenges with implementing NIR spectroscopy. This is contrary to the literature that indicates that younger persons have greater acceptance of new technology (Chimento-Díaz et al., 2022).

4.3.3 Number of years working at SASA

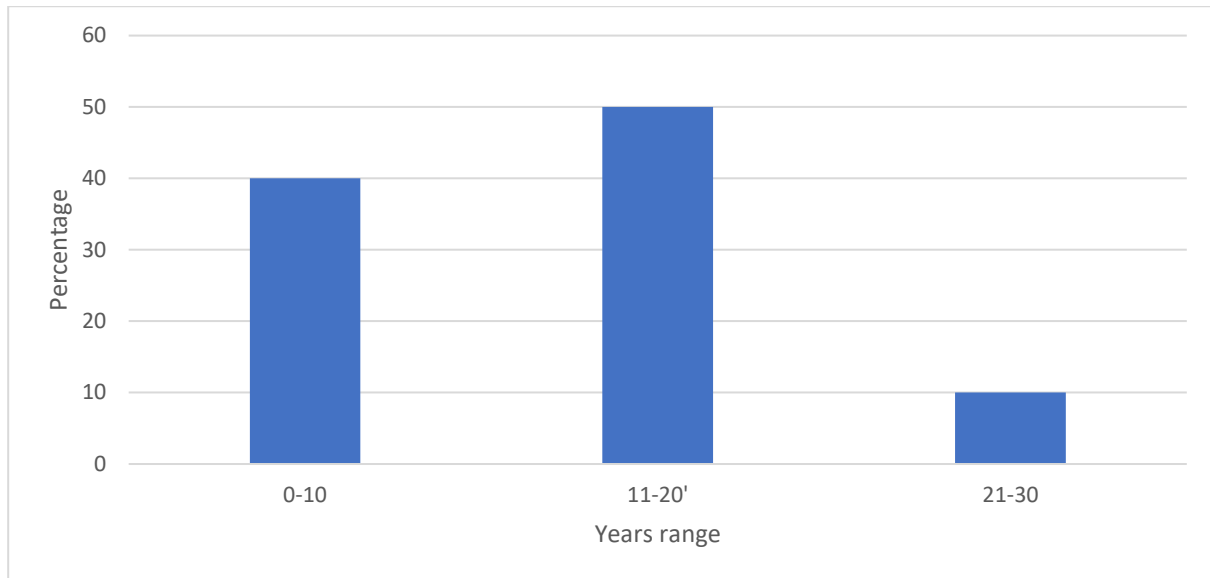
4.3.3.1 Aim of the question

The question aimed to illustrate the number of years of experience of participants in the sugar industry. This was meant to explore the respondents' experiences regarding the introduction of NIR spectroscopy at CTS.

4.3.3.2 Results and Discussion

Figure 4-2 depicts that one (10%) respondent had between 21 and 30 years of experience, five (50%) respondents had between 11 and 20 years of experience, and four (40%) respondents had between 0 and 10 years of experience.

Figure 4-2: Participants' years of experience in the sugar industry



More than half of the participants had been with the organisation for more than 10 years. All participants were involved in the implementation of NIR spectroscopy. The participants appreciated NIR spectroscopy technology but experienced challenges in its implementation, which implies that the organisation did not address the question of technology design, change management, and technology acceptance (Mlekus et al., 2020).

4.3.4 Current position

4.3.4.1 Aim of the question

The question sought to determine whether the respondents were managers or supervisors.

4.3.4.2 Results and Discussion

Five (50%) respondents were managers and five (50%) respondents were supervisors.

The participants' positions had no effect on the study. The researcher interviewed both managers and supervisors who were involved in the implementation of NIR spectroscopy. They all faced similar challenges in the implementation of NIR spectroscopy at CTS.

4.4 Section B: Challenges related to adopting the NIR spectrophotometer at CTS

4.4.1 What was your experience when adopting the NIR spectrophotometer on your site?

4.4.1.1 Aim of the question

The aim of the question was to examine the participants' overall experience regarding the implementation of NIR spectroscopy at CTS.

4.4.1.2 Results and Discussion

Table 4-1: What was your experience when adopting the NIR spectrophotometer?

Themes	Frequency	Participants
Good experience	Less than half	MN01, MN05, SP02, and SP05
Bad experience	Half of the participants	MN02, MN03, MN04, SP01, and SP04,
Not sure	Only one	SP03

The presented data indicate variation in relation to the participants' experience with adopting NIR spectroscopy. Half of the respondents thought they were not fully included in adoption as there was a lack of communication and no training. However, some thought that the technology adoption was communicated adequately.

The research findings outlined in the study revealed variation in relation to experience when adopting NIR spectroscopy. A fair number of participants indicated that they had a good experience as they had a fair understanding of the technology, and the results were faster than expected, which enabled them to monitor the process. This concurs with literature that emphasises that NIR spectroscopy is a rapid and high-precision method (Lan, 2020:95).

MN01: *"I have been responsible for the overall method. I have [a] fair understanding of the method development and I have dealt with the service providers."*

MN05: *"Results were coming out faster than the conventional method and much easier to operate."*

SPO2: *"Even the differences were very little, and it was quite convenient because you just putting it to one instrument."*

SP05: *"It was [a] good experience. Technical support was always available when required."*

MNO2: *"We did few trials, then later we were informed that the instrument was going to be purchased. When we started using it, then we were basically told that the results were too different to the conventional method."*

MN03: *“There is always a perception that it takes about 30 years to introduce technology into the sugar industry, while that is quite funny but I think it is because of the structures.”*

MNO4: *“After we got it communicating, the other challenge was the Mill Group Board itself here and the guys they didn’t understand that this was a project. They wanted us to report when we are doing something, and they expected it to work.”*

SP01: *“I was not involved in terms of feedback, whether it’s working or not, the data is comparable or its not comparable.”*

SP04: *“There wasn’t really much given to us so we can understand what NIRS [NIR spectroscopy] is and how does it work.”*

SP03: *“I can’t specifically say how was my experience because already it was in operation.”*

4.4.2 What were the challenges?

4.4.2.1 Aim of the question

The question sought to identify the challenges confronted during the implementation of NIR spectroscopy.

4.4.2.2 Results and Discussion

Table 4-2 lists the participants’ challenges experienced during the implementation of NIR spectroscopy.

Table 4-2: Challenges experienced

Themes	Frequency	Participants
Secondary method	More than half of the participants	MN01, MN02, MN03, MNO4, MN05, SP01, SP02, and SP05
Setting up	Less than half	MN01, SP03, and MN02
Poor communication or structures	Half	MN02, MN03, SP01, SP04, and SP05
Fear of change	Less than half	MN05, SP03, and SP04

The participants expressed that the main challenge was the comparison of results from the NIR spectroscopy with results from the conventional method, and that the growers expected identical results. Regarding setting up the infrastructure in the mills, some participants indicated that they did not understand the whole process. They were given instructions on what had to be done. Some participants indicated structural inefficiencies that resulted in it taking too long to obtain approval for anything that

had to be bought or implemented. Processes that require committee approval take a long time and cause delays. Staff morale was lacking as they feared losing their jobs.

The first challenge was that NIR spectroscopy is a secondary method, which means that the results would not be identical to the primary method. This is in line with the literature that highlights the limitations of NIR spectroscopy as a primary method, and initial calibration against the primary method is essential (Pasquini, 2018). In some cases, developing a calibration equation that covers all possible samples is impossible. Data collection of several hundred to thousands of samples may be needed for natural items. In this situation, it is crucial to cover the whole spectrum of considerations evenly (Zhang et al., 2018).

MN04: “I think the big challenge is that we were comparing the results with the conventional method, [and] it won’t be exactly the same because NIR spectroscopy works on the equations. The more data you have, the more it becomes accurate, the more it becomes close to the original.”

SP03: “At this current moment, the installation of NIR spectroscopy is linked to the actual process that we have in terms of designs. Now we are testing on two operations. Sometimes we experienced chokes during operation because tubes are narrow in order to accommodate NIRS. It instilled fear to the employees because once it started working, that meant we would need to cut some of the employees.”

MN03: “The challenges are trying to deal with the miller, trying to get their engineers, trying to look at drawings, positioning of it. They came across a lot of components and design problems.”

Poor communication regarding how decisions were made and how the NIR spectroscopy method was communicated to individuals occurred. This is evident as the goal of CTS is to give specific mills a specialised service to assess the quality of growers’ sugarcane deliveries to the mill for sugarcane payment purposes (SASA, 2021). The participants could not make decisions rapidly as they reported to various boards.

