Factors influencing the approach to risk assessment in Scientific and Legal metrology in South Africa

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DECLARATION

I, TSHIFHIWA ELMON MADIBA, hereby declare that the study entitled 'Factors influencing the approach to risk assessment in Scientific and Legal metrology in South Africa' is my own work. All sources that I have used or referred to have been duly acknowledged. I further declare that this work has not been submitted to any other university or academic institution for examination. Wherever I have used verbatim extracts from copyrighted texts or images, I have clearly acknowledged the source.

Signature: ……………………………………………

Date: 23/05/2024

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ABSTRACT

This study addresses the complex landscape of risk assessment in the field of scientific and legal metrology in the context of South Africa. The main objectives of the study were to identify key factors influencing the approach to risk assessment, evaluate the effectiveness of existing practices and propose recommendations to improve the accuracy and reliability of measurements.

The research revealed a complex interplay of variables that influence risk assessment practices. Attitudes towards privacy and security risks were found to be of central importance. A positive correlation suggests that organizations and individuals with positive attitudes are more likely to undertake effective risk assessment. In particular, clear direction and support from senior management and regulators were identified as statistically significant factors, highlighting the importance of organizational structures and leadership in promoting effective risk assessment.

Using a robust statistical framework, the study evaluated the effectiveness of existing risk assessment practices. Perceived behavioral control played a central role, with a higher score correlating positively with effective risk assessment. The results also highlight the impact of social pressure: companies that feel pressured to prioritize aspects other than privacy and security risks are less likely to conduct effective risk assessments.

In response to the challenges and opportunities identified, the study proposes recommendations aimed at improving the accuracy and reliability of measurements in the field of scientific and legal metrology. The focus is on promoting a positive attitude towards risk, providing clear guidance and support, and dealing with perceived behavioral control and social pressure.

To further advance the field, future research efforts should explore new technologies, evolving regulatory landscapes, and the dynamic socio-cultural factors that influence risk assessment in metrology. Exploring the intersection of digital progress and risk management could uncover new insights for proactive practices.

This research sets the stage for a nuanced understanding of risk assessment in scientific and legal metrology and paves the way for informed policy and practice in an ever-evolving landscape.

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CHAPTER 1. INTRODUCTION

1.1 Problem Statement:

Risk assessment is a critical element of both scientific and legal metrology. The way risk assessment is approached is influenced by several factors in both fields of metrology. Scientific metrology focuses on providing accurate and precise measurements for research and development purposes in a controlled laboratory environment. The requirements for accuracy and precision of measurements play an important role in risk assessment in scientific metrology and are regulated by national and international metrology organizations (Esche et al., 2019; Karaboce, 2020; Kudva & Potter, 1992).

In contrast, legal metrology deals with measurements in real, unregulated environments and focuses on ensuring fairness in commercial transactions and emphasizes measurement accuracy to protect consumers (Bošnjaković et al., 2018). Legal metrology is also subject to laws and regulations at the national or regional level that provide guidelines and requirements for measurement and risk management and influence the approach to risk assessment (Esche et al., 2019).

The study aims to identify gaps in the current approach to risk assessment in scientific and legal metrology in South Africa and propose new methods for conducting risk assessments in these areas. The need for accurate measurement is essential for promoting fairness, safety, and security in various industries, and the study aims to promote fairness in business, research, development, and consumer protection, and to support informed decision making in scientific and legal metrology.

The study also aims to conduct a comprehensive literature review of risk assessment in scientific and legal metrology to provide an up-to-date and holistic understanding of the factors that influence risk assessment in these areas. The literature review will also examine how these factors relate to the South African context and identify gaps and limitations in the current approach to risk assessment in South African scientific and legal metrology. The study will explore potential solutions to address these gaps and improve the risk assessment process in these areas.

The literature review in the research proposal provides a definition of risk assessment in the context of scientific and legal metrology, and examines various approaches to conducting risk assessments, including quantitative and qualitative methods used to assess risk. The review also examines different types of risks that are assessed, such as environmental, health, and safety risks.

The literature review also examines the factors that influence risk assessment in scientific and legal metrology. These factors include the equipment used, the measurement method, the environment in which the measurements are made, and the regulatory requirements that govern the measurement process. It also examines the role of national and international metrology organizations in regulating risk assessment in scientific measurement, as well as laws and regulations at the national or regional level that provide guidelines and requirements for measurement and risk management in legal metrology.

Following an extensive literature review, the study will identify specific gaps in the current approach to risk assessment in scientific and legal metrology in South Africa. The study will focus on identifying any areas where the current risk assessment process is inadequate or could be improved. For example, the study could identify a lack of standardization in the risk assessment process, a lack of data on specific risks, or the need for more effective communication and collaboration among stakeholders involved in the risk assessment process.

The study proposes to address the gaps in the current approach to risk assessment in scientific and legal metrology in South Africa by proposing new methods for conducting risk assessments. These proposed methods will be based on the results of the literature review and will take into account the specificities of the South African context. The proposed methods may include the development of new measurement techniques or the implementation of new regulations that promote more effective risk assessment processes. The study aims to contribute to the development of more effective and efficient risk assessment processes in South African scientific and legal metrology.

1.2 Background of the study

Metrology, which is the science of measurement, is crucial in ensuring the accuracy and dependability of measurements in different sectors such as healthcare, commerce, and environmental monitoring. With the growth of new technologies, the increasing complexity of measurement systems, and the growing demand for accurate measurements, the importance of metrology is becoming more apparent (Rodrigues Filho & Gonçalves, 2015a). To ensure the accuracy of measurements, risk assessments must be conducted to identify and evaluate the potential hazards associated with the measurement process.

Metrology encompasses two interrelated fields, scientific and legal metrology, each with different frameworks and goals. Scientific metrology focuses on the development and refinement of measurement methods, while legal metrology ensures that measurements made in commerce meet legal requirements (Kudva & Potter, 1992; Sivitski & Põodra, 2021). Both areas play an important role in ensuring the precision and reliability of measurements and contribute to the development and maintenance of the international measurement system.

Several factors including the increasing complexity of measurement systems, the increasing demand for accurate measurements, and the need for consistency across different measurement domains. As measurement systems have become more complex, it has become more difficult to identify all potential sources of error, making it more difficult to conduct accurate risk assessments (Thiel et al., 2015). The demand for accurate measurements has led to the development of new technologies and techniques for measurement, increasing the importance of risk assessment in metrology (Esche et al., 2019). To ensure consistent measurements across all domains, there is also a need to develop risk assessment methods that are applicable to a wide range of measurement systems.

The growth of new technologies and the increasing use of digital measurement systems have also impacted the way risk is assessed in metrology. While digital measurement systems are more accurate and reliable than traditional systems, they can also be vulnerable to privacy and security issues. Therefore, it is important to conduct risk assessments to ensure that measurement data are secure and protected from tampering (Filho et al., 2016). In addition, the growing awareness of the importance of data privacy and security has influenced the approach to risk assessment in metrology. Measurement data can be sensitive and vulnerable to tampering (Thiel et al., 2014). This requires the development of risk assessment methods to ensure the security of the measurement process and protect data from unauthorized access.

1.3 Context of the Study

The context of the study focuses on metrology, the science of measurement, which plays a critical role in ensuring the accuracy and reliability of measurements in various industries. In South Africa, the National Regulator for Compulsory Specifications (NRCS) is responsible for legal metrology, which ensures the accuracy and reliability of measurements for trade, health, safety, and the environment (Cecilia, 2020).

The approach to risk assessment in scientific and legal metrology is influenced by several factors. Increasing complexity of measurement systems is one of the most important factors affecting the approach to risk assessment (Sorochkina et al., 2020). As measurement systems become more complex, it becomes increasingly difficult to identify all potential sources of error, making it more difficult to conduct accurate risk assessments. Inaccurate risk assessments can lead to inaccurate and unreliable measurements, which can have significant consequences for industries that rely on these measurements (Kudva & Potter, 1992).

Another factor affecting the approach to risk assessment in metrology is the need to ensure consistency between different measurement domains. To ensure that measurements are accurate and reliable, it is necessary to ensure that the measurement process is consistent across all domains. This requires the development of risk assessment methods that are applicable to a wide range of measurement systems. International measurement standards such as the International Organization for Standardization standard (ISO) provide a common framework for the measurement process and ensure that measurements are consistent across all domains (Esche et al., 2019).

The demand for more accurate measurements has also led to the development of new technologies and techniques for measurements, such as digital measurement systems. These advances have made it possible to take measurements with greater accuracy and precision, increasing the importance of measurement risk assessment (Filho et al., 2016). However, digital measurement systems are susceptible to privacy and security issues, so risk assessments must be conducted to ensure that measurement data are secure and protected from tampering (Thiel et al., 2014). The increasing use of digital measurement systems has also led to the development of new risk assessment methods tailored to the specific challenges of digital measurement systems.

The South African context of metrology is unique and can influence the approach to risk assessment in scientific and legal metrology. There are several factors that impact the approach to risk assessment in South Africa, including the legal framework, the use of technology, and the influence of context on the approach to risk assessment. The legal framework for metrology in South Africa is established by the NRCS, which is responsible for ensuring that measurements used for trade, health, safety, and environmental purposes are accurate and reliable. The NRCS has developed a set of regulations, policies, and guidelines to ensure that the measurement process is consistent across all sectors and that the risks associated with measurements are appropriately managed (Cecilia, 2020). The regulatory framework in South Africa is also influenced by international measurement standards such as ISO, which provide a common framework for the measurement process and ensure that measurements are consistent across all sectors.

The use of technology in measurement is increasing in South Africa, and there is a need to ensure that risk assessments are conducted to ensure that measurement data is secure and protected from tampering. The NRCS has developed guidelines and policies to ensure that the risks associated with the use of technology in measurements are appropriately managed. NRCS also works closely with industry stakeholders to ensure that measurement systems are accurate and reliable.

The influence of context on the approach to measurement risk assessment is also important in South Africa. In South Africa, there are a variety of industries that rely on accurate and reliable measurement, including the health, environmental, mining, and commercial sectors (Monakali et al., 2022). South Africa's unique social, economic, and political context can impact the approach to measurement risk assessment. For example, socioeconomic factors such as poverty and inequality can impact the resources available for measurement systems and risk assessment.

Another unique aspect of the South African context is the prevalence of informal markets, especially in rural areas. Informal markets often operate outside of the formal legal framework, so the measurements used in these markets may not meet legal requirements (Agboola et al., 2017). Therefore, there is a need for risk assessment methods that address the unique challenges of informal markets, such as the use of non-standard measurement tools and the lack of standardized measurement procedures. The impact of informal markets on metrology risk assessment is an area that needs further research, as it has significant implications for industries that rely on accurate and reliable measurement.

The use of technology is another factor influencing the approach to risk assessment in scientific and legal metrology in South Africa. Digital measurement systems have become increasingly prevalent in many industries, including the health, environmental, and commercial sectors (Ardianto & Yulianti, 2021). These systems offer the potential for increased accuracy and precision in measurements, but also pose new risks such as cyberattacks and data breaches. The use of digital measurement systems requires the development of new risk assessment methodologies that address the unique challenges of these systems, such as the need to ensure the security and integrity of measurement data.

In addition to the use of technology, the regulatory framework also plays an important role in risk assessment in scientific and legal metrology in South Africa. The National Regulatory Compulsory Specifications (NRCS) is responsible for legal metrology in South Africa and is tasked with ensuring the accuracy and reliability of measurements used for commercial, health, safety and environmental purposes. The NRCS is guided by the Legal Metrology Act, which sets out the legal requirements for measuring instruments and the procedures to ensure their accuracy and reliability. Compliance with legal metrology requirements is necessary to ensure that measurements are accurate and reliable. Non-compliance may result in legal sanctions and damage to reputation.

Finally, the international context of metrology also plays a role in assessing risk in scientific and legal metrology in South Africa. International measurement standards such as ISO 17025 provide a common framework for the measurement process and ensure that measurements are consistent across the board. Compliance with these standards is essential for global companies as they ensure that their measurements are internationally recognized and accepted (Esche et al., 2019). The development of international measurement standards has also led to the development of new risk assessment methods that are applicable to a wide range of measurement systems.

Therefore, the approach to risk assessment in scientific and legal metrology in South Africa is influenced by a number of complex factors, including the historical context of metrology in South Africa, the prevalence of informal markets, the use of technology, the legal framework, and the international context of metrology. These factors must be considered to ensure that measurements are accurate and reliable, and to protect the industry that relies on them. Further research is needed to develop risk assessment methodologies that address the unique challenges of the South African context and ensure that measurement systems are trustworthy and effective.

1.4 Research Questions

This study aims to conduct a comprehensive investigation of the factors influencing the approach to risk assessment in both scientific and legal metrology in the context of South Africa as the leading country in this field on the African continent:

- What are the key factors influencing the approach to risk assessment in both scientific and legal metrology in South Africa?
- How has the increasing complexity of measurement systems affected risk assessment in scientific and legal metrology in South Africa?
- What risk assessment methods are currently used for scientific and legal metrology in South Africa, and how effective are they in identifying and mitigating potential risks?
- How has the need for consistency across measurement domains impacted risk assessment in scientific and legal metrology in South Africa?
- What privacy and security risks are associated with digital measurement systems in South Africa, and how are they considered in risk assessment?

1.5 Research objectives

The first objective is to identify key factors that influence the approach to risk assessment in scientific and legal metrology in South Africa. To this end, data will be collected and analyzed from relevant stakeholders, including regulators, metrology experts, and industry professionals. Questionnaires will be used in the data collection to gain insight into stakeholder attitudes and perceptions of risk assessment in scientific and legal metrology. Data will be analyzed using statistical techniques to identify key factors that influence the approach to risk assessment in this field.

The second objective is to evaluate the effectiveness of current risk assessment practices in scientific and legal metrology in South Africa. This will be done by examining relevant case studies and real-world examples to determine whether current risk assessment practices ensure accurate and reliable measurements. The assessment will help identify areas where current risk assessment practices can be improved and addressed in the proposed research.

The third objective is to propose recommendations to improve risk assessment practices in scientific and legal metrology in South Africa. These recommendations are based on the research findings and aim to improve the accuracy and reliability of measurements in the field. The recommendations will take into account the current legal framework and policies that govern risk assessment in scientific and legal metrology in South Africa.

1.6 Justification of the Study

Examining the factors that influence the approach to risk assessment in scientific and legal metrology in South Africa is important to policy makers, measurement practitioners, and scientists for several reasons. First, accurate and reliable measurements are essential for the safety and health of citizens, as well as for the environment and commerce. Inaccurate measurements can have serious consequences, especially in areas such as public health and environmental management, where even the smallest error can lead to devastating consequences (Kudva & Potter, 1992). Therefore, it is critical for policy makers and practitioners to have a thorough understanding of the factors that influence the approach to risk assessment in metrology.

Second, the study will have a direct impact on the effectiveness of metrology risk assessment in South Africa. As mentioned earlier, South African metrology is at a crossroads where the introduction of new technologies has changed the landscape of metrology and requires the development of new and innovative measurement methodologies (Rodrigues Filho & Gonçalves, 2015a).By examining the effectiveness of existing risk assessment methods and identifying opportunities for improvement tailored to the South African context, the study will provide valuable insights for policy makers and practitioners to develop and implement effective metrology risk assessment methods.

Third, the study will contribute to the existing body of knowledge by highlighting the importance of effective risk assessment in South African metrology. The results of this study will provide a foundation for future research in this area and help improve our understanding of the factors that influence the approach to risk assessment in scientific and legal metrology in South Africa.

A specific example of how this study can have a direct impact on policy makers and practitioners is in the area of informal markets in South Africa. Informal markets, also known as the informal economy or shadow economy, refer to economic activities that are not regulated by the government and are not subject to taxation or formal monitoring. The informal market makes a significant contribution to the South African economy, accounting for at least 10% of the country's gross domestic product (GDP). However, the informal market is largely unregulated, which can lead to inaccurate measurements and pose a risk to public health and safety (Agboola et al., 2017).

This study can help policymakers and practitioners develop effective risk assessment methods for informal markets. By understanding the unique challenges and opportunities in measuring informal markets, such as the lack of standardized measurement tools and the use of non-traditional measurement methods, policymakers and practitioners can develop appropriate risk assessment methods to ensure the safety and accuracy of measurements in informal markets.

Another example of how this study can have a direct impact is environmental management in South Africa. The country is home to several industries that rely heavily on accurate measurements, such as mining and agriculture (Greeff, 2022). Inaccurate measurements in these industries can lead to environmental degradation and pose a threat to public health and safety. By examining the factors that influence the approach to risk assessment in metrology, policy makers and practitioners can develop effective risk assessment methods to ensure measurement accuracy in these industries.

Investigating the factors that influence the approach to risk assessment in scientific and legal metrology in South Africa is of great importance to policy makers, practitioners, and researchers. The study will have a direct impact on the effectiveness of risk assessment in metrology in South Africa and will provide valuable insights for policy makers and practitioners to develop and implement effective methods for risk assessment in metrology. In addition, the study will contribute to the existing body of knowledge by highlighting the importance of effective metrology risk assessment in South Africa. The specific examples show how this study can have a direct impact on policy makers and practitioners in areas such as informal markets, manufacturing, energy, etc.

1.7 Delimitations of the Study

The study's delimitations outline the specific limitations of the research on the factors that influence the approach to risk assessment in scientific and legal metrology. The following are the major delimitations of the study:

i) Geographic delimitation: this study focuses exclusively on the approach to risk assessment in scientific and legal metrology in South Africa. While other countries may have different approaches due to different resources and infrastructures, the scope of this study is limited to South Africa.

ii) Conceptual delimitation: the study focuses on the factors influencing risk assessment in scientific and legal metrology in South Africa, using specific theoretical concepts such as risk assessment and metrology. However, it does not address other related concepts such as quality assurance or statistical analysis.

iii) Methodological delimitation: the study analyses only the most commonly used measurement tools and methods for scientific and legal metrology in South Africa and excludes other measurement tools and methods that are not commonly used.

iv) Scope delimitation: the study focuses on laboratory measurements, industrial measurements and legal metrology and excludes other measurement applications such as environmental measurements.

v) Regulatory Delimitation: the study examines only the regulations and standards that govern scientific and legal metrology in South Africa and excludes regulations and standards of other countries or international bodies.

1.8 Operational Definitions

The following are some of the key operational definitions:

1) Scientific Metrology: Scientific metrology refers to the field of metrology concerned with the development and use of measurement techniques, instruments and procedures for scientific applications. It includes laboratory measurements, industrial measurements, and other measurements used for scientific purposes (Bošnjaković et al., 2018).
2) Legal Metrology: Legal metrology refers to the area of metrology that focuses on the use of measurements in legal transactions, such as commerce. This includes the use of

measurement to ensure that goods and services are accurately described and marked, and that transactions are fair and equitable (Toro et al., 2018).

3) Risk Assessment: Risk assessment refers to the process of identifying and evaluating the risks associated with a particular activity or system. In the context of scientific and legal metrology, risk assessment refers to the process of evaluating the risks associated with inaccurate measurements (Esche et al., 2019).
4) Inaccurate Measurements: Inaccurate measurements refer to measurements that deviate from the true value of the measured quantity. In the context of scientific and legal metrology, inaccurate measurements can have significant consequences, including financial losses, litigation, and loss of credibility (Nazim et al., 2019a).
5) Risk Assessment Approaches: Risk assessment approaches refer to the methods and techniques used to evaluate the risks associated with inaccurate measurements in scientific and legal metrology. These approaches may include quantitative risk assessments, qualitative risk assessments, or a combination of both (Sorochkina et al., 2020).
6) Regulations and Standards: regulations and standards refer to the rules and guidelines that govern scientific and legal metrology. These regulations and standards are intended to ensure that measurements are accurate, reliable, and consistent, and that they meet certain technical, financial, and legal requirements (Cecilia, 2020).
7) Stakeholders: Stakeholders are those individuals and organizations that are affected by or have an interest in the results of scientific and legal metrology. In the context of this study, stakeholders may include metrology laboratories, manufacturers, trade organizations, regulatory agencies, and consumers (Ardianto & Oktriana, 2021).

