Improving Customer Service in South African laboratories using a Laboratory Information Management System.

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DECLARATION

I, Karabo Maloka, thus certify that this research paper is my unique creation except where indicated. During the entire research process, I have complied with all applicable laws, and ethical standards that will enable me to fulfil all the requirements for the degree of Master of Business Administration at the University of the Witwatersrand.

Karabo Maloka

Signed at Bryanston, South Africa.

On the 29th of February 2024

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ABSTRACT

Laboratories are essential to maintaining the highest standards of quality and safety for the different services that the public uses. These services range across various industries from accurately diagnosing diseases, drug safety, research and innovation to food and water quality amongst others. As a result, these laboratories need to ensure that they provide comprehensive services that will adhere to the various crucial demands.

Several studies, such as an article written by Laboratory Equipment Magazine (2018), outline that many laboratories, both in the academic and commercial sectors, still utilise paper-based techniques due to a variety of issues, including cost, complexity, data security, regulatory compliance, and user acceptability. According to Huser and Cimino (2013), one such technology that can be utilised to meet these service needs is a Laboratory Information Management System (LIMS), which offers these laboratories a reliable means of managing their operations and gathering sample findings.

The purpose of this study was to fill the research gap on how South African laboratories might enhance the services they offer to their clients by using a Laboratory Information Management System.

In the context of the South African Laboratory sector, this study presented and evaluated a SERVQUAL model that illustrated the relationship between service quality elements (reliability, responsiveness, assurance, empathy and tangibles) and customer satisfaction. The research questions from the study were addressed using quantitative data through an online distributed questionnaire. Convenience sampling was used in this study to choose a sample of 113 study participants. At the end of the study, only two of the five proposed hypotheses have been supported by the study's results. These results supported the third hypothesis (Assurance) and the fifth hypothesis (Tangibles), which suggests that assurance, tangibles, and customer satisfaction are positively correlated. Based on the components that were used for this study, the results did not demonstrate that a Laboratory Information Management System assists with

improving customer service as only 2 out of the five hypotheses were supported.

This has served as a beneficial starting point to further expand on this research as it can provide much-needed benefits for the South African laboratory community at large.

KEYWORDS: Laboratory Information Management System, LIMS, Customer Service, Laboratories, Customer Satisfaction.

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ABBREVIATIONS

- LIMS – Laboratory Information Management System
- FDA – Food and Drug Administration
- ISO – International Organisation for Standardisation
- SANAS – South African National Accreditation System
- GMP - Good Manufacturing Practice
- GLP - Good Laboratory Practice

CHAPTER 1 - INTRODUCTION

1.1. Background of the study

The purpose of this study is to explore how a Laboratory Information Management System (LIMS) can assist laboratories in South Africa to improve their customer service requirements.

In the modern era, many organisations find themselves in an ever-evolving environment where they need to provide high-quality services through digital systems for them to gain a competitive edge (Delone & McLean, 2003). According to the South African National Accreditation System and National (2023), the South African laboratory industry is quite competitive, as many of these organisations provide similar services within their respective industries.

A large portion of the literature available today highlights that laboratories play a crucial role in the daily lives of many South Africans. In the healthcare sector, an article by Bateman (2018) outlines those clinical and diagnosis laboratories in South Africa play a critical role in researching and diagnosing diseases as well as providing healthcare surveillance. According to The Department of Agriculture, Forestry and Fisheries (2017), the use of soil analysis, crop testing, and pesticide monitoring, in South African laboratories can help to ensure food safety, agricultural production, and environmental sustainability. In environmental and conservation industries, South African laboratories assist in safeguarding South Africa's natural resources, evaluate the quality of the air and water, and assist with conservation initiatives (Department of Environmental Affairs, 2018). According to the Council for Scientific and Industrial Research (2023), industrial, quality control and compliance laboratories play an important role in manufacturing, mining, and energy segments in South Africa. In the scientific research and innovation sector, South African laboratories contribute to innovation and technological advancements in the country (National Research Foundation (NRF), 2023).

In many of these industries, there has been mounting pressure for them to move away from manual, paper-based processes which currently prevent them from providing the best services to their customers as stated by the International Organization for Standardization (2017). Unfortunately, many of these laboratories often operate in environments where their processes are manual (van van Wyk & Gerber, 2015) which in turn affects their turnaround times and credibility. The existing literature on customer satisfaction is extensive and outlines that customer satisfaction is a key factor for organisations to gain a competitive advantage Grigoroudis et al., (2019). This study revealed that customers are always on the lookout for better services and are ready to switch to anyone who can provide better services. Bolton and Ruth (1998) further outline that satisfied customers ensures that organisations become economically viable since the customer retention rate will increase and will require extended usage of their services to continue. Purchasing a laboratory information management system is one method by which labs can obtain a competitive advantage, according to an article by the European Medicines Agency (2016), a laboratory Information Management System is an important asset for laboratories in carrying out testing in a fast and efficient manner.

When computer technology advanced and the demand for effective data administration in laboratories increased in the late 20th century, Laboratory Information Administration Systems (LIMS) began to be used (Shaw & Lewars, 2003). A first-generation LIMS system was introduced in 1982 with limited functionality at the time enabling laboratories to manage their data in a better manner (Gibbon, 1999). In the modern era, modern LIMS applications have developed enhanced features and functionality to align with the ever-changing laboratory, technological and business demands. These functionalities include but are not limited to; automated sample scheduling, sample status tracking, quality control, automated result capture, reporting capabilities as well as being able to display key performance indicators in the form of dashboards (Skobelev, 2011). These functionalities span across various industries, with each industry having more specialised processes and requirements based on their area of specialisation.

A study by Nkomo and Mokgatle (2014), reported that a LIMS can improve laboratory operations by assisting in the management of the laboratory's workflow process which results in a faster and more effective response to their customer's requirements.

1.2. Context of the Study

The context of this study will be around how South African laboratories can make use of a Laboratory Information Management System to improve the services they provide to their customers. The South African National Accreditation System and National (2023) stipulates that the South African laboratory industry consists of a variety of sectors that play a pivotal role in the country, and these include but are not limited to research, water testing, pharmaceuticals, healthcare, agriculture, and environmental monitoring. All these sectors are required to comply with stringent regulatory requirements as well as ensuring the result data that is generated is credible (Mtenzi, 2019). Furthermore, these laboratories play a significant role in supporting quality control and scientific advances in South Africa. This research study focused on a wide range of laboratory industries, and these are outlined below.

Healthcare Diagnostics Industry

South African Healthcare laboratories provide diagnostic services which assist with patient care which includes pathology testing, microbiology, clinical chemistry, haematology, and immunology (Mabotja, 2018). This sector is crucial in identifying and managing diseases and leads to better patient outcomes as well as improved public health (Masebe & Masebe, 2017). As a result, it is important for the testing and results from this sector to be of the highest standards and credibility.

Pharmaceutical and Drug Testing

The South African pharmaceutical laboratories are involved in research, quality control and development of pharmaceutical products for the country (Darkoh & Du Plessis, 2019). These laboratories provide essential services that ensure the

safety, efficacy, and quality of the drugs that are administered are of a high standard.

Environmental and Industrial Testing

South African Environmental and Industrial laboratories are involved in the testing of air, water, soil, and other environmental samples (Laboratory Equipment Magazine, 2018). These laboratories also support environmental monitoring initiatives, and compliance with regulatory standards and ensure that quality control in several industries is adhered to (Pillay & Odume, 2021, p. 2021).

Research and Development

The research and development laboratories in South Africa provide essential services which contribute to the country's scientific advancements as well as various innovation initiatives (Seodigeng et al., 2021). Unfortunately, research by Pillay et al., (2014) revealed that many of these laboratories in South Africa are still paper based in their operations and struggle to transition to electronic means of performing their daily operations. This revelation poses a major risk for these laboratories as they have the potential to not be able to provide reliable and impactful services to their customers.

1.3. Research Problem

South African laboratories face varying amounts of pressure when it comes to customer satisfaction (Anderson, 2008). Many of these customer satisfaction traits are based on operational deficiencies, poor infrastructure, and skilled staff. In addition to this, prior research conducted by Mulaudzi (2020) found that poor customer service in South African laboratories was a result of long turnaround times, limited access to information, error-prone results as well as inefficient communication.

Further research has also highlighted that laboratories in developed nations have improved their customer satisfaction requirements through the

implementation of a Laboratory Information Management System (Mtenzi, 2019). This study uncovered that developing countries struggle with limited resources such as IT infrastructure and expertise needed to implement a Laboratory Information Management System which is a major deficiency for them. This poses a major concern as some authors have outlined that not having a LIMS to manage the laboratory operations poses a risk to the reliability of the data that they send to their customers (LabWare, 2023).

South African laboratories may encounter challenges in meeting international regulatory standards, particularly in pharmaceutical testing and clinical trials, due to the lack of automated systems for ensuring compliance. The reliance on manual data entry in these labs increases the likelihood of errors, potentially leading to unreliable results and compromised data integrity (Makhubele, 2022). Similar issues are prevalent in many sub-Saharan African laboratories, where limited access to LIMS contributes to high error rates, inefficient resource management, and difficulties in maintaining regulatory compliance (Moss, 2020). In contrast, developing nations such as Brazil and India have made progress in adopting LIMS, which has enhanced their laboratory operations (Gupta & Kumar, 2021). In developed countries, LIMS is widely implemented, resulting in high levels of efficiency, accuracy, and compliance. These nations often leverage advanced LIMS features, including automation and AI integration, to further improve data management and laboratory productivity (Smith & Jones, 2019).

Significant advancements in Laboratory Information Management Systems (LIMS) technology have been made since the onset of COVID-19, alongside changes in laboratory customer satisfaction trends. Agaram Technologies (2024) highlighted that the pandemic led to the integration of artificial intelligence (AI) and automation into LIMS to meet the increased demand for faster data processing and analysis. Furthermore, recent technological developments have resulted in LIMS with mobile accessibility and more user-friendly interfaces, allowing laboratory staff to manage tasks and access data remotely, a capability that became particularly valuable as remote work gained popularity during the pandemic. These advancements have made data

management more efficient, enabling laboratories to handle large volumes of data with minimal manual intervention (Agaram Technologies, 2024).

With their ability to provide complete solutions for sample tracking, data administration, and workflow automation, Laboratory Information Management Systems (LIMS) are essential to contemporary laboratory operations (Miliard, 2018). Although the introduction of LIMS has been linked to increased productivity and data integrity, there is still a big gap regarding how LIMS implementations specifically benefit customer satisfaction in laboratory settings (Jones & White, 2020).

The actionable findings of this research could unearth how resource-constrained laboratories could prioritise putting LIMS modules in place that deal with their most urgent problems, such as sample tracking and data management, and then progressively add more sophisticated features like automation and artificial intelligence (Smith & Jones, 2019). Other opportunities from these findings could outline how robust capability is available on certain open-source LIMS platforms for a far lower price than on proprietary ones. By tailoring these systems to their unique requirements, laboratories can lessen their need on pricey proprietary software (Moss, 2020).

By examining the relationship between LIMS usage and customer satisfaction, identifying critical variables that affect customer satisfaction in the context of LIMS usage, and suggesting tactics for utilising LIMS to raise overall customer satisfaction in laboratories, this research seeks to close this knowledge gap.

1.4. Research Objectives

For this study, these research objectives have been determined.

1. To investigate the extent to which the Reliability of a Laboratory Information Management System (LIMS) influences customer satisfaction for South African Laboratories.
2. To determine how the Responsiveness of a Laboratory Information Management System (LIMS) impacts customer satisfaction for South African Laboratories.
3. To examine how the Assurance of a Laboratory Information Management System (LIMS) influences customer satisfaction for South African Laboratories.
4. To determine how Empathy in a Laboratory Information Management System (LIMS) impacts customer satisfaction for South African laboratories.
5. To determine the influence of Tangibles of a Laboratory Information Management System influence customer satisfaction for South African laboratories.

1.5. Research Questions

For this study, these research questions have been identified.

1. How does the Reliability of a Laboratory Information Management System (LIMS) influence customer satisfaction for South African Laboratories?
2. How does the Responsiveness of a Laboratory Information Management System (LIMS) influence customer satisfaction for South African Laboratories?
3. How does the Assurance of a Laboratory Information Management System (LIMS) influence customer satisfaction for South African Laboratories?
4. How does Empathy in a Laboratory Information Management System (LIMS) influence customer satisfaction for South African laboratories?

5. How do the Tangibles of a Laboratory Information Management System (LIMS) influence customer satisfaction for South African laboratories?