MN02: “Before the instrument was purchased, results from trials were not shared, we don’t know.”

SP01: “When the project started, there was not much communication on what is happening, what are we doing?”

SP04: *“I did not understand it and getting the information on why it was causing a lot of work because of double analysis. You will analyse the sample on the conventional part and come back and analyse it on NIR spectroscopy again.”*

Fear of change is contrary to the literature, which indicates that businesses must adapt to an ever-changing environment to suit the requirements of their customers to remain competitive in a global economy (Kuswujanto & Wening, 2019). Staying competitive requires a company to continue evolving and adjusting processes and technology to achieve a competitive advantage over its competitors.

MN01: *“The sugar industry worldwide is considered one of the best methods for cane payment. So why would you now change something that is so-called world class to something else?”*

Employees have a crucial strategic role in the development of technology because they define the overall product strategy, oversee its execution, and take appropriate action in the cyber-physical production system. However, this necessitates certain knowledge, abilities, and a separate skill paradigm. Knowledge management, increasing production system automation, digital communication, interactive management functions, and staff flexibility are factors that affect the demand for new talents (Erkutlu & Chafra, 2020). On the other hand, relatively few studies in the literature have addressed the skills required and how to offer the skills for new technology applications so that the skills are passed on and are successfully employed in businesses. Untrained and uneducated workers have a negative impact on businesses.

The research findings outlined in the study revealed variation in relation to experience when adopting NIR spectroscopy. A fair number of participants indicated that they had a good experience as they had a fair understanding of the technology, and the results were faster than expected, which enabled them to

4.4.3 Did these challenges affect plant or employee productivity?

4.4.3.1 Aim of the question

This question sought to determine if and how the challenges affected employees and plant productivity.

4.4.3.2 Results and Discussion

Table 4-3: Did these challenges affect plant and employee productivity?

Themes	Frequency	Participants
Yes	More than half	SP02, SP03, SP04, SP05, MN01, MN02, MN03, MN04, and MN05
No	Only one	SP01 and SP05

The challenges affected the plant as the plant required redesign, and dedicated employees are required for the project.

The NIR spectroscopy process brought uncertainty at CTS, as most managers did not understand why they were conducting analysis in duplicate.

MN03: *“It did affect productivity in terms of the plant.”*

SP03: *“I think as much as we know that this project had to cut some of the employees with time, they had to accept that because we know we are moving with the times.”*

MNO5: *“Employees productivity dropped.”*

MN04: *“It didn’t. We had a specific person working on this, there was somebody who was hired as fixed-term contractor specifically for the project.”*

SP04: *“It did. Personally, for me, I don’t like working with something I really don’t understand.”*

SP01: *“Because we were not involved in the research, the challenge that was there is the double analysis.”*

They thought that a heavy workload was placed on their shoulders. People in the plant expected the results from the NIR spectroscopy to be the same as the results from the conventional method, as they disregarded the concept of repeatability and reproducibility ([Walford, 2019](#)). In addition, there was resistance to change as factory personnel thought that the traditional method was adequate.

Setting up the actual instrument in terms of design was complex as it took longer than expected and external expertise was required to modify the plant.

4.4.4 What are you doing or have done about those challenges?

4.4.4.1 Aim of the question

The researcher wanted to understand if SASA has managed to overcome the challenges experienced.

4.4.4.2 Results and Discussion

Table 4-4: What are you doing or have done about those challenges?

Themes	Frequency	Participants
Method withdrawn	All participants	SP01, SP2, SP03, SP04, SP05, MN01, MN02, MN03, MN04, and MN05

The participants unanimously agreed that the use of the NIR spectroscopy method was withdrawn.

The respondents unanimously stated that the technology had been withdrawn. Over the years, there has been an increase in worldwide interest shown by sugar industries in the potential use or implementation of NIR spectroscopy analysis as a research and management tool ([Phetpan et al., 2018](#)). It is therefore important to understand that NIR spectroscopy is a very broad area of research and application.

SP01: *“At the moment, we are not using NIR Spectroscopy.”*

MN02: *“When it was done, it was yay.”*

MN01: *“Ultimately, it came down to rands and cents.”*

NIR spectroscopy comprises four skills pillars: spectroscopy, chemometrics, instrument construction, and analytical chemistry. The pillars simultaneously ensure proper technology use (Pasquini, 2018). The educational gap in NIR spectroscopy has been noticed. Individuals thus need proper training in all aspects of NIR spectroscopy (Pasquini, 2018). The participants further indicated that they would recommend this technology to others despite the challenges encountered. The participants acknowledged that workshops were conducted to introduce NIR spectroscopy; however, the majority still believed that additional workshops and training were necessary for CTS as this technology may present more opportunities for the industry.

4.5 Section C: Understanding the functioning of NIR spectroscopy.

4.5.1 What is your overall understanding of the functioning of NIR spectroscopy?

4.5.1.1 Aim of the question

The question sought to facilitate an overall understanding of NIR spectroscopy functioning.

4.5.1.2 Results and Discussion

Table 4-5: What is your overall understanding of the functioning of NIR spectroscopy?

Themes	Frequency	Participants
Efficient reflectance	All participants	SP01, SP02, SP03, SP04, SP05, MN01, MN02, MN03, MN04, and MN05
Quick	All participants	SP01, SP02, SP03, SP04, SP05, MN01, MN02, MN03, MN04, and MN05

The participants unanimously expressed that they understood NIR spectroscopy as efficient.

The findings of the study indicated that the managers were aware of NIR spectroscopy functioning.

MN01: *“The method that we use for cane is reflectance rather than what other people use, which is transmission.”*

MN02: *“It’s a quicker way of getting your results because it uses basically the beam light that goes into the sample.”*

NM03: *“It’s a very simple process, passes light through any object.”*

MN04: *“Secondary method, it saves time, it saves cost.”*

MNO5: *“The instrument can save a lot of time, energy, resources, and chemicals, resulting in positive financial gains.”*

SP01: *“It is a very nice and quick method of analysing because the minute you put a sample, you get your result.”*

SP02: *“There is very low maintenance on the instrument itself.”*

SP04: *“It works using infrared laser. The range of the spectrophotometer to analyse where the sucrose, where it is on the spectrum, then you can quickly tell how much sugar is there”*

Many managers defined NIR spectroscopy as a quick and efficient technology. This concurs with the literature that emphasises that the major strength of NIR spectroscopy is its provision of data in seconds and that no sample preparation is required (Afara et al., 2021). The process of NIR spectroscopy analysis involves spectra collection using samples of known values, the characterisation of the sample properties, establishing the validation model, and targeting parameters of known samples over the targeted analyte. All models are built by chemometrics application. Chemometrics uses statistical principles, computer science, and mathematics to process chemical information to acquire the construction and composition of the analyte (Otto, 2016).

4.5.2 Has the NIR spectrophotometer changed the way you do things in the plant?

4.5.2.1 Aim of the question

The question aimed to determine if NIR spectroscopy had any impact on plant operations.

4.5.2.2 Results and Discussion

Table 4-6: Has NIR spectroscopy changed how you do things in the plant?

Themes	Frequency	Participants
Yes	More than half	SP01, SP02, SP03, SP05, MN01, MN02, MN05
No	Less than half of the participants	SP04, MN03, MN04

Some participants believed that NIR spectroscopy changed how things were done in the plant, while others thought there was no impact.

The findings also indicated that some managers had not seen any changes in how they did things in the plants because NIR spectroscopy technology has been on trial for the past 23 years.

SP01: *“NIRS you do away with two instruments and have one instrument where you get both brix and sucrose produced at the same time.”*

SP02: *“Now with NIRS, a lot more parameters that we are able to test, it is quicker, it means we should be able to run quicker to a more timeless check in the product.”*

SP04: *“It did not really change anything; there wasn’t any change.”*

MN03: *“It’s a disappointment for us because it hasn’t changed anything. All the 23 years of work. Can you imagine doing a project for 23 years, a lot of other technology must have come out and overtook this technology.”*

MN04: *“Nothing has changed for now.”*

The literature indicates that NIR spectroscopy analysis is not new in the sugar industry, and some conventional sugar methods can be replaced with NIR spectroscopy measurements to reduce cost (Dos Santos et al., 2013; Salgo et al., 1998). NIR spectroscopy technology used in laboratory settings is widely established. However, deploying these technologies in the plant still faces technical obstacles because of size restrictions, power requirements, high dust sensitivity, and vibration (Nawi et al., 2014). The majority of managers witnessed changes in their operations.