1.9 Structure of the Paper

1) Introduction: this section provides an overview of the research problem and background information on scientific and legal metrology. The introduction also includes a summary of the research questions, objectives, and hypotheses.
2) Literature Review: this section provides a comprehensive review of the existing literature on the factors that influence the approach to risk assessment in scientific and legal metrology. This section also provides a summary of the current state of knowledge on this topic and identifies gaps in the literature that the study aims to address.

3) Research Framework: this section presents the theoretical framework that will guide the study of factors influencing the approach to risk assessment in scientific and legal metrology in South Africa.
4) Research Methodology: this section describes the research design, data collection methods, and data analysis techniques used in the study. This section also provides a detailed description of the sample population and the sampling techniques used.
5) Results: This section presents the results of the study, including the descriptive statistics and the results of the statistical tests used to evaluate the research hypotheses.
6) Discussion: this section provides a detailed interpretation of the results and highlights the main findings of the study. This section also compares the results to the existing literature and discusses the implications of the results for scientific and legal metrology.
7) Conclusion: this section summarises the major findings of the study and provides recommendations for future research. This section also includes a conclusion on the contribution of the study to scientific and legal metrology.
8) References: This section provides a list of all sources cited in the study, formatted according to the appropriate referencing style.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

Scientific and legal metrology are essential to ensure accurate measurements and reliable data in various sectors such as manufacturing, commerce, healthcare, and environmental monitoring. According to the International Organization of Legal Metrology (OIML), legal metrology is "the part of metrology concerned with activities related to legal requirements for measurements and measuring instruments" (Kuzmenko, Pronenko, and Pototskyi 2022; Scotti 2014). Legal metrology is governed by laws, regulations, and standards that aim to protect consumers and ensure fair trade by ensuring the accuracy, reliability, and traceability of measurements.

Risk assessment is an essential part of scientific and legal metrology because it helps identify and evaluate potential risks associated with measurements and measuring devices. Risk assessment involves the systematic identification, analysis, and evaluation of hazards and their associated risks to determine the most appropriate risk management strategies. In the context of scientific and legal metrology, risk assessment can help identify potential sources of measurement error, uncertainty, and bias, as well as the potential impact on public health, safety, and environmental protection (Stayner et al., 2002).

Several factors can influence the approach to risk assessment in scientific and legal metrology in South Africa. These factors include legal and regulatory frameworks, cultural norms, organizational structures and processes, technological advances, and stakeholder expectations. Understanding these factors is critical to developing effective risk assessment strategies that can improve the accuracy, reliability, and traceability of measurements while minimizing potential risks to public health, safety, and environmental protection (Esche et al., 2019) .

Ensuring traceability of measurement results to internationally recognized standards is a significant hurdle in scientific and regulatory metrology. Traceability is the ability to establish a link between measurements and a known reference, following a continuous chain of calibrations using appropriate procedures and equipment. It plays a critical role in ensuring the accuracy and reliability of measurement results and is a mandatory aspect of legal metrology in many countries, including South Africa (Imai, 2013).

Another important aspect of scientific and legal metrology is the use of appropriate measurement methods and equipment. Inaccurate or outdated measurement methods and equipment can lead to significant errors and biases in measurement results, which can have serious consequences for public health, safety, and environmental protection (Hall, 2019). For example, inaccurate measurements of air pollutants can lead to incorrect assessments of air quality and associated health risks.

In summary, scientific and legal metrology is critical to ensure accurate measurements and reliable data in various sectors such as manufacturing, commerce, public health, and environmental monitoring. Risk assessment is an essential component of scientific and legal metrology because it helps identify and evaluate potential risks associated with measurements and measuring devices. Several factors can influence the approach to risk assessment in scientific and legal metrology in South Africa, including legal and regulatory frameworks, cultural norms, organizational structures and processes, technological advances, and stakeholder expectations. Understanding these factors is critical to developing effective risk assessment strategies that can improve the accuracy, reliability, and traceability of measurements while minimizing potential risks to public health, safety, and environmental protection. The following table summarises each section of the literature review and the major concepts or questions used to formulate the research questions for each section of this study:

Section of Literature review	**Key Concepts/ Research Gap/**	**Articles**	**References**
(2.2) Overview of Risk Management in Organisations	(1) What is scientific and legal metrology, and why is it important for public safety and consumer protection? (2) What are the key risk factors that need to be addressed in scientific and legal metrology, and why?	5	(Franco et al., 2012) (Scotti, 2014) (Mester, 2018) (Brown, 2021) (Simkin et al., 2022)
(2.3) Importance of Risk Assessment to Organisations	(3) What is risk management in business, and why is it important for organizational success? (4) What are the key components of a risk management	5	(Dobrota, 2012; Peterson, 2020a) (Simkin et al., 2022) (Stayner et al., 2002) (Sivitski & Põodra, 2021)

	framework, and how do they relate to risk assessment in scientific and legal metrology?		
(2.4) Approaches to Risk Assessment with Organisations	(5) Why is risk assessment important for businesses operating in South Africa? (6) How can effective risk assessment help businesses to mitigate risks and achieve their strategic objectives?	3	(Yolande Smit, 2012a) (Van Wyk et al., 2004a) (O'Neal & Clavaud, 2016)
(2.5) Approaches to Risk Assessment within Organisations	(7) What are the different approaches to risk assessment in business, and how do they compare in terms of effectiveness and efficiency? (8) How can businesses determine which risk assessment approach is most appropriate for their needs?	3	(Aven, 2016a) (Khan et al., 2020) (Gritzalis et al., 2019)
(2.6) Risk Assessment in South African Organisations: A Review of Current Practices	(9) What are the current practices for risk assessment in South African businesses operating in the scientific and legal metrology sector? (10) How effective are these practices in identifying and mitigating risks, and what improvements can be made?	3	(Moloi, 2016a) (Vuković et al., 2018) (Kuzmenko et al., 2022)
(2.7) Factors Influencing the Approach to Risk Assessment in South African Organisations	(11) What are the key factors that influence the approach to risk assessment in South African businesses operating in the scientific and legal metrology sector? (12) How do these factors impact the	5	(Zitha & Klerk, 2022) (Visser & Joubert, 2008) (Hall, 2019) (Imai, 2013) (Brown, 2021)

	effectiveness and efficiency of risk assessment in these businesses?		
(2.8) Challenges in Implementing Risk Assessment in South African Organisations	(13) What are the main challenges that businesses in South Africa face when implementing risk assessment in the scientific and legal metrology sector? (14) How can these challenges be overcome, and what strategies are most effective for addressing them?	3	(Tarazona, 2013) (Simkin et al., 2022) (Pandya et al., 2021)
(2.9) Overview of the Legal Metrology Act 8 of 2014	(15) How effective is the Act 8 of 2014 in ensuring that it achieves its objectives of promoting fair trade and consumer protection?	3	(Fisher Jr et al., 2019) (Pasaribu et al., 2020) (Rodrigues Filho & Gonçalves, 2015b)
(2.10) Overview of the Standards Act 8 of 2008	(16) How effective is the Act 8 of 2008 and does it ensure that it achieves its objectives of promoting the development, maintenance, and advancement of standards in various industries?	2	(B. Chili & S. Matsiliza, 2022) (Alsaidi et al., 2020)
(2.11) Overview of the Accreditation for Conformity Assessment, Calibration and Good Laboratory Practice Act 19 of 2006 of South Africa	(17) How effective is effectiveness of the Act 19 of 2006 of South Africa and ensure that it achieves its objectives of promoting conformity assessment, calibration, and good laboratory practice in various industries.	2	(Dhatt et al., 2005) (Peet & MacCurtain, 1997)

2.2 Overview of Risk Management in Organisations

Risk management is a critical component in any industry or organization because it involves identifying, evaluating, and controlling risks that could impede the achievement of organizational goals (Peterson, 2020b). It is important to emphasize that risk management does not aim to completely eliminate risks, but to effectively manage them to facilitate the achievement of objectives (Behl & Nayak, 2019). In a business context, risk management involves identifying and evaluating risks associated with various aspects such as business operations, products or services, markets, and stakeholders. It includes assessing the likelihood and impact of risks, implementing strategies to mitigate or transfer them, and monitoring and evaluating the overall effectiveness of the risk management process (Văduva et al., 2016).

The International Organization for Standardization (ISO) has developed the standard ISO 31000:2018, which provides guidelines for the principles, framework, and process of risk management (Proenca et al., 2017). According to ISO 31000:2018, the risk management process includes the identification of internal and external factors that may affect the organization's objectives, stakeholders, and the risk management process itself. In addition, it includes the identification of risks that could affect the achievement of organizational objectives (Olechowski et al., 2016). The process also includes assessing the likelihood and impact of the identified risks, comparing the results with the established risk criteria, developing and implementing strategies to address the risks, and continuously monitoring and reviewing the effectiveness of the risk management process and making necessary adjustments (Govender, 2019).

The application of the risk management process extends to various areas within an organization, including financial risk management, operational risk management, strategic risk management, and compliance risk management (Vereshchagin & Shemyakina, 2021). Financial risk management addresses risks associated with financial transactions, investments, and market volatility (Hughes, 2019). Operational risk management addresses risks related to business activities such as process failures, supply chain disruptions, and technology failures (Pastrana-Jaramillo & Osorio-Gómez, 2020). Strategic risk management addresses risks related to strategic objectives such as market competition, innovation, and regulatory changes (Slagmulder & Devoldere, 2018). Compliance risk management focuses on managing risks related to legal and regulatory compliance.

Effective implementation of risk management depends on fostering a risk-aware culture where employees understand their roles and responsibilities in risk management and where open communication and collaboration among stakeholders is encouraged (Stayner et al., 2002). Organizations that adopt a risk management approach can improve their decision-making processes, increase their resilience to risk, and create value for their stakeholders.

2.3 Importance of Risk Assessment to Organisations

Risk assessment is an important process for organizations to identify and evaluate potential risks that could negatively impact operations, finances, reputation, and stakeholders. According to (Bejinariu, 2020b), risk assessment is a proactive process that enables organizations to identify and analyze potential risks and develop effective strategies to manage and mitigate those risks. The importance of risk assessment in business cannot be overstated, as it helps companies protect their assets and reputations, comply with regulatory requirements, and make informed decisions based on accurate risk information (Farkas et al., 2020) (Donič, 2020).

One of the key benefits of risk assessment is that it enables organizations to identify and prioritize risks based on their likelihood and potential impact, and allocate resources accordingly. This ensures that organizations focus on the most critical risks and take action to mitigate them, while avoiding wasting resources on less significant risks (Bejinariu, 2020b). In addition, risk assessment helps organizations anticipate and plan for potential risks, which reduces the likelihood of unexpected incidents and improves their ability to respond effectively to crises (Crandall, 2020) (Mt-Isa et al., 2016).

In addition, risk assessment is a key component of effective governance and risk management practices because it provides a framework for identifying and managing risks at all levels of the organization (Aven, 2016b). As noted by (Van Der Heijden, 2019), organizations that adopt a risk-based approach to governance are better able to detect and prevent fraud, meet regulatory requirements, and improve their overall performance and reputation.

In addition, risk assessment can also help improve companies' overall financial performance by identifying potential risks that could impact revenue, profit, and cash flow. When companies understand the potential financial impact of risks, they can make informed decisions about their investments, pricing strategies, and risk transfer mechanisms such as insurance (Tjoa et al., 2008).

Thus, risk assessment is a critical process for companies to ensure their long-term sustainability and success. By identifying and managing potential risks, companies can protect their assets, comply with regulatory requirements, improve their performance and reputation, and enhance their overall financial performance.

2.4 Approaches to Risk Assessment within Organisations

According to (Aven, 2016c), the process of risk assessment involves the identification, analysis, evaluation, and control of potential risks. This process is critical for organizations because it enables them to make informed decisions and take action to mitigate risks. Risk assessment can be performed using a variety of approaches, such as quantitative, qualitative, and semi-quantitative approaches (Aven, 2016c) (Cebi, 2021).

Qualitative risk assessment, on the other hand, uses subjective assessments and experiences to identify and evaluate risks. This approach is suitable for companies engaged in low to medium risk activities, such as retail and service industries (Bernard et al., 2020). The advantage of qualitative risk assessment is that it is less time consuming and less expensive compared to quantitative risk assessment (Peters & Svanström, 2019).

Semi-quantitative risk assessment is a combination of quantitative and qualitative approaches This approach is suitable for companies operating in medium- to high-risk sectors, such as manufacturing and healthcare (Krausmann et al., 2017). Semi quantitative risk assessment combines the benefits of quantitative and qualitative approaches and provides a more comprehensive understanding of risks (Carvalho & Melo, 2015).

To determine the most appropriate approach to risk assessment, organizations should consider the complexity of the risk, available data, and resources (Aven, 2016b). For example, if a company is dealing with complex risks that require a detailed understanding of the potential consequences, a quantitative approach to risk assessment would be more appropriate. However, if an organization is dealing with low-risk activities and has limited resources, a qualitative approach would be more appropriate.

Thus, organizations can use different approaches to risk assessment depending on the nature and complexity of the risks. Quantitative, qualitative and semi-quantitative approaches have their advantages and disadvantages, and organisations should choose the most appropriate approach depending on the resources available, the data available and the complexity of the risk.

2.5 Risk Assessment in South African Organisations: A Review of Current Practices

Risk assessment is an essential process of risk management in companies operating in South Africa. In recent years, the number of risks facing companies in South Africa has increased. These risks include regulatory compliance, financial risks, operational risks, reputational risks, and cyber risks, among others (Van Wyk et al., 2004b).

Current risk assessment practices in South African companies are primarily reactive and focused on compliance. Most companies focus on risk assessment only when required to do so by regulators, and they often conduct only a one-time risk assessment rather than ongoing assessments. This approach is ineffective in mitigating risk because it does not take into account the ever-changing risk landscape (Yolande Smit, 2012b).

Another problem with current practices is that the focus is primarily on identifying risks rather than assessing and prioritizing them. As a result, organizations may not have a clear understanding of the risks that pose the greatest threat to their business. Inadequate risk assessment practices can also lead to missed opportunities, lost revenue, reputational damage, and legal and financial penalties (Moloi, 2016b).

Current risk assessment practices in South African companies are not completely effective in identifying and mitigating risks (Van Wyk et al., 2004b). The reactive and compliance-focused approach to risk assessment means that companies address risks only after they have occurred, limiting the effectiveness of risk management.

In addition, focusing on compliance rather than risk mitigation means that companies may not take all necessary actions to address risks. This approach can result in the implementation of ineffective risk mitigation strategies that do not address the organization's specific risks (Van Wyk et al., 2004b) . For effective risk management, it is imperative that organizations take a more proactive approach to risk assessment and mitigation.

To improve risk assessment practices in South African companies, they should adopt a more proactive and comprehensive approach to risk assessment. First, a systematic risk assessment process should be put in place. This process should include the identification, evaluation, and prioritization of risks based on their likelihood of occurrence and impact on the business (Yolande Smit, 2012b). This process should also include developing and implementing risk mitigation strategies and monitoring the effectiveness of those strategies.

Second, risk management should be integrated into the overall business strategy in South Africa. This integration can help prioritize risks and allocate resources effectively. It can also ensure that risk management is an integral part of decision-making processes and is consistent with the overall goals of the business (Visser & Joubert, 2008).

Third, employees of companies operating in South Africa should be trained and educated in risk management. This will help them identify potential risks and take appropriate action to mitigate them (Mbuyiselo, Sifumba et al., 2017). It will also ensure that employees are aware of their role and responsibilities in risk management and understand the importance of risk management to the company.

Organizations operating in the field of scientific and legal metrology are exposed to various risks that can have serious consequences. Current risk assessment practices in the industry are primarily reactive and focused on compliance and are not effective in mitigating risk (Tarazona, 2013). To improve risk assessment practices, companies should take a more proactive and comprehensive approach to risk assessment, integrate risk management into overall business strategy, and train and educate employees (Sivitski & Põodra, 2021) (Rodrigues Filho et al., 2018). In this way, companies, particularly in the scientific and legal metrology sector in South Africa, can better identify and mitigate risks, avoid negative consequences, and improve overall business efficiency.

2.6 Factors Influencing the Approach to Risk Assessment in South African Organisations

Risk assessment is a crucial process that enables businesses to identify and evaluate potential risks associated with their operations and make informed decisions about risk mitigation strategies (Van Wyk et al., 2004b). In South Africa, the approach to risk assessment in businesses operating in the scientific and legal metrology sector is influenced by various factors. This section will discuss the key factors that influence the approach to risk assessment in South African businesses and how they impact the effectiveness and efficiency of risk assessment.

The regulatory environment is an important factor influencing the approach to risk assessment in South African companies engaged in scientific and legal metrology (Meyer et al., 2010). South Africa's complex regulatory landscape requires compliance with various regulations, standards, and guidelines related to risk assessment and management (Keyter et al., 2018). This regulatory framework shapes the scope, methodology, and risk management strategies used in risk assessment.

Another factor that influences the approach to risk assessment in South African businesses is the level of risk tolerance. Businesses that operate in high-risk industries such as the scientific and legal metrology sector may have a low tolerance for risk and may adopt a more conservative approach to risk assessment and management. This may result in a more cautious approach to risk assessment, with a focus on identifying and mitigating potential risks rather than taking calculated risks to achieve business objectives.

The organizational culture of businesses also influences the approach to risk assessment. Organizational culture refers to the shared values, beliefs, and attitudes that shape the behavior of employees within an organization (Kachalov & Sleptsova, 2020) . Businesses with a strong culture of risk management are more likely to adopt a comprehensive and systematic approach to risk assessment, whereas those with a weaker culture of risk management may adopt a more reactive and ad hoc approach.

The availability of resources, such as financial and human resources, also influences the approach to risk assessment in businesses. Businesses with limited resources may adopt a less comprehensive approach to risk assessment due to financial constraints or limited expertise (Bejinariu, 2020a). This may result in a less effective and efficient risk assessment process, with potential risks being overlooked or underestimated.

Finally, the level of stakeholder involvement also impacts the approach to risk assessment in businesses. Stakeholder involvement refers to the participation of various stakeholders, such as employees, customers, and suppliers, in the risk assessment process (Saravanamuthu, 2018). Businesses that involve stakeholders in the risk assessment process are more likely to identify a wider range of potential risks and to gain buy-in for risk management strategies from key stakeholders.

The approach to risk assessment in South African businesses operating in the scientific and legal metrology sector is influenced by various factors, including the regulatory environment, level of risk tolerance, organizational culture, availability of resources, and level of stakeholder involvement. These factors impact the effectiveness and efficiency of risk assessment in these businesses by shaping the scope and methodology of risk assessments, as well as the risk management strategies that businesses adopt.

2.7 Challenges in Implementing Risk Assessment in South African Organisations

In today's fast-paced and unpredictable business environment, it is important for organizations to implement effective risk assessment strategies. Risk assessment helps organizations identify potential threats and vulnerabilities and develop strategies to mitigate them. The implementation of risk assessments in companies in South Africa is particularly important in the scientific and legal metrology sector, where accuracy and precision are paramount. However, discussions with experts in the sector indicate that risk assessment in this sector faces several challenges that hinder its effective implementation.

One of the biggest challenges for companies in South Africa in conducting risk assessments is the lack of knowledge and skills. Recent annual reports from the National Metrology Institute of South Africa and the National Regulator for Compulsory Specifications (NRCS), which are responsible for scientific and legal metrology, highlight that a lack of knowledge and skills among staff is one of the biggest challenges facing companies. In addition, scientific and legal metrology organisations in South Africa face the challenge of limited resources, including financial, human, and technological resources. The lack of resources hinders the conduct of risk assessments because their ability to conduct comprehensive risk assessments is limited.

The lack of knowledge and skills of employees is due to various factors, including inadequate training and development programs. Therefore, it is necessary to invest in training and development programs to improve employee knowledge and skills. This will ensure that employees have the necessary knowledge and skills to conduct effective risk assessments. Companies can also engage the services of external consultants who specialize in risk assessments to train and support employees.

Another factor contributing to the lack of knowledge and skills is the complexity of risk assessment processes. Risk assessment processes can be complex and require a high level of expertise (Drăghici, 2017). Therefore, organizations need to ensure that their employees are adequately trained in the use of risk assessment tools and methods. This can be achieved through on-the-job training, workshops and seminars.