1.6. Rationale

The outcome of the research questions in this paper will outline how a Laboratory Management Information System can be used to ensure that customer service in laboratories is of the highest standard. Not only will this study uncover how laboratories can become successful in streamlining their operations, but it will also expose how they can service their customers rapidly and efficiently.

These good and timely services to their customers will ensure that they can meet their objectives in a timely and effective manner as well. These effects will ensure that South African laboratories are a credible and reliable source of valuable information and can compete not only with the local industry but the global one at large as well. The impact of not having a Laboratory Information Management System will result in South African laboratories not being compliant with global regulations and provision of unreliable services which harm customer perception and preference.
This research will aid in contributing to the continued discussion, especially for developing countries globally.

1.7. Delimitations

This study employed a deductive quantitative research approach. To create a representative sample, data was gathered from South African laboratory industry workers who were 18 years of age or older across the country. A survey questionnaire was developed and incorporated the dimensions of the SERVQUAL framework. This anonymous questionnaire consisted of a 5-point Likert scale with measuring items based on prior research for obtaining the data. Emails, LinkedIn, and WhatsApp were used to distribute the link to the survey, which was hosted on Qualtrics. For the data analysis and hypothesis testing component, IBM SPSS Amos, SPSS, as well as Structural Equation

Modelling (SEM) software were utilised. The amount of time available for data gathering and analysis posed a restriction on this study.

1.8. Definition of terms

The operational definitions outlined below are in the context of customer service using a Laboratory Information Management System.

1.8.1. Concepts Related to Customer Service in Laboratories.

According to Oliver (1997), the degree to which a company's goods or services either match or exceed the expectations of its clients is known as customer satisfaction. It is a crucial sign of client loyalty and the possibility of recurring business. Customer satisfaction is seen as an important factor for laboratories to succeed (Fondoh, 2020). The study also outlined that a high level of quality will need to be demonstrated to assist these laboratories in remaining competitive. This study focused on a clinical laboratory in Cameroon where the clinicians in this case are the customers of the laboratory. What this ultimately outlined is that long wait times for receiving results are deemed as bad customer service.

Information Data Silos

Most of the work performed by laboratories concerns the production of laboratory results. Oftentimes, laboratories consist of several departments each tasked with performing specific requirements that will be filtered down to the results that will be provided to their respective customers. The relationship between all these departments is an important part of the service provided to customers as these need to be in sync regarding the resulting output (Chorghay & Profile, 2023).

According to Chorghay and Profile (2023), the challenge faced by most laboratories is that these lab departments are bombarded with large amounts of data that often results in scattered information that cannot be accessed quickly and easily. The laboratory staff will most likely have to take a long time to gather

information manually and be faced with information that is scattered and not available in real time. The other issue that is often faced as well is that due to this scattered information, it is difficult to find the root cause of various issues that are associated with laboratory data (Chorghay & Profile, 2023).

Providing a good service to customers requires the laboratory to have information available in real-time where data across all the lab departments is unified and transparent for ease of use. This will be done through a good issue-tracking system that will be able to monitor these issues and allow the lab to reduce the response time for these. If a laboratory can proactively manage the issues that face, they will be able to provide proactive customer service. This will allow the laboratories to focus on their day-to-day activities which in turn will result in quicker turnaround times for issuing results to their customers.

Quality Management as a concept of customer service

One measure used for ensuring that a laboratory can fulfil the requirements of quality management, they need to be audited. An audit ensures that certain compliance and accreditation requirements are fulfilled. In the laboratory space, a standard version of measuring quality standards for laboratories is the ISO 17025 Standard. The concept of laboratory accreditation is seen as an important factor in ensuring that quality management is upheld across various organisations. Modern laboratories face many challenges that put pressure on them to remain viable and competitive. As a result, these laboratories need to find new and modern ways of operating that will ensure they can deliver quality services to their customers (Chorghay & Profile, 2023).

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Obtaining accreditation is one such method that laboratories can use to ensure their products are of the appropriate local and global standards. This is where the ISO 17025 standard comes into play. ISO 17025 is a global standard used to measure quality requirements and reliability of results for testing laboratories across the globe, including South Africa. According to a study conducted by Maphumulo and Bhengu (2019), it was revealed that South African laboratories lack adequate quality improvement programs especially post-apartheid. This is due to several reasons and resource constraints, but it ultimately means that

the laboratories are not meeting their quality objectives which is a risk for their customer satisfaction needs.

1.8.2. Laboratory Information Management System as a Concept of Customer Satisfaction

A Laboratory Information Management System mostly referred to as “LIMS”, is a software system that offers laboratories a modern way of managing their day-to-day operational activities (Wadhwa & Kapoor, 2019).

It wasn't until the 1970s that laboratory samples were managed in a very time-consuming and highly manual process. These manual processes often result in samples that are processed late or are faced with a lot of transcription errors regarding the data that is produced. This revelation pushed organisations to find solutions that would streamline their processes and resulted in them creating in-house customised solutions to bridge this gap. Other organisations looked at reaching out for commercial off-the-shelf solutions as well (Gibbon, 1999).

At this point, the first-generation Laboratory Information System came out in 1982 with limited features, including reporting functionality. Then around 1988, the second generation of LIMS systems arrived with relational database capabilities being included to make sure that data is handled more effectively (Gibbon, 1999). The third generation of LIMS came out around the early 1990s with advancements in computing. By 2012 the LIMS software had evolved significantly with more features and an increase in cloud and software as a service (Gibbon, 1999).

The Organisational learning theory is observed when getting more information regarding the features of a Laboratory Information Management System. One of the key features of the system is that it fosters a culture of knowledge-sharing within the organisation. Due to the continuous improvements in the system, it will allow a culture of lifelong learning to take place in the organisation.

LIMS Features and Functionality

Since its inception, there have been several organisations that produce LIMS software. As a result, the industry has become quite competitive which has forced these organisations to implement more and more functionality that will

allow them to remain competitive. Despite these many variations, there remain a few basic features that a Laboratory Information Management System can and should do (Skobelev, 2011).

The few basic features that can be found in most LIMS software are outlined below:

1. Sample Management

One of the main features and advantages of having a LIMS is with regards to its ability to assist with the management of samples. The process usually begins when samples are received in the laboratory from various sources. All the information related to the sample is registered and captured in the LIMS. Throughout the sampling process, the LIMS can perform a full chain of custody of the sample. In other words, it will be able to track when and who registered the sample, and which other location or section it was sent to for testing, it then results in entry status and final review until the reporting of the results (Skobelev, 2011).

2. Instrument Integration

Most modern LIMS software has the capability of integration with laboratory instruments. Laboratories use these instruments to test samples and obtain results from the machines. Laboratories that do not have a LIMS often have to use paper-based methods of capturing this information which poses large amounts of risk when it comes to data integrity and transcription errors. The LIMS interface to these instruments removes this risk by automating that process so that the results will go directly to the LIMS system after processing by the lab analyst (Khan & Findlay, 2010).

3. Compliance Readiness

A modern LIMS provides laboratories with several features that can assist them with compliance with regulatory bodies. The International Organisation for Standardisation is an independent organisation that develops standards across various industries which cover a range of functional areas such as technology and management systems among others International Organization for Standardization (2023). These standards consist of specifications that enforce quality and consistency across the board.

4. Customer Relationship Management

The ability of laboratories to keep a good relationship with their customers is a key part of ensuring that they are sustainable and competitive. The LIMS system will assist laboratories by making sure that all communication with the customer is recorded (Sepulveda & Young, 2013). The LIMS system can manage a list of the customer's contacts, send reports and invoices, and communicate via email.

1.9. Structure of the dissertation

This paper consists of the following structure:

- The first part of the paper will be the premise of the research study. This chapter will detail the background regarding why this study is being conducted. This will also include justification related to who this research will benefit in the end.
- The second part of this paper will focus on the critical literature review of the study. It will position South African Laboratories regarding how their customer service requirements are impacted by not having a Laboratory Information Management System.
- The third part of this paper will highlight how the data will be collected for this study as well as how the methods used will be justified.
- The fourth part of this study will focus on the data collection which will serve as the premise of answering the research questions that have been outlined in the paper.
- The fifth section of the paper will address whether the results adequately address the study questions when the data collection is finished.
- The final section of this paper (the 6th part) will provide conclusions and recommendations which are evidence-based.

CHAPTER 2 - LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1. Introduction

This chapter will focus on the research gaps that are based on how a Laboratory information management system can assist laboratories to improve their customer satisfaction requirements. The review will begin with an analysis of the concepts relating to customer satisfaction in laboratories. The next part of the review will uncover the conceptual framework of the study. It will begin with a discussion of concepts around a Laboratory Information Management System for South African laboratories. This will be followed by an overview of the benefits surrounding having a Laboratory Information Management System The concepts discussed in the introduction will then confirm that a Laboratory Information Management System will be able to improve customer satisfaction in South African laboratories.

2.2. Empirical Review of Literature

What has been outlined from the study is that a Laboratory Information Management System is a crucial tool that laboratories can use to improve their customer service.

The following synthesis is arranged in accordance with the themes that surfaced from the publications that were selected for further examination and subjected to a systematic review. Below is a table that summarises the conclusions drawn from the data extraction.

Table 2.1 Summary of Review of Literature

Theme	References	Research Gap
Efficiency and automation	(Shaw & Petzold, 2014)	More investigation might focus on how LIMS-enabled laboratories result in increases in laboratory productivity and turnaround times as well as how they correlate to higher customer satisfaction, especially when it comes to achieving service dependability standards.
Data Integrity	(Jones & George, 2016)	Future research could address any discrepancies between consumer expectations and actual experiences by examining the relationship between LIMS-mediated improvements in data accuracy and integrity and customer perceptions of service reliability.
Training and Support	(Li et al., 2015)	The success of customer service and training programs linked to LIMS installation in how they fulfil user requirements and expectations, particularly in terms of empathy and responsiveness, might be investigated further.

System user Interface	(Rahil-Khazen et al., 2016)	Future studies could examine the relationship between system design characteristics and customers' perceptions of service tangibles, as well as the effects of LIMS usability and interface design on user satisfaction.
Interoperability	(Patel et al., 2016)	Additional investigation may be conducted to examine the impact of LIMS integration and interoperability on improving customer satisfaction and service quality, specifically with regard to responsiveness and reliability aspects.
Customer Satisfaction	(Fondoh, 2020)	This paper does not link and outline the features and functionalities that a LIMS provides in contributing to customer satisfaction. Additional research is required to uncover the impact of customer satisfaction as a result of features and functionality of a LIMS.

2.2.1. Efficiency and automation

(Shaw & Petzold, 2014) outline the importance of implementing a LIMS in a high-throughput laboratory setting. The further examines how LIMS-enabled automation and streamlined procedures increase productivity, shorten response times, and improve overall laboratory operations.

2.2.2. Data Integrity

The introduction of a LIMS in a multidisciplinary toxicology lab is covered in the study conducted by (Jones & George, 2016). It emphasises how vital the LIMS's assurance of data integrity and accuracy is for preserving the calibre of laboratory results.

2.2.3. Training and Support

In this research article conducted by (Li et al., 2015) a web-based LIMS used for clinical surveillance is evaluated. It talks about how crucial end users' training and customer service are to the efficient usage of the LIMS. To resolve user problems and improve their satisfaction, sufficient support and training are necessary.

2.2.4. System user Interface

A prototype LIMS for the qualitative and quantitative study of phospholipids is presented in this article by (Rahil-Khazen et al., 2016). It highlights how crucial interface design and system usability are to raising user pleasure and productivity. Features of interface design and usability are essential for laboratory operations and satisfaction.

2.2.5. Interoperability

The problems and solutions associated with implementing clinical laboratory informatics systems, such as LIMS, are examined in this systematic study by (Patel et al., 2016). To maintain uninterrupted patient care and smooth data flow, both necessary for satisfying client expectations for responsiveness and dependability of service, it emphasises the significance of integration and interoperability with current hospital and laboratory systems.

2.2.6. Customer Satisfaction for Hospital Laboratory

Fondoh (2020) evaluated the satisfaction of clinicians in a Cameroonian hospital in relation to the laboratory services that they receive. For Clinical laboratories, it is important to ensure that their customers are satisfied due to how complex and vital that service is. In this instance the customer in the hospital is the clinician and the service provider is the laboratory. The study looked at data from satisfaction surveys sent to clinicians in 2017. The results of the study outlined that most clinicians were dissatisfied with the service they were receiving from the laboratories. This was linked to long waiting times for receiving results, poor communication, and lack of transparency regarding information and data. These challenges can be attributed to the manual processes that are experienced at the laboratory. Due to this, their processes are taking longer, and have transcription errors, there is also no way of having an indicator of where the laboratory status of samples are. These points expose the importance of having a Laboratory Information Management System which will assist in addressing all these points.