4.5.3 What are the significant benefits of using an NIR spectrophotometer?

4.5.3.1 Aim of the question

The question sought to identify the benefits of using NIR spectroscopy.

4.5.3.2 Results and Discussion

Table 4-7: What are the significant benefits of using NIR spectroscopy?

Themes	Frequency	Participants
Cost savings	All participants	SP01, SP02, SP03, SP04, SP05, MN01, MN02, MN03, MN04, and MN05
Time efficiency	All participant	SP04, MN03, and MN04
Health and safety	All participants	SP01, SP02, SP03, SP04, SP05, MN01, MN02, MN03, MN04, and MN05

Most participants identified benefits of using NIR spectroscopy such as cost savings, time efficiency, and friendliness to environmental health and safety.

The participants also identified that the significant benefits of using NIR spectroscopy are cost saving (economical), time efficiency (it takes less than a minute to analyse multiple analytes), and environmental, health, and safety benefits (no use of hazardous chemicals).

SP01: *“It was easier to use, you only have one machine to maintain.”*

SP02: *“Moved away from using lead. The cost of lead is ridiculous and it is not safe.”*

SP03: *“It is more efficient, it would be faster, and there would be less human errors in terms of adjustments.”*

MN01: *“Firstly, it has huge cost saving, you get the cost saving, unfortunately by losing employees because NIRS is a fully automated system.”*

MN02: *“The benefit is the time and the amount of sample that you can do. Increased efficiency, I think that’s like the biggest benefit.”*

MN05: *“Safety benefit that no hazardous chemicals were required.”*

NIR spectroscopy is a cost-saving and environmentally friendly tool. No sample pre-treatment or use of chemicals are required (Barra et al., 2021). It has been used in various disciplines, such as medical science, forensics, and biochemistry. NIR spectroscopy has existed for nearly 50 years. In contrast to

other analytical procedures of comparable age, this method is still in its infancy and has the potential for long-term growth (Pasquini, 2018).

4.5.4 *Based on your experience when adopting an NIR spectrophotometer, would you recommend this technology to someone else?*

4.5.4.1 *Aim of the question*

The question sought to determine if the participants, knowing the benefits of NIR spectroscopy, would recommend NIR spectroscopy despite the challenges encountered.

4.5.4.2 *Results and Discussion*

Table 4-8: Based on your experience when adopting NIR spectroscopy, would you recommend this technology to someone else?

Themes	Frequency	Participants
Yes	All participants	SP01, SP02, SP03, SP04, SP05, MN01, MN02, MN03, MN04, and MN05
No	None	

All the participants were enthusiastic about recommending this technology based on its benefits as discussed in the previous section.

The participants further indicated that they would recommend this technology to others despite the challenges encountered.

MN01: *“The technology is actually very good and, as I said, when you trying to replace a world-class method with a better technology, it doesn’t sell, but it does have significant benefits.”*

MN02: *“Personally, I would, but I think in the South African sugar industry there is more work that needs to be done.”*

MN03: *“Yes! Presenting the whole project and findings from the people that get an output out of it, there were some complexities in terms of understanding it.”*

SP03: *“Yes! I think it will also be less costly compared to the traditional process, with efficient results and less human errors.”*

SP05: *“Yes, this technology is economical. There is no use of chemicals, water and so forth.”*

The participants acknowledged that workshops were conducted to introduce NIR spectroscopy; however, the majority still believed that additional workshops and training were necessary for CTS as this technology may present more opportunities for the industry.

4.6 Section D: Future improvements

4.6.1 *Are there any improvements relating to NIR spectroscopy that you would like to see happening in the future?*

4.6.1.1 *Aim of the question*

The question aimed to facilitate an understanding of elements that require improvement.

4.6.1.2 *Results and Discussion*

Table 4-9: Are there any improvements relating to NIR spectroscopy that you would like to see happen in the future?

Themes	Frequency	Participants
Yes	All participants	SP01, SP02, SP03, SP04, SP05, MN01, MN02, MN03, MN04, and MN05
No	None	N/A

All the participants thought that there was room for improvement at SASA; including from the design, communication, and overall presentation and research of new technologies.

MN01: *“If and when there is some changes in the NIR spectroscopy technology that can be used and try to convince growers otherwise, it will and should be done.”*

MN02: *“I think maybe what is important for the future is to establish what is different from us to Brazil and those other countries that have implemented NIR spectroscopy.”*

MN03: *“Definitely more interventions with growers, not just the mill groups, finding out what are the gaps and how did they understand it.”*

SP03: *“Yes, because at this current moment, the NIR spectroscopy is only for cane. If they can extend the project, I’m sure they can be able to do it on the diffuser so that it can analyse mix juice that we also get, that will be more accurate compared to how we are doing it now.”*

SP04: *“I would not mind implementing it fully, less equipment problems.”*

NIR spectroscopy comprises four skills pillars: spectroscopy, chemometrics, instrument construction, and analytical chemistry. The pillars simultaneously ensure proper technology use (Pasquini, 2018). The

educational gap in NIR spectroscopy has been noticed. Individuals thus need proper training in all aspects of NIR spectroscopy (Pasquini, 2018).

4.6.2 In your opinion, should SASA consider workshops about NIR spectroscopy?

4.6.2.1 Aim of the question

The question sought to establish if more information on the subject matter is required.

4.6.2.2 Results and Discussion

Table 4-10: In your opinion, should SASA consider workshops about NIR spectroscopy?

Themes	Frequency	Participants
Yes	More than half of the participants	SP01, SP02, SP03, SP04, SP05, MN04, and MN05
No	Two participants	MN02 and MN03
Not sure	One participant	MN01

The participants acknowledged that workshops were organised, but the majority still thought that more workshops should be organised to address all the identified gaps and that the growers should be included in the workshops. Some thought that there was no need for workshops because they had all the information they needed.

SP01: *“Yes, I think they should because NIR spectroscopy is a system that I think is more ideal for SASA.”*

SP02: *“Yes, I do think so, especially that they have stopped using it.”*

SP03: *“Yes, we never got the full details and also the whole operation of the process, the benefits of it and how it should operate, we were not fully clear on the whole process.”*

SP04: *“They should. If they still want to continue with it, but for everything to go or to be implemented, I think the growers need to also kind of understand it.”*

SP05: *“Yes, awareness should be created to ensure that all staff understand how it works and address other concerns they may have regarding the technology.”*

MN01: *“We have a presentation that we have sent out and sort of present it to our relevant parties on the work that we have done. I do not know now whether anything further can be done because that same presentation goes through our Cane Testing Services committee and via SASA Council.”*

MN02: *“At this stage, no, we have lot of information but it’s not useful because we are not using it.”*

MN03: *“No, they understand it, it’s driven by the financial point. It’s stats so they do not understand that it could be plus or minus, there are outliers because it is reflectance scans.”*

4.7 Summary

This chapter presented and discussed the researcher’s key findings on the challenges of implementing and using NIR spectroscopy at CTS. Thematic analysis and interpretation of the pragmatic results were employed in this chapter. The participants indicated that organisational and environmental factors brought about challenges in the implementation of NIR spectroscopy.

Chapter Five focuses on a summary of the study and recommendations for future research.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The results and findings of the study were discussed in Chapter Four. These results responded to the study's research objectives. Chapter Five outlines the conclusion, recommendations, and limitations of the study. The researcher discusses the implications for future research. Lastly, Chapter Five provides an indication of whether the collected data and findings shed light on the research problem stipulated in Chapter One, and crucially if the study answered the research questions.

5.2 Conclusions

The study had four objectives, namely, to provide an overview of NIR spectroscopy functioning, to investigate the challenges in introducing NIR spectroscopy at CTS, to measure the extent of these challenges' effects on NIR spectroscopy at CTS, and to recommend how to address the challenges.

The study was qualitative and used structured interviews to collect data. The participants indicated that NIR spectroscopy is a very fast and efficient technology. Overall, the findings of the study indicated that the participants appreciated the NIR spectroscopy itself as it presented cost and time savings and environmental benefits. However, NIR spectroscopy is not entirely advantageous as it could lead to job losses. New technology adoption at CTS must therefore focus on reskilling and training employees.

Most challenges revealed by the study can be addressed through the proper introduction of technology at CTS. Moreover, the study revealed that as NIR spectroscopy is emerging in the sugar industry at large, CTS cannot do away with it.

In conclusion, based on the researcher's observations, the research questions were answered, and the aim of the study was realised. However, the discoveries of the study are the tip of the iceberg.