In addition to the lack of knowledge and skills and limited resources, many different legal frameworks and standards is also a major challenge for organisations in South Africa in conducting risk assessments (Yadav et al., 2020). The legal frameworks and standards makes it difficult for companies to conduct effective risk assessments because there are no guidelines to guide them. As a result, companies may not be able to effectively identify and mitigate risks.

To overcome this challenge, organisations need to work with different regulators to develop legal frameworks and standards tailored to the needs of scientific and legal metrology. This will provide organisations with guidelines they can follow to ensure that risk assessment processes are conducted consistently and effectively. Regulators can also provide technical assistance and training to organisations to ensure they are able to comply with the different regulatory framework and standards.

Thus, the implementation of risk assessment in South African scientific and legal metrology organisations faces several challenges. These challenges include lack of knowledge and skills, limited resources, and different regulatory frameworks and standards. However, companies can overcome these challenges by investing in training and development programs, taking a proactive approach to risk assessment, working with regulators to develop legal frameworks and standards, and taking a collaborative approach to risk assessment. By addressing these challenges, companies can implement effective risk assessment strategies that help them identify potential threats and vulnerabilities and develop strategies to mitigate them.

2.8 Overview of the Legal Metrology Act 8 of 2014

The South African Legal Metrology Act of 2014 is an important piece of legislation designed to ensure fair and accurate measurements in business transactions. The Act is based on the recommendations of the International Organization of Legal Metrology (OIML) and is aligned with the International System of Units (SI).

The law regulates the use of measuring instruments and units of measurement in commerce and provides for the accreditation of testing laboratories and certification bodies. It also establishes the National Regulator for Compulsory Specifications (NRCS, which is responsible for enforcing the law.

One of the Act's primary goals is to protect consumers from being deceived or misled in commerce by ensuring that measurements are accurate, fair, and transparent. The Act accomplishes this by regulating the use of measuring instruments such as scales, meters, and gages, and requiring that they be verified for accuracy before use.

In addition to protecting consumers, the Act also aims to promote fair trade by ensuring that all companies use the same measurement standards. This helps prevent unfair competition and creates a level playing field for all companies.

The law covers a wide range of products and services, including food, pharmaceuticals, petroleum products, and electrical appliances. It requires that all measurements taken in these sectors must be accurate and transparent, and that all measuring instruments used must be certified and calibrated.

The law also provides for the use of legal units of measurement in commerce. These include the International System of Units (SI) and other units of measurement recognized by the OIML. The use of legal units of measurement helps promote international trade and makes it easier for companies to operate in multiple countries.

The South African Legal Metrology Act of 2014 is an important piece of legislation that promotes fair trade and protects consumers from being deceived or misled in business transactions. It is aligned with international standards and provides a strong framework for regulating the use of measuring devices and units of measurement in commerce. The law is enforced by the National Regulatory Commission for Mandatory Specifications (NRCS), which plays a critical role in ensuring compliance.

2.9 Overview of the Standards Act 8 of 2008

The South African Standards Act of 2008 is a major piece of legislation that provides a framework for the development, maintenance, and implementation of national standards in various industries. The Act is administered by the South African Bureau of Standards (SABS), which is responsible for promoting standardization and ensuring that standards are maintained and updated.

The Standards Act applies to all industries and sectors of the economy, including manufacturing, construction, health care, and agriculture. It requires that all national standards be developed through a transparent and consultative process involving industry experts, stakeholders, and the public. The development of national standards is guided by principles such as transparency, inclusiveness and consensus building to ensure that standards meet the needs of all stakeholders.

The Act establishes SABS as the body responsible for developing and maintaining national standards. The SABS is also responsible for certifying products, services, and systems that meet the national standards, and for providing training and accreditation services to ensure that testing laboratories and certification bodies meet the required standards. In addition, the SABS is responsible for promoting the use of standards in various industries to improve quality, safety and competitiveness.

One of the main objectives of the Standards Act is to promote quality and safety in products, services and systems. The Act requires that all products, services and systems to which national standards apply must be certified by SABS or an accredited certification body before they can be sold or used in South Africa. This certification process ensures that products, services and systems meet the required quality and safety standards and comply with relevant regulations and legislation.

The Act also encourages the use of international standards in South Africa where possible. The SABS is responsible for adopting and promoting international standards relevant to South Africa and for ensuring that these standards are incorporated into national standards where necessary. The adoption of international standards helps ensure that South African products and services are recognized in the global marketplace and can compete with products and services from other countries.

Another important objective of the Standards Act is to promote the competitiveness of South African industry in the world market. The Act recognizes the importance of standardization in international trade and promotes the adoption of internationally recognized standards to facilitate trade and improve market access for South African products and services. By promoting the use of standards in various industries, the Act helps to improve the quality and safety of products, services and systems in South Africa, which in turn can increase their competitiveness in the global market.

In addition to promoting quality, safety, and competitiveness, the Standards Act also plays a critical role in promoting innovation and sustainability in various industries. The Act recognizes the importance of innovation and sustainability to economic growth and development and encourages the development of standards that support these goals. For example, the Act encourages the development of renewable energy, water conservation, and waste management standards, to name a few.

Overall, the South African Standards Act of 2008 is an important piece of legislation that promotes quality, safety, competitiveness, innovation and sustainability in various industries. The Act provides a legal framework for the development, maintenance and implementation of national standards and ensures that products, services and systems that meet national standards are certified and recognized in South Africa. The Act plays a critical role in promoting standardization, improving the quality and safety of products, services and systems, and fostering economic growth and development in South Africa.

2.10 Overview of the Accreditation for Conformity Assessment, Calibration and Good Laboratory Practice Act 19 of 2006 of South Africa

The Accreditation for Conformity Assessment, Calibration and Good Laboratory Practice Act of 2006 is a major piece of legislation that establishes a framework for the accreditation of conformity assessment bodies (CABs), calibration laboratories, and testing laboratories in South Africa. The Act aims to improve the quality and reliability of conformity assessment, calibration and testing services and to ensure that these services meet international standards.

The Act establishes the South African National Accreditation System (SANAS) as the national accreditation body responsible for the accreditation of CABs, calibration laboratories and testing laboratories in South Africa. SANAS is responsible for assessing the technical competence and impartiality of these bodies and ensuring that they meet the required standards for performing conformity assessment, calibration and testing services.

One of the main objectives of the Act is to ensure that conformity assessment, calibration and testing services in South Africa are reliable and meet international standards. The Act requires CABs, calibration and testing laboratories to be accredited by SANAS before they can provide conformity assessment, calibration or testing services in South Africa. This ensures that these services are provided by competent and impartial bodies that meet the required standards for providing such services.

The Act also promotes the use of international standards in conformity assessment, calibration and testing services. SANAS is responsible for adopting and promoting international standards relevant to South Africa and ensuring that these standards are incorporated into the accreditation requirements for CABs, calibration and testing laboratories. This promotes global harmonization of accreditation requirements, which facilitates trade and improves market access for South African products and services.

Another important objective of the Act is to improve the competitiveness of South African industry in the global marketplace. The Act recognizes the importance of accreditation in international trade and promotes the adoption of internationally recognized accreditation standards to facilitate trade and improve market access for South African products and services.

The Act also provides for the establishment of technical committees to oversee the accreditation process and ensure that accreditation requirements are relevant and appropriate to the industry or sector they are intended to regulate. These committees are composed of industry experts and stakeholders who assist and advise in the development and maintenance of accreditation requirements.

In addition, the law provides for the recognition of accreditation bodies from other countries that have signed international mutual recognition agreements. This ensures that conformity assessments, calibrations and tests performed by accredited bodies from other countries are recognized in South Africa, promoting global harmonization of accreditation requirements and facilitating trade.

Overall, the Accreditation for Conformity Assessment, Calibration and Good Laboratory Practice Act of 2006 of South Africa is an important piece of legislation that promotes the quality, reliability and competitiveness of conformity assessment, calibration and testing services in South Africa. The Act provides a legal framework for the accreditation of CABs, calibration laboratories and testing laboratories and ensures that these bodies meet the required standards for the provision of these services. The Act plays a critical role in promoting standardization, improving the quality and reliability of services, and facilitating trade in South Africa.

2.11 Conclusion of Literature Review

The literature review on risk assessment in the field of scientific and legal metrology in South Africa provides insights into the key factors that influence the approach to risk assessment in this field. The literature review highlights the importance of risk management practices in complying with relevant laws and regulations and in managing potential risks that may arise in the course of business.

One of the biggest challenges companies in South Africa face in implementing risk assessment is a lack of awareness and knowledge. Many companies in the sector do not have a clear understanding of the importance of risk assessment or do not have the necessary knowledge or experience to effectively implement risk assessment practices. This can lead to ineffective risk management, increased exposure to potential risks, and potential legal and financial consequences.

To address this challenge, organizations can use strategies such as education and training to improve risk awareness and risk management practices. This can include workshops, seminars and other training programs that help business owners, managers and employees understand the importance of risk assessment and key principles and practices. By improving knowledge and awareness, companies can better understand potential risks and develop effective risk management strategies to mitigate them.

Another challenge for companies in the scientific and legal metrology sector in South Africa is limited resources. Many companies in this sector may not have the resources to invest in risk assessment practices, including human resources, technology, and funding. This can make it difficult for companies to effectively manage potential risks and ensure compliance with laws and regulations.

To overcome this challenge, companies can explore strategies such as collaboration and partnerships with other companies, organizations and government agencies. By collaborating and partnering with others in the industry, companies can pool resources and expertise to improve risk management and ensure compliance with relevant laws and regulations. This can also lead to cost savings and improved overall business performance.

A complex regulatory environment is another challenge that scientific and legal metrology companies in South Africa face when implementing risk assessment practices. The regulatory environment in this sector can be complex and difficult to navigate, with many different laws, regulations and standards that companies must comply with. This can make it difficult for companies to effectively manage potential risks and ensure compliance.

To overcome this challenge, companies can use strategies such as technology and innovation to improve risk management. This includes using technology and software to streamline compliance processes, automate risk assessments and improve overall risk management practices. Through the use of technology and innovation, organizations can improve their ability to effectively manage potential risks and ensure compliance with laws and regulations.

In summary, effective risk assessment practices are critical for companies in the scientific and legal metrology sector in South Africa to ensure legal and regulatory compliance and manage potential risks. However, companies in this sector face several challenges in implementing risk assessment practices. Effective strategies to address these challenges include education and training, collaboration and partnerships, technology and innovation, and expert advice. Future research in this area should focus on examining the effectiveness of different risk assessment strategies, the potential of technology and innovation, the cultural factors that influence risk assessment practices, the challenges and opportunities for collaboration and partnerships, and the impact of risk assessment.

CHAPTER 3. RESEARCH FRAMEWORK

3.1 Introduction

In this chapter, we present the theoretical framework that explores the factors that influence the approach to risk assessment in scientific and legal metrology in South Africa. The introduction of digital measurement systems has brought several benefits, including increased precision, efficiency, and accessibility. However, it has also raised concerns about privacy and security risks, particularly in scientific and legal metrology. The aim of this study is therefore to examine the attitudes, subjective norms, and perceived behavioral control of individuals and organizations regarding the privacy and security risks associated with digital measurement systems in South Africa.

To achieve this goal, we draw on the conceptual foundations of the Theory of Planned Behavior and the Theory of Reasoned Action. These frameworks provide a theoretical structure for understanding how individuals and organizations perceive and respond to privacy and security risks associated with digital measurement systems. Attitudes, subjective norms, and perceived behavioral control play a central role in influencing the behavior of individuals and organizations in assessing and mitigating these risks. By examining these factors, this study aims to identify barriers and facilitators to effective risk assessment and to develop interventions that promote more successful risk assessment practices.

The chapter begins with a concise overview of the research question and the significance of the study. It then explains the concepts of Theory of Planned Behavior and Theory of Reasoned Action and highlights their relevance to the research question. The hypotheses derived from these concepts are presented along with a discussion of the metrics used to operationalize the variables related to risk assessment.

In addition, this chapter provides a review of the existing literature on this topic and how this study contributes to the current state of knowledge. In addition, an overview of the research methodology is provided, which includes the research design, sampling strategy, data collection methods, and data analysis techniques.

In summary, this chapter provides a comprehensive understanding of the theoretical framework underlying this study and its connection to the research question. The hypotheses and metrics serve as guiding principles for data collection and analysis. In addition, the chapter addresses the existing literature, research methodology, ethical considerations, and limitations of the study. Overall, this chapter is significant as a foundational component of the research project and forms the basis for Chapter 4: Research Methodology.

3.2 Theoretical Framework

This research study relies on two theoretical frameworks used to answer research questions or test hypotheses. A theoretical framework can be defined as a conceptual model that outlines the structure of a research study and provides a background for investigating and justifying the study or solving a particular problem. It has been stated that a theoretical framework is a logically conceived, described, and justified arrangement of variables that are important to the researcher (Lederman & Lederman, 2015). Theoretical frameworks serve as a blueprint for the structure of a research study and can be used in all research approaches, including quantitative, qualitative, and mixed methods research (Heale & Noble, 2019).

Theory is an important aspect of research because it provides the means to explain and predict phenomena and to advance knowledge. Theories organize research ideas, guide research and become stronger as supporting evidence is gathered, and provide a context for predictions (Passey, 2020). Theories are developed to explain, predict, and measure phenomena and consist of interconnected, coherent models and ideas. Theoretical frameworks serve as a structure that supports a theory in a research study and are essential for interpreting reality.

In research, theories simplify and explain phenomena through the use of models and ideas by connecting nonconcrete phenomena to tangible phenomena. Theories guide research studies by demonstrating how different variables are related to one another and allow one to move from the general to the particular or from the particular to the general (Heale & Noble, 2019). The use of theoretical frameworks such as Theory of Reasoned Action and Theory of Planned Behaviour in this study allows for a clear and systematic approach to understanding the factors that influence risk assessment in legal and scientific metrology.

3.2.1 Theory of Reasoned Action

The Theory of Reasoned Action (TRA) is a well-established social psychological theory that explains the relationship between attitudes, intentions, and behavior. It was originally proposed by Martin Fischbein and Icek Ajzen in the late 1960s and has since gained acceptance as a framework for understanding and predicting human behavior (Haziq et al., 2014).

According to this theory, individuals' behavior is influenced by their intentions, which in turn are shaped by their attitudes toward the behavior and subjective norms. Attitudes refer to a person's positive or negative evaluation of a particular behavior, while subjective norms refer to the perceived social pressure to engage in or refrain from such behavior (Mahyarni, 2013).

In the context of TRA, a person's intention to perform a behavior is determined by both their attitude toward that behavior and the subjective norms they perceive (Mahyarni, 2013). Simply put, the more positive a person's attitude toward a behavior and the greater his or her perception of social approval of that behavior, the more likely he or she is to intend to perform it.

Furthermore, the theory states that the stronger a person's intention to perform a behavior, the more likely they are to actually perform it. However, various factors such as external constraints or unforeseen circumstances can act as obstacles between intention and behavior.

The TRA has been applied in many fields, including health, environment, measurement, and consumer behavior, and has proven to be a valuable tool for predicting and understanding human behavior in the context of scientific and legal measurement (Nazim et al., 2019b).

3.2.2 Theory of Planned Behaviour

The Theory of Planned Behaviour (TPB) is a widely accepted psychological framework that attempts to explain human behaviour by focusing on the concept of intention. The theory was originally proposed by Icek Ajzen in 1985 and later revised and expanded. According to TPB, intention is considered the most important determinant of behaviour. Intention reflects a person's willingness to engage in a particular behaviour and is influenced by three key factors: attitudes, subjective norms, and perceived behavioural control (Ajzen, 2011).

(Kiriakidis, 2115) asserts that attitude refers to a person's positive or negative evaluation of the behaviour. A positive attitude toward the behaviour increases the likelihood of intention to perform it, while a negative attitude decreases intention. Subjective norms refer to the person's perceived social pressure to engage in or refrain from the behaviour. This includes the influence of important people such as family, friends, or colleagues. The greater the perceived normative pressure, the stronger its influence on the intention to perform the behaviour. Perceived behavioural control refers to the individual's assessment of how easy or difficult it is to perform the behaviour. When individuals believe they have control over the performance of the behaviour, their intention to perform it is higher. Conversely, the perception of barriers or obstacles, such as limited resources or abilities, decreases the intention to perform the behaviour.

TPB has applications in a variety of fields, including health, environment, education, and marketing, and allows for better understanding and prediction of human behaviour. The theory is flexible and allows for the inclusion of additional variables such as emotions or moral considerations to increase its predictive power. Overall, the theory of planned behaviour provides a comprehensive framework for understanding human behaviour, emphasising the importance of intention and influencing factors. The theory has been extensively studied and applied in various fields. It has demonstrated its effectiveness in predicting and changing behaviour in numerous research studies.

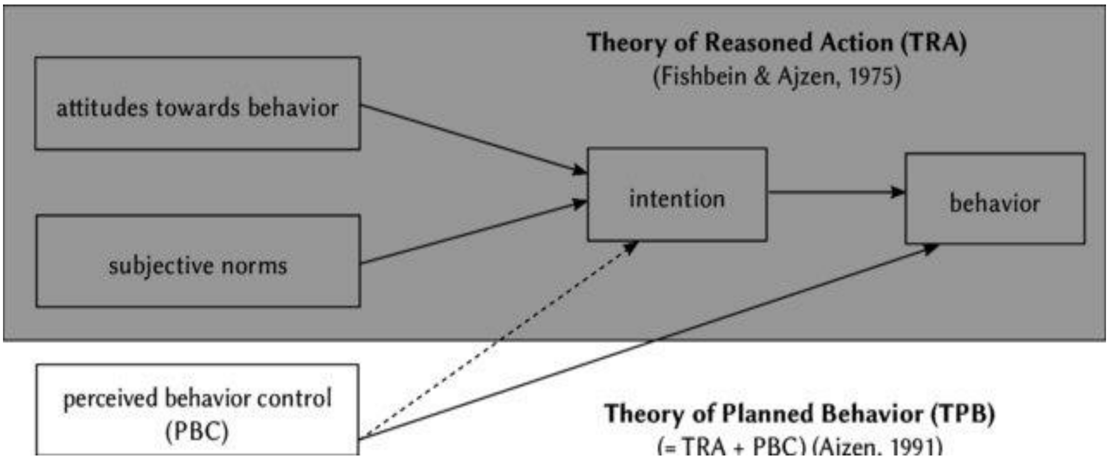

Figure 1: Theory of Reasoned Action (TRA) and Theory of Planned Behaviour (TPB) as adopted from (Lee, 2016)

3.3 Conceptual Framework

The factors influencing the approach to risk assessment in scientific and legal metrology in South Africa can be explored using the Theory of Reasoned Action (TRA) and the Theory of Planned Behaviour (TPB). These theories provide a valuable framework for understanding how attitudes, subjective norms, and perceived behavioural control impact an individual's intention to conduct risk assessments.

Attitudes towards risk assessment play a crucial role as they shape one's overall evaluation of risk assessment as a behavior. In the realm of scientific and legal metrology, positive attitudes towards risk assessment enhance the intention to conduct risk assessments, while negative attitudes may lead to avoidance or delay. According to (Murad et al., 2016), positive attitudes are associated with perceiving risk assessment as important, useful, and relevant to one's work. Conversely, negative attitudes stem from viewing risk assessment as time-consuming, burdensome, and irrelevant to one's professional responsibilities.

Subjective norms refer to an individual's perception of social pressure or expectations regarding risk assessments. If an individual perceives that conducting risk assessments is valued or expected by peers and supervisors, they are more likely to have a positive intention to perform them. Conversely, if an individual feel that risk assessments are neither valued nor expected by their surroundings, regular risk assessment conduct becomes less probable. (Cadet, 2020) suggests that subjective norms significantly influence an individual's intention to conduct risk assessments. For instance, if someone perceives that their peers or supervisors do not prioritize risk assessment, they are unlikely to engage in it regularly, even if they hold positive attitudes towards the practice.

Perceived behavioural control refers to an individual's belief in their ability to effectively conduct risk assessments (Roth et al., 2016). Several factors influence this perception, including the individual's expertise and knowledge in the field, access to relevant resources, and the organizational culture surrounding risk assessment.