2.3. Theoretical Framework

This study's theoretical foundations, based on the Service Quality Theory, are explained in this section. To support a conceptual framework that can be used to explain how a Laboratory Information Management System can assist in improving customer satisfaction for South African laboratories is reviewed.

2.3.1. Service Quality Theory

Based on the SERVQUAL model, which compares customers' expectations and perceptions of the services they received, five dimensions of service quality are evaluated (Parasuraman et al., 1985). Reliability, assurance, responsiveness, empathy, and tangibles are these five dimensions.

According to Cronin Jr and Taylor (1992), the Service Quality Theory's origins can be found in the 1980s, when scholars started to realise how crucial it was to comprehend and gauge service quality across a range of businesses. Since

then, the theory has been further critiqued and improved by academics where they have created other frameworks that solve its shortcomings (Grönroos, 1984).

This framework provides valuable insights into the strengths and weaknesses of service delivery, enabling organisations to identify areas for improvement and take appropriate actions to enhance customer satisfaction and service quality (Sureshchandar et al., 2002). The SERVQUAL framework is the most appropriate tool for gauging customer satisfaction in a variety of service-oriented sectors (Carman, 1990). This model is based on the idea that consumers' expectations of the services they receive in relation to their actual experiences have an impact on their views of the quality of those experiences.

The key dimensions of the framework outlined by Parasuraman et al., (1985) below:

1. **Reliability** - The capacity of a service provider to deliver on their promises of accuracy and consistency is referred to as reliability.
2. **Responsiveness** - The ability and readiness of service providers to aid clients in a timely and useful manner is referred to as responsiveness.
3. **Assurance** - Assurance pertains to the proficiency, civility, reliability, and dependability of service suppliers.
4. **Empathy** - The level of consideration, one-on-one care, and understanding that service providers show their clients is known as empathy.
5. **Tangibles** - The physical buildings, tools, staff attire, and promotional materials related to the service are examples of tangibles.

The Service Quality Theory is ideal for this study as it can be efficiently utilised in the context of a LIMS, which is an essential part of laboratory operations that frequently provide services to both internal and external clients.

Surveys and interviews with laboratory staff are tools that may be used in the empirical assessment of SERVQUAL's applicability in the setting of LIMS. Perceptions of service quality can be measured using these measures in all five

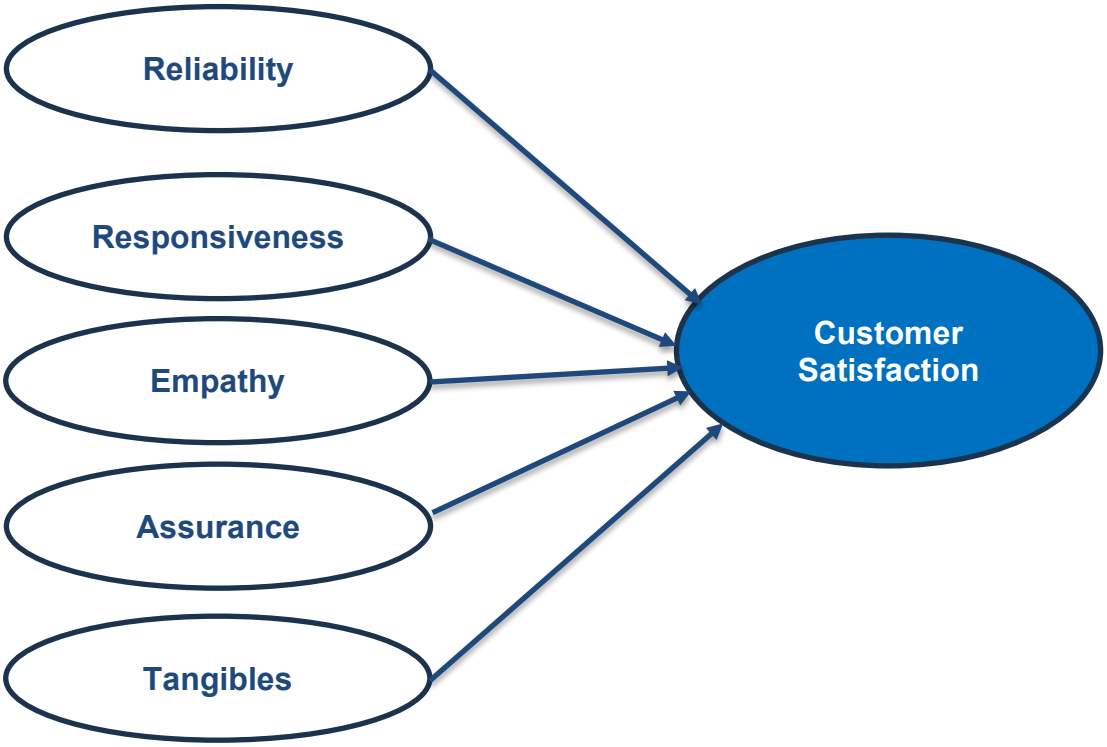
of the previously listed dimensions. Researchers can, for example, create surveys that are specific to each category and ask participants to score how much they agree with statements about tangibles, certainty, responsiveness, empathy, and reliability (Sureshchandar et al., 2002).

However, a few limitations and challenges are encountered when making use of the SERVQUAL theory. The first limitation with the SERQUAL model is that it is intended to be a general-purpose instrument for evaluating service quality in a range of sectors. SERVQUAL's five dimensions; tangibles, reliability, assurance, responsiveness, and empathy may not adequately describe LIMS since it is a specialised system with distinct technological and operational features (Ravichandran, 2018). The challenge with this is that the model might miss important LIMS-specific features that are essential for assessing the efficacy and calibre of LIMS in a laboratory scenario, like system integration capabilities, data management efficiency, and regulatory compliance (Bakar et al., 2018).

2.4. Conceptual Model

The conceptual model below has been derived from the Service Quality Theory which is the most appropriate model for measuring customer satisfaction amongst all the other identified theories. This theory has been expanded in further expose the predictor variables for this study in relation to customer satisfaction.

Figure 2.1 Conceptual Model



Examining the link between the five independent variables and the dependent variable is the goal of the study. The goal with this study is to measure whether Customer Satisfaction is positively impacted by each of these predictor variables. This would imply that assurance (users expect the LIMS to assure them of compliance to regulatory standards and adhere to best practices), reliability (expectation from users that the LIMS will process and maintain data reliably), tangibles (user interface design and accessibility of features), responsiveness (the speed and effectiveness of LIMS support), and empathy (provision of training and user-centric personalised features in a LIMS) supplied by a LIMS system are meant to result in positive customer satisfaction for South African laboratory users.

2.5. Development of Hypotheses

The hypotheses below have been outlined below based on the identified variables.

H1: The Reliability of a LIMS positively impacts customer satisfaction in the laboratory setting.

Finding a correlation between Laboratory Information Management Systems (LIMS) dependability and customers' satisfaction levels is necessary to develop a hypothesis about the impact of LIMS reliability on customer satisfaction. According to Muhanna and Bhattacherjee (2012), customer satisfaction levels and reliability are positively correlated. The service quality theory specifically asserts that users are more likely to report higher levels of system satisfaction when they believe the LIMS system to be dependable (Sureshchandar et al., 2002).

$H1_0$: Reliability of a LIMS has no positive impact on Customer Satisfaction.
$H1_1$: Reliability of a LIMS impacts customer satisfaction positively.

H2: The Responsiveness of a LIMS positively impacts customer satisfaction in the laboratory setting.

Hypothesis H2 suggests that specific features of LIMS, such as automated sample tracking and real-time data access, have a positive impact on customer satisfaction and loyalty. The service quality theory demonstrates a direct relationship between customer satisfaction and expectations regarding how a product or service will perform (Sureshchandar et al., 2002).

$H2_0$: Responsiveness of a LIMS has no positive impact on Customer Satisfaction.
$H2_1$: Responsiveness of a LIMS has a positive impact on Customer Satisfaction.

H3: Assurance in a LIMS system positively impacts customer satisfaction in the laboratory setting.

Hypothesis H3 proposes that operational efficiency and effective communication act as mediators between the implementation of a LIMS and customer satisfaction. It suggests that the positive impact of LIMS on customer satisfaction is achieved through improved operational efficiency and enhanced communication (Bryman & Bell, 2015). According to Sureshchandar et al., (2002) the service quality theory in relation to customer satisfaction, assurance pertains to the proficiency, reliability, and dependability of service providers.

$H3_0$: Assurance of a LIMS has no positive impact on Customer Satisfaction.
$H3_1$: Assurance of a LIMS impacts Customer Satisfaction positively.

H4: Perceived empathy in a LIMS system positively impacts customer satisfaction in the laboratory setting.

Hypothesis H4 suggests that empathy has a positive impact on customer satisfaction as confirmed by the Expectancy-Disconfirmation Theory (Oliver, 1997). The Service Quality Theory's application to empathy in a LIMS system emphasises how critical it is to both meet and beyond clients' expectations in terms of support and help. System providers may improve customer satisfaction, build loyalty, and trust, and promote long-term success in the cutthroat industry by putting empathy first (Carman, 1990).

$H4_0$: Empathy in a LIMS has no positive impact on Customer Satisfaction.
$H4_1$: Empathy in a LIMS has a positive impact on Customer Satisfaction.

H5: Tangibles of a LIMS system positively impact customer satisfaction in the laboratory setting.

Hypothesis H5 suggests that tangibles have a positive impact on customer satisfaction. In a LIMS system, tangibles can improve customer satisfaction in several ways which include enhanced user experience through the system

interface, credibility, and reliability of the laboratory results as well as ease of use and accessibility (Venkatesh & Bala, 2008).

$H5_0$: Tangibles in a LIMS have no positive impact on Customer Satisfaction.
$H5_1$: Tangibles in a LIMS have a positive impact on Customer Satisfaction.

CHAPTER 3 - RESEARCH METHODOLOGY

3.1. Introduction

This section aimed at providing a detailed view of the methodology that will be utilised for addressing the proposed hypothesis from the literature review. The chapter also outlined the various tools and resources that have been used as well (Kumar, 2019). The research approach is a critical factor in determining the overall strategy that was be used in conducting this study (Creswell, 2017). As a result, the most appropriate approach for this study was a Quantitative research approach. This approach was geared towards the collection of data and the performance of various analyses through statistical methods to test the research hypothesis. Once the research approach was defined, a research design framework was outlined. The research design will cover the plan of action that will be used for answering a research question and testing a hypothesis.

3.2. Research Approach

A quantitative research approach was used for this research study. In a quantitative research approach, issues or hypotheses are addressed through the collection and analysis of numerical data (Bryman & Bell, 2015). The focus on measurement, statistical analysis, and the use of structured devices for data collecting are characteristics of this method as detailed by Hair et al. (2018). Hair et al. (2018) also outlines that deductive methods are frequently linked to quantitative research techniques, which involve gathering data via experiments, surveys, or other structured tools. As a result, a deductive research approach was selected for this research study. According to Trochim (2006), a deductive approach is a type of research methodology that begins with a broad theory, hypothesis, or assumption and uses data analysis or empirical observation to test or validate it. This method entailed going from a broad comprehension to detailed observations or forecasts. Thereafter, statistical methods were used in data analysis to test hypotheses and make conclusions.

3.3 Research Design

This research design will serve as a strategic approach that will consist of the various components of the research study. The design will outline the framework for collecting, measuring, and reporting the data to be investigated (Jimenez, 2023). In this study a cross-sectional research design was adopted. According to Babbie (2016), an observational study that gathers data from a population or sample at one specific moment in time is defined as a cross-sectional research design. Its goal is to concurrently collect data on the variables of interest from various people or groups within the population. Cross-sectional research designs have the advantage of being efficient, economical, and able to shed light on the features of a population at a particular point in time (Polit & Beck, 2017). Among the limitations include the possibility of responder and collection bias, as well as the inability to prove causation or identify the direction of connections between variables (Creswell, 2017).