5.3 Recommendations

These recommendations are based on the key research findings. In relation to the key research findings acknowledged from this study regarding the challenges of NIR spectroscopy at CTS, the following is recommended:

5.3.1 Demographics of the research participants

SASA is commended for their employment equity. From the participants, it was observed that there is a balance of genders in management. All the participants have been with the organisation for several years.

Training employees is crucial for SASA employees to understand technology design, change management, and technology acceptance.

5.3.2 How does NIR spectroscopy work?

The findings suggested that the participants understood how NIR spectroscopy works. The participants indicated that it is faster and more efficient than conventional methods. Building up preparatory techniques from the beginning is highly advised so that subsequent samples may be measured more carefully (Zhang et al., 2018). The participants argued that it was easy to use NIR spectroscopy and the monitoring process at CTS. It is recommended that managers are taught the actual calibrations and analytical side of NIR spectroscopy, as they mentioned that they depended on external people to update the calibrations.

The participants also mentioned that the approval process took longer than anticipated. This is because of how CTS works. CTS services various boards of millers and growers. It is recommended that there should be a working committee responsible for NIR spectroscopy that meets regularly. The committee should be able to make decisions so that NIR spectroscopy can be implemented effectively. Committee members from all parties involved should be well trained on NIR spectroscopy functioning.

5.3.3 What are the challenges faced by CTS management in the introduction of NIR spectroscopy?

The participants indicated that they were challenged by NIR spectroscopy being a secondary method. It is recommended that training is provided for the managers as this is how the secondary method works. CTS should develop a broader and larger library to allow for accurate results.

The participants mentioned that the South African sugarcane payment method is considered one of the best methods worldwide. It is recommended that CTS works hard to ensure that NIR spectroscopy works to its best ability as it is secondary to the best primary method.

The findings also revealed that setting up the actual instrument in terms of design was challenging. The participants argued that it took a great deal of work and time to set up the NIR spectroscopy in the plant. A proper implementation plan with a timeframe is recommended for any new technology or innovation to avoid frustration.

Corporate-context communication procedures can also foster or stifle creativity. Poor communication occurred regarding how decisions were made and how decisions were communicated to individuals. This led to more challenges whereby employees feared change and feared for their jobs. CTS must have a proper technology implementation plan or policy, so that employees do not fear moving with the times

and new innovations. The participants indicated that workshops were conducted, but the challenges experienced were beyond the workshop scope.

Top management can encourage innovation by establishing an organisational environment that embraces change and is supportive of innovations that advance the company's basic goal and vision. Among top management's required leadership behaviours and communication techniques are outlining how innovation fits into the organisation's overall strategy, stressing its significance to subordinates, rewarding innovation both formally and informally, highlighting the firm's history of innovation, and assembling a capable executive team that can paint a compelling picture of the organisation's future (Justino et al., 2022). Slack and size are two of the most-raised aspects of the organisational setting that influence creativity. Slack and size are also topics of extensive research, although there is no clear evidence of the link to creativity. The relationship between size and innovation cannot be proved. Scholars recommend using more precise measurements of organisational characteristics rather than only generic measures (Justino et al., 2022).

5.3.4 To what extent do these challenges affect the implementation of NIR spectroscopy?

The findings indicated that NIR spectroscopy has been withdrawn at CTS, as the results were not the same as the primary method. According to the SMRI, the South African sugar industry is one of the lowest-cost producers in the world and is a strategically significant agro-processing sector in South Africa.

For various reasons, the sugar industry is mature and is exhibiting indications of decline, including increased production costs (sugarcane and factory), loss of expertise, tariffs on sugar-containing beverages, and dumped cheap imported sugar. The industry is contending with an evolving and increasingly competitive economy. Disruptive and potentially game-changing technologies will be required to bring about the crucial shift for the sector to stay competitive and sustainable in the future. It is recommended that CTS reviews its decision to terminate using the NIR spectroscopy method as a lot of money was invested in NIR spectroscopy. In addition, the method offers cost savings, time, health, and environmental benefits.

Most participants believed that cost savings would come from job redundancies. It is recommended that SASA develops a plan to reskill people as technology is already available for the industry to move with the times. Untrained workers have a negative impact on business (Erkutlu & Chafra, 2020). In addition, the technology itself produced what it was intended to produce. SASA must therefore find ways to work around results interpretation, which include statistical calculations within acceptable confidence levels. Rapid technological progress affects workforce development in two ways (Ra et al., 2019). Firstly, the need for specialised abilities is probably changing faster and subsequently resulting in a shorter shelf life for skills. It will be necessary to be able to unlearn old technologies and practices and learn new

ones to adapt properly to disruptions caused by technological breakthroughs. In other words, new technology itself can provide a remedy for the problems it creates.

Secondly, creativity in the workplace is essential for adapting to changing needs and utilising technology to its fullest potential. Since employees now and in the future are affected by exponential technology breakthroughs, learning must be ongoing and pursued by all participants. Furthermore, the current educational systems are insufficient for fostering continual learning. It is necessary to establish a learning society.

SASA should also learn from other sugar industries, such as in Brazil. In Brazil, brix and polarisation analysis in extracted juice and brix, polarisation, and prepared sugarcane fibre determinations are used to measure sugarcane quality indicators to determine the payment provided to producers. In addition, Indonesia found it essential to develop efficient and trustworthy techniques to analyse all samples. NIR spectroscopy technology was found to be the best alternative to the traditional analytical approach (Kuswurjanto, 2019). Both Brazil and Indonesia are already using the NIR spectroscopy to determine polarisation in sugarcane for payment purposes (Kuswurjanto & Wening, 2019).

5.4 Implications for further research

Considering the findings presented, the environmental and organisational aspects of the implementation of NIR spectroscopy were observed as being crucial, notwithstanding the technological challenges. Consequently, SASA should draw upon the TOE framework theoretical lens to identify the challenges of NIR spectroscopy implementation in the organisational context (Ganguly, 2022). Further study can be undertaken to assess the growers' understanding of NIR spectroscopy implementation, and a comparison can be made. It will be interesting to observe the actual TOE framework used by SASA. TOE framework advances, which have been labelled radical, involve substantial deviations from existing technology or procedures. A regulated adoption rate is permitted in sectors where technology advancements result in gradual and even synthetic change. Businesses must respond swiftly and decisively to adopt new technologies in discontinuous-change sectors if they want to preserve and improve their competitiveness. Firms must consider whether technology is competence enhancing or competence destroying when assessing its potential to bring about discontinuous change. While competence-destroying breakthroughs render many existing technologies and several forms of knowledge outdated, competence-enhancing innovations allow businesses to progressively transition as they build on their expertise (Justino et al., 2022).

REFERENCES

- AFARA, I.O., SHAIKH, R., NIPPOLAINEN, E., QUERIDO, W., TORNIANEN, J., SARIN, J.K., KANDEL, S., PLESHKO, N. & TOYRAS, J. 2021. Characterization of connective tissues using near-infrared spectroscopy and imaging. *Natural Protocols*, 16:1297-1329.
- ANASTAS, J.W. 2004. Quality in qualitative evaluation: Issues and possible answers. *Research on Social Work Practice*, 14(1):57-65.
- ASSARROUDI, A., NABAVI, F.H., ARMAT, M.R., EBADI, A. & VAISMORADI, M. 2018. Directed qualitative content analysis: The description and elaboration of its underpinning methods and data analysis process. *Journal of Research in Nursing*, 23(1):42-55.
- BAKER, J. 2011. The technology–organization–environment framework. In: Dwivedi, Y.K., Scott, L.M. & Schneberger, L. (Eds.). *Information Systems Theory: Explaining and Predicting Our Digital Society*. Hamburg: University of Hamburg. pp. 232-243.
- BARRA, I., HAEFELE, S.M., SAKRABANI, R. & KEBEDE, F. 2021. Soil spectroscopy with the use of chemometrics, machine learning and pre-processing techniques in soil diagnosis: Recent advances – A review. *Trends in Analytical Chemistry*, 135:116166. Available at: <https://dspace.lib.cranfield.ac.uk/handle/1826/16207>.
- BORGMAN, H.P., BAHLI, B., HEIER, H. & SCHEWSKI, F. 2013. *Cloudrise: Exploring cloud computing adoption and governance with the TOE framework*. Paper presented at the 46th Hawaii International Conference on System Sciences, Maui, Hawaii, 7-10 January. Available at: [https://www.scirp.org/\(S\(lz5mqp453edsnp55rrgct55.\)\)/reference/referencespapers.aspx?referenceid=2396262](https://www.scirp.org/(S(lz5mqp453edsnp55rrgct55.))/reference/referencespapers.aspx?referenceid=2396262).
- BOUGIE, R. & SEKARAN, U. 2019. *Research Methods for Business: A Skill-Building Approach*. New Jersey: John Wiley & Sons.
- BRAITHWAITE, K.S., TOM, L. & KUNIATA, L.S. 2019. Planthopper transmission of Ramu Stunt Virus, a tenuivirus causing the sugarcane disease Ramu Stunt, and its distribution in Papua New Guinea. *Plant Disease*, 103(10):2527-2535.
- CARDOZO, N.P., DE OLIVEIRA BORDONAL, R. & LA SCALA, N. 2018. Sustainable intensification of sugarcane production under irrigation systems, considering climate interactions and agricultural efficiency. *Journal of Cleaner Production*, 204:861-871.
- CASTLEBERRY, A. & NOLEN, A. 2018. Thematic analysis of qualitative research data: Is it as easy as it sounds? *Currents in Pharmacy Teaching and Learning*, 10:807-815.
- CHERUBIN, M.R., CARVALHO, J.L.N., CERRI, C.E.P., NOGUEIRA, L.A.H., SOUZA, G.M. & CANTARELLA, H. 2021. Land use and management effects on sustainable sugarcane-derived bioenergy. *Land*, 10(1):72 (24 pages). Available at: <https://www.mdpi.com/2073-445X/10/1/72>.