Expertise and knowledge in the field of scientific and legal metrology are crucial factors affecting perceived behavioural control in conducting risk assessments. Individuals with higher levels of expertise and knowledge are more likely to feel confident in their ability to perform risk assessments effectively (Klein et al., 2021). Conversely, those with lower levels of expertise and knowledge may lack confidence in conducting risk assessments and tend to avoid or delay them.

The availability of resources, such as data and tools, also plays a role in an individual's perceived behavioural control when conducting risk assessments (Silwimba & Fadun, 2023). Access to necessary resources increases confidence in conducting risk assessments effectively, while a lack of access may decrease confidence and contribute to avoidance or delay.

Organizational culture is another influential factor shaping perceived behavioural control in conducting risk assessments (Kimbrough & Componation, 2009). Organizational culture encompasses norms, values, and expectations that shape employee behavior in the workplace.

In the context of scientific and legal metrology, the organizational culture surrounding risk assessment can impact an individual's intention to conduct risk assessments.

Figure 1 highlights that combining TRA and TPB provides a more comprehensive understanding of the factors influencing the approach to risk assessment in scientific and legal metrology in South Africa. Both theories emphasize the importance of attitudes, subjective norms, and perceived behavioural control as determinants of behavior, including the behavior of conducting risk assessments.

3.3.1 Navigating risk assessment in Scientific and Legal Metrology

The objective of this research proposal is to investigate the factors that influence the approach to risk assessment in scientific and legal metrology in South Africa. Given the importance of measurement accuracy in these areas, this study aims to investigate an extremely important topic. The research questions relate to various aspects of risk assessment in scientific and legal metrology in South Africa. One of the research questions is: "What are the most important factors influencing the approach to risk assessment in scientific and legal metrology in South Africa?" To answer this question, the theoretical and conceptual frameworks of the Theory of Reasoned Action and the Theory of Planned Behavior can be used.

The Theory of Reasoned Action assumes that a person's behavior is determined by their intention to perform that behavior and their perception of the social norms associated with it. This theory states that behavior is influenced by attitudes and subjective norms (Yzer, 2017a). On the other hand, the theory of planned behavior states that behavior is influenced by intention, perceived behavioral control, and attitude toward the behavior (Rossi & Armstrong, 1999). These theories are applicable to the research question because they provide a theoretical basis for understanding how attitudes, subjective norms, and perceived behavioral control influence the approach to risk assessment in scientific and legal measurements in South Africa.

The application of these theories can help to understand the factors that influence the approach to risk assessment in scientific and legal measurement. For example, the Theory of Planned Behavior can clarify how an inspector's intention to conduct risk assessments and his or her perception of control over the process influence his or her approach to risk assessment. Similarly, the Theory of Reasoned Action can explain how an inspector's attitude toward risk assessment and his or her perception of social norms regarding that behavior influence his or her approach to risk assessment. Using these theories, researchers can gain insight into the factors that influence the approach to risk assessment in scientific and legal metrology in South Africa.

The Theory of Planned Behavior and Theory of Reasoned Action frameworks can help answer the research question by providing a theoretical basis for understanding the factors that influence the approach to risk assessment in scientific and legal metrology in South Africa. These theories can be used to examine how attitudes, subjective norms, and perceived behavioral control influence the approach to risk assessment in these areas. In addition, this framework can help identify barriers and facilitators to effective risk assessment in scientific and legal metrology in South Africa.

The application of the Theory of Planned Behavior and the Theory of Reasoned Action can therefore serve as a valuable framework for exploring the factors that influence the approach to risk assessment in scientific and legal metrology in South Africa. These theories provide a theoretical basis for understanding how attitudes, subjective norms, and perceived behavioral control influence the approach to risk assessment. This framework can help answer the research question by identifying the barriers and facilitators to effective risk assessment in these areas. By applying these theories, the research can contribute to a deeper understanding of the factors that influence the approach to risk assessment in scientific and legal metrology in South Africa.

One possible hypothesis that can be derived from the proposed theoretical framework is that inspectors' attitudes, subjective norms, and perceived behavioral control significantly influence their approach to risk assessment in scientific and legal metrology in South Africa. Another hypothesis could be that the barriers and facilitators to effective risk assessment in these areas can be identified and addressed by applying the theory of planned behavior and the theory of reasoned action.

To collect quantitative data, surveys can be conducted to measure inspectors' attitudes, subjective norms, and perceived behavioral control related to risk assessment in scientific and legal metrology in South Africa. Surveys can be developed using validated scales from previous studies that measure the Theory of Planned Behavior and Theory of Reasoned Action constructs. Qualitative data can be collected through interviews with inspectors and other stakeholders involved in scientific and regulatory measurement to identify barriers and facilitators to effective risk assessment in South Africa. Interview questions can be developed based on the theoretical framework and previous studies in the field. The data collected can then be analyzed using statistical techniques such as regression analysis for the quantitative data and thematic analysis for the qualitative data.

In relation to this research question, the following hypotheses will be tested:

H1: Attitudes toward risk assessment will positively influence the approach to risk assessment in scientific and legal metrology in South Africa.

H2: Subjective norms related to risk assessment will positively influence the approach to risk assessment in scientific and legal metrology in South Africa.

H3: Perceived behavioral control over the risk assessment process will positively influence the approach to risk assessment in scientific and legal metrology in South Africa.

H4: Barriers to effective risk assessment will negatively impact risk assessment in scientific and legal metrology in South Africa.

H5: Enablers to effective risk assessment will positively impact risk assessment in scientific and legal metrology in South Africa.

In the context of risk assessment in scientific and legal metrology, the following measures can be used to operationalize the variables of this research question:

Attitude: this can be measured using a Likert scale where participants rate their agreement with statements such as "I believe risk assessment is an important part of scientific and legal metrology" or "I believe risk assessment is a waste of time"

Subjective Norms: This can be measured using a Likert scale on which participants rate their agreement with statements such as "My colleagues and supervisors in scientific and legal metrology expect me to conduct risk assessments" or "Regulations and policies in scientific and legal metrology require me to conduct risk assessments"

Perceived behavioral control: this can be measured using a Likert scale on which participants rate their agreement with statements such as "I have the knowledge and skills needed to conduct risk assessments" or "I have the resources (e.g., time, equipment) needed to conduct risk assessments"

Barriers and enablers: these can be measured using open-ended questions or a checklist of potential barriers and enablers to effective risk assessment in scientific and legal metrology, *such as lack of training, lack of resources, lack of peer or supervisor support, or clear policies and regulations.*

3.3.2 Impact of Measurement System Complexity on Risk Assessment.

The increasing complexity of measurement systems is a major challenge in the field of risk assessment in scientific and legal metrology. This complexity results from the integration of multiple components and the use of advanced technologies. It leads to various risks such as measurement errors, uncertainties, and inconsistencies that can undermine the accuracy and reliability of measurements.

To answer the research question of how the increasing complexity of measurement systems has affected risk assessment in scientific and legal measurements in South Africa, the Theory of Planned Behavior (TPB) and the Theory of Reasoned Action (TRA) provide a valuable framework for understanding the behavior of individuals involved in scientific and legal measurements. TPB and TRA provide insight into how attitudes, perceptions, and intentions influence behavior, including the adoption of new measurement technologies and methods. These theories state that behavior is influenced by three key factors: Attitudes, subjective norms, and perceived behavioral control. Attitudes refer to a person's positive or negative evaluation of a behavior, subjective norms refer to perceived social pressure to behave, and perceived behavioral control reflects a person's perception of his or her ability to successfully perform the behavior (Yzer, 2017b).

In the context of risk assessment in scientific and legal measurement, TPB and TRA are relevant in several ways. First, attitudes toward new measurement technologies and methods have a significant impact on their adoption and use in scientific and legal measurements. For example, if inspectors or stakeholders view new measurement technologies as unreliable or too complex, they may be reluctant to adopt them despite their potential benefits. Second, subjective norms play a critical role in the adoption of new measurement technologies and methods. If inspectors or stakeholders observe their peers using certain technologies or methods, they are more likely to adopt them. Finally, perceived behavioral control can also influence the adoption and use of new measurement technologies and methods. If stakeholders feel that their skills or resources are not sufficient for a particular technology or method, they are less likely to adopt it.

Using TPB and TRA in the context of risk assessment in scientific and legal metrology can help identify potential barriers and facilitators to the adoption and use of new measurement technologies and methods. Understanding the attitudes, subjective norms, and perceived behavioral control of stakeholders can help in developing strategies that address these factors and promote the adoption and use of new measurement technologies and methods.

For example, one possible strategy might be to develop training programs and educational resources to improve stakeholders' perceived behavioral control. Providing stakeholders with the necessary skills and resources can increase their confidence in using new measurement technologies and methods, thereby promoting their adoption and use. In addition, efforts can be made to cultivate positive attitudes toward new measurement technologies and methods by highlighting their benefits and addressing any concerns or misconceptions stakeholders may have. Finally, efforts can be made to improve subjective norms regarding the adoption and use of new measurement technologies and methods by highlighting their use among colleagues and peers.

Thus, the increasing complexity of measurement systems presents a significant challenge for risk assessment in scientific and legal metrology. By applying the frameworks of TPB and TRA, valuable insights can be gained into the attitudes, perceptions, and intentions of stakeholders, leading to the identification of potential barriers and facilitators to the adoption and use of new measurement technologies and methods. By understanding these factors, strategies can be developed to address them and promote the adoption and use of new measurement technologies and methods to improve the accuracy and reliability of measurements in scientific and legal metrology.

In relation to this research question, the following hypothesis is tested:

H6: Attitudes toward new measurement technologies and methods will positively influence the adoption and use of these technologies in scientific and legal metrology.

H7: Subjective norms will positively influence the adoption and use of new measurement technologies and methods in scientific and legal metrology.

H8: Perceived behavioral control will positively influence the adoption and use of new measurement technologies and methods in scientific and legal metrology.

In the context of risk assessment in scientific and legal metrology, the following measures can be used to operationalize the variables:

Attitudes: A Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) could be used to assess stakeholder attitudes toward new measurement technologies and methods.

Subjective Norms: A Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) could be used to assess perceptions of social pressure exerted on the adoption and use of new measurement technologies and methods.

Perceived behavioral control: a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) could be used to assess the perceived ability of stakeholders to successfully adopt and use new measurement technologies and methods. In addition, a self-efficacy measure could be used to assess stakeholders' confidence in their ability to use new measurement technologies and methods.

3.3.3 Effectiveness of Current Risk Assessment Methods in South African Metrology

In the field of scientific and legal metrology, risk assessment is of great importance to ensure the accuracy and reliability of measurements. Risk assessment methods play an important role in identifying potential risks associated with measurement systems and enable the implementation of appropriate risk management strategies. This research question aims to examine the current risk assessment methods used in scientific and legal metrology in South Africa and evaluate their effectiveness in identifying and mitigating potential risks. To answer this question, the Theory of Planned Behavior (TPB) and the Theory of Reasoned Action (TRA) are used as theoretical frameworks to gain insight into the factors that influence the effectiveness of risk assessment methods.

These theories relate directly to the research question on risk assessment methods in scientific and legal metrology in South Africa. Risk assessors' attitudes, subjective norms, and perceived behavioral control can influence their effectiveness in identifying and mitigating potential risks associated with measurement systems (Yzer, 2017b). For example, if risk assessors have a positive attitude toward risk assessment and view it as an integral part of their work, they are likely to conduct more thorough assessments. In addition, if risk assessors perceive that their colleagues and stakeholders place great importance on risk assessment, they may be motivated to conduct thorough assessments.

The TPB and TRA frameworks can be applied to the research question by examining the factors that influence the effectiveness of risk assessment methods in scientific and legal metrology in South Africa. Attitudes, subjective norms, and perceived behavioral control can be assessed to determine their influence on the use and effectiveness of risk assessment methods. For example, a survey of risk assessors can provide information about their attitudes toward risk assessment, perceived social pressures to conduct thorough assessments, and their perceived ability to conduct effective assessments. Survey results can provide insight into the effectiveness of risk assessment methods in identifying and mitigating potential risks.

Consequently, ensuring the effectiveness of risk assessment methods in scientific and legal metrology is critical to maintaining measurement accuracy and reliability. The TPB and TRA frameworks serve as valuable tools for evaluating the factors that influence the use and effectiveness of risk assessment methods. By understanding the attitudes, subjective norms, and perceived behavioral control of risk assessors, opportunities can be identified to improve the effectiveness of risk assessment methods in identifying and mitigating potential risks associated with measurement systems in South Africa.

Within this research question, the following hypotheses/propositions derived from the theoretical and conceptual framework will be tested:

H9: Attitudes, subjective norms, and perceived behavioural control influence the effectiveness of risk assessment methods in scientific and legal metrology in South Africa.

H10: Positive attitudes toward risk assessment and belief in its importance lead to more thorough assessments.

H11: Perceived social pressure to conduct thorough assessments increases motivation to conduct assessments.

H12: Perceived ability to conduct effective assessments positively affects the use and effectiveness of risk assessment methods.

In the context of risk assessment for scientific and regulatory measurements, the following measures can be used to operationalize the variables:

Attitudes: can be measured using Likert scales or semantic differential scales to assess the level of agreement with statements related to risk assessment, such as "I believe risk assessment is an important part of my job" or "I enjoy conducting risk assessments."

Subjective norms: can be assessed using questions that explore perceived social pressures to conduct thorough risk assessments, such as "How much do you think your colleagues think risk assessments are important?" or "How much do stakeholders expect you to conduct thorough risk assessments?"

Perceived behavioural control: can be assessed using questions that examine perceived ability to conduct effective assessments, e.g., "How confident are you in your ability to conduct thorough risk assessments?" or "Do you have the resources necessary to conduct effective risk assessments?"

Effectiveness of risk assessment methods: can be assessed through a survey of inspectors to determine the number of risks identified and the effectiveness of risk management strategies implemented.

3.3.4 Measurement Consistency and Risk Assessment in Scientific and Legal Metrology

Ensuring consistency between different measurement domains is a critical element in scientific and legal metrology, as it ensures the reliability, accuracy, and comparability of measurements in different domains. This research question aims to investigate the impact of consistency requirements between measurement domains on risk assessment in scientific and legal metrology in South Africa. The Theory of Planned Behavior (TPB) and the Theory of Reasoned Action (TRA) are selected theories and concepts that relate directly to understanding the factors that influence risk assessment in this context.

The need for consistency across measurement domains can influence risk assessment in scientific and legal measurements in a number of ways, and the TPB and TRA offer insights into these influences. For example, if there are inconsistencies in measurement standards or practices across domains, this may influence risk assessors' attitudes toward measurement accuracy and reliability. If risk assessors perceive discrepancies or variations in measurement practices, this may influence their perception of the validity and credibility of the risk assessment process (Yzer, 2017b).

In addition, subjective norms may also play a role in the impact of consistency across measurement domains on risk assessment. Social norms, professional standards, and legal requirements can influence risk assessors' perceptions of the importance of consistency in measurement practices. For example, if there are established norms or standards that mandate consistent measurement practices across domains, risk assessors may feel obligated to follow these norms and incorporate them into their risk assessment process.

In addition, the need for consistency across measurement domains may influence perceived behavioral control. If risk assessors believe they have the necessary control and resources to ensure consistency across measurement domains, this may have a positive impact on their confidence in conducting risk assessments. Conversely, a lack of control or resources to ensure consistency may affect risk assessors' ability to conduct accurate and reliable risk assessments.

The TPB and TRA can also help answer the research question by providing a framework for identifying potential barriers and facilitators to consistency in risk assessments across measurement domains. By understanding the attitudes, subjective norms, and perceived behavioral control of risk assessors, the framework can identify factors that hinder or enable measurement consistency, leading to the development of strategies to address these challenges. For example, interventions can be developed to address attitudes, norms, or perceived behavioral control that impede consistency in risk assessment practices. This may include providing training and resources, establishing clear guidelines and standards, and promoting a culture of consistency in measurement practices.

Therefore, the Theory of Planned Behavior (TPB) and the Theory of Reasoned Action (TRA) provide a theoretical framework that is directly relevant to the research question examining the impact of consistency requirements in different measurement domains on risk assessment in scientific and legal measurement in South Africa. These theories highlight the influences of attitudes, subjective norms, and perceived behavioral control on risk assessment in relation to consistency across measurement domains. In addition, the TPB and TRA provide a framework for answering the research question by identifying potential barriers to effective risk assessment in scientific and legal measurement.

The following hypotheses are tested as part of this research question:

H13: Greater consistency across measurement domains will positively influence risk assessors' attitudes toward measurement accuracy and reliability, leading to more accurate and reliable risk assessments.

H14: Stronger social norms, professional standards, and regulatory requirements mandating consistent measurement practices across domains will positively influence risk assessors' *perceptions of the importance of consistency and lead to greater adherence to consistent measurement practices in risk assessment.*

H15: Increased perceptions of oversight and resources to ensure consistency across measurement domains will positively influence risk assessors' confidence in conducting risk assessments and lead to more accurate and reliable risk assessments.

The following measures can be used to operationalize risk assessment variables for scientific and legal measurements:

Attitudes: This can be measured using a Likert scale to assess risk assessors' attitudes toward measurement accuracy and reliability, e.g., "On a scale of 1-10, how important do you think measurement accuracy is in risk assessments?"

Subjective Norms: This can be measured using a Likert scale to assess risk assessors' perceptions of social norms, professional standards, and regulatory requirements related to consistency of measurement practices, e.g., "To what extent do you believe there are established norms or standards that mandate consistent measurement practices in different areas of risk assessment?"

Perceived Behavioral Control: This can be measured using a Likert scale to assess risk assessors' perceived control and resources to ensure consistent measurement practices, e.g., "How confident are you in your ability to ensure consistent measurement practices across risk assessment domains?"

Barriers and facilitators: These can be measured with open-ended or closed-ended questions to identify potential barriers and facilitators to consistent risk assessment, e.g., "What are the biggest challenges you face in ensuring consistent measurement practices across risk assessment domains?" or "What resources or policies do you find helpful in ensuring consistent measurement practices across risk assessment domains?"

3.3.5 Privacy and Security Risks of Digital Measurement Systems in South Africa

The introduction of digital measurement systems has brought numerous benefits, including increased accuracy, efficiency, and accessibility. However, these benefits have also led to concerns about privacy and security risks. This research question aims to examine the privacy and security risks associated with digital metering systems in South Africa and assess how these risks are addressed in the risk assessment process. To achieve this, the theories of planned behavior and reasoned action are used as a conceptual framework to understand how individuals and organizations perceive and respond to these risks.

The selected theories and concepts are directly relevant to this research question because they provide a framework for understanding how individuals and organizations perceive privacy and security risks associated with digital metering systems in South Africa. These theories assume that individuals' attitudes, subjective norms, and perceived behavioral control influence their behavior, including their approach to risk assessment. In particular, attitudes toward privacy and security risks associated with digital measurement systems, subjective norms influenced by social pressures from peers, colleagues, or organizations, and perceived behavioral control related to the ability to assess and mitigate these risks are important factors to consider.

The Theory of Planned Behavior and Theory of Reasoned Action frameworks can help answer the research question in several ways. First, they provide a theoretical perspective to understand the cognitive and social factors that influence individuals' and organizations' behaviors related to privacy and security risks associated with digital measurement systems. By examining individuals' attitudes, subjective norms, and perceived behavioral control, insights can be gained into how these factors influence risk assessment practices.

Second, the framework can help identify the barriers and facilitators to effective risk assessment of digital measurement systems in South Africa. For example, if there are generally positive attitudes toward privacy and security risks, but subjective norms influenced by organizational or social pressures prevent effective risk assessment, measures can be developed to address these social influences and promote more effective risk assessment.

Third, the framework can support the development of interventions aimed at promoting more effective risk assessment practices. If perceived behavioral control is identified as a barrier, interventions can be developed to increase individuals' self-efficacy and confidence in assessing and mitigating privacy and security risks associated with digital measurement systems.

Finally, the framework can help develop guidelines and recommendations for organizations and policymakers to improve risk assessment practices related to digital metering systems. By understanding the factors that influence individual and organizational behavior, the framework can facilitate the adoption of best practices, policies, and regulations that promote robust risk assessment processes and mitigate privacy and security risks.