The research study utilised a convenience sampling technique to select participants from laboratories operating in diverse industries, including healthcare, pharmaceuticals, biotechnology, and environmental sciences, which use a LIMS system. Once the sampling method was completed, a structured questionnaire was used as the survey instrument for this study. In this instance the questionnaire was based on the SERVQUAL paradigm, which is a structured questionnaire with five dimensions; reliability, responsiveness, assurance, empathy, and tangibles (Parasuraman et al., 1985). An online survey tool was used to gather data where demographic data was collected and evaluated with regards to how satisfied laboratory staff are with the LIMS's level of service. Once this data was collected, the demographic details and survey responses of the participants were compiled using descriptive statistics.
The underlying structure of the questionnaire items were also evaluated using factor analysis applied to the SERVQUAL dimensions. Each SERVQUAL dimension's mean score was computed to assess the degree of customer satisfaction. Thereafter as a means of finding predictors of overall customer satisfaction, regression analysis was performed.

3.4 Data Collection Methods

Several crucial measures were taken while designing a questionnaire for data collection purposes and these were based on previously published research to guarantee its validity, reliability, and efficacy in gathering the needed data. The SERVQUAL framework's five pillars are reliability, responsiveness, assurance, empathy, and tangible and are all covered in the questionnaire. A 5-point Likert scale with measuring items based on earlier research was used in this anonymous questionnaire to collect the data. The poll was hosted on Qualtrics, and the link was sent via emails, WhatsApp, and LinkedIn to participants.

To gauge customer opinions of service quality in relation to laboratory services and LIMS usage, researchers can modify the SERVQUAL scale created by Parasuraman et al. (1985). On a Likert scale, respondents indicate whether they agree or disagree with the statements that represent each facet of service quality on this scale. The SERVQUAL scale has been widely modified by researchers for use in a variety of service contexts, including as retail, hospitality, and healthcare. For instance, Carman (1990) demonstrated the SERVQUAL scale's versatility by modifying it to measure patient perceptions of service quality in hospital environments. In this research study the scales were adjusted to align with LIMS related functionality and laboratory services.

Studies on the use of service quality ideas in healthcare laboratories have been conducted, despite the paucity of literature specifically addressing the adaptation of the SERVQUAL framework for laboratory services. To improve customer satisfaction, Fatima, Humayun, Iqbal, and Shafiq (2019), for example, looked at the aspects of service quality in healthcare laboratories and stressed the significance of tangibles, responsiveness, and reliability.

The features of the target population, the size of the sample, and the goals of the research may all influence the administration method selection. The popularity of online surveys can be attributed to their accessibility and convenience of administration, as demonstrated by studies conducted in a variety of disciplines, such as consumer satisfaction research (e.g., Al-Borie & Damanhouri, 2012).

The measurement items to be used for this study as per the SERVQUAL framework are as follows: Reliability (RL), Responsiveness (RS), Assurance (AS), Empathy (EM) and Tangibles (TN).

3.5 Population and Sample

A good way of identifying which population or sample to analyse is by selecting an appropriate unit of analysis.

3.5.1 Target Population

According to a research article compiled by Sekaran and Bougie (2016) a target population is defined as a complete group of people or components that share the researcher's interests and to whom the study's conclusions are meant to be applied.

In the context of this study, the target population can be classified into the following groups:

- **Laboratory Personnel:**(National Institute for Occupational Safety and Health, 2011) defines this group as scientists, researchers, laboratory technicians, and other employees who work directly with the LIMS daily. Their insights, opinions, and experiences are crucial for assessing how well the system works to enhance overall performance, data management, and workflow efficiency.
- **Customers:** Another significant demographic in the study is the laboratory's customers or clients, which could include medical professionals, academic institutions, pharmaceutical corporations, environmental agencies, or other organisations. Key indications of client success include their level of satisfaction, preferences, and expectations regarding laboratory services, data quality, turnaround times, and communication. These individuals also interact with the LIMS to view their test results virtually (Schwaig et al., 2002).

The setting of South African laboratories is characterised by a varied establishments and facilities catering to many fields and uses, supporting research and development, public health, environmental sustainability, industrial

growth, and law enforcement. In 2023, The South African National Accreditation System (SANAS) reported 2059 registered laboratories which boast a wide variety of organisations that are made up of calibration, forensics, mechanical and physical testing, chemical, microbiological, veterinary, pharmaceutical, medical as well as inspection and certification bodies (South African National Accreditation System & National, 2023). It should be noted that this list of laboratories only displays the number of laboratories that are accredited and registered on the SANAS database and thus does not include many others which are operating without any accreditation. As a result, the size of the target population is unknown at the time of this research paper as there is no central place of information where all South African laboratories have been published.

3.5.2 Sample Size

Araujo et al., (2019), argue that selecting the right sample size is crucial to guaranteeing the validity and dependability of study results. A few examples of the variables that affect sample size are the study design, statistical considerations, practical limitations, and research aims.
According to an often-referenced recommendation, Structural Equation Modelling (SEM) requires a minimum sample size of 100 for an unknown population (Kline, 2015). With an unknown population in the current study, the sample size of 100 was determined by using a 20:1 observation ratio per variable. Hair et al. (2018) provided additional support for the computed sample size. A sample size of 100 is thought to be sufficient to obtain a respectable degree of statistical precision, especially when calculating population metrics like mean satisfaction scores or user proportions.

According to Sekaran and Bougie (2016), a sample size of 100 yields a reasonably modest margin of error when paired with a confidence level that is normally set at 95%. This indicates that there is a high probability that the estimated satisfaction levels obtained from the sample data will closely match the genuine population characteristics. Although a sample size of 100 achieves a balance between statistical rigor and practical issues, especially in

investigations where time and resource restrictions are significant, larger sample sizes may yield more precision (Kothari, 2004).

The appropriate population relevant to this study includes laboratory staff who interact with the LIMS and are affected by its impact on customer service. The sample size for quantitative data collection (surveys, questionnaires) will be determined based on statistical considerations, such as power analysis, desired effect size, and sampling adequacy.
A non-probability sampling method will be used for this study which is a more convenient method as it is less resource intensive. In this instance, a convenience sampling method has been selected for the study. Neuman, (2013) defines convenience sampling as the process of choosing participants or cases based on their accessibility and suitability for the researcher. This sampling method was the most appropriate for the following reasons:

- Participants in the study will be easily available, given they are regular users and staff of the LIMS.
- Babbie, (2016) outlines that convenience sampling offers important insights if the study's goal is to investigate laboratory users' perspectives, experiences, and levels of satisfaction with the LIMS. It enables researchers to record a wide variety of viewpoints and experiences in a constrained amount of time.
- Convenience sampling is frequently considered appropriate since it is feasible given the limitations of the research setting and resources according to Neuman (2013), particularly considering the emphasis on evaluating customer satisfaction within a particular context (i.e., laboratory users interacting with the LIMS).

3.6 Data Analysis Strategies and Interpretation

Once the data is analysed the results will be reported by outlining conclusions on this analysis (Creswell, 2017). The research question will determine the process of interpreting these results and compare them to previous studies of a similar nature to determine future implications. This will be done by testing the

links between variables and hypotheses for quantitative analysis by using statistical techniques like regression analysis.

3.6.1 Validity and Reliability

The degree to which a research study assesses what it purports to measure is referred to as validity (Trochim, 2006). DeVellis (2016) outlines that validity evaluates the accuracy with which a measurement tool captures the construct or idea that it is designed to evaluate. Different components of measurement accuracy are addressed by different forms of validity, such as construct validity, criterion validity, and content validity.

The first type of validity is content validity which assures that every pertinent facet of the construct being assessed is sufficiently covered by the measuring tool (DeVellis, 2016). Shadish et al. (2002) define criterion validity as the degree to which scores on a measurement tool correspond with scores on a criterion measure. The third concept is constructing validity which assesses if a measurement tool faithfully captures the underlying theoretical notion that the tool is designed to assess (Trochim, 2006).

The consistency, stability, or repeatability of measurements made with a research instrument are referred to as reliability (DeVellis, 2016). If a measurement tool yields consistent results when used repeatedly under comparable circumstances, it is deemed trustworthy (Heale & Twycross, 2015). Different features of measurement consistency are assessed by different forms of reliability, such as test-retest, internal consistency, and inter-rater reliability.

Heale and Twycross (2015) define internal coherence as the degree of consistency or agreement between the items in a measurement tool. The second concept of reliability is called Test-Retest Reliability which evaluates how stable scores are over time by giving the same people the assessment twice (Streiner & Norman, 2008). Inter-rater reliability is the third concept and is

defined by DeVellis (2016) as the consistency of ratings or conclusions reached by several raters or observers.

The Pearson product-moment correlation coefficient is a statistical measure used to assess the strength and direction of the linear relationship between two continuous variables (Pallant, 2021). The measuring items in this research proposal were evaluated for validity and reliability by using SPSS software. The measure of internal consistency reliability known as Cronbach's alpha, or just "Cronbach's alpha," is used to determine how closely a group of items or questions on a scale or questionnaire measure the same underlying construct. Higher numbers indicate better internal consistency. It shows the degree of correlation between the items in a scale (Cronbach, 1951). In this study, reliability analysis was performed on the measuring items and resulted in a Cronbach alpha value above 0.6 which declared the data as reliable.

3.7 Possible Limitations and Challenges

This sampling process for online surveys often has several issues that need to be considered. These online surveys quite often don’t store the respondents’ details and are conducted on platforms that do not verify the individuals who participate (Wright, 2005). The way these surveys are conducted can often lead to non-probability samples which then results in some form of bias.
It is due to these limitations that caution must be practised when putting the survey together. The survey should be issued to direct participants who will be able to provide correct and impactful information for this study as far as possible.

The challenge with making use of the SERQUAL model is that when subjective experiences are crucial to total user satisfaction, the challenge of quantifying intangible characteristics might lead to an inadequate or distorted view of LIMS performance (Kettinger & Lee, 2005). Using SERVQUAL's dimensions, it is also challenging to quantify intangible features of LIMS effectively, such as user satisfaction with system usability or the perceived ease of system integration (Parasuraman, Zeithaml, & Berry, 1985).

In the context of LIMS, SERVQUAL prioritises issues of service quality over technical ones. SERVQUAL might not be able to fully capture technical quality metrics including integration capabilities, data correctness, and system uptime (Kettinger & Lee, 2005). This limitation may result in an inadequate assessment of LIMS, where important technical flaws might go unnoticed and endanger laboratory operations (Babakus & Boller, 1992).

3.8 Ethical Considerations

This research study will be conducted ethically while considering the privacy and confidentiality of the involved participants. Other considerations to be considered include ensuring that the study is conducted in a manner in which potential risks or harm to participants are minimised. The study will also be conducted in a manner that avoids deceiving participants and avoids conflicts of interest. The data that is collected will also be stored in a safe and secure manner while protecting data and privacy regulations. A participation consent letter is included as part of this study which will detail the ethical considerations to the participants (see Appendix B). As a result, consent was given when one participated in the study by completing the questionnaire.

3.9 Proposed Schedule and Timelines

The following schedule outlines an overview of the various areas of the research study.

Timeline	Tasks
09 April 2023	Conduct and finalise literature review
30 April 2023	Develop Research Methodology and Design.
01 June 2023	Complete the survey questionnaire and consent forms.
30 August 2023	Finalise the list of participants and conduct a pre-test survey.
10 September 2023	Conduct Survey.
30 September 2023	Collect and analyse the data.
01 October 2023	Write a research report.

29 February 2024	Present research findings to panel.

CHAPTER 4 - DATA ANALYSIS

4.1 Introduction

The statistical analysis and findings from the data-gathering process regarding the variables affecting customer satisfaction in South African laboratories that are using a laboratory information management system are presented in this chapter. An outline of descriptive statistics, validity and reliability testing, and an in-depth treatment of SEM, path modelling, and hypothesis testing will be provided before the chapter closes.

4.2 Descriptive statistics

The demographic profile is included in this section, with information on the respondents' age, gender, and number of years laboratory experience.

4.2.1 Sample Description

The research survey was sent out to 189 participants with a total of 113 respondents as displayed on table 4.1.

Table 4.1 Demographics

Statistics				
		Please confirm your gender	Please select your age group	How many years of laboratory experience do you have?
N	Valid	111	112	112
	Missing	2	1	1
Total		113	113	113

Table 4.2 below shows how the respondents' genders are distributed. The findings indicate that, of the 113 respondents, the majority identified as male (n=74) at 65.5%, followed by female respondents (n=33) at 29.2% with the remaining 4 respondents classifying themselves as either non-binary (n=1) at 0.6% or preferring not to say (n=3) at 2.7%.

Table 4.2 Gender Distribution

Gender				
	Frequency	Percent	Valid Percent	Cumulative Percent
Male	74	65.5	66.7	66.7
Female	33	29.2	29.7	96.4
Non-binary / third gender	1	.9	.9	97.3
Prefer not to say	3	2.7	2.7	100.0
Total	111	98.2	100.0	
System	2	1.8		
Total	113	100.0		

Figure 4.1 Pie Chart Displaying the Distribution of Gender.