- CHIMENTO-DÍAZ, S., SÁNCHEZ-GARCÍA, P., FRANCO-ANTONIO, C., SANTANO-MOGENA, E., ESPINO-TATO, I. & CORDOVILLA-GUARDIA, S. 2022. Factors associated with the acceptance of new technologies for ageing in place by people over 64 years of age. *International Journal of Environmental Research and Public Health*, 19(5):2947. Available at: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8910177/>.
- DANIEL, B.K. 2019. Using the TACT framework to learn the principles of rigour in qualitative research. *The Electronic Journal of Business Research Methods*, 17(3):118-129.
- DA SILVA MELO, B.H., SALES, R.F., DA SILVA BASTOS FILHO, L., DA SILVA, J.S.P., DE ALMEIDA SOUSA, A.G.C., PEIXOTO, D.M.C. & PIMENTEL, M.F. 2022. Handheld near infrared spectrometer and machine learning methods applied to the monitoring of multiple process stages in industrial sugar production. *Journal of Food Chemistry*, 369:130919. Available at: <https://pubmed.ncbi.nlm.nih.gov/34461514/>.
- DE CAMARGO, M.S., BEZERRA, B.K.L., HOLANDA, L., OLIVEIRA, A., VITTI, A.C. & SILVA, M.A. 2019. Silicon fertilization improves physiological responses in sugarcane cultivars grown under water deficit. *Journal of Soil Science and Plant Nutrition*, 19(1):81-91.
- DE MATOS, M., SANTOS, F. AND EICHLER, P., 2020. Sugarcane world scenario. In *Sugarcane biorefinery, technology and perspectives* (pp. 1-19). Academic Press
- DOORASAMY, M. 2019. Material Flow Cost Accounting Practices and Resource Efficiencies in South African Sugar Industry. Doctoral Thesis. Durban: University of KwaZulu-Natal.
- DOS SANTOS, C.A.T., LOPO, M., PÁSCOA, R.N. & LOPES, J.A. 2013. A review on the applications of portable near-infrared spectrometers in the agro-food industry. *Applied Spectroscopy*, 67(11):1215-1233.
- DUBB, A. J. 2017. Interrogating the logic of accumulation in the sugar sector in Southern Africa. *Journal of Southern African Studies*, 43(3):471-499.
- EILU, E. 2018. Adoption of electronic fiscal devices (EFDs) for value-added tax (VAT) collection in Kenya and Tanzania: A systematic review. *The African Journal of Information and Communication (AJIC)*, 22:111-134.
- ERKUTLU, H. & CHAFRA, J. 2020. Impact of technology in organizations. *Journal of Organizational Psychology and Behavior*, 2(1):107-111.
- EVANS, D.L. & JOSHI, S.V. 2020. Origins, history and molecular characterization of creole cane. *BioRxiv*, 30 July. Available at: <https://www.biorxiv.org/content/10.1101/2020.07.29.226852v1>.
- FINGER, R., SWINTON, S.M., EL BENNI, N. & WALTER, A. 2019. Precision farming at the nexus of agricultural production and the environment. *Annual Review of Resource Economics*, 11:313-335.
- GANGULY, K.K. 2022. Understanding the challenges of the adoption of blockchain technology in the logistics sector: The TOE framework. *Technology Analysis & Strategic Management*, 11

- February:1-15. Available at: <https://www.tandfonline.com/doi/full/10.1080/09537325.2022.2036333?scroll=top&needAccess=true&role=tab>.
- GONÇALVES, M.T.V., MOROTA, G., DE ALMEIDA COSTA, P., VIDIGAL, P.M.P., BARBOSA, M.H.P. & PETERNELLI, L.A. 2021. Near-infrared spectroscopy outperforms genomics for predicting sugarcane feedstock quality traits. *PLOS ONE*, 16(3):e0236853. Available at: <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0236853>.
- HAGENDORFF, T. 2020. The ethics of AI ethics: An evaluation of guidelines. *Minds and Machines*, 30:99-120.
- HAYASHI JR, P., ABIB, G. & HOPPEN, N. 2019. Validity in qualitative research: A processual approach. *The Qualitative Report*, 24:98-112.
- HUMBLE, A. & RADINA, M.E. 2019. *How Qualitative Data Analysis Happens*. New York: Routledge.
- JENSEN, T., BAILLIE, C., BRAMLEY, R., DI BELLA, L., WHITEING, C. & DAVIS, R. 2010. Assessment of sugarcane yield monitoring technology for precision agriculture. In: *Proceedings of the 32nd Annual Conference of the Australian Society of Sugar Cane Technologists (ASSCT 2010)*. Brisbane: Publishing Project Management. pp. 410-423.
- JUSTINO, M., TENGEH, R. & TWUM-DARKO, M. 2022. A revised technology-organisation-environment framework for brick-and-mortar retailers adopting M-commerce. *Journal of Risk and Financial Management*, 15(7):289. Available at: <https://www.mdpi.com/1911-8074/15/7/289>.
- KAWULA, N. 2019. Farmers' Perceptions and Attitudes to Technology Adoption in the Ugu District of KwaZulu-Natal, South Africa. Master's Thesis. Durban: University of KwaZulu-Natal.
- KONG, Q., KURIYAN, K., SHAH, N. & GUO, M.J. 2019. Development of a responsive optimisation framework for decision-making in precision agriculture. *Computers & Chemical Engineering*, 131:106585. Available at: <https://www.sciencedirect.com/science/article/abs/pii/S0098135419305952>.
- KUMARI, SNEHA & KUMBHAR -PATKAR, VIDYA & PATIL, YOGESH. 2017. Measuring the Impact of Technology Trends and Forecasts in Sugar Industry Towards Sustainable Health-Care Services. *Indian Journal of Public Health Research & Development*. 8. 939. 10.5958/0976-5506.2017.00453.3.
- KUSWURJANTO, R. 2019. Study on application of near infrared (nir) spectroscopy for sugar cane juice analysis to replace conventional analysis methods. *Earth and Environmental Science*, 355:012059. Available at: <https://iopscience.iop.org/article/10.1088/1755-1315/355/1/012059>.
- KUSWURJANTO, R. & WENING, O.P. 2019. Application of near infrared spectroscopy to determine sugarcane quality in core sampler system. In: *Proceeding of the 2nd International Conference on Food and Agriculture*, Vol. 2. Available at: <https://publikasi.polije.ac.id/index.php/ProceedingICOFA/article/view/1857>.