The application of the Theory of Planned Behavior and the Theory of Reasoned Action can provide valuable insights into understanding the privacy and security risks associated with digital measurement systems in South Africa and how these risks can be addressed through the risk assessment process. The selected theories and concepts provide a theoretical framework for examining individual and organizational attitudes, subjective norms, and perceived behavioral control, which ultimately supports the development of interventions.

The hypotheses derived from this framework based on this research question are as follows:

H16: Individuals and organizations with positive attitudes toward privacy and security risks associated with digital measurement systems are more likely to conduct effective risk assessments.

H17: Individuals and organizations with higher levels of perceived behavioral control in assessing and mitigating privacy and security risks associated with digital measurement systems are more likely to conduct effective risk assessment.

H18: Individuals and organizations that perceive social pressure to prioritize other aspects of digital measurement systems (e.g., cost, efficiency) over privacy and security risks are less likely to conduct effective risk assessment.

The following metrics can be used to operationalize risk assessment variables for scientific and legal measurement related to this research question:

Attitudes: measured with Likert scales or other scales that assess the extent to which individuals or organizations view privacy and security risks associated with digital measurement systems as important or relevant.

Subjective Norms: Measured using scales that assess the extent to which individuals or organizations perceive social pressure from peers, colleagues, or organizations to prioritize privacy and security risks in their evaluation of digital measurement systems.

Perceived Behavioral Control: Measured using scales that assess the extent to which individuals or organizations perceive their ability to assess and mitigate privacy and security risks associated with digital measurement systems.

Effective risk assessment practices: Measured by objective measures of the quality and extent to which individuals or organizations conduct risk assessments, or by self-assessments of the extent to which individuals or organizations use recommended risk assessment practices.

3.4 Conclusion of Research Framework

This chapter has examined various theoretical frameworks that can be used to understand the factors that influence the approach to risk assessment in scientific and legal metrology in South Africa. The Theory of Planned Behavior and the Theory of Reasoned Action emerged as useful frameworks for understanding how individuals and organizations perceive and respond to privacy and security risks associated with digital measurement systems.

Hypotheses derived from the selected frameworks suggest that positive attitudes toward privacy and security risks, higher levels of perceived behavioral control, and lower levels of social pressure to prioritize other aspects of digital measurement systems may lead to more effective risk assessment practices.

Metrics selected to operationalize risk assessment variables in South Africa include attitudes, subjective norms, perceived behavioral control, and effective risk assessment practices. By using these frameworks and metrics, it is possible to gain valuable insight into the factors that influence the approach to risk assessment in scientific and regulatory measurements in South Africa. This information can be used to develop strategies, policies, and recommendations to promote effective risk assessment practices and mitigate privacy and security risks associated with digital measurement systems.

Overall, this chapter demonstrates the importance of understanding the cognitive and social factors that influence individual and organizational behavior related to risk assessment. By leveraging this knowledge, policymakers, organizations, and individuals can work toward promoting more effective risk assessment practices and ensure that scientific and legal metrology in South Africa is conducted in a manner that prioritizes privacy and security.

CHAPTER 4. RESEARCH METHODOLOGY

4.1 Research approach

The research methodology proposed for this study on the factors influencing risk assessment in scientific and legal metrology in South Africa involves a quantitative research approach. The choice of a quantitative approach is based on its ability to provide structured and numerical insights into the factors influencing risk assessment in scientific and legal metrology.

Quantitative methods such as surveys are used for data collection in this study. Surveys provide a systematic and structured approach to collecting numerical data and allow statistical analysis to draw conclusions and identify patterns in the data (Campbell et al., 2020).

To ensure the reliability and validity of the data collected, this study follows established data collection methods and ethical guidelines. The approach assumes that the participants have the necessary knowledge and experience to contribute valuable insights to the research question.

Purposive sampling techniques are used in this study to ensure that only people with relevant knowledge and experience are included. This sampling technique allows for the selection of participants who are most relevant to the research question, thus improving the quality of the data collected (Frels & Onwuegbuzie, 2013).

The quantitative research approach in this study assumes that the results of the data analysis will contribute to a comprehensive understanding of the factors influencing risk assessment in scientific and legal metrology. This improved understanding can subsequently influence policy and practice in this area.

4.2 Research design

In determining the research design for this study, a purely quantitative approach was deliberately chosen, focusing on the collection and analysis of numerical data. This decision is motivated by the objective of comprehensively investigating the factors that influence risk assessment in scientific and legal metrology in South Africa.

The primary method of data collection will be a structured survey of scientific and legal metrology professionals in South Africa. This survey instrument has been carefully designed to elicit responses that can be subjected to statistical analysis. Through the use of quantitative methods, the study aims to gain precise and measurable insights into the various aspects that determine risk assessment practices in this area.

The assumptions included in this research design revolve around the sincerity and accuracy of the participants' responses. It is assumed that the data collected is a true reflection of the broader population engaged in scientific and legal metrology in South Africa. It is also assumed that the quantitative approach adopted is not only suitable to answer the research questions, but will also yield meaningful and valuable results. These assumptions are in line with established best practices in quantitative research and analysis.

Purposive sampling techniques will be used to ensure that participants have relevant knowledge and experience. This methodological decision is intended to improve the quality of the data collected by selecting the individuals who are most relevant to the research question (Östlund et al., 2011).

Although the quantitative research design is efficient in both data collection and analysis, the potential drawbacks must also be considered. These include limiting the results to numerical data, which could lose the richness of qualitative nuances. However, for the objectives of this study, which are better suited to a statistical investigation, the advantages of a quantitative approach are significant (Castro et al., 2010).

4.3 Data collection methods

The research methodology used in this study was based on a quantitative approach designed solely to investigate and analyze the factors influencing the approach to risk assessment in scientific and legal metrology in South Africa. The primary method of data collection within this quantitative paradigm was the use of a structured questionnaire.

The questionnaire was carefully crafted to elicit responses from a wide range of professionals actively involved in scientific and legal metrology, including metrology experts, regulators and policy makers. By utilizing the efficiency and reach of online survey platforms such as SurveyMonkey or Google Forms, the questionnaire served as a robust tool to gain valuable insights. It aimed to fully understand the views of these professionals on various aspects of risk assessment practices, taking into account existing policies, procedural frameworks and the factors that drive the approach to risk assessment. The questionnaire contained a mixture of closed and open-ended questions so that the collection of quantitative data was both structured and insightful.

The use of a questionnaire in this quantitative research design offered notable advantages. It allowed for a systematic and comprehensive examination of the factors influencing the approach to risk assessment in scientific and legal metrology in the South African context. This method was particularly beneficial in capturing a broader range of perspectives from professionals actively working in the field (Zhang et al., 2017).

However, it was imperative to recognize the potential challenges associated with the use of questionnaires in quantitative research. One major challenge was the potential for response bias or social desirability bias. Response bias can occur when participants give answers that do not accurately reflect their true feelings, often influenced by a desire to portray themselves in a positive light (Lewis et al., 2023). Social desirability bias occurs when respondents base their answers on social norms or expectations. Careful measures were taken in the design of the questionnaire to mitigate these biases. The anonymity of the respondents was guaranteed and the questions were formulated in an unbiased and non-misleading way.

Although the method of the questionnaire was efficient, there were potential problems in achieving a high response rate. To counteract this, the questionnaire was deliberately designed to be concise and user-friendly. Participants were reminded in good time and asked to complete the questionnaire.

Therefore, the quantitative methodology chosen, which focused on the administration of a structured questionnaire, was well suited to this study. It ensured a rigorous and focused investigation into the factors that shape the approach to risk assessment in scientific and legal metrology in South Africa. The resulting quantitative data was subjected to careful analysis and contributed to nuanced insights into risk assessment practices in this particular area.

4.4 Population and sample

This study took a quantitative approach using only data collection methods such as questionnaires. The study focused on professionals actively involved in scientific and legal measurements in South Africa, including metrologists, regulators, policy makers and various stakeholders involved in the risk assessment processes.

The questionnaire was the only data collection tool used to gain insights from a target group involved in scientific and legal metrology in South Africa. The sample size for the questionnaire was set at 30 respondents due to the limited number of practitioners in scientific and legal Metrology in the context of South Africa. This sample size was determined based on statistical considerations to ensure the accuracy of the findings obtained. The aim of the questionnaire was to collect information on current risk assessment practices, policies and procedures and the factors that influence the approach to risk assessment.

A limited sample size was deliberately chosen for this quantitative approach to ensure precision and resource efficiency. The sample comprised scientific and legal metrology experts in South Africa. Statistical principles were followed in determining the sample size to achieve adequate representation without redundancy.

This quantitative research approach enabled a thorough investigation of risk assessment practices within the specified area. The questionnaire, as the primary instrument, was structured to collect quantitative data and provide numerical insights into prevailing risk assessment practices, policies and procedures. The study design focused on statistically analyzing this quantitative data to draw meaningful conclusions and insights.

By using only quantitative research techniques with a sample size of 30 respondents, this study aimed to provide a rigorously analyzed and statistically sound insight into the factors influencing the approach to risk assessment in scientific and legal metrology in South Africa. The choice of a quantitative approach and the specific sample size were aligned with the research questions and ensured that the type of data collected was best suited to achieve the research objectives while ensuring statistical robustness.

4.4.1 Population

This study used an exclusively quantitative research approach to investigate risk assessment practices in scientific and legal metrology in South Africa. The study targeted metrology practitioners in the public and private sectors, including metrologists, inspectors, quality controllers and government officials responsible for enforcing metrology legislation.

The chosen method of data collection was exclusively via questionnaires, so qualitative methods were not considered. The sample size for this quantitative approach was determined based on statistical considerations and the specific research questions. The aim of the study was to collect a comprehensive data set that would provide a detailed understanding of the factors influencing the risk assessment approach.

A relatively small sample of scientific and legal metrology professionals in South Africa was selected for the questionnaires, namely 30 respondents. This sample size was chosen with statistical accuracy in mind to ensure that the findings obtained were both meaningful and resource efficient. The questionnaire was designed to capture quantitative data on current risk assessment practices, policies, procedures and factors influencing the approach.

This exclusively quantitative research approach was intended to contribute to the understanding of risk assessment practices in scientific and legal metrology. The use of a limited sample size and structured questionnaires ensured that the data collected could be subjected to statistical analysis to gain an accurate insight into the factors influencing risk assessment practice in the field. The choice of research approach and sample size was in line with the research questions and objectives and emphasized the precision and statistical robustness of the study.

4.4.2 Sample and sampling method

The sampling method used in this study was based on purposive sampling to identify participants with expertise and experience in scientific and legal metrology in South Africa, particularly those involved in risk assessments. Purposive sampling was deemed appropriate for this study as it enabled the inclusion of participants who had the necessary knowledge and experience to answer the research questions.

The target sample included professionals actively involved in scientific and legal metrology in South Africa, such as scientists, engineers, technicians, legal experts, policy makers and regulators. To ensure a comprehensive examination of the factors influencing approaches to risk assessment in this area, participants were selected on the basis of gender, race, age, experience and area of expertise.

The expected sample size for this study was approximately 35±10 participants. This number was deemed sufficient to provide enough data to answer the research questions while keeping the data manageable for in-depth analysis. The data was collected using a questionnaire distributed to professionals in the field of scientific and legal metrology.

The questionnaire contained closed-ended questions to enable a quantifiable investigation into the factors influencing the approach to risk assessment in scientific and legal metrology in South Africa. The exact number of respondents was determined based on the expected response rate and the need for a statistically significant sample size.

Potential respondents were invited to participate in the study via email or other suitable communication channels and informed consent was obtained prior to distribution of the questionnaire. The responses to the questionnaire were then quantitatively analyzed to draw conclusions about the factors influencing risk assessment practices in scientific and legal metrology in South Africa.

Consequently, the sample for this study was selected through a purposive sampling of practitioners working in scientific and legal metrology and risk assessment in South Africa. In selecting the sample, attention was paid to demographic diversity, which included different genders, races, age groups, years of experience and areas of expertise. Data was collected using a quantitative questionnaire. Participants were invited to take part in the study via email or other communication channels and gave their informed consent prior to participation.

4.5 Research instruments

In this study, the only research instrument used to collect data was a questionnaire. The questionnaire was carefully designed to capture data in a quantitative format. It contained closed-ended questions to elicit responses from a wide range of professionals in the field of scientific and legal metrology in South Africa.

The questionnaire covered various aspects related to risk assessment practice, policy, procedures and factors influencing the approach to risk assessment. To ensure a representative sample, the questionnaire was distributed online through professional networks and associations in the field, using stratified random sampling by gender, race, age, professional experience and area of expertise.

While the questionnaire offered the advantage of a larger sample size and easier quantitative data analysis, the closed nature of some questions limited the depth of information obtained. To improve the clarity and comprehensibility of the questionnaire, a pretest was conducted with a small group of participants so that adjustments could be made to improve the precision of the questions.

Consequently, the study relied solely on a questionnaire as a research tool to quantitatively collect data on the factors influencing the approach to risk assessment in scientific and legal metrology in South Africa. The design and administration of the questionnaire was carefully conducted to ensure the reliability and validity of the data obtained.

4.6 Data collection procedure

The effectiveness of this research study depends on the quality and reliability of the data collected. To achieve this, the study applies a quantitative approach to data collection through the distribution of questionnaires. In this section, the methodology and its application in collecting quantitative data are explained in detail below:

4.6.1 Questionnaires

Data collection involves the use of questionnaires to gather information from laboratory managers and metrology experts in accredited laboratories in South Africa. These questionnaires aim to gain insight into risk assessment practices in metrology. The use of questionnaires is particularly beneficial for this study as it allows for the collection of a considerable amount of data from a larger number of participants in a shorter time frame. The questionnaire was carefully designed to ensure clarity and contains a mixture of closed questions.

The questionnaire is emailed to the target audience along with a detailed explanation of the research objectives and the intended use of the data collected. Respondents are given a deadline by which they must complete and submit the questionnaire. This ensures that the data collection is carried out efficiently within a certain time frame and that an immediate analysis is possible.

The data collected from the questionnaires is analyzed using statistical software such as SPSS to identify trends and patterns. Descriptive statistics such as frequency distributions, measures of central tendency and measures of dispersion are used to analyze the closed questions.

4.7 Data analysis strategies and interpretation

Data analysis and interpretation play a central role in this research project, using a quantitative research approach to gain insights from surveys. The exclusive use of quantitative methods ensures a targeted and rigorous analysis of the collected data.

Descriptive statistics, including measures of central tendency, variability and distribution, are used to analyze the quantitative data from the surveys. These statistics, such as mean and standard deviation, summarize and describe the variables of the study . The aim is to provide a comprehensive overview of the survey data that facilitates the identification of trends, patterns and response distributions.

Regression analysis, a statistical technique for modeling relationships between variables, is applied to identify factors that influence the approach to risk assessment in scientific and legal metrology in South Africa. The dependent variable is the approach to risk assessment, while the independent variables include factors such as the level of education of those working in metrology, the status of laboratory accreditation and the legal framework for metrology. The aim of the analysis is to identify the most influential factors and examine their interactions.

The analysis will combine the results of descriptive statistics and regression analysis to identify key findings and draw conclusions that are consistent with the research objectives. This approach provides a solid framework for uncovering relationships and patterns within the quantitative data.

The data analysis section focuses specifically on quantitative techniques and emphasizes statistical evidence of relationships between variables. The limitations of the study, such as potential response bias and small sample size, are acknowledged in the context of quantitative research. Recommendations for future research are made, with an emphasis on improving the quantitative aspects of data collection.

4.8 Possible limitations and challenges of the study

Accessibility of data: Limited access to relevant data can prevent a comprehensive understanding of the factors influencing risk assessment in South African metrology. To remedy this, careful planning, peer review and sourcing of data through various channels are critical.

Sample size and representativeness: One potential limitation is sample size, which affects generalizability. Therefore, future studies should use more comprehensive sampling methods for a larger, more diverse sample to ensure broader representation.

Response bias: Concerns about response bias are addressed by adapting the research instrument to cultural norms and by taking steps to maintain confidentiality and a positive relationship.

Time and resource constraints: Time and resource constraints can affect data quality. A proactive remedy involves careful planning and allocation of resources to ensure rigorous data collection and analysis.

4.9 Ethical Considerations

Informed consent: Participants were fully informed about the study, emphasizing the voluntary nature of participation, confidentiality and the right to withdraw without consequences.

Privacy measures: Participant privacy and confidentiality were ensured through rigorous practices, including data encryption and secure storage.

Ensuring wellbeing: The study prioritized the well-being of participants by minimizing harm and discomfort through ethical considerations.

Commitment to voluntary participation: Participants took part in the study voluntarily and without external pressure, and their decision to participate or withdraw from the study was fully respected.

Transparent reporting: Results were reported transparently, preserving the participants' perspective and ensuring anonymity.

Ethical approvals: The required ethical approvals were obtained from the University of Witwatersrand and any changes to the procedure were ethically communicated and approved.

CHAPTER 5. ANALYSIS OF QUANTITATIVE RESULTS

5.1 Introduction

This chapter summarizes the results of a multi-faceted investigation into risk assessment in the areas of scientific and legal metrology in South Africa. The research had a broad objective, namely to examine the critical elements that impact on risk assessment, i.e. equipment, measurement methods, environmental aspects and legal requirements. In addition, the significant influence that national and international metrology organizations have on risk assessment processes related to legal requirements was investigated.

A fundamental focus was placed on the central role of accurate measurements in maintaining fairness, safety and security in various industries, which ultimately contributes to informed decision-making in the field of scientific and legal metrology. The study was guided by specific objectives aimed at identifying key factors influencing risk assessment approaches, evaluating the effectiveness of existing practices and proposing recommendations to improve the precision of risk assessment, thereby strengthening the reliability of measurements in practice.

With a robust sample size of 30 respondents, the results of the study, closely aligned with the defined objectives, are meticulously presented and analyzed. The completed questionnaires were coded using Excel and then exported to SPSS (Statistical Package for the Social Sciences) for detailed analysis. Both descriptive statistics (mean, minimum, maximum and standard deviation) and inferential statistics (Cronbach's alpha coefficient, factor analysis, correlations and t-test) were used to ensure a comprehensive understanding of the research findings.

5.2 Demographic Information

Table 5.1 indicates the demographic characteristics of the participants involved in the research.

Table 1: Demographic composition of the sample (respondents)

	Demographic Variable	**Frequency**	**Percentage**
Gender	Male	10	33.3%
	Female	20	66.7%
	Prefer not to say	0	0.0%
Qualification	High School Certificate	1	3.3%
	Diploma or Equivalent	11	36.7%
	Bachelor's	7	23.3%
	Master's	9	30.0%
	PhD	2	6.7%
Field of work	Scientific Metrology	13	43.3%
	Legal Metrology	14	46.7%
	Both Scientific and Legal Metrology	3	10.0%
Years of experience in metrology	0 to 2 years	0	0.0%
	3 to 5 years	7	23.3%
	6 to 9 years	7	23.3%
	10 to 15 years	11	36.7%
	Over 15 years	5	16.7%
Training or education in risk assessment in metrology	Yes	17	56.7%
	No	13	43.3%
Frequency of performing risk assessments	Daily	9	30.0%
	Weekly	2	6.7%
	Monthly	4	13.3%
	Occasionally	11	36.7%
	Rarely	4	13.3%
	Never	0	0.0%
Primary motivation for conducting risk assessments in metrology	Compliance with regulations and standards	13	43.3%
	Enhancing measurement accuracy and reliability	5	16.7%
	Ensuring safety in metrology processes	5	16.7%
	Minimising non-compliant rate in the industry	3	10.0%
	Improving decision-making processes	4	13.3%
Sample size		30	100.0%

5.2.1 Gender distribution

The gender distribution in the study sheds light on an interesting aspect of the metrology workforce. The majority of respondents, 66.7%, described themselves as female, while 33.3% were male. This distribution is thought-provoking about the gender dynamics in the field of metrology, considering that women have always been underrepresented in STEM professions.