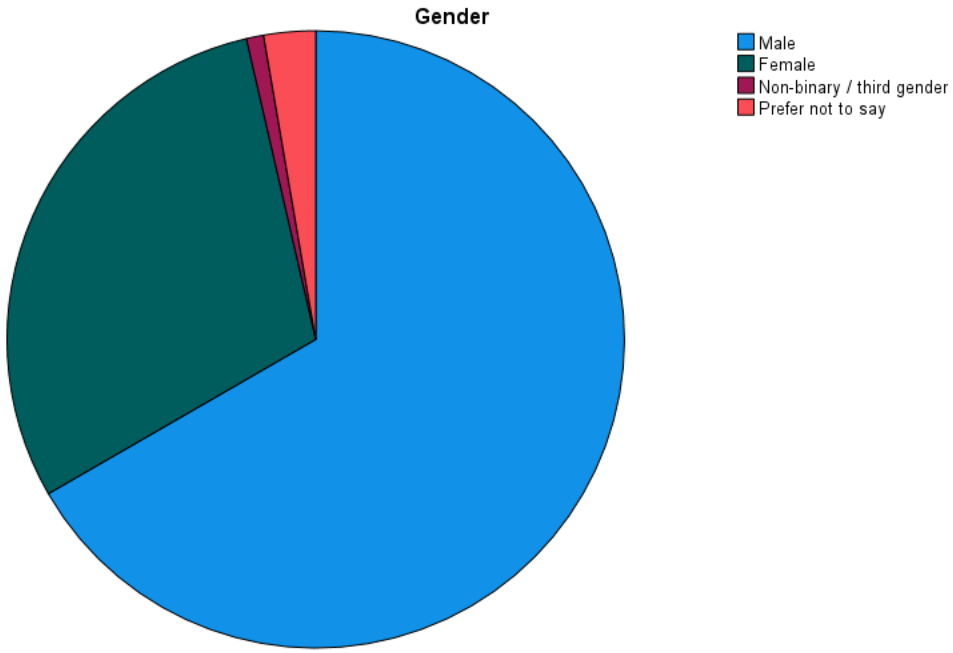


Table 4.3 shows that 15 respondents belonged to the 25–34 age group at 13.4% representation, with 59 respondents belonging to the 35-44 age group at 52.7%, 30 respondents belonging to the 45-54 age group at 26.8%, 5 respondents belonging to the 55-64 age group at 4.5% and 3 respondents in the over 65 years category at 2.7% representation.

Table 4.3 Age Group Distribution

Age Group					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	25 - 34 Years	15	13.3	13.4	13.4
	35 - 44 Years	59	52.2	52.7	66.1
	45 - 54 Years	30	26.5	26.8	92.9
	55 - 64 Years	5	4.4	4.5	97.3
	Over 65 Years	3	2.7	2.7	100.0
	Total	112	99.1	100.0	
Missing	System	1	.9		
Total		113	100.0		

Figure 4.2 Pie Chart Displaying the Distribution of Age.

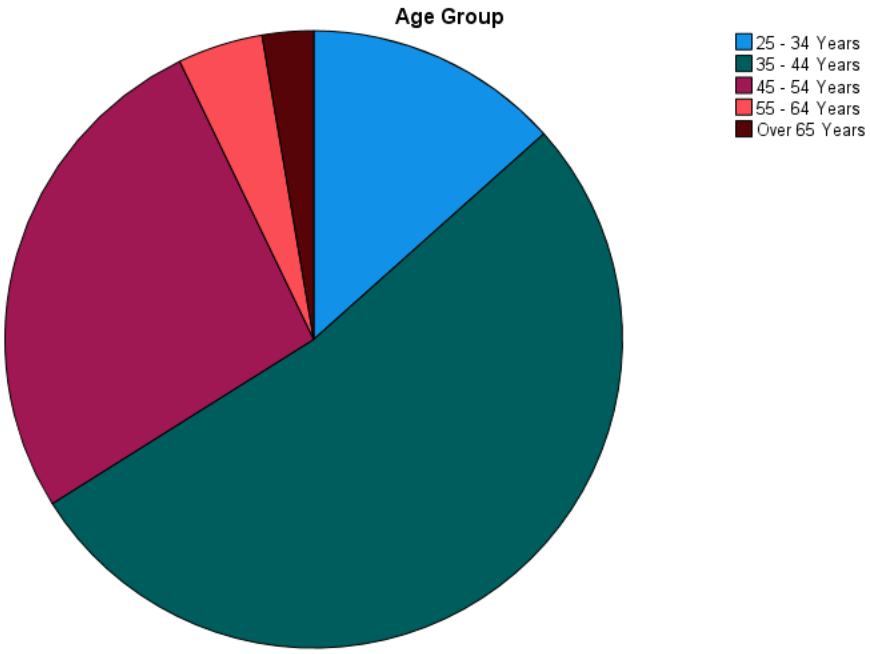
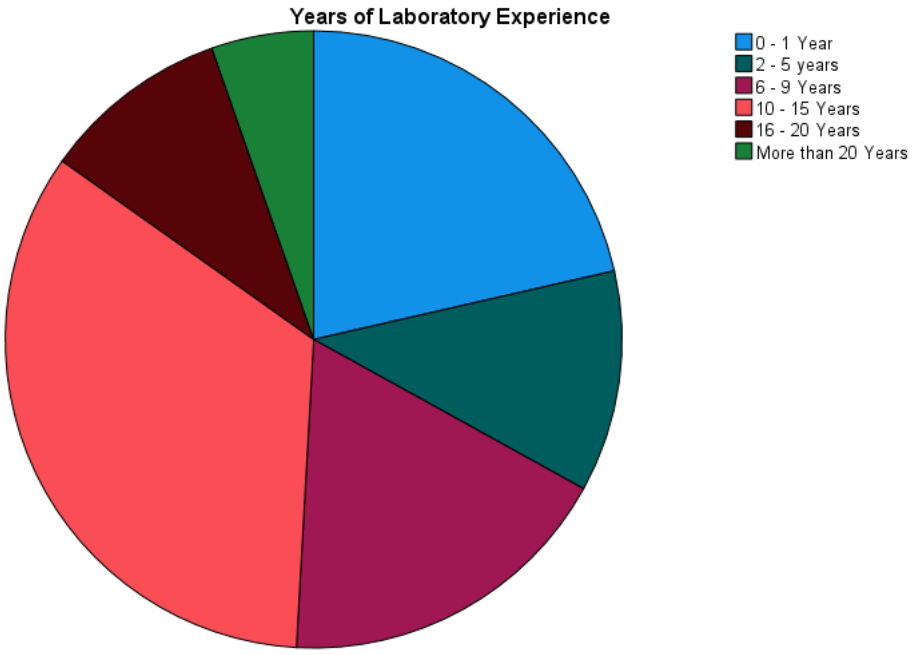


Table 4.4 below demonstrates that 21.4% of respondents have 0-1 years of experience, 11.6% of respondents have 2-5 years of laboratory experience, 17.9% have 6-9 years of laboratory experience, 33.9% of respondents have 10-15 years of laboratory experience, 9.8% have 16-20 years of laboratory experience while the remaining 5.4% have more than 20 years of laboratory experience.

Table 4.4 Years of Laboratory Experience

Years of Laboratory Experience					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0 - 1 Year	24	21.2	21.4	21.4
	2 - 5 years	13	11.5	11.6	33.0
	6 - 9 Years	20	17.7	17.9	50.9
	10 - 15 Years	38	33.6	33.9	84.8
	16 - 20 Years	11	9.7	9.8	94.6
	More than 20 Years	6	5.3	5.4	100.0
	Total	112	99.1	100.0	
Missing	System	1	.9		
Total		113	100.0		

Figure 4.4 Pie Chart of Laboratory Experience



4.3 Evaluation of Measurement Instruments

An overview of the analysis and discussion of the measurement instrument's validity and reliability results is provided in this section. A five-point Likert scale (Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree) was used to rate the research constructs. The variables are outlined as follows in the Likert scale:

- RL – Reliability (RL1-RL3)
- RS - Responsiveness (RS1-RS3)
- AS – Assurance (AS1-AS3)
- EM – Empathy (EM1-EM3)
- TN – Tangibles (TN1-TN3)
- CS – Customer Satisfaction (CS1-CS3)

A descriptive analysis for numerical measurements of shape, dispersion, and central tendency is outlined in Table 4.5 below.

Table 4.5 Descriptive Statistics

Descriptive Statistics

Research Construct		N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
		Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
RL	**RL1**	113	4.00	1.00	5.00	4.4220	1.12832	1.273	-2.080	.227	3.317	.451
	RL2	113	4.00	1.00	5.00	4.4037	.94604	.895	-2.067	.227	4.445	.451
	RL3	113	4.00	1.00	5.00	4.5780	.89934	.809	-2.563	.227	6.414	.451
RS	**RS1**	113	4.00	1.00	5.00	4.3148	.97878	.958	-1.732	.227	2.729	.451
	RS2	113	4.00	1.00	5.00	4.4167	.94609	.895	-1.976	.227	3.763	.451
	RS3	113	4.00	1.00	5.00	4.3796	.90354	.816	-1.812	.227	3.320	.451
AS	**AS1**	113	4.00	1.00	5.00	4.6331	.74469	.555	-2.875	.227	9.942	.451
	AS2	113	4.00	1.00	5.00	4.5648	.82671	.683	-2.480	.227	6.634	.451
	AS3	113	4.00	1.00	5.00	4.5741	.83670	.700	-2.661	.227	7.854	.451
EM	**EM1**	113	4.00	1.00	5.00	4.5556	.80549	.649	-2.429	.227	6.751	.451
	EM2	113	4.00	1.00	5.00	4.6389	.78443	.615	-2.622	.227	6.922	.451
	EM3	113	4.00	1.00	5.00	4.4907	.91119	.830	-1.954	.227	3.445	.451
TN	**TN1**	113	4.00	1.00	5.00	4.4460	.80920	.655	-1.659	.227	2.902	.451
	TN2	113	4.00	1.00	5.00	4.5093	.79345	.630	-2.025	.227	4.497	.451
	TN3	113	4.00	1.00	5.00	4.4299	1.00988	1.020	-2.028	.227	3.574	.451
CS	**CS1**	113	4.00	1.00	5.00	4.6636	.77855	.606	-2.993	.227	9.619	.451

	CS2	113	4.00	1.00	5.00	4.6444	.79324	.629	-2.950	.227	9.252	.451	
	CS3	113	4.03	1.00	5.03	4.7012	.07354	.78176	.611	-3.154	.227	10.192	.451

4.3.1 Descriptive Analysis

Three items were used to measure the first variable, RL (Reliability), the second variable, RS (Responsiveness) was measured with 3 items, the third variable AS (Assurance) was measured using 3 items, the fourth variable EM (Empathy) was measured with 3 items as well, TN (Tangibles) was assessed using three items and finally CS (Customer Satisfaction) was assessed using 3 items.

It is necessary to analyse the standard deviation, mean, kurtosis, and skewness data from descriptive analysis to comprehend the distribution and properties of the data. To grasp the data's central tendency and variability, an analysis of the mean and standard deviation is analysed. According to Field (2013), higher values in the dataset are indicated by a higher mean, and smaller values are indicated by a lower mean. Greater variability in the data is indicated by a higher standard deviation, and less variability is suggested by a smaller standard deviation.

Pallant (2021) outlines that a distribution that is entirely symmetrical has a skewness value of 0. When the data has a larger tail on the right side of the distribution, it is said to be skewed to the right (positive skewness, >0). If the data has a larger tail on the left side of the distribution, it is skewed to the left, as shown by negative skewness (<0).

Kurtosis gauges how flat or peaky the distribution of the data is. A normal distribution is indicated by a kurtosis value of 3 (mesokurtic). Leptokurtic, or peaked distribution with heavier tails, is indicated by positive kurtosis (>3). When kurtosis is negative (<3), the distribution is flatter, and the tails are lighter (platykurtic) as defined by Field (2013).

The results of the statistics from table 4.5 are discussed below:

4.3.1.1. Reliability Analysis

Mean: The respondents' perceptions of the high degree of reliability in the services offered are supported by the high mean scores for RL1, RL2, and RL3.
Standard Deviation: The low standard deviations imply that the responses are consistently distributed in a close cluster around the mean.
Kurtosis and Skewness: The kurtosis and skewness values are within an acceptable range, suggesting that their distributions are roughly normal.