- LAN, W., JAILLAIS, B., LECA, A., RENARD, C.M.G.C. & BUREAU, S. 2020. A new application of NIR spectroscopy to describe and predict purees quality from the non-destructive apple measurements. *Food Chemistry*, 310:125944. Available at: <https://pubmed.ncbi.nlm.nih.gov/31835215/>.
- LESTER, J.N., CHO, Y. & LOCHMILLER, C.R. 2020. Learning to do qualitative data analysis: A starting point. *Human Resource Development Review*, 19:94-106.
- MAAMA, H., DOORASAMY, M. & RAJARAM, R. 2021. Cleaner production, environmental and economic sustainability of production firms in South Africa. *Journal of Cleaner Production*, 298:126707. Available at: <https://www.sciencedirect.com/science/article/abs/pii/S0959652621009276>.
- MARTÍNEZ-ROS, E. 2019. Revisiting product and process innovations. *International Journal of Business Environment*, 10(3):270-280.
- MARZO, C., DÍAZ, A.B., CARO, I. & BLANDINO, A. 2019. Status and perspectives in bioethanol production from sugar beet. In: Ray, R.C. & Rmachandran, S. (Eds.). *Bioethanol Production from Food Crops*. London: Academic Press. pp. 61-79.
- MEKONNEN, M.M., ROMANELLI, T.L., RAY, C., HOEKSTRA, A.Y., LISKA, A.J. & NEALE, C.M.U. 2018. Water, energy, and carbon footprints of bioethanol from the US and Brazil. *Environmental Science & Technology*, 52:14508-14518.
- MEZA-PALACIOS, R., AGUILAR-LASSERRE, A.A., MORALES-MENDOZA, L.F., PÉREZ-GALLARDO, J.R., RICO-CONTRERAS, J.O. & AVARADO-LASSMAN, A. 2019. Life cycle assessment of cane sugar production: The environmental contribution to human health, climate change, ecosystem quality and resources in México. *Journal of Environmental Science and Health*, 54:668-678.
- MLEKUS, L., BENTLER, D., PARUZEL, A., KATO-BEIDERWIEDEN, A.-L. & MAIER, G.W. 2020. How to raise technology acceptance: User experience characteristics as technology-inherent determinants. *Gruppe. Interaktion. Organisation. Zeitschrift für Angewandte Organisationspsychologie (GIO)*, 51:273-283.
- MOHAMED, M. 2018. Challenges and benefits of industry 4.0: An overview. *International Journal of Supply and Operations Management*, 5:256-265.
- MONTEIRO, L.A., SENTELHAS, P.C. & PEDRA, G.U. 2018. Assessment of NASA/POWER satellite-based weather system for Brazilian conditions and its impact on sugarcane yield simulation. *International Journal of Climatology*, 38(3):1571-1581.
- MOODLEY, M. 2018. An Investigation to Discover the Various Challenges Faced by Sugarcane Farmers in Kwa-Zulu Natal. Honnours Thesis. Sandton: Independent Institute of Education. Available at: <https://iiespace.iie.ac.za/handle/11622/341>.
- NAPIERKOWSKI, C.M. & PARSONS, R.D. 1995. Diffusion of innovation: Implementing changes in school counselor roles and functions. *The School Counselor*, 42:364-369.

- NASSAJI, H. 2015. *Qualitative and Descriptive Research: Data Type Versus Data Analysis*. London: Sage Publications.
- NAWI, N.M., CHEN, G. & JENSEN, T. 2013. Visible and shortwave near infrared spectroscopy for predicting sugar content of sugarcane based on a cross-sectional scanning method. *Journal of Near Infrared Spectroscopy*, 21:289-297.
- NAWI, N.M., CHEN, G. & JENSEN, T. 2014. In-field measurement and sampling technologies for monitoring quality in the sugarcane industry: A review. *Precision Agriculture*, 15:684-703.
- NDINYA, C.A. 2019. The genetic diversity of popular African leafy vegetables in western Kenya. In: Nandwani, D. (Ed.). *Genetic Diversity in Horticultural Plants*. Cham: Springer. pp. 127-159.
- NOBLE, H. & SMITH, J. 2015. Issues of validity and reliability in qualitative research. *Evidence-Based Nursing*, 18:34-35.
- NOYAKAZA, B. 2019. An evaluation of competitiveness of South African sugar exports. Unpublished MSc Agric thesis, Department of Agriculture and Animal Health, School of Agriculture and Environmental Sciences, University of South Africa.
- NOWELL, L.S., NORRIS, J.M., WHITE, D.E. & MOULES, N.J. 2017. Thematic analysis: Striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods*, 16(1):1609406917733847. Available at: <https://journals.sagepub.com/doi/full/10.1177/1609406917733847>.
- OTTO, M. 2016. *Chemometrics: Statistics and Computer Application in Analytical Chemistry*. Weinheim: John Wiley & Sons.
- PANDEY, P. & PANDEY, M.M. 2021. *Research Methodology Tools and Techniques*. Romania: Bridge Center.
- PASQUINI, C. 2018. Near infrared spectroscopy: A mature analytical technique with new perspectives – A review. *Analytica Chimica Acta*, 1026:8-36.
- PATHIRANA, S. & YARIME, M. 2018. Introducing energy efficient technologies in small- and medium-sized enterprises in the apparel industry: A case study of Sri Lanka. *Journal of Cleaner Production*, 178:247-257.
- PERLO, V., BOTHA, F.C., FURTADO, A., HODGSON-KRATKY, K. & HENRY, R.J. 2020. Metabolic changes in the developing sugarcane culm associated with high yield and early high sugar content. *Plant Direct*, 4:e00276. Available at: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7656173/>.
- PHETPAN, K., UDOMPETAIKUL, V. & SIRISOMBOON, P. 2018. An online visible and near-infrared spectroscopic technique for the real-time evaluation of the soluble solids content of sugarcane billets on an elevator conveyor. *Computers and Electronics in Agriculture*, 154:460-466.
- PHUPHAPHUD, A., SAENGPRACHATANARUG, K., POSOM, J., MARAPHUM, K. & TAIRA, E. 2020. Non-destructive and rapid measurement of sugar content in growing cane stalks for

- breeding programmes using visible-near infrared spectroscopy. *Biosystems Engineering*, 197:76-90.
- PITAKASO, R. & SETHANAN, K. 2019. Adaptive large neighborhood search for scheduling sugarcane inbound logistics equipment and machinery under a sharing infield resource system. *Computers and Electronics in Agriculture*, 158:313-325.
- PRICE, R., JOHNSON, M., VIATOR, P., LARSEN, J. & PETERS, A. 2011. Fiber optic yield monitor for a sugarcane harvester. *Transactions of the ASABE*, 54(1):31-39.
- RA, S., SHRESTHA, U., KHATIWADA, S., YOON, S.W. & KWON, K. 2019. The rise of technology and impact on skills. *International Journal of Training Research*, 17:26-40.
- RASHIDI, M.N., BEGUM, R.A., MOKHTAR, M. & PEREIRA, J.J. 2014. The conduct of structured interviews as research implementation method. *Journal of Advanced Research Design*, 1(1):28-34.
- ROSENSTEIN, L.D. 2019. *Research Design and Analysis: A Primer for the Non-Statistician*. Hoboken: John Wiley & Sons.
- ROSS, P.T. & BIBLER ZAIDI, N.L. 2019. Limited by our limitations. *Perspectives on Medical Education*, 8(4):261-264.
- ROSSEL, R.A.V., WALVOORT, D.J.J., MCBRATNEY, A.B. & JANIK, L. 2006. Visible, near infrared, mid infrared or combined diffuse reflectance spectroscopy for simultaneous assessment of various soil properties. *Geoderma*, 131(1-2):59-75.
- ROTIMI, T.D. 2018. Technology transfer in developing countries: Issues and way forward. *International Journal of Innovative Research and Advanced Studies (IJIRAS)*, 5(7). Available at: https://www.academia.edu/37310528/Technology_Transfer_In_Developing_Countries_Issues_And_Way_Forward.
- RUTBERG, S. & BOUIKIDIS, C.D. 2018. Focusing on the fundamentals: A simplistic differentiation between qualitative and quantitative research. *Nephrology Nursing Journal*, 45(2):209-213.
- SALGO, A., NAGY, J. & MIKÓ, É. 1998. Application of near infrared spectroscopy in the sugar industry. *Journal of Near Infrared Spectroscopy*, 6:A101-A106.
- SARTIPI, F. 2020. Diffusion of innovation theory in the realm of environmental construction. *Journal of Construction Materials*, 1:2-4.
- SCHMITT, G., MLADENOW, A., STRAUSS, C. & SCHAFFHAUSER-LINZATTI, M. 2019. Smart contracts and Internet of Things: A qualitative content analysis using the technology-organization-environment framework to identify key-determinants. *Procedia Computer Science*, 160:189-196.
- SEXTON, J., EVERINGHAM, Y., DONALD, D., STAUNTON, S. & WHITE, R. 2018. A comparison of non-linear regression methods for improved on-line near infrared spectroscopic analysis of a sugarcane quality measure. *Journal of Near Infrared Spectroscopy*, 26:297-310.