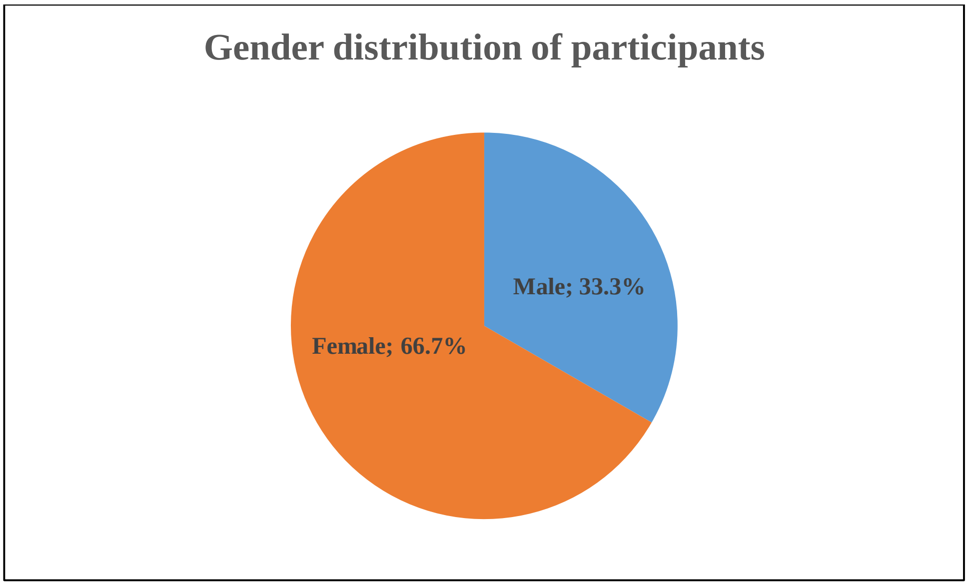

Figure 2 represents the percentage of males, females, and those who preferred not to disclose their gender

Remarkably, none of the respondents wanted to withhold information about their gender, indicating a willingness to contribute to the study in a transparent manner. This level of openness is crucial to the reliability of the data collected.

5.2.2 Qualifications

The analysis of qualifications shows that the respondents have different educational backgrounds. The largest group (36.7%) had a degree or equivalent, suggesting that a significant proportion of scientist, metrologists, inspectors, etc. have had training beyond school.

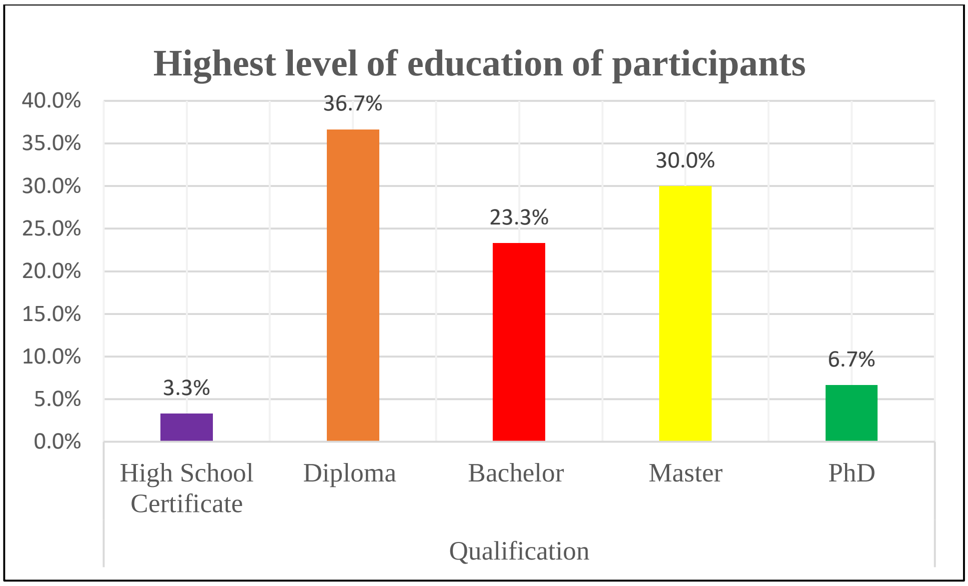

Figure 3 represents display the distribution of educational qualifications among respondents.

In addition, 30.0% of respondents had a master's degree, suggesting a significant number of individuals with advanced knowledge and experience. This educational diversity within the sample bodes well for a comprehensive examination of risk assessment practices, as it includes perspectives from different levels of education.

5.2.3 Field of work

The distribution of respondents across the various fields of work shows an interesting panorama of the metrology landscape. 43.3% of respondents work in scientific metrology, 46.7% work in legal metrology and a small but significant percentage (10.0%) work in both scientific and legal metrology.

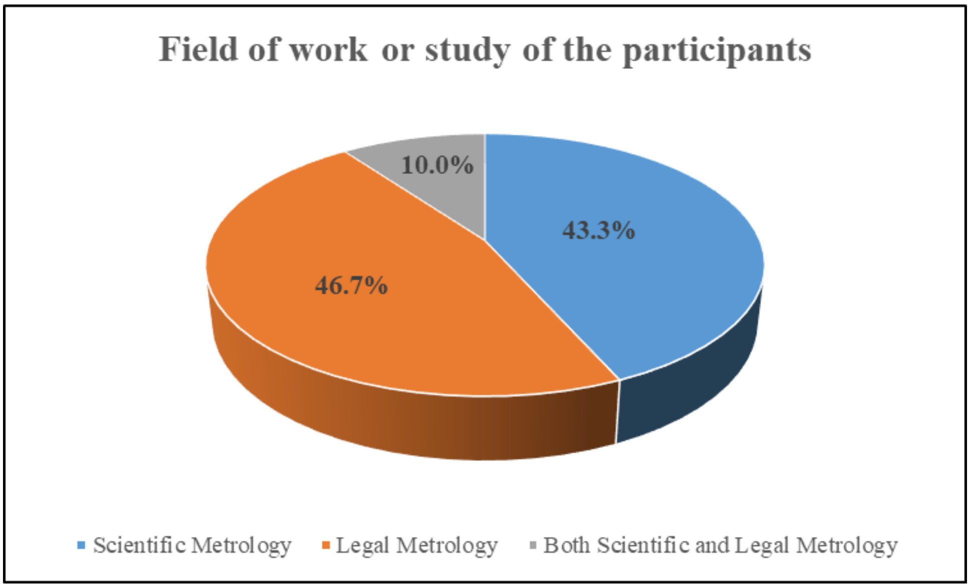

Figure 4 illustrate the percentage of respondents in scientific metrology, legal metrology, and those involved in both field.

This diversity of professional fields increases the value of the study, as it enables the investigation of risk assessment practices in different contexts. Scientific and legal metrology may present different challenges and priorities, and this diversity allows for a nuanced understanding of how risk assessment is approached in these contexts.

5.2.4 Years of experience in metrology

Respondents' years of experience provide a temporal dimension to the demographic analysis. A notable finding is that the majority of respondents have between 6 and 15 years of experience in metrology. This experienced group brings a wealth of experience that can provide historical perspectives on the evolution of risk assessment practices.

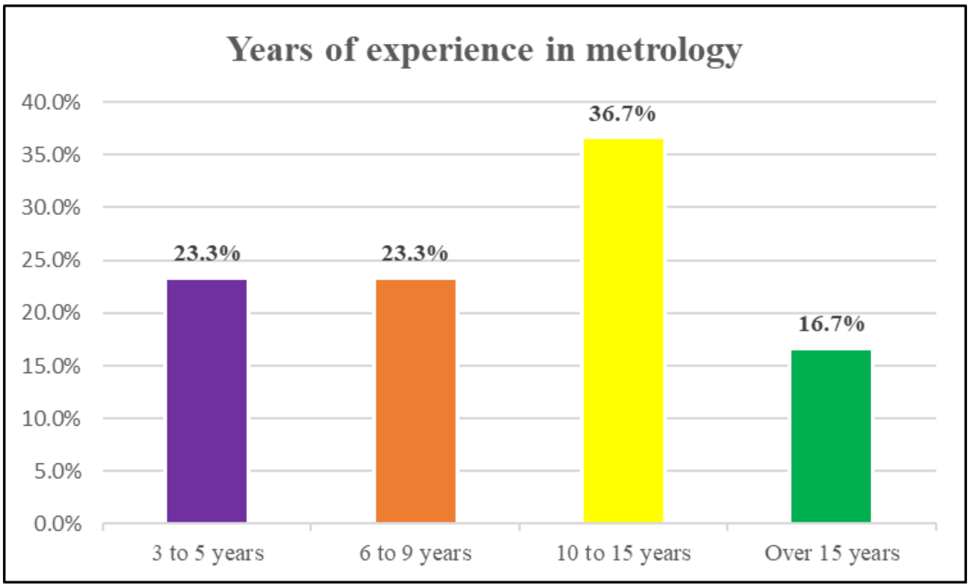

Figure 5 represents the distribution of respondents based on their years of experience.

Understanding how risk assessment has changed over the years is critical to assessing the current state and predicting future trends. An experienced cohort is well positioned to provide insights into the changes, challenges and successes in this area.

5.2.5 Education or training in risk assessment in metrology

More than half of respondents (56.7%) indicated that they had received education or training in risk assessment. This result underlines the commitment of metrology staff to continuing professional development and keeping up to date with the latest technology.

This statistic has far-reaching implications. Educated and trained professionals are likely to approach risk assessment with a more informed perspective, potentially leading to more effective and sophisticated practices. This section of the analysis therefore serves as a foundation for understanding the risk assessment knowledge landscape in the metrology community.

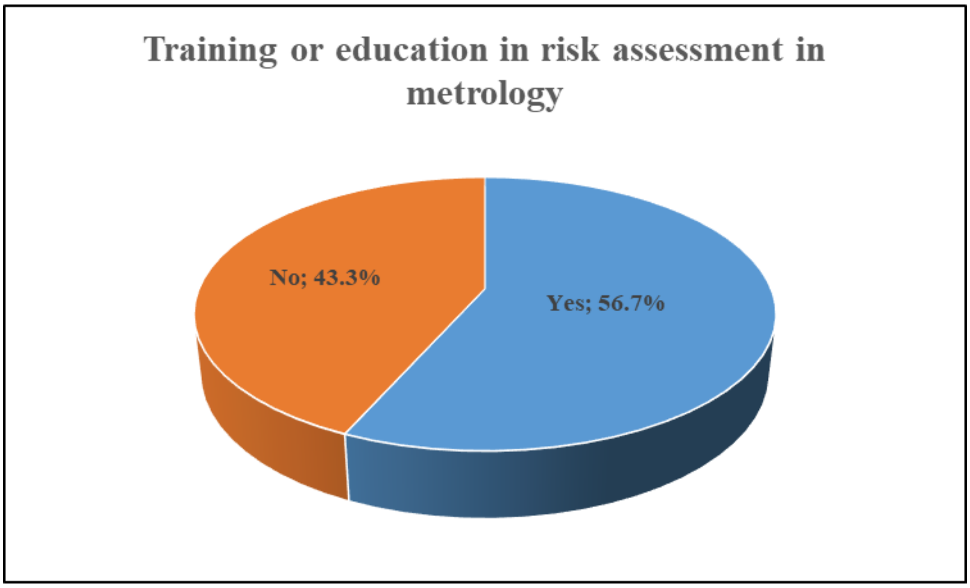

Figure 6 shows the percentage of respondents who have received training or education in risk assessment.

5.2.6 Frequency of conducting risk assessments

The frequency with which respondents conduct risk assessments provides an insight into the way metrology professionals work. Interestingly, 36.7% of respondents indicated that they conduct risk assessments occasionally, suggesting that these assessments are not conducted consistently and regularly.

how often respondents perform risk assessments.

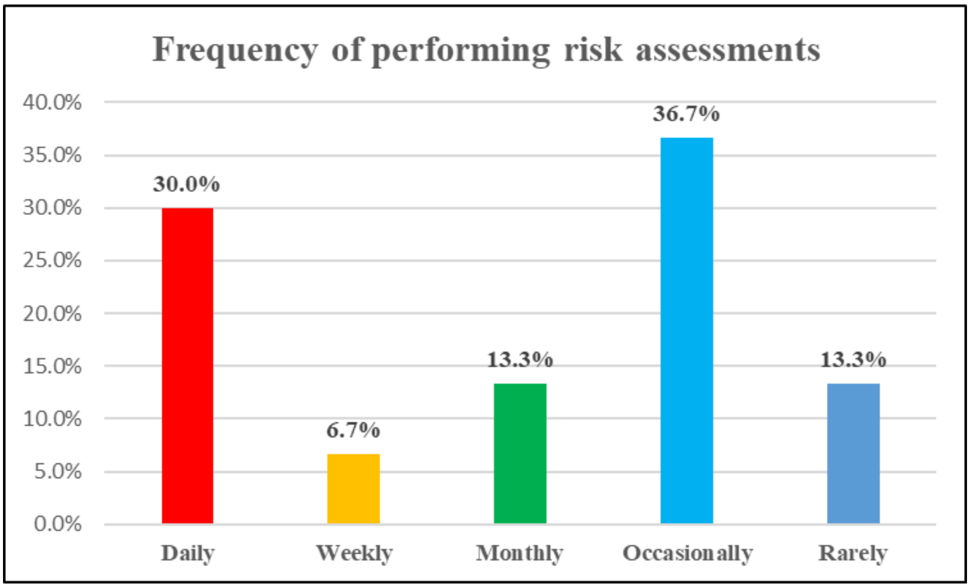

Figure 7 highlights how often respondents perform risk assessments.

Conversely, 30.0% of respondents conduct risk assessments on a daily basis, indicating a proactive and continuous approach to risk management. The frequency of risk assessments is central to understanding the real-time response of metrology practice to potential risks.

5.2.7 The main motivations for carrying out risk assessments

The motivations that drive professionals to carry out risk assessments are varied and reflect the multi-faceted considerations in the field of metrology as shown in Figure 8.

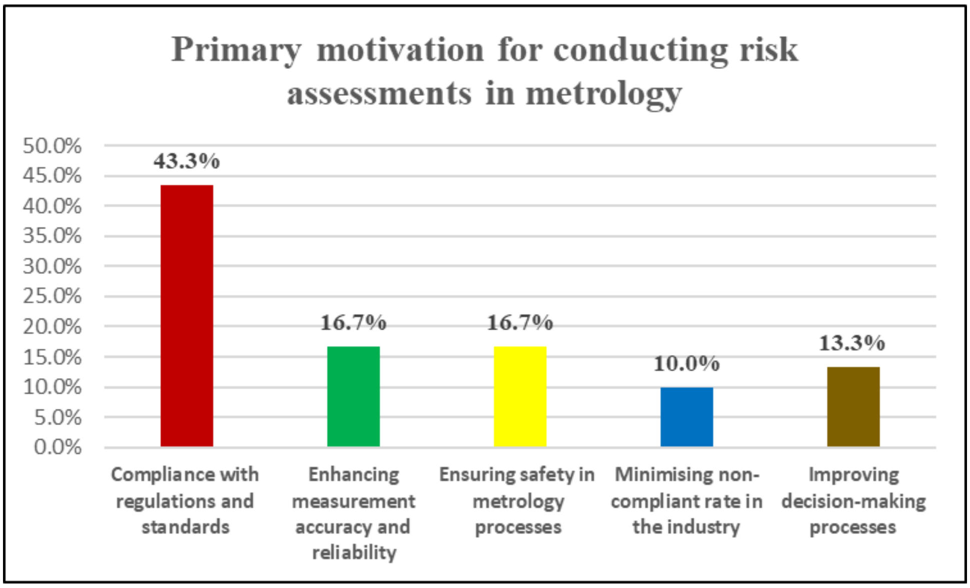

Figure 8 shows show the percentage of respondents motivated by compliance, accuracy, safety, industry standards, and decision-making.

a) Compliance with regulations and standards

The main motivation for carrying out risk assessments is compliance with regulations and standards. 43.3% of respondents cited this as their main motivation. This result is consistent with the regulatory nature of metrology, where compliance with established standards is paramount to ensuring the accuracy and reliability of measurements.

b) Improving measurement accuracy and reliability

A remarkable 16.7% of respondents indicated a desire to improve the accuracy and reliability of measurements. This group is likely to view risk assessment as a proactive measure to maintain the accuracy of their metrology activities, contributing to the overall quality of measurements.

c) Ensuring the safety of metrology processes

Security is an important concern for 16.7% of respondents. This indicates an awareness of the potential risks associated with metrology processes and the importance of protecting against them to ensure the well-being of employees and the integrity of measurements.

d) Minimizing the non-compliance rate in the industry

A smaller but still significant percentage (10.0%) cite minimizing the rate of non-compliance in the industry as their primary motivation. This indicates a strategic approach using risk assessments as a tool to align with industry standards and best practice.

e) Improving decision-making processes

The motivation to improve decision-making processes was cited by 13.3% of respondents. This indicates that the role of risk assessment is recognized not only for regulatory compliance and safety, but also for supporting sound metrology decision making.

5.3 Descriptive statistics

5.3.1 Factors Influencing Risk Assessment in Scientific and Legal Metrology

a. Attitudes toward Risk Assessment

This section deals with the responses to the attitudes towards risk assessment. The Cronbach's alpha for this section, a measure of internal consistency, was calculated to be 0.8, exceeding the generally accepted threshold of 0.7 set by Field (2009). This indicates a high reliability of the survey instrument. The mean and standard deviation of the responses are shown in Table 2.

Table 2: Attitudes toward Risk Assessment

Variable	Mean	Standard Deviation
Risk assessment is an important part of scientific and legal metrology.	4.83	0.38
Risk assessment contributes to ensuring measurement accuracy and reliability.	4.67	0.55
Risk assessment enhances decision-making processes in scientific and legal metrology.	4.47	0.73
Risk assessment improves overall safety in scientific and legal metrology.	4.67	0.55
Risk assessment provides valuable insights into non-compliant rate of product in the local market.	4.50	0.63

Values close to 5 in Table 2 indicate strong agreement with the statements. Respondents strongly affirmed the importance of risk assessment in scientific and legal metrology, its role in ensuring measurement accuracy and reliability, its contribution to decision-making processes and its impact on overall safety. In addition, respondents agreed that risk assessment provides a valuable insight into the non-compliance rate of products in the local market. The standard deviations, which are all below 1, indicate a high level of agreement among respondents.

To better capture the overarching variable of attitude towards risk assessment, a composite variable was calculated. As shown in Table 3, the mean value of this composite variable is close to 5, indicating a high level of agreement among respondents.

Table 3:Composite Variable for Attitudes toward Risk Assessment

Variable	Mean	Standard Deviation
Composite variable for attitudes toward risk assessment.	4.63	0.43

In Table 3, the high mean and low standard deviation illustrate the high level of agreement among respondents regarding their attitudes towards risk assessment in scientific and legal metrology.

b. Subjective Norms Related to Risk Assessment

This part of the study provides information on the subjective norms in connection with risk assessment. The calculated Cronbach's alpha for this section is 0.8, which underlines the reliability of the survey instrument. The results are shown in Table 4.

Table 4: Subjective Norms regarding Risk Assessment

Variable	Mean	Standard Deviation
My colleagues in scientific and legal metrology expect me to conduct risk assessments.	3.90	1.03
My supervisors in scientific and legal metrology emphasise the importance of risk assessment.	4.17	0.79
Regulations and policies in scientific and legal metrology require me to conduct risk assessments.	4.13	0.86
There is a social or personal expectation within the scientific and legal metrology community to perform risk assessments.	3.70	0.88
Risk assessment is considered a professional norm in scientific and legal metrology.	4.17	0.95

Table 4 illustrates the means and standard deviations for various statements related to subjective norms. Mean values close to 4 indicate agreement. Respondents expressed agreement with the statements about the expectations of colleagues and superiors, legal requirements, social or personal expectations and the professional norm associated with risk assessment. To gain a comprehensive understanding, a composite variable for subjective norms related to risk assessment was calculated as indicated in Table 5.

Table 5:Composite Variable for Subjective Norms related to Risk Assessment

Variable	Mean	Standard Deviation
Composite variable for subjective norms related to risk assessment.	4.01	0.61

In Table 5, the mean value of the composite variable close to 4 underlines a robust agreement among respondents on subjective norms related to risk assessment.

c. Perceived behavioural control towards risk assessment

This section deals with the results on perceived behavioral control. The calculated Cronbach's alpha for this section is 0.9, indicating a highly reliable research instrument (Field, 2009). Table 6 shows the mean and standard deviation of the responses.