4.3.1.2. Responsiveness Analysis

Mean: While marginally lower than the Reliability dimension's mean scores, the RS1, RS2, and RS3 mean scores nevertheless show a high degree of responsiveness.
Standard Deviation: There is some variety in the replies, as indicated by the moderate standard deviations.
Kurtosis and Skewness: The values of kurtosis and skewness indicate that the responses have roughly normal distributions.

4.3.1.3. Assurance Analysis

Mean: The respondents' perceived level of assurance is strong, as seen by the high mean scores for AS1, AS2, and AS3.
Standard Deviation: Consistency in responses is indicated by the relatively low standard deviations.
Kurtosis and Skewness: The data for these two metrics show that the responses roughly follow normal distributions.

4.3.1.4 Empathy Analysis

Mean: The high mean scores for EM1, EM2, and EM3 further indicate that respondents thought there was a great degree of empathy.
Standard Deviation: There is some variety in the replies, as indicated by the moderate standard deviations.
Kurtosis and Skewness: The values of kurtosis and skewness indicate that the responses have roughly normal distributions.

4.3.1.4 Tangibles Analysis

Mean: The high mean ratings for TN1, TN2, and TN3 indicate that respondents thought highly of tangibles.

Standard Deviation: There appears to be some diversity in the replies, as indicated by the moderate to high standard deviations.

Kurtosis and Skewness: The data for these two metrics show that the responses roughly follow normal distributions.

4.3.1.5 Customer Satisfaction

Mean: The high mean scores for CS1, CS2, and CS3 show that customers are generally satisfied with the services they receive.

Standard Deviation: There is some variety in the replies, as indicated by the moderate standard deviations.

Kurtosis and Skewness: The values of kurtosis and skewness indicate that the responses have roughly normal distributions.

4.3.2 Reliability Analysis

DeVellis (2016) outlines that reliability analysis's main goal is to guarantee that a survey or instrument yields accurate and consistent data, which enhances the overall calibre of research findings.

Table 4.6 Reliability Scale

Item-Total Statistics								
Research Construct		Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha	Factor Loading
RL	**RL1**	8,9817	2,946	0,760	0,579	0,843	0,877	0,874
	RL2	9,0000	3,482	0,789	0,625	0,804		0,835
	RL3	8,8257	3,712	0,763	0,588	0,832		0,827
RS	**RS1**	8,7963	2,924	0,837	0,702	0,829	0,901	0,917
	RS2	8,6944	3,115	0,801	0,652	0,861		0,860
	RS3	8,7315	3,314	0,776	0,608	0,882		0,826
AS	**AS1**	9,1389	2,544	0,860	0,743	0,912	0,935	0,934
	AS2	9,2071	2,261	0,883	0,781	0,890		0,901

	AS3	9,1979	2,274	0,859	0,739	0,911		0,898
EM	**EM1**	9,1296	2,662	0,837	0,722	0,914	0,930	0,963
	EM2	9,0463	2,614	0,900	0,810	0,868		0,884
	EM3	9,1944	2,330	0,845	0,735	0,915		0,876
TN	**TN1**	8,9392	2,847	0,751	0,644	0,841	0,878	0,976
	TN2	8,8759	2,698	0,854	0,741	0,759		0,820
	TN3	8,9553	2,313	0,723	0,561	0,890		0,765
CS	**CS1**	9,3456	2,377	0,933	0,871	0,956	0,970	0,957
	CS2	9,3648	2,329	0,935	0,875	0,955		0,957
	CS3	9,3080	2,364	0,935	0,874	0,955		0,954

Key: RL (Reliability), RS (Responsiveness), AS (Assurance), EM (Empathy), TN (Tangibles), CS (Customer Satisfaction).

4.3.2.1 Reliability Statistics Analysis - Cronbach Alpha Coefficient

For every construct (Reliability, Responsiveness, Assurance, Empathy, Tangibles and Customer Satisfaction), the internal reliabilities of Cronbach's alpha were evaluated.

The results indicate that the constructs' Cronbach alpha values were as follows:

- Reliability – 0.874
- Responsiveness – 0.901
- Assurance – 0.935
- Empathy – 0.930
- Tangibles – 0.878
- Customer Satisfaction – 0.970

According to Streiner and Norman (2008) benchmarks between the values of 0.80 to 1.0 can be described as “almost perfect”. Based on this analysis all the above constructs can be described as almost perfect and thus defined as reliable.

4.3.2.2 Reliability Statistics Analysis – Composite Reliability Estimates

Table 4.7 Composite Reliability Estimates

Variables		λ	λ²	1-λ²	Sum λ	Sum λ²	Sum 1-λ²	n	Ave Variance Extracted	Composite Reliability
RL	RL1	0,874	0,764	0,24	2,536	2,145	0,86	3	0,715	0,883
	RL2	0,835	0,697	0,30						
	RL3	0,827	0,684	0,32						
RS	RS1	0,917	0,841	0,16	2,603	2,263	0,74	3	0,754	0,902
	RS2	0,860	0,739	0,26						
	RS3	0,826	0,682	0,32						
AS	AS1	0,934	0,872	0,13	2,732	2,489	0,51	3	0,830	0,936
	AS2	0,901	0,811	0,19						
	AS3	0,898	0,806	0,19						
EM	EM1	0,963	0,926	0,07	2,722	2,474	0,53	3	0,825	0,934
	EM2	0,884	0,781	0,22						
	EM3	0,876	0,767	0,23						
TN	TN1	0,976	0,953	0,05	2,561	2,211	0,79	3	0,737	0,893
	TN2	0,820	0,672	0,33						
	TN3	0,765	0,585	0,41						
CS	CS1	0,957	0,917	0,08	2,868	2,742	0,26	3	0,914	0,970
	CS2	0,957	0,915	0,08						
	CS3	0,954	0,911	0,09						

RL (Reliability) Composite Reliability = 0.940A A very high degree of internal consistency dependability is shown. The scale's items appear to be quite dependable and consistent in measuring the latent construct, as indicated by the CR rating of 0.940.

RS (Responsiveness) Composite Reliability = 0.860: This figure is marginally lower than the others, but still rather good. It shows a reliable internal consistency that is acceptable. Even if it can be a little less than perfect, it still implies that the scale items measure the construct very consistently.

AS (Assurance) Composite Reliability = 0.917: As with the previous value, this one also shows a high degree of reliability for internal consistency. It implies

that the latent construct may be measured with good reliability using the scale items.

EM (Empathy) Composite Reliability = 0.930: Once more, this figure shows an extremely high degree of dependability for internal consistency. has good internal consistency among the items and can be relied upon to produce consistent and stable results when evaluating empathy.

TN (Tangibles) CR = 0.933: This shows a very high degree of internal consistency reliability, much like the earlier numbers. It implies that the scale's items are extremely dependable and consistent when gauging the construct.

CS (Customer Satisfaction) CR = 0.940: This indicates an extremely high degree of dependability for internal consistency. It suggests that the scale items measure the latent construct with a high degree of consistency and dependability.

4.3.3 Validity Testing

The process of determining how well a measure accurately reflects a construct or idea is known as validity testing. Ensuring the validity and meaning of the inferences generated from the data is an essential aspect of the research technique (Trochim, 2006).

4.3.3.1 Convergent Validity

The degree of positive correlation between results from various assessment tools that are theoretically supposed to measure the same construct is known as convergent validity (DeVellis, 2016).

Table 4.8 Factor Loading

Variables		Factor Loading
RL	RL1	0,874
	RL2	0,835
	RL3	0,827
RS	RS1	0,917
	RS2	0,860
	RS3	0,826
AS	AS1	0,934
	AS2	0,901
	AS3	0,898
EM	EM1	0,963
	EM2	0,884
	EM3	0,876
TN	TN1	0,976
	TN2	0,820
	TN3	0,765
CS	CS1	0,957
	CS2	0,957
	CS3	0,954

Principal component analysis and varimax rotation were used to carry out an EFA. The requirement for minimal factor loading was established at 0.50. To guarantee appropriate levels of explanation, the commonality of the scale which represents the degree of variance in each dimension was also evaluated. According to the data displayed in table 4.8 above, every commonality was greater than 0.50.

The factor loadings for each observed variable on the extracted factors are shown in this "Rotated Factor Matrix" table following the application of a Varimax rotation with Kaiser normalization. Five factors have been extracted, as the table demonstrates.

4.3.3.2 Discriminant Validity: Correlation Matrix

A heuristic utilised in structural equation modelling (SEM) to evaluate the discriminant validity of latent constructs is the Fornell-Larcker criteria. According to this, each construct's square root of the average variance extracted (AVE) must be larger than the correlations between that construct and the other constructs in the model for discriminant validity to be proven (Hair et al., 2018).

Table 4.9 Inter-item correlation matrix

Correlations							
	RL	**RS**	**AS**	**EM**	**TN**	**CS**	**AVE**
RL	1						0,715
RS	.751**	1					0,754
AS	.754**	.803**	1				0,830
EM	.653**	.770**	.844**	1			0,825
TN	.573**	.753**	.772**	.782**	1		0,737
CS	.681**	.781**	.934**	.866**	.842**	1	0,914

Overall, the correlation matrix indicates a favourable relationship between customer satisfaction and many LIMS service quality factors, such as assurance, responsiveness, empathy, and tangibles. Customer satisfaction

seems to be most strongly impacted by assurance and empathy, then by tangibles, responsiveness, and reliability.

The optimum AVE values are those that are greater than the squared correlations between the model's latent variables and other constructs. In this study, the Convergent validity is supported as the AVE values are greater than the squared correlations, which shows that the latent constructs explain more variance in their indicators than they share with other constructs.

4.4 Structural Equation Modelling (SEM)

Researchers can simultaneously test complicated theoretical models and hypotheses by using Structural Equation Modelling (SEM), a statistical tool for analysing the correlations between observable and latent variables (Kline, 2015). Several fit indices are used in structural equation modelling (SEM) to evaluate how well the model fits the observable data and are outlined below.

4.4.1 Model Fit Indicators

4.4.1.1 Chi-square Index

Kline, (2015) outlines that the chi-square (χ^2) statistic is a commonly used fit metric in structural equation modelling (SEM) that assesses the difference between the observed and model-implied covariance matrices. The suggested model's fit to the observed data is evaluated using the chi-square index. Good model fit is shown by a non-significant chi-square value, which implies that there is no significant difference between the observed and model-implied covariance matrices. For the model to be a good fit, the Chi-square minimum value (CMIN) is divided by the degree of freedom.

Table 4.10 CMIN Index

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	51	263,386	120	0	2,195
Saturated model	171	0	0		
Independence model	18	2685,111	153	0	17,55

Based on table 4.10 above, the CMIN/df is 2.195 which is >2 and <5 and thus represents a good fit.

4.4.1.2 Baseline Comparison Index

Table 4.9 below shows the Baseline Comparison Indices (BCI) for which the fit statistics and the Comparative Fit Index (CFI) compare quite well. According to Moshagen and Erdfelder (2016), a CFI value of less than 0.95 indicates that the model fits the data very well. In this analysis a CFI value of 0.943 was recorded and this indicates that there is a very good model fit.

Table 4.11 Baseline Comparison Index

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	0,902	0,875	0,944	0,928	0,943
Saturated model	1		1		1
Independence model	0	0	0	0	0

4.4.1.3 Root Mean Square Error of Approximation

Table 4.12 shows the default model's RMSEA of 0.103; Byrne (2016) states that a successful model fit requires an RMSEA of less than 0.08. Consequently, this suggests a fair-fitting model.

Table 4.12 Root Mean Square Error of Approximation

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	0,103	0,086	0,12	0
Independence model	0,384	0,372	0,397	0

4.4.1.4 Goodness of Fit Index

The GFI of 0.799 is shown in Table 4: 11. For a successful model fit, a GFI of ≤ 1 is advised according to Byrne (2016). The reported GFI is 0.799 which represents a relatively good fit for this model.

Table 4.13 Goodness of Fit Index

Model	RMR	GFI	AGFI	PGFI
Default model	0,028	0,799	0,713	0,561
Saturated model	0	1		
Independence model	0,482	0,109	0,004	0,098

4.5 Hypothesis Testing and Path Modelling

Path modelling is a statistical method for examining the connections between latent and observable variables. It is often referred to as structural equation modelling or SEM as outlined by Byrne (2016). Path modelling involves formulating a set of conjectures regarding the relationships between variables and testing those relationships with actual data.