- SHARABIANI, V.R. & NAZARLOO, A.S. 2019. Prediction of protein content of winter wheat by canopy of near infrared spectroscopy (NIRS), using partial least squares regression (PLSR) and artificial neural network (ANN) models. *Journal of Agricultural Science*, 29(1):43-51.
- SINGH, P. & TIWARI, A.K. 2018. *Sustainable Sugarcane Production*. Florida: CRC Press.
- STATISTA. 2022. *Production of Sugar Cane in South Africa from 2000 to 2022*. Available at: <https://www.statista.com/statistics/1140105/production-of-sugar-cane-in-south-africa/>.
- SOUTH AFRICA. 1978. *The Sugar Act, No. 9 of 1978*. Pretoria: Government Printer.
- SOUTH AFRICAN SUGAR ASSOCIATION (SASA). 2000. *Sugar Industry Agreement, 2000*. Available at: https://sasa.org.za/custom_content/Sugar-Industry-Agreement.pdf.
- SOUTH AFRICAN SUGAR ASSOCIATION (SASA). 2018. *Constitution of the South African Sugar Association*. Available at: https://sasa.org.za/custom_content/Constitution-of-the-South-African-Sugar-Association.pdf.
- SOUTH AFRICAN SUGAR TECHNOLOGISTS ASSOCIATION. 1985. *Laboratory Manual for South African Sugar Factories Including the Officials Methods*. Available at: <https://sasta.co.za/laboratory-manual/>.
- SUGAR MILLING RESEARCH INSTITUTE (SMRI). 2022. *The South African Sugar Industry*. Available at: <https://www.smri.org/sugarfacts/Pages/sasugarindustry.aspx>.
- TADESSE, W., BISHAW, Z. & ASSEFA, S. 2018. Wheat production and breeding in sub-Saharan Africa: Challenges and opportunities in the face of climate change. *International Journal of Climate Change Strategies and Management*, 11(5):696-715.
- TEMBON, M.N.F. 2021. Investigation of the Environmental Impacts of Bioethanol Production: A Case for Ethanol From Sugarcane in KwaZulu-Natal, South Africa. Doctoral Thesis. Pretoria: University of South Africa.
- TENA, E., MEKBIB, F., SHIMELIS, H. & MWADZINGENI, L. 2016. Sugarcane production under smallholder farming systems: Farmers preferred traits, constraints and genetic resources. *Cogent Food and Agriculture*, 2(1):1191323. Available at: <https://www.tandfonline.com/doi/full/10.1080/23311932.2016.1191323>.
- THOMAS, J.R., MARTIN, P., ETNIER, J. & SILVERMAN, S.J. 2022. *Research Methods in Physical Activity*. Illinois: Human Kinetics.
- TOHARISMAN, A.T. 2016. An overview of sugar sector in Indonesia. *Sugar Tech*, 18:636-641.
- TRUONG, D., LIU, R.X. & YU, J. 2020. Mixed methods research in tourism and hospitality journals. *International Journal of Contemporary Hospitality Management*, 32:1563-1579.
- WALFORD, S. 2019. Near infrared spectroscopy: Rethinking the analysis of sugarcane factory streams. In: Engelsen, S.B., Sorensen, K.M. & Van den Berg, F. (Eds.). *Proceedings of the 18th International Conference on Near Infrared Spectroscopy, 2019*. Chichester: IM Publications Open. pp. 129-133.

- WALKER, J.L. 2012. The use of saturation in qualitative research. *Journal of Cardiovascular Nursing*, 22(2):37-46.
- WAY, M.J. & GOEBEL, F.R. 2007. Monitoring *Eldana saccharina* and other anthropod pests in South African sugarcane. *Proceedings of the International Society of Sugar Cane Technologists*, 26:780-786.

- WELKER, C.A., MCKAIN, M.R., VORONTSOVA, M.S., PEICHOTO, M.C. & KELLOGG, E.A. 2019. Plastome phylogenomics of sugarcane and relatives confirms the segregation of the genus *Tripsidium* (Poaceae: Andropogoneae). *Taxon: The Journal of the International Association for Plant Taxonomy*, 68:246-267.
- YANG, Y., ZHANG, X., YIN, J. & YU, X. 2020. Rapid and nondestructive on-site classification method for consumer-grade plastics based on portable NIR spectrometer and machine learning. *Journal of Spectroscopy*, 2020:6631234. Available at: <https://downloads.hindawi.com/journals/jspec/2020/6631234.pdf>.
- YOUNG, D.S. & CASEY, E.A. 2018. An examination of the sufficiency of small qualitative samples. *Social Work Research*, 43:53-58.
- ZEEBAREE, M., SATTAR, S., AQEL, M., QADER, A.N. & ZEBARI, D. 2020. Impact of innovation technology in enhancing organizational management. *Studies of Applied Economics*, 38(4):1183. Available at; <https://ojs.ual.es/ojs/index.php/eea/article/view/3970>.
- ZHANG, Z., LI, H., YUN, Y., MA, P., YI, L., REN, D., ZHANG, L., YAN, J., DONG, N. & DENG, B. & LU, H. 2018. Chemometrics in instrumental analysis of complex systems – In honor and memory of Yi-Zeng Liang. *Journal of Chemometrics*, 32(11):e3095. Available at: <https://analyticalsciencejournals.onlinelibrary.wiley.com/doi/10.1002/cem.3095>.
- ZULU, N.S., SIBANDA, M. & TLALI, B.S. 2019. Factors affecting sugarcane production by small-scale growers in Ndwedwe Local Municipality, South Africa. *Agriculture*, 9(8):1-14.

APPENDICES

Appendix A: Ethical clearance from University of KwaZulu-Natal



18 March 2022

Nozibusiso Pretty Chiliza (200201201)
Grad School Of Bus & Leadership
Westville Campus

Dear NP Chiliza,

Protocol reference number: HSSREC/00003729/2021

Project title: Investigating challenges of Near Infrared Spectroscopy in the Cane Testing Services at South African Sugar Association

Degree: Masters

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 09 December 2021 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL**.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

This approval is valid until 18 March 2023.

To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

All research conducted during the COVID-19 period must adhere to the national and UKZN guidelines.

HSSREC is registered with the South African National Research Ethics Council (REC-040414-040).

Yours sincerely,



Professor Dipane Hlalele (Chair)

/dd

Humanities and Social Sciences Research Ethics Committee

Postal Address: Private Bag X54001, Durban, 4000, South Africa

Telephone: +27 (0)31 260 8350/4557/3587 Email: hssrec@ukzn.ac.za Website: <http://research.ukzn.ac.za/Research-Ethics>

Founding Campuses: ■ Edgewood ■ Howard College ■ Medical School ■ Pietermaritzburg ■ Westville

INSPIRING GREATNESS

Appendix B: South African Sugar Association (SASA) gatekeeper letter



SOUTH AFRICAN SUGAR ASSOCIATION
Kwa-Shukela, 170 Flanders Drive, Mount Edgecombe
P.O. Box 700, Mount Edgecombe, KwaZulu-Natal, 4300
Telephone: +27 31 508 7000
Website: www.sasa.org.za

Nozibusiso Chiliza
200201201
Master of Commerce in Leadership
College of Law and Management Studies
Graduate School of Business & Leadership
University of KwaZulu Natal

RE: GATEKEEPER'S PERMISSION TO CONDUCT RESEARCH

Nozibusiso Chiliza is a Master of Commerce in Leadership student (200201201) at University of KwaZulu Natal and an employee of South African Sugar Association. The ethical clearance is granted as the research study participation will be done with duly informed consent from the participating managers. The title of the research project is: ***"Investigating challenges of Near Infrared Spectroscopy in the Cane Testing Service at the South African Sugar Association."***

The research will be qualitative in nature as data will be collected through structured interviews, company records and peer reviewed journals as the researcher seeks to understand challenges of NIRS in the Cane Testing Service. Therefore, the sampling will be conducted by engaging managers and supervisors at Cane Testing Service. It is further my understanding that all information collected from managers will be done with duly informed consent from the participating individuals, and that participants can refuse participation with no negative consequences, and any input cannot be traced back to participants.

I confirm that I am aware of the methodology that will be used in her research and support the conduct of this research in this organization.

Yours Sincerely

17 May 2021

Seelan Naidoo
Industry Affairs Director
South African Sugar Association

Appendix C: Research interview schedule

Research interview

Schedule

Participant

No.