Table 6: Perceived Behavioral Control towards risk assessment

Variable	Mean	Standard Deviation
I have the knowledge and skills required to conduct risk assessments.	3.97	0.93
I have access to the necessary resources (e.g., time, equipment) to conduct risk assessments.	3.70	0.88
Conducting risk assessments is within my control.	3.50	1.01
I feel confident in my ability to effectively perform risk assessments.	3.90	1.03
I believe I have sufficient authority to make decisions based on risk assessment outcomes.	3.33	1.18

Values close to 4 in Table 6 indicate agreement with the statements. Respondents agreed that they have the knowledge and skills necessary to conduct risk assessments, that they have access to the necessary resources, that they can control the process, that they have confidence in their abilities, and that they believe they have sufficient authority to make decisions based on risk assessments. However, the standard deviations for the last three distributions are greater than 1, indicating a lack of consensus among respondents. To gain a comprehensive understanding, a composite variable for perceived behavioral control was calculated (see Table 7).

Variable	Mean	Standard Deviation
Composite variable for perceived behavioural control.	3.68	0.87

In Table 7, the mean value of the composite variable close to 4 indicates that the respondents agree with the perceived behavioral control. The standard deviation is below 1, indicating a relatively high level of agreement.

d. Enablers and Barriers to Effective Risk Assessment within Scientific and Legal Metrology

This section presents the findings in relation to the barriers to conducting risk assessments. It also discusses the factors that enable or support effective risk assessment.

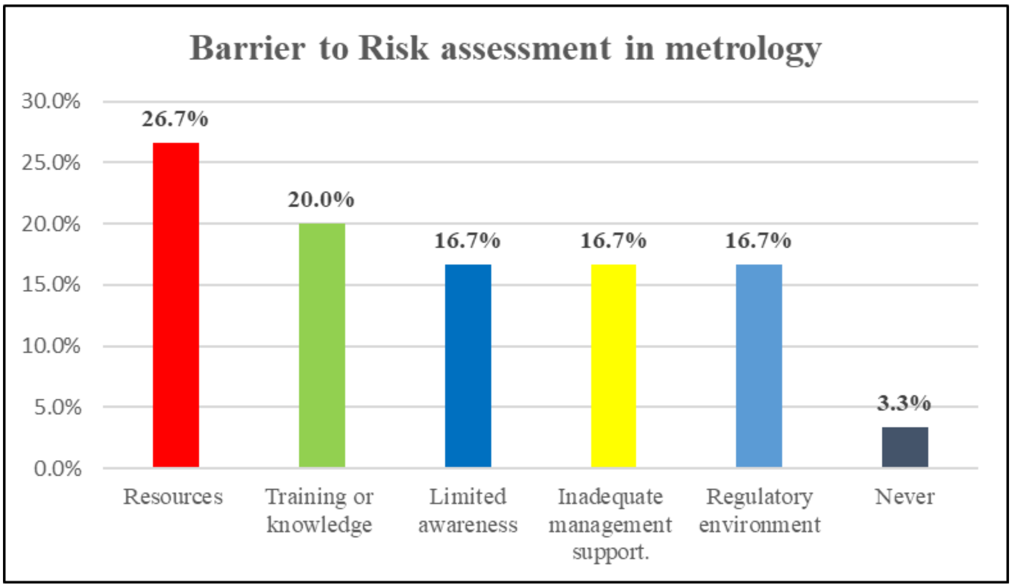

Figure 9 shows Major Barriers Encountered in risk assessment

Figure 9 shows the main barriers faced by respondents when conducting risk assessments. analysis of the main barriers shows that 26.7% of respondents face a lack of adequate resources, while 20% struggle with insufficient training or knowledge. In addition, 16.7% of respondents state that their awareness or understanding is limited, and an equally high percentage face insufficient support or commitment from management. A further 16.7% struggle with complex legal requirements or a lack of clear guidelines. Interestingly, 3.3% of respondents say they have never encountered obstacles when conducting risk assessments.

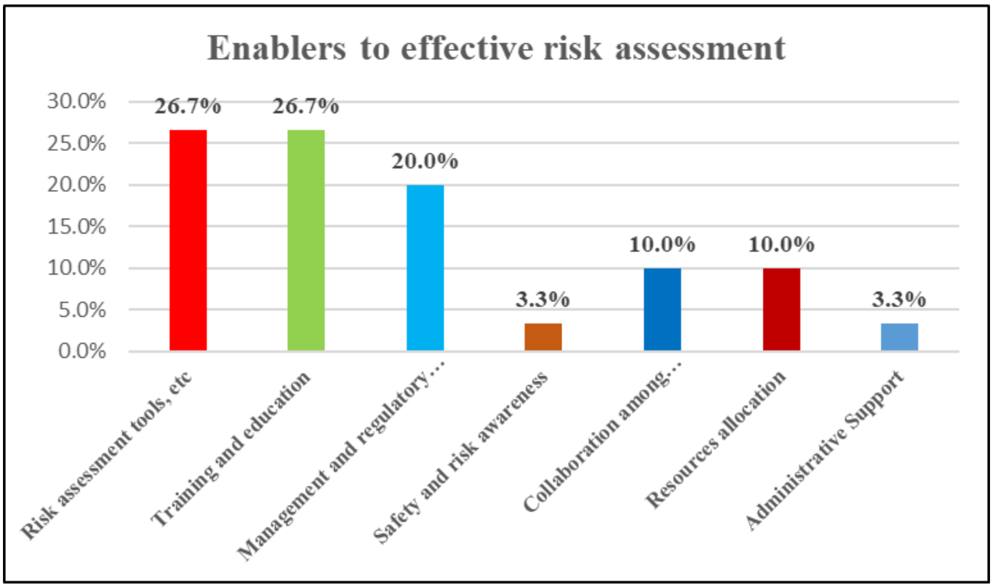

Figure 10 shows enablers to Effective Risk Assessment

Figure 10 shows the factors that enable or support effective risk assessment. It shows that 26.7% of respondents cited the availability of comprehensive risk assessment tools and methods, as well as sufficient training and education in risk assessment practices. In addition, 20% of respondents indicated that clear guidance and support from management and regulators facilitates risk assessment. In addition, 10% of respondents indicated that there is collaboration and knowledge sharing between stakeholders, while the same percentage cited adequate allocation of resources for risk assessment. Interestingly, 3.3% of respondents indicated that administrative support from colleagues plays a crucial role in effective risk assessment.

5.3.2 Complexity of Measurement Systems within scientific and legal metrology in South Africa?

a. Attitudes towards Complexity of Measurement Systems

The assessment of attitudes towards the complexity of measurement systems shows a positive trend among respondents. The mean values, which are predominantly 4, indicate a high level of agreement with the statements that confirm the benefits and reliability of the new measurement technologies. This positive attitude is of crucial importance in the context of risk assessment, as it indicates a general openness and receptiveness to the introduction and use of advanced measurement methods.

Table 7: Attitude towards measurement complexity in metrology.

Variable	Mean	Standard Deviation
I believe that new measurement technologies and methods enhance accuracy and reliability in scientific and legal metrology.	4.47	0.57
I perceive new measurement technologies and methods as beneficial for risk assessment in scientific and legal metrology.	4.30	0.70
I consider new measurement technologies and methods as reliable tools for measurement in scientific and legal metrology.	4.13	0.63
I think that new measurement technologies and methods are necessary to keep up with evolving measurement requirements.	4.53	0.63

The individual components of attitude, such as the belief that new measurement technologies improve accuracy and reliability (mean = 4.47), that they are seen as beneficial for risk assessment (mean = 4.30), that they are considered reliable measurement tools (mean = 4.13), and that their need to keep pace with evolving measurement requirements is recognized (mean = 4.53), together contribute to a comprehensive understanding. The reliability of the instrument, as indicated by Cronbach's alpha ($\alpha = 0.8$), increases the credibility of these results.

Table 8: Composite variable for attitudes towards complexity of measurements systems

Variable	Mean	Standard Deviation
Composite variable for attitudes towards complexity of measurements systems.	4.36	0.52

The composite variable for attitudes towards measurement system complexity with a mean of 4.36 and a standard deviation of 0.52 further consolidates these positive attitudes. This indicates a consistent and high level of agreement among respondents and underscores the shared view of the importance and effectiveness of new measurement technologies.

b. Subjective Norms towards Complexity of Measurement Systems

Subjective norms provide information about the perceived social pressure in connection with the introduction of new measurement technologies. The mean values close to 4 in the first two distributions indicate general agreement among respondents. It is assumed that colleagues and peers in scientific and legal metrology expect them to adopt and apply new measurement technologies and methods (mean = 3.83). Such adoption is also implicitly expected from the regulatory authorities (mean = 3.80).

Table 9: Subjective norms towards complexity of measurements systems

Variable	Mean	Standard Deviation
My colleagues and peers in scientific and legal metrology expect me to adopt and use new measurement technologies and methods.	3.83	0.70
There is an implicit expectation from regulatory bodies to adopt and use new measurement technologies and methods.	3.80	0.76
I feel pressure from the industry to adopt and use new measurement technologies and methods.	3.07	1.11

However, the mean value close to 3 in the third distribution indicates a rather neutral attitude towards the perceived pressure from the industry. The associated higher standard deviation indicates a wider range of responses, which means that while the expectations of colleagues and regulators are aligned, the influence of the industry is perceived differently by respondents.

Table 10: Composite variable for subjective norms towards complexity of measurements systems

Variable	Mean	Standard Deviation
Composite variable for subjective norms towards complexity of measurements systems.	3.57	0.70

The composite variable for subjective norms regarding the complexity of measurement systems reflects a general agreement with a mean of 3.57 and a standard deviation of 0.70. However, the slightly lower mean compared to attitudes indicates a nuanced view, suggesting that while societal pressures are recognised, the intensity of these pressures may vary among respondents.

c. Perceived Behavioral Control towards Complexity of Measurement Systems

Perceived behavioral control refers to respondents' confidence and perceived ability to adopt new measurement technologies. The mean scores close to 4 in the first two distributions indicate general agreement among respondents. They are confident that they are able to successfully introduce and use new measurement technologies and believe that they have the necessary knowledge and skills (mean = 3.87 and 3.57 respectively).

Table 11: Perceived behavioural control towards complexity of measurements systems

Variable	**Mean**	**Standard Deviation**
I feel confident in my ability to successfully adopt and use new measurement technologies and methods.	3.87	0.94
I believe I have the necessary knowledge and skills to effectively utilise new measurement technologies and methods.	3.57	1.10
I have access to the resources (e.g., time, equipment) required to adopt and use new measurement technologies and methods.	3.00	0.98

However, the mean of 3 in the third distribution indicates a rather neutral attitude towards access to resources such as time and equipment required for the introduction and use of new measurement technologies and methods. The associated standard deviation indicates varying responses, suggesting that confidence in one's own abilities is generally high, but perceptions of resource availability vary more widely among respondents.

Table 12: Composite variable for perceived behavioural control towards complexity of measurements systems

Variable	**Mean**	**Standard Deviation**
Composite variable for perceived behavioural control towards complexity of measurements systems.	3.48	0.88

The composite variable for perceived behavioral control versus measurement system complexity with a mean of 3.48 and a standard deviation of 0.88 indicates a more neutral and diverse view. This means that although the respondents have confidence in their personal abilities, they perceive the availability of the necessary resources rather differently.

d. Perceived Challenges Associated with the Increasing Complexity

Respondents identified various challenges related to the increasing complexity of measurement systems in scientific and legal metrology. The graphical representation in Figure 11 visually underlines these results and provides a quick and intuitive overview of the perceived challenges associated with the increasing complexity of measurement systems. A detailed breakdown shows that 40% of respondents perceived an increased time and effort required for risk assessment due to system complexity, indicating a significant problem. In addition, 26.7% of respondents perceived problems in identifying and assessing risks associated with complex measurement systems, highlighting the multifaceted nature of these challenges.

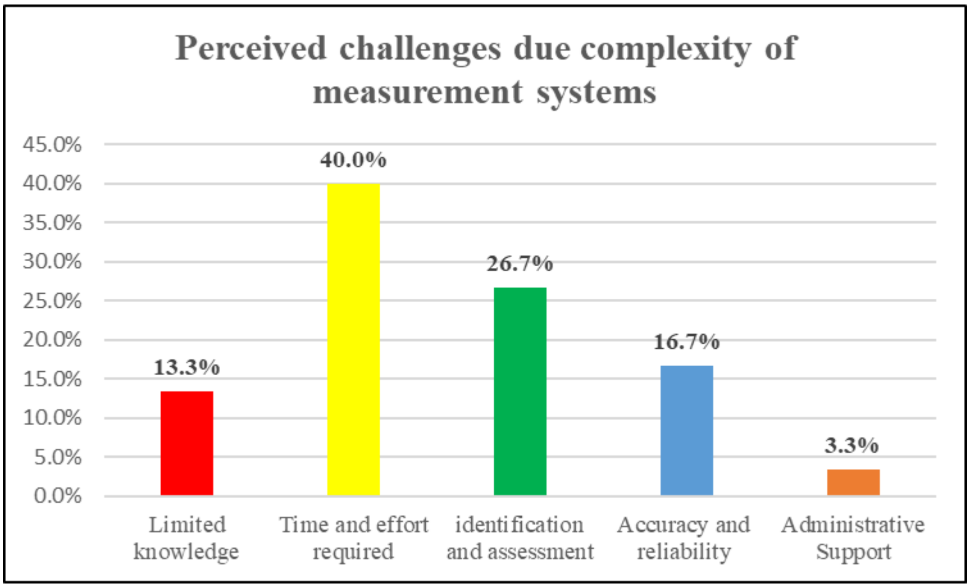

Figure 11 shows the perceived challenges associated with the increasing complexity of measurement systems in scientific and legal metrology

A remarkable 16.7% reported an impact on the accuracy and reliability of measurement results, while 13.3% experienced difficulties in understanding and implementing complex measurement technologies. These figures highlight the diverse challenges that scientific and legal metrology professionals face due to the increasing complexity of measurement systems.

e. Main Risks and Uncertainties Introduced by Complex Measurement Systems

Identifying the most important risks and uncertainties arising from complex measurement systems is crucial for risk assessment. The graphical representation in Figure 12 provides a visual snapshot of the key risks and uncertainties perceived by respondents and helps to quickly interpret these key findings.

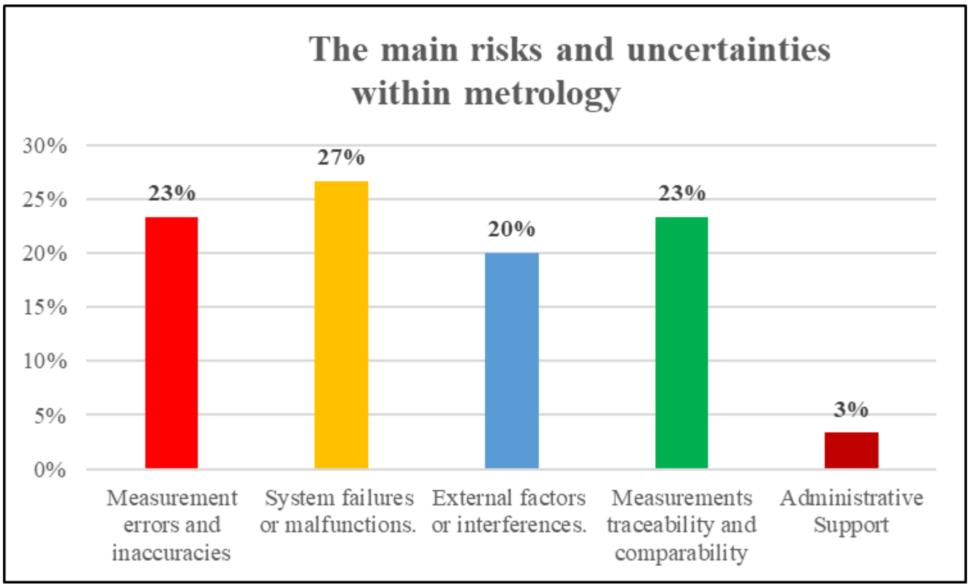

Figure 12 shows key risks and uncertainties due to complex measurement systems.

Respondents cited potential errors and inaccuracies (23.3%) and difficulties in ensuring traceability and comparability of measurements (23.3%) as key risks. In addition, 26.7% reported difficulties in detecting and limiting system failures or malfunctions, while 20% cited increased susceptibility to external factors or disruptions.

These findings highlight the critical nature of the challenges that complex measurement systems present. They range from technical aspects such as errors and traceability to operational challenges in detecting system failures.

f. Specific Barriers or Difficulties Encountered in Adopting and Using New Technologies

Respondents pointed to specific obstacles or difficulties encountered when introducing and using new measurement technologies. At the top of the list was resistance from stakeholders or colleagues (30%), indicating organizational and interpersonal challenges. Insufficient resources or funding to implement complex measurement systems was cited by 26.7% of respondents, indicating a specific barrier for organizations.

23.3% of respondents cited a lack of training and knowledge about new measurement technologies and methods. This demonstrates the importance of continuous learning and professional development in the face of technological advancement. Compatibility issues with existing systems or infrastructure were cited by 16.7% of respondents, indicating the need for seamless integration of new technologies into existing facilities.

These results make it clear that the introduction of new measurement technologies is not only a technical challenge, but also brings with it a variety of obstacles that affect organizational, financial and pedagogical areas.

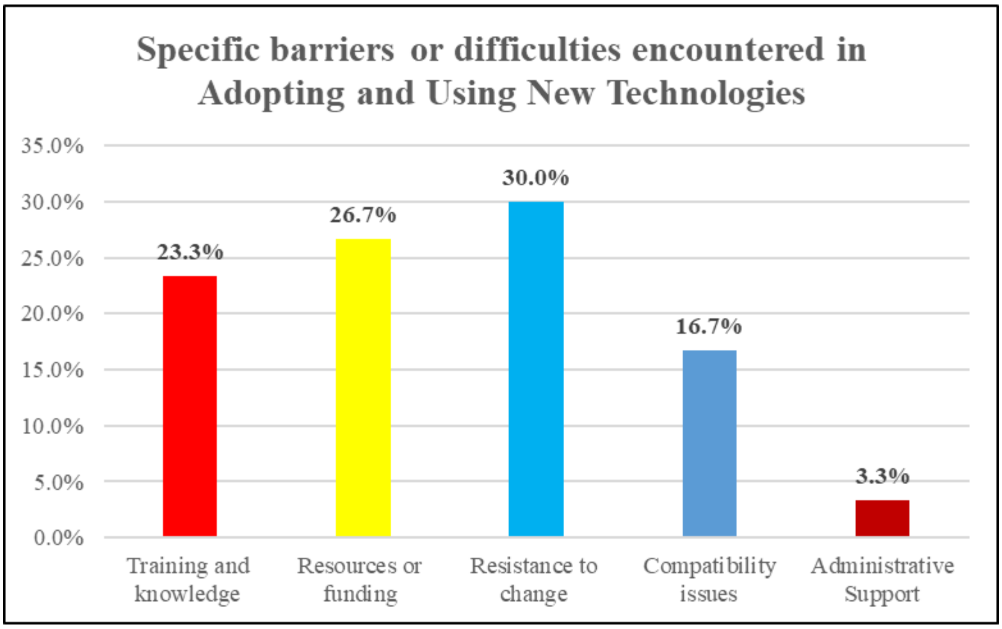

Figure 13 summarizes specific barriers or difficulties encountered in Adopting and Using New Technologies

The graphical representation in Figure 13 visually summarizes these specific barriers and provides a quick overview of the main challenges that professionals face when introducing and using new measurement technologies.

5.3.3 Effectiveness of current risk assessment methods in South African metrology.

a. Attitudes towards Current Risk Assessment Methods within Scientific and Legal Metrology

The aim of this section was to determine respondents' attitudes towards current risk assessment methods. However, the reliability of this section was below the acceptable threshold with a Cronbach’s alpha of 0.6 (Field, 2009), so this questionnaire item was excluded due to unreliability risks.