Table 4.14 demonstrates the path coefficients as well as the hypothesis where the following is uncovered:

Table 4.14 Path Coefficients and Hypothesis Results

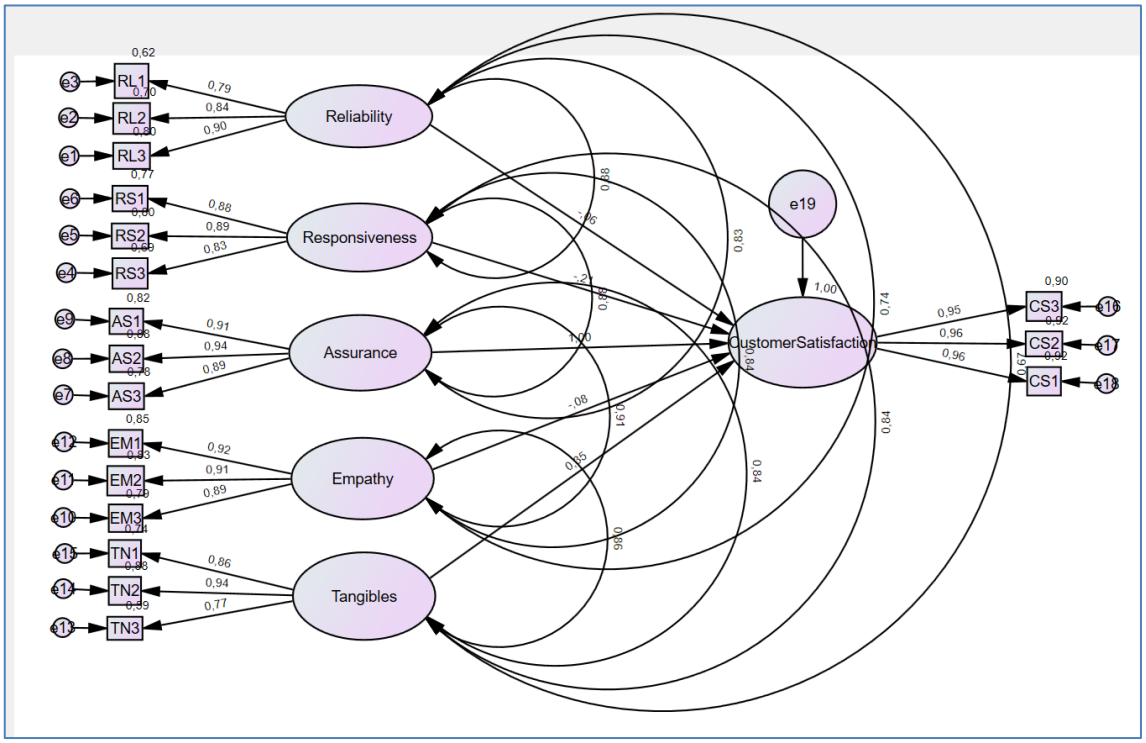
			Hypotheses	Estimate	P	Results
Customer Satisfaction	<---	Reliability	H1	-0,063	0,596	Not Significant and not supported.
Customer Satisfaction	<---	Responsiveness	H2	-0,207	0,171	Not Significant and not supported.

Customer Satisfaction	<---	Assurance	H3	0,998	< 0,001	Significant and Supported
Customer Satisfaction	<---	Empathy	H4	-0,085	0,492	Not Significant and not supported.
Customer Satisfaction	<---	Tangibles	H5	0,354	< 0,001	Significant and Supported.

This research report evaluated how a laboratory information management system can assist in improving customer satisfaction for South African Laboratories.

The impact of reliability on customer satisfaction was negative and not significant, as a result, H1 is not supported. The impact of responsiveness on customer satisfaction was negative and not significant, as a result, H2 is not supported. The impact of assurance on customer satisfaction was positive and significant ($p < 0.001$), supporting H3. The impact of assurance on customer satisfaction was positive and significant ($p < 0.001$), supporting H3. The impact of empathy on customer satisfaction was negative and not significant, as a result, H4 was not supported. The impact of tangibles on customer satisfaction was positive and significant ($p < 0.001$), supporting H5.

Figure 4.5 Conceptual Model



4.6 Summary of Results

The summary of the Hypotheses results is outlined below.

H1: The Reliability of a LIMS positively impacts customer satisfaction in the laboratory setting.

The first hypothesis (H1) is not supported, as the data has demonstrated. This suggests that the reliability of LIMS and customer satisfaction are not positively correlated. This implies that the reliability of a Laboratory Information Management system does not positively impact customer satisfaction.

H2: The Responsiveness of a LIMS positively impacts customer satisfaction in the laboratory setting.

The second hypothesis (H2) is not supported, as the data has demonstrated. This suggests that responsiveness and customer satisfaction are not positively correlated. This outlines that the responsiveness of a Laboratory Information Management system does not positively impact customer satisfaction.

H3: Assurance in a LIMS system positively impacts customer satisfaction in the laboratory setting.

The third hypothesis (H3) is supported, as the data has demonstrated. This suggests that assurance and customer satisfaction are positively correlated. This outlines that assurance in a Laboratory Information Management system positively impacts customer satisfaction.

H4: Perceived empathy in a LIMS system positively impacts customer satisfaction in the laboratory setting.

The fourth hypothesis (H4) is not supported, as the data has demonstrated. This suggests that empathy and customer satisfaction are not positively correlated. This outlines that perceived empathy in a Laboratory Information Management system does not positively impact customer satisfaction.

H5: Tangibles of a LIMS system positively impact customer satisfaction in the laboratory setting.

The fifth hypothesis (H5) is supported, as the data has demonstrated. This suggests that tangibles and customer satisfaction are positively correlated. This outlines that tangibles of a Laboratory Information Management system positively impact customer satisfaction.

CHAPTER 5 - DISCUSSION OF RESULTS

The research findings are thoroughly reviewed in this chapter, taking into consideration the body of existing literature. The findings of the hypothesis are presented first, then the findings are connected to earlier published literature. The implications of these findings will be discussed concerning how the South African laboratory industry will be affected.

5.1 Findings

The findings related to whether a laboratory information management system assists in improving customer satisfaction for South African laboratories are discussed below.

5.1.1 H1 The Reliability of a LIMS positively impacts customer satisfaction in the laboratory setting.

$H1_0$: Reliability of a LIMS has no positive impact on Customer Satisfaction.
$H1_1$: Reliability of a LIMS has a positive impact on Customer Satisfaction.

The findings from the first hypothesis demonstrate that there is no relationship between the reliability of a LIMS and customer satisfaction. This implies that the reliability of a LIMS is unlikely to affect the level of customer satisfaction for South African laboratories.

Technical Difficulties and System Unavailability:

Despite measures taken to guarantee dependability, LIMS may experience technical problems such hardware malfunctions, software bugs, or system outages (Brown et al., 2016). According to research, even small disruptions in LIMS performance can cause delays in processing test results and reporting, which could have an impact on client satisfaction (Rojo et al., 2017).

User View of Trustworthiness:

According to Al-Harbi et al. (2017), reliability includes users' opinions on the system's accuracy, consistency, and predictability in addition to its uptime. Research indicates that variables like data accuracy, result consistency, and system responsiveness all of which can change depending on a user's experience may have an impact on consumers' subjective evaluations of LIMS reliability (Fondoh, 2020).

5.1.2 H2: The Responsiveness of a LIMS positively impacts customer satisfaction in the laboratory setting.

$H2_0$: Responsiveness of a LIMS has no positive impact on Customer Satisfaction.
$H2_1$: Responsiveness of a LIMS has a positive impact on Customer Satisfaction.

The findings from the second hypothesis demonstrate that there is no relationship between the responsiveness of a LIMS and customer satisfaction. This implies that the responsiveness of a LIMS is unlikely to affect the level of customer satisfaction for South African laboratories.

The relationship between a Laboratory Information Management Systems (LIMS) responsiveness and customer satisfaction in a laboratory setting may not always be clear-cut, even though responsiveness is widely regarded as an essential aspect of service quality for customer satisfaction in a variety of service industries, including healthcare settings. Here are several justifications and examples from the literature to show that a LIMS's responsiveness may not always have a favourable effect on customer satisfaction.

The implementation of LIMS is complex.

Service delivery delays or disruptions may result from the complicated and difficult process of integrating and implementing a LIMS into laboratory

workflows (Rojo et al., 2017). According to studies, LIMS implementation-related technical problems, system outages, and training needs might have a detrimental impact on responsiveness and general customer satisfaction (Brown et al., 2016).

Incompatible Expectations:

Consumers may have irrational expectations for the LIMS's functionality and performance, which could cause them to become unhappy when their expectations aren't fulfilled (Jeyaraj et al., 2016).
According to research, lower customer satisfaction levels may arise from a mismatch between their expectations and the LIMS's actual responsiveness (Al-Harbi et al., 2017).

5.1.3 H3: Assurance in a LIMS system positively impacts customer satisfaction in the laboratory setting.

$H3_0$: Assurance of a LIMS has no positive impact on Customer Satisfaction.
$H3_1$: Assurance of a LIMS has a positive impact on Customer Satisfaction.

The findings from the third hypothesis demonstrate a positive relationship between assurance and customer satisfaction. The assurance of a LIMS has a positive impact on customer satisfaction for South African laboratory users.

Security and Confidentiality of Data:

Sensitive information is protected, and data confidentiality is ensured by the security elements of a LIMS, such as audit trails, user authentication, and data encryption (Rojo et al., 2017). Consumer satisfaction and trust in laboratory services are positively impacted by the assurance of data confidentiality and privacy, which they place a high value on (Fondoh, 2020).

Credibility and Compliance:

The legitimacy and integrity of laboratory services are improved by adherence to accrediting criteria and regulatory standards (Brown et al., 2016). Customers receive assurance of compliance from a LIMS that makes adhering to quality standards and regulatory norms easier, which boosts their happiness and confidence in the laboratory's abilities (Rojo et al., 2017).

5.1.4 H4: Perceived empathy in a LIMS system positively impacts customer satisfaction in the laboratory setting.

Hypothesis H4 suggests that empathy has a positive impact on customer satisfaction as confirmed by the Expectancy-Disconfirmation Theory (Oliver, 1997).

$H4_0$: Empathy in a LIMS has no positive impact on Customer Satisfaction.

$H4_1$: Empathy in a LIMS has a positive impact on Customer Satisfaction.

The findings from the fourth hypothesis demonstrate that there is no relationship between the empathy of a LIMS and customer satisfaction.

This implies that the empathy of a LIMS is unlikely to affect the level of customer satisfaction for South African laboratories.

Human Interaction and Technical Interface:

According to Rojo et al. (2017), LIMS primarily acts as a technical interface for laboratory operations, with an emphasis on process automation, data management, and sample tracking. Although LIMS has the potential to improve operational efficiency, it might not directly support individualised customer engagement or human connections, both of which are essential for exhibiting empathy (Brown et al., 2016).

Accessibility of Information and Communication:

Active listening, comprehending the problems of the client, and offering pertinent information and assistance are all components of empathetic communication (Al-Harbi et al., 2017). Although LIMS can help with communication by providing reporting capabilities and alerts about results, it could not immediately attend to the psychological or emotional requirements of users, which are crucial for empathy (Jeyaraj et al., 2016).

5.1.5 H5: Tangibles of a LIMS system positively impact customer satisfaction in the laboratory setting.

$H5_0$: Tangibles in a LIMS have no positive impact on Customer Satisfaction.
$H5_1$: Tangibles in a LIMS have a positive impact on Customer Satisfaction.

The findings from the fifth hypothesis demonstrate a positive relationship between tangibles and customer satisfaction. The tangible of LIMS has a positive impact on customer satisfaction for South African laboratory users.

Personalisation and Flexibility:

According to Brown et al. (2016), tangibles also include LIMS's adaptability and flexibility in meeting the unique requirements and preferences of laboratory users. According to research, users' happiness can be increased by the LIMS's configurable features and options, which help to match the system with their workflow requirements (Jeyaraj et al., 2016).

Modernity and Quality:

Customers' opinions of service quality and dependability can be favourably impacted by tangibles like the technological sophistication and modernity of a LIMS (Al-Harbi et al., 2017). Consumers' satisfaction with laboratory services may increase if they correlate the sophisticated features and visual appeal of

LIMS with professionalism, competence, and efficiency (Parasuraman et al., 1985).

5.2 Summary of Findings

In conclusion, this study showed that all six of the theories are validated as demonstrated in the table below. H1 did not receive support and demonstrated an unfavourable correlation between reliability and customer satisfaction. H2 did not receive support and demonstrated an unfavourable correlation between responsiveness and customer satisfaction. H3 was validated and demonstrated that there was a favourable correlation between assurance and customer satisfaction. H4 also did not receive support as the study revealed an unfavourable correlation between empathy and customer satisfaction. There was support for the correlation between tangibles and customer satisfaction with H5.