Section A: Demographic information

1. Gender: Female Male
2. Age: 18–25 26–35 36–45 46–55 56–59
3. How long have you worked for your organisation?
4. What is your current position?

Pseudonym: **Date of interview:**

Section B: Challenges in adopting NIR spectroscopy

1. What was your experience when adopting NIR spectroscopy on your site?
2. What were the challenges?
3. Did these challenges affect plant or employee productivity?
4. What are you doing or have done about those challenges?

Section C: Understanding the functioning of NIR spectroscopy

1. What is your overall understanding of the functioning of NIR spectroscopy?
2. How has NIR spectroscopy changed the way you do things in the plant?
3. What are the significant benefits of using NIR spectroscopy?
4. Based on what you experienced when adopting NIR spectroscopy, would you recommend this technology to someone else?

Section D: Future improvements

1. Are there any improvements relating to NIR spectroscopy that you would like to see happen in the future?
2. In your opinion, should SASA consider workshops about NIR spectroscopy?

Thank you for your participation!

Appendix D: Informed Consent form



Informed Consent Letter 3C

UNIVERSITY OF KWAZULU-NATAL
GRADUATE SCHOOL OF BUSINESS AND LEADERSHIP

Dear Respondent,

Master of Commerce in Leadership Studies (MCLS) Research Project

Researcher: Nozibusiso Chiliza [REDACTED]
Supervisor: Bibi Zaheenah Chummun (+27 31 260 8943)
Research Office: hssrec@ukzn.ac.za (031 3587/4457/8350)

I, Nozibusiso Chiliza an MCLS (Master of Commerce in Leadership Studies) student, at the Graduate School of Business and Leadership, of the University of KwaZulu Natal. You are invited to participate in a research project entitled Investigating challenges of Near Infrared Spectroscopy in the Cane Testing Service at the South African Sugar Association. The aim of this study is to investigate management challenges in introduction of NIRS in the Cane Testing Services at SASA.

Through your participation I hope to understand the challenges in introduction of NIRS. The results of the study are intended to contribute to recommendations that will enable CTS and SASA to understand and overcome any challenges that come with NIRS introduction.

Your participation in this project is voluntary. You may refuse to participate or withdraw from the project at any time with no negative consequence. There will be no monetary gain from participating in this study. Confidentiality and anonymity of records identifying you as a participant will be maintained by the Graduate School of Business and Leadership, UKZN.

If you have any questions or concerns about participating in this study, you may contact me or my supervisor at the numbers listed above.

The interview has only 10 questions should take you about 30 minutes to complete. I request to record the interview session for easy reference. I would like to appreciate and thank you in advance for your interest, time, and support for participating on this project.

Sincerely

Investigator's signature _____ Date _____

This page is to be retained by the participant

UNIVERSITY OF KWAZULU-NATAL
GRADUATE SCHOOL OF BUSINESS AND LEADERSHIP
Master of Commerce in Leadership Studies (MCLS) research project
Researcher: Nozibusiso Chiliza [REDACTED]
Supervisor: Bibi Zaheenah Chummun (+27 31 260 8943)
Research office: hssrec@ukzn.ac.za (031 3587/4457/8350)

CONSENT

I,,
(full name of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participate in the research project.

I understand that I am at liberty to withdraw from the project at any time should I so desire.

SIGNATURE OF PARTICIPANT..... DATE

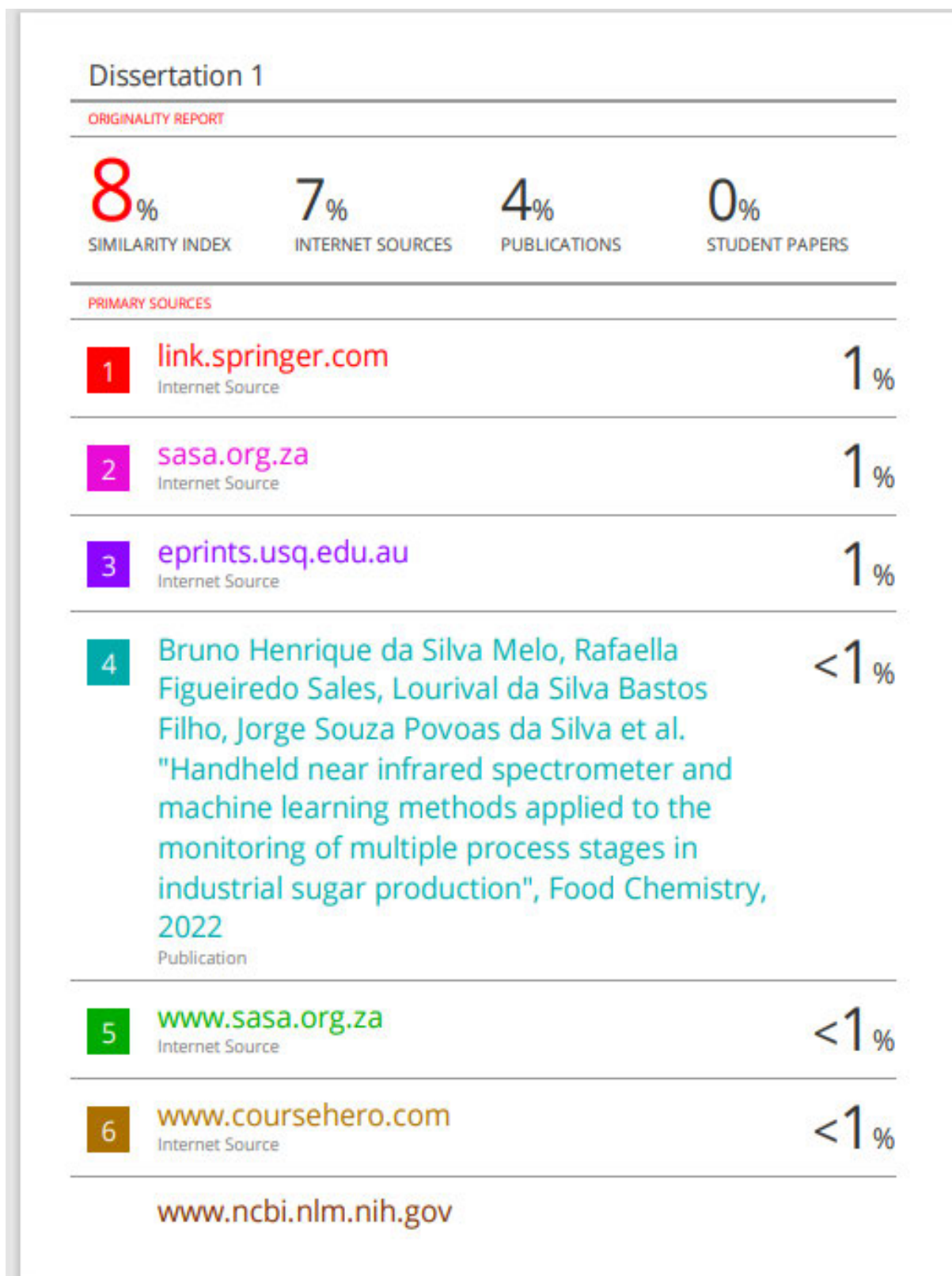
.....

This page is to be retained by the researcher

Appendix E: Participant biographic data

Number	Participant code	Gender	Age range	Number of years at SASA	Current position
1	MN01	Male	46-55	14	Manager
2	MN02	Female	26-35	11	Manager
3	MN03	Male	46-55	23	Manager
4	MN04	Male	46-55	16	Manager
5	MN05	Male	46-55	11	Manager
6	SP01	Female	36-45	13	Supervisor
7	SP02	Female	26-35	6	Supervisor
8	SPO3	Female	26-35	5	Supervisor
9	SP04	Female	36-45	7	Supervisor
10	SP05	Female	36-45	7	Supervisor

Appendix F: Originality report



Appendix G: Proofread letter confirmation



09 February 2023

To whom it may concern

Re: Proofreading and academic editing: N.P. Chiliza

I, J.L. van Aswegen of Grammar Guardians, hereby confirm proofreading and academic editing of the master's thesis entitled "Investigating Challenges of Near Infrared Spectroscopy in the Cane Testing Services at South African Sugar Association" by Nozibusiso Chiliza (student number 200201201) during January 2023. The editor does not accept responsibility for post-editing changes made by the author.

Please contact me on [REDACTED] or at jeanne@grammarguardians.co.za regarding any queries that may arise.

Kind regards,

[REDACTED]
J.L. van Aswegen

Grammar Guardians