Table 5.1 Hypotheses summary

	Hypothesis	Results
H1	The reliability of a LIMS has no positive impact on Customer Satisfaction.	Not Supported
H2	Responsiveness of a LIMS has no positive impact on Customer Satisfaction.	Not Supported
H3	Assurance of a LIMS has a positive impact on Customer Satisfaction.	Supported
H4	Empathy in a LIMS has no positive impact on Customer Satisfaction.	Not Supported

H5	Tangibles of a LIMS system positively impact customer satisfaction in the laboratory setting.	Supported

In comparison to other current literature, the observation that tangibles and assurance are the main supported items gives a limited viewpoint.

1. Possible limitations of the current Research

One of the main causes of the emphasis on assurance and tangibles can be the constraints imposed by the study's scope or design.

Narrow Scope of Study:

The study may naturally highlight the most immediate, visible benefits, like improved physical or digital infrastructure (tangibles) and enhanced compliance (assurance), if it only looked at the short-term effects of LIMS implementation or concentrated on a small number of laboratories with particular needs (such as those under strict regulatory scrutiny). In the early phases of adoption, these are frequently the areas where LIMS has the greatest direct influence (Kettinger & Lee, 2005).

2. Differences in Context

The emphasis on tangibles and assurance could also be explained by the circumstances of the laboratories under study.

Early adoption in Developing Regions

One of the main issues in regions like South Africa, where LIMS adoption is still in its infancy. Therefore, compared to other SERVQUAL dimensions, the benefits in terms of assurance (e.g., data security, regulatory compliance) and tangibles (e.g., user-friendly interfaces) are probably going to be more noticeable (Moss, 2020).

Regulatory Focus

Assurance may be given top priority in laboratories operating in highly regulated environments to guarantee compliance with international standards. This concentration may result in a more limited understanding of the advantages of LIMS, ignoring the possible advancements in other domains like empathy and responsiveness, which are more pertinent in less controlled settings (Gupta & Kumar, 2021).

3. Methodological Differences

The methodology of the study may possibly have contributed to the seeming emphasis on tangibles and certainty.

Survey Design and Bias

Some SERVQUAL dimensions may have been given more weight than others by design in the surveys utilised in the study. For example, respondents may have given more attention to compliance and infrastructure upgrades if the questions were structured around these topics, emphasising assurance and tangibles over other dimensions (Kettinger & Lee, 2005).

Participation Demographics

Participants that work directly with IT infrastructure or regulatory compliance may naturally emphasise assurance and tangibles in their responses to the study. This bias may obscure the apparent value of responsiveness, empathy, and dependability in raising customer satisfaction (Smith & Jones, 2019).

4. SERVQUAL Weakness

The SERVQUAL model may not accurately represent the subtleties of how technology such as LIMS affects customer satisfaction because it was initially created for the service industry. As per Smith and Jones (2019), the model may not sufficiently capture the ways in which LIMS enhances responsiveness and reliability by means of automation and data management.

Particularly in areas where LIMS usage and technical infrastructure are still evolving as with most developing countries, SERVQUAL might not adequately

account for the cultural and contextual variations in perceptions of service quality (Moss, 2020).

CHAPTER 6 - RECOMMENDATIONS AND CONCLUSIONS

An overview of the study's key findings is provided in this chapter, along with a discussion of the study's contributions, limitations, and suggestions for further research.

6.1 Summary of main findings

Only two of the five hypotheses were supported form this study. As a result, there is a positive relationship between the assurance of a LIMS with customer satisfaction as well as the tangibles of a LIMS and customer satisfaction. However, the relation strength of reliability, responsiveness and empathy of a LIMS and customer satisfaction is not as strong. These negative findings should be interpreted with caution as they go against the literature that exists.

6.2 Implications

This research study outlines a few implications for the South African Laboratory Industry. It is clear from this study that the main key items that a Laboratory Information Management System are seen as positive elements for customer satisfaction. For most laboratories, a Laboratory Information Management System (LIMS) is essential in guaranteeing compliance readiness in laboratories.

According to Hubbard and Weisenseel (2019) user interfaces, hardware, documentation, support services, customisation choices, and system performance are examples of tangibles in LIMS that are essential to improving customer satisfaction. The research study supports this narrative in that through excellent handling of tangible issues, LIMS can enhance overall client satisfaction and loyalty. These implications can be taken advantage of by South African laboratory users as they will not only assist with customer satisfaction but also assist in achieving several other positive effects that are brought about by LIMS. It is therefore recommended that South African laboratories should

make the investment in cutting-edge, user-friendly LIMS interfaces that are both aesthetically pleasing and easily accessible. Making sure the LIMS is compatible with mobile devices and allowing remote access can further enhance the user experience, especially for customers who need to access real-time data from many places (Gupta & Kumar, 2021).

A crucial component of the SERVQUAL paradigm, reliability focuses on the capacity to produce accurate and trustworthy outcomes regularly. By eliminating human error, automating data collecting and analysis procedures, and guaranteeing consistently accurate and repeatable results, LIMS improves reliability (Bakar et al., 2018). It is recommended that South African laboratories should concentrate on deploying LIMS solutions with strong error-checking procedures and data integrity assurance to improve reliability. To keep LIMS reliable and avoid data loss or system failures, regular system updates and maintenance are also necessary (Smith & Jones, 2019).

Responsiveness refers to a service provider's capacity and willingness to assist clients quickly. By automating repetitive operations and optimising workflows, LIMS increases responsiveness. This lowers turnaround times and enables laboratories to react swiftly to customer requests and enquiries (Makhubele, 2022). It is recommended that laboratories need to concentrate on LIMS optimisation in order to minimise bottlenecks and improve workflow effectiveness. Putting quick reporting and real-time data processing into practice can greatly increase responsiveness, which will increase customer satisfaction (Moss, 2020).

Assurance encompasses staff members' expertise, politeness, and capacity to foster confidence and trust. By guaranteeing data confidentiality, upholding regulatory standards, and offering audit trails that strengthen the validity of laboratory results, LIMS adds to assurance (Kettinger & Lee, 2005). It is recommended that the compliance of South African laboratories' LIMS with pertinent national and international standards should be guaranteed. Furthermore, teaching employees how to utilise LIMS effectively and explain its

advantages to clients helps foster trust and reassure them of the laboratory's dependability and expertise (Ravichandran, 2018).

According to the SERVQUAL paradigm, empathy means giving each client personalised, considerate attention. By enabling laboratories to customise services to match particular client demands, such as offering unique reporting formats or satisfying unique data requests, LIMS helps promote empathy (Gupta & Kumar, 2021). The recommendation is that by providing individualised reports or data views that cater to the interests of each client, laboratories can leverage LIMS to give their clients a more personalised experience. Dedicated support channels made available to clients via the LIMS can help improve the sense of individualised care (Smith & Jones, 2019).

6.3 Limitations

The goal of this study was to learn more about the elements influencing customer satisfaction using a Laboratory Information Management System (LIMS) in the laboratory industry in South Africa. Despite adding to the existing body of literature, the study has certain limitations. The sample size might not be an accurate representative of the population as a whole because of the unknown population size. In addition, due to this being an online poll, it's possible that respondents weren't entirely focused on providing accurate answers, which could have influenced the findings. Finally, sample bias and variability were limited because participants were chosen through convenience sampling.

6.4 Future Research

The results of this study can serve as a baseline for future investigations into practical ways a Laboratory Information Management System can assist with improving customer satisfaction for South African laboratories.

Future research should consider a wider, more impartial assessment of how LIMS influences each SERVQUAL dimension to resolve these inconsistencies and constraints. This could be comparative studies between various locations and laboratory types, or longitudinal studies that monitor the long-term effects of LIMS installation.

A more thorough approach to LIMS adoption should be promoted for South African laboratories, emphasising not only tangibles and assurance but also improving responsiveness, empathy, and reliability. This more expansive approach will assist in realising LIMS's full potential for raising customer satisfaction and service quality.

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APPENDIX A – RESEARCH INSTRUMENT

SECTION 1 - DEMOGRAPHICS

This section will assist in uncovering more information regarding you and the organization you represent. (Please mark your appropriate response with an (x) in the associated box).

1.1 Age: _____ Years

1.2 Gender: Female ❑ Male ❑ Non-binary ❑ Prefer not to say ❑

1.3 What industry is your current laboratory in? _____

1.4 How long have you been working in a laboratory? Less than 1 year ❑ 1-5 years ❑ More than 5 years ❑

1.5 What is your current Role in the organization? _____

1.6 How many different operations does the lab currently support such as Stability, EM, Micro, Chemical Testing? Please list them._____

_____

_____

1.7 Is the laboratory required to support any regulatory requirements i.e. ISO, FDA, HIPAA?

_____

_____

_____

SECTION 2 – SERVQUAL SURVEY

(Please mark your appropriate response with an (x) in the associated box).

(Please rate your level of agreement from a scale of 1 to 5 where 1 indicates "Strongly Agree" and 5 indicates "Strongly Disagree"

1. RELIABILITY	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
▪ The LIMS provides accurate and dependable results.	❑	❑	❑	❑	❑
▪ The LIMS consistently performs its intended functions without errors.	❑	❑	❑	❑	❑
▪ The LIMS maintains the confidentiality and security of data.	❑	❑	❑	❑	❑

2. RESPONSIVENESS	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
▪ The LIMS promptly addresses any technical issues or concerns raised by users.	❑	❑	❑	❑	❑
▪ The LIMS team is responsive and attentive to user needs and inquiries.	❑	❑	❑	❑	❑
▪ The LIMS provides timely updates and notifications regarding system changes or maintenance.	❑	❑	❑	❑	❑

3. ASSURANCE	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
▪ The LIMS team demonstrates the necessary expertise and knowledge in operating and supporting the system.	❑	❑	❑	❑	❑
▪ Users have confidence in the LIMS' ability to meet their laboratory data management needs.	❑	❑	❑	❑	❑
▪ The LIMS ensures the integrity and accuracy of data throughout the system.	❑	❑	❑	❑	❑

4. EMPATHY	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
▪ The LIMS team shows a genuine understanding of users' specific laboratory processes and requirements.	❑	❑	❑	❑	❑
▪ The LIMS team is approachable and willing to provide assistance or guidance when needed.	❑	❑	❑	❑	❑
▪ The LIMS considers user feedback and suggestions for system improvements.	❑	❑	❑	❑	❑

5. TANGIBLES	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
▪ The LIMS interface is user-friendly and intuitive.	❑	❑	❑	❑	❑
▪ The LIMS provides clear and well-organized data presentation and reporting.	❑	❑	❑	❑	❑
▪ The LIMS offers a reliable and efficient data backup and recovery system.	❑	❑	❑	❑	❑

6. OVERALL CUSTOMER SATISFACTION	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
▪ Overall, the LIMS meets my expectations in terms of service quality.	❑	❑	❑	❑	❑
▪ I am satisfied with the overall performance and functionality of the LIMS.	❑	❑	❑	❑	❑
▪ I would recommend the LIMS to other laboratories based on its service quality.	❑	❑	❑	❑	❑

APPENDIX B – PARTICIPATION CONSENT LETTER

Participant Information Sheet (PIS)

Wits Business School

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Dear Participant,

My name is Karabo Maloka. I am currently pursuing a Master's in Business Administration at the University of the Witwatersrand, Johannesburg. I am conducting a research study about Improving Customer Service in South African laboratories using a Laboratory Information Management System (LIMS).

I would like to extend an invitation for you to participate in an online survey as a part of this research study. The survey is expected to take approximately 7 minutes to complete.

This survey will take place online at a time that is suitable for you and will be confidential. When I share the results of the research study, I will not include your name or anything else that could identify you. If you decide to participate in the research study, it should be because you want to volunteer, you do not have to take part. You can stop being in the study at any time and you do not have to answer any questions that you do not want to. You will not get any direct benefits if you choose to join the research study. You will not lose any services, benefits, or rights you would normally have if you decided not to join.

Taking part in the research study will not cost you anything and you will not be paid for being in this research study. This research study will be written up as a research report and it will be available on the university library website. If you would like to receive a summary of this report, I will be happy to send it to you. If you have any questions during or afterwards about this research study, feel free to contact me at the details listed below.

If you have any concerns or complaints about the ethical procedures of this research study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email hrecnon-medical@wits.ac.za.

Yours sincerely,
Karabo Maloka
Researcher: Name: Karabo Maloka
Email: 8220229@students.wits.ac.za

Do you consent to participate??

- ◯ YES, I consent
- ◯ NO, I do not consent