When examining attitudes towards current methods of risk assessment in scientific and legal metrology, respondents were asked to indicate their opinion on various aspects using a Likert scale. The results are presented below:

Table 13: Attitudes towards Current Risk Assessment Methods

Variable	Mean	Standard Deviation
Risk assessment is an important part of my job in scientific and legal metrology.	4.23	0.73
I believe that conducting thorough risk assessments is necessary to ensure the accuracy and reliability of measurements.	4.30	0.84
I enjoy conducting risk assessments in scientific and legal metrology.	3.77	0.90
I believe that risk assessment methods currently used in South African metrology are effective in identifying potential risks.	3.47	0.97

The analysis shows that respondents are generally positive about the methods of risk assessment in scientific and legal metrology. The composite variable with a mean close to 4 underlines the general agreement with the importance, necessity and, to a certain extent, the pleasure associated with carrying out risk assessments.

Table 14: Composite Variable for Attitudes towards Current Risk Assessment Methods

Variable	Mean	Standard Deviation
Composite variable for attitude towards current risk assessment methods within scientific and legal metrology.	3.94	0.58

Despite the exclusion of one questionnaire item due to reliability concerns, the remaining variables convey a positive overall picture. Respondents recognised the critical role of risk assessment in their area of responsibility, indicating an openness to the concept. The differentiated assessment of the effectiveness of current methods indicates possible areas for improvement. The decision to exclude an element of the questionnaire due to reliability concerns demonstrates a desire to maintain the quality and trustworthiness of the research tool.

b. Subjective Norms towards Current Risk Assessment Methods within Scientific and Legal Metrology

Subjective norms, which are crucial for understanding the social context of risk assessment, were assessed using a reliable research instrument (Cronbach's alpha = 0.7). Table 15 shows the mean and standard deviation of the responses.

Table 15: Subjective Norms towards Current Risk Assessment Methods

Variable	Mean	Standard Deviation
My colleagues place great importance on conducting thorough risk assessments in our work.	3.70	0.88
Stakeholders expect me to conduct thorough risk assessments in scientific and legal metrology.	3.63	0.72
I feel motivated to conduct thorough risk assessments due to the perceived social pressure from my professional network.	3.23	0.82

The mean values close to 4 in the first two distributions indicate a consensus among the respondents. They agree that their colleagues emphasize the importance of thorough risk assessments and that stakeholders expect them to conduct such assessments. The low standard deviations indicate a high level of agreement.

In addition, the mean value close to 3 in the third distribution indicates neutrality. Respondents neither strongly agreed nor disagreed that they feel motivated to conduct thorough risk assessments due to perceived social pressure from their professional network. The low standard deviation indicates a general neutrality of the respondents.

In order to obtain a consolidated picture of the subjective norms, a composite variable was calculated (Table 16).

Table 16: Composite Variable for Subjective Norms towards Current Risk Assessment Methods

Variable	Mean	Standard Deviation
Composite variable for subjective norms towards current risk assessment methods within scientific and legal metrology.	3.52	0.62

The mean value of the composite variable, which is close to 4, indicates a high degree of agreement between the respondents regarding the subjective norms in relation to the current risk assessment methods. The standard deviation below 1 supports the conclusion of a high level of agreement.

c. Perceived Behavioral Control towards Current Risk Assessment Methods within Scientific and Legal Metrology

In this section, perceived behavioral control is examined in the context of current risk assessment methods. With a Cronbach's alpha of 0.9, this section is considered reliable (Field, 2009). Table below shows the mean and standard deviation of the responses.

Table 17: Perceived Behavioral Control towards Current Risk Assessment Methods

Variable	Mean	Standard Deviation
I feel confident in my ability to conduct thorough risk assessments.	3.77	0.94
I have the necessary knowledge and skills to effectively assess potential risks in scientific and legal metrology.	3.57	0.9
I have access to the resources (e.g., time, tools, information) required to conduct effective risk assessments.	3.10	0.96

The mean values close to 4 in the first two distributions indicate agreement. Respondents are confident that they are able to carry out thorough risk assessments and believe that they have the necessary knowledge and skills. The low standard deviations indicate a high level of agreement.

However, a mean score closes to 3 in the third distribution indicates neutrality. Respondents neither strongly agreed nor disagreed that they have access to the resources needed to conduct effective risk assessments. The low standard deviation indicates general neutrality. A composite variable was calculated to provide a nuanced perspective on perceived behavioral control (Table 18).

Table 18:Composite Variable for Perceived Behavioral Control towards Current Risk Assessment Methods

Variable	Mean	Standard Deviation
Composite variable for perceived behavioural control towards current risk assessment methods.	3.48	0.84

The mean value of the composite variable, which is close to 3, indicates a general neutrality in perceived behavioral control towards the current risk assessment methods. The standard deviation below 1 underlines the neutral attitude of the respondents.

d. Effectiveness of Risk Assessment Methods within Scientific and Legal Metrology

This section aimed to assess the perceived effectiveness of current risk assessment methods in the context of scientific and legal metrology. Participants were asked to rate the effectiveness of these methods in detecting potential risks or non-compliant products and the frequency with which they encounter risks in their measurements. Responses were measured on a Likert scale, with 1 being "not effective" or "not often" and 5 being "very effective" or "very often"

Participants were asked how they rated the effectiveness of current risk assessment methods. The mean score for the effectiveness of these methods in identifying potential risks or non-compliant products was 3.26, indicating moderate effectiveness. However, the standard deviation of 0.86 indicates some variability in the responses, suggesting different opinions among participants. Another aspect that was considered was the frequency of occurrence of potential risks related to non-compliance during the measurements. The mean was 2.80 and the standard deviation was 1.21, indicating a wider range of responses regarding the frequency of occurrence of risks.

Table 19: Effectiveness of Risk Assessment Methods within Scientific and Legal Metrology

Variable	Mean	Standard Deviation
How effective do you find the current risk assessment methods in identifying potential risks or non-compliant products?	3.26	0.86
How frequently do you encounter potential risks related to non-compliance with regulations or standards during your measurements in scientific and legal metrology?	2.80	1.21

In order to obtain a comprehensive overview, a composite variable was created for the effectiveness of the risk assessment methods. The mean of this composite variable was 3.03, indicating an overall moderate perception of the effectiveness of current risk assessment methods. The standard deviation of 0.95 shows a certain variability in the opinions of the respondents.

Table 20: Composite Variable for Effectiveness of Risk Assessment Methods within Scientific and Legal Metrology

Variable	Mean	Standard Deviation
Composite variable for effectiveness of risk assessment methods with Scientific and Legal Metrology	3.03	0.95

The aim of this section was to gain an insight into participants' perceptions of the effectiveness of risk assessment methods. However, it is important to note that this section had to be removed due to the low reliability (Cronbach's alpha of 0.5) and the use of different scales for the questions. Despite its exclusion, the original intention was in line with the research question and theoretical framework, which aimed to evaluate the effectiveness of current risk assessment methods in the field of scientific and legal metrology.

5.3.4 Measurement consistency within Scientific and Legal Metrology

a. Attitudes towards Measurement Consistency within Scientific and Legal Metrology

The segment on attitudes to consistency of measurement in scientific and legal metrology had problems with reliability, reflected in a Cronbach's alpha of 0.6, which is below the recommended value of 0.7 (Field, 2009). This raised concerns about the consistency of responses in this section and prompted its removal from the study to ensure the integrity of the research.

Table 21: Attitudes towards Measurement Consistency within Scientific and Legal Metrology

Variable	Mean	Standard Deviation
Measurement accuracy is crucial for reliable risk assessments.	4.53	0.57
Consistency in measurement practices across domains enhances the accuracy and reliability of risk assessments	4.40	0.62
Inconsistent measurement practices in different domains undermine the validity and credibility of risk assessments.	4.13	0.90

Table 22: Composite variable for Attitudes towards Measurement Consistency

Variable	Mean	Standard Deviation
Composite variable for attitudes towards measurement consistency within scientific and legal metrology.	4.36	0.52

Despite the removal of this section, the results of the analysis of the attitude table prior to exclusion indicate a predominantly positive attitude among respondents. The mean scores, particularly in relation to the importance of measurement accuracy and the positive impact of consistency on reliability, were remarkably high.

However, a closer look at the standard deviation of responses, particularly in relation to concerns about inconsistency, indicates a degree of disagreement between respondents. The composite variable, although not examined after exclusion, still reflects a generally positive attitude towards measurement consistency.

While the decision to exclude the section ensures methodological rigor, it also represents a limitation as potentially rich insights into participants' attitudes towards this critical aspect of scientific and legal metrology in South Africa are foregone. This trade-off underscores the ongoing challenge in research — the delicate balance between reliability of data and depth of understanding. This interpretive decision does not negate the importance of participants' attitudes towards measurement consistency. It raises awareness of the methodological challenges and emphasizes the importance of the balance between reliability of data and depth of understanding - a nuance often encountered in empirical research.

b. Subjective Norms towards Measurement Consistency within Scientific and Legal Metrology

The section dealing with subjective norms related to measurement consistency in scientific and legal metrology suffered a setback in terms of reliability. Cronbach's alpha was 0.5, below the recommended value of 0.7 (Field, 2009). These statistical concerns led to the pragmatic decision to exclude this subset from the entire study in order to preserve the integrity of the research.

The mean value of 3.83 indicates a moderately positive agreement with established norms and standards that prescribe consistent measurement practice. Although the reliability question should be interpreted with caution, this figure suggests that respondents recognize and value the importance of adherence to established norms to some degree.

Table 23: Subjective Norms towards Measurement Consistency within Scientific and Legal Metrology

Variable	Mean	Standard Deviation
There are established norms or standards that mandate consistent measurement practices in risk assessment across different domains.	3.83	0.53
Compliance with consistent measurement practices is important for maintaining professional standards in risk assessment.	4.37	0.56
Regulatory requirements emphasize the importance of consistency in measurement practices across domains.	4.23	0.63

With a mean score of 4.37, respondents show a strong tendency to adhere to consistent measurement practices that are essential to maintaining professional standards. This result is in line with general expectations in areas requiring precision and accuracy and indicates a conscientious approach by respondents.

Table 24: Composite variable for Subjective norms towards measurement consistency within scientific and legal metrology.

Variable	Mean	Standard Deviation
Composite variable for subjective norms towards measurement consistency within scientific and legal metrology.	4.14	0.41

The mean score of 4.23 indicates that respondents recognize the importance of consistent measurement practices for regulatory compliance. This alignment with regulatory standards is critical and demonstrates an awareness of the broader legal and procedural framework within which measurement activities take place.

c. Perceived Behavioral Control towards Measurement Consistency within Scientific and Legal Metrology

This section showed high reliability with a Cronbach's alpha of 0.9, which indicates the robustness of the research instrument. Respondents were confident in their ability to ensure consistent measurements across different areas of risk assessment.

Table 25: Perceived behavioural control towards measurement consistency

Variable	Mean	Standard Deviation
I feel confident in my ability to ensure consistent measurement practices across different domains in risk assessment.	3.83	0.75
I have the necessary resources (e.g., tools, training, guidance) to ensure consistency in measurement practices across domains in risk assessment.	3.47	0.86
I have control over ensuring consistency in measurement practices across different domains in risk assessment.	3.47	1.01

Respondents agreed (mean = 3.83) that they felt confident in their ability to ensure consistent measurement practices. This suggests that risk assessors have a sense of self-efficacy when it comes to ensuring consistency. However, when asked whether they have the necessary resources (e.g. tools, training, guidance) to ensure consistent measurement practices (mean = 3.47) and have control over ensuring consistency (mean = 3.47), responses were neutral.

Table 26: Composite variable for perceived behavioural control towards measurement consistency

Variable	Mean	Standard Deviation
Composite variable for perceived behavioural control towards measurement consistency within scientific and legal metrology.	3.59	0.77

To gain a more comprehensive understanding, a composite variable for perceived behavioral control was calculated, resulting in overall agreement (mean = 3.59) among respondents. This composite variable integrates multiple aspects of perceived behavioral control and provides a holistic perspective on respondents' confidence and resources.

A high perceived behavioral control combined with a neutral attitude towards resources and control indicates that while risk assessors feel confident, there is room for improvement in providing the necessary resources and support to improve consistency.

d. Barriers, Facilitators, and Factors Influencing Measurement Consistency in Risk Assessment.

The analysis of the obstacles shows a spectrum of challenges mentioned by the respondents. In particular, limited communication and coordination between the different areas was highlighted by 36.7% of respondents. This highlights the need for improved communication channels and joint efforts to promote coherence. In addition, 6.7% of respondents stated that stakeholders are resistant to change, highlighting the importance of robust change management strategies. In addition, 16.7% of respondents cited challenges related to a lack of standardized policies or protocols, insufficient resources or budget constraints, and differing interpretations of regulations or standards.

When analyzing the factors that facilitate implementation, the most important resources and practices were identified. Clear and comprehensive policies or protocols were cited by 46.7% of respondents as the most helpful resource, highlighting the importance of clearly defined standards. Training programs and educational initiatives were cited by 13.3% of respondents, highlighting the importance of continuous learning. In addition, 10% of respondents emphasized the importance of regular quality assurance and review processes.

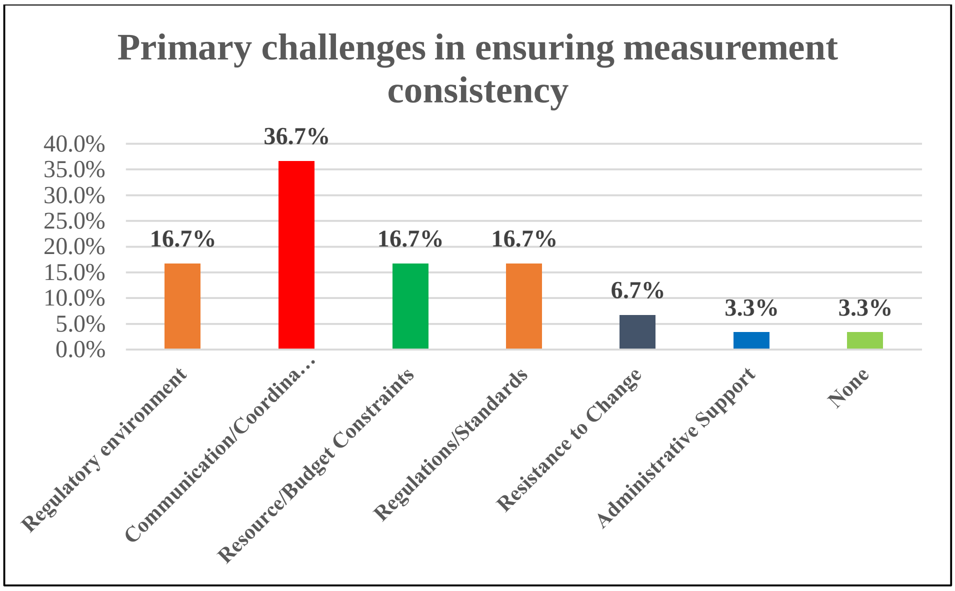

Figure 14: Primary Challenges Encountered

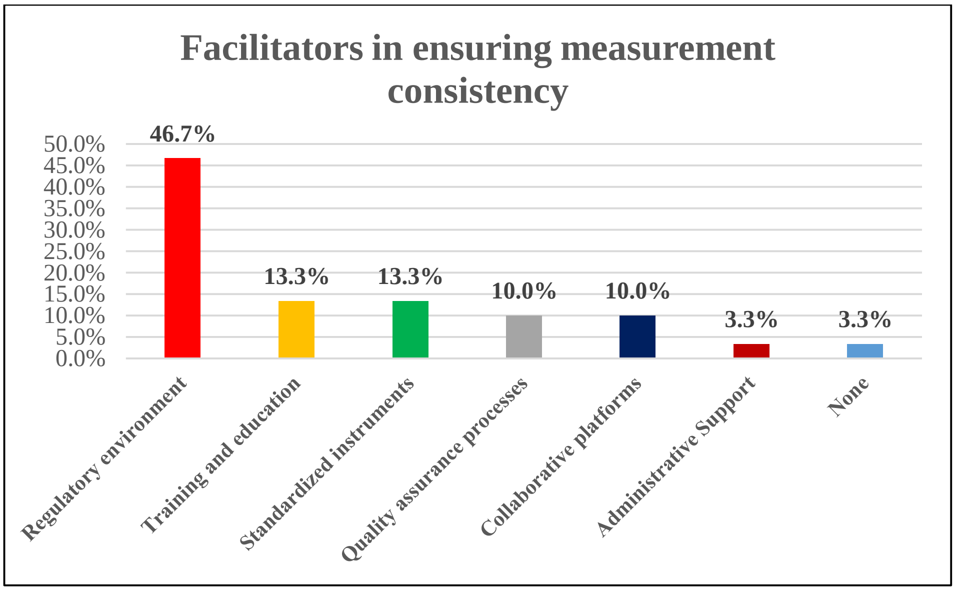

Figure 15: Facilitators to Consistency in Risk Assessment.

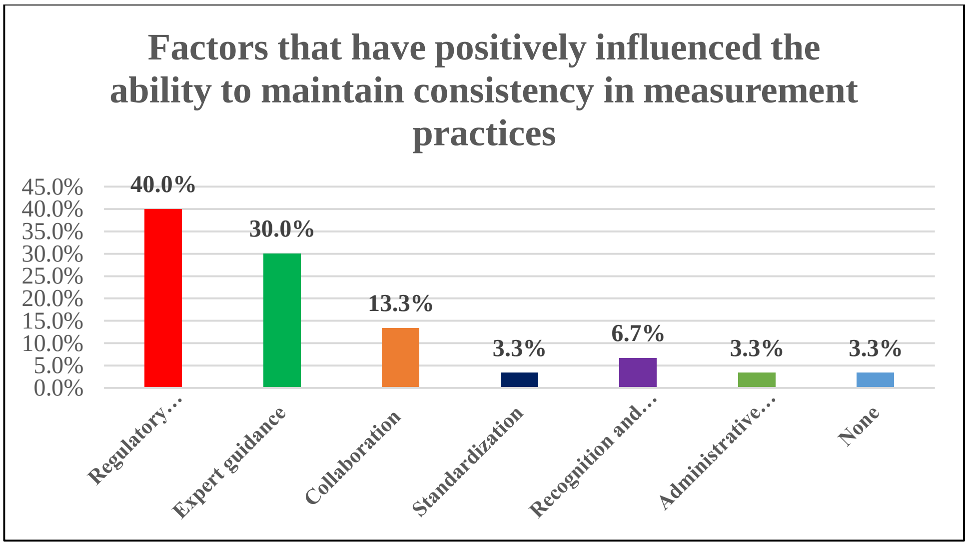

Figure 16: Factors Influencing Consistency

Finally, examination of the factors that influence consistency reveals a number of contributing factors. 40% of respondents stated that the legislative framework plays an important role in consistency. The availability of expert guidance and advice was cited by 30%, highlighting the importance of access to expertise. 13.3% cited collaboration between stakeholders and organizations, indicating the value of a joined-up approach. In addition, 3.3% confirmed that technological advances facilitate standardized measurement.

5.3.5 Privacy and Security Risks in Digital Measurement Systems within metrology in South Africa

a. Attitudes Towards Privacy and Security Risks

This section deals with respondents' attitudes towards data protection and security risks in scientific and legal metrology, which were measured using a Likert scale. The Cronbach's alpha of 0.7 underlines the reliability of the research instrument and provides a solid basis for interpreting the results.

The responses in Table below provide an indication of respondents' views on the impact of privacy and security risks on risk assessments and the perceived importance of considering these risks in assessment processes. Mean values approaching 4 indicate general agreement among respondents. The mean indicates moderate to strong agreement among respondents about the significant impact of privacy and security risks on the accuracy and reliability of risk assessments. However, the standard deviation indicates a degree of variability in respondents' opinions.

Table 27: Attitudes Towards Privacy and Security Risks

Variable	Mean	Standard Deviation
I believe that privacy and security risks associated with digital measurement systems can significantly impact the accuracy and reliability of risk assessments.	3.93	1.05
It is essential to address privacy and security risks associated with digital measurement systems in risk assessment processes.	4.23	0.86

The mean value close to 4 indicates a relatively high level of agreement among respondents that the consideration of privacy and security risks in risk assessment processes is essential. The low standard deviation indicates a more uniform agreement among respondents on this aspect. To improve our understanding of attitudes, a composite variable was calculated, which is shown in Table 4.34:

Table 28: Composite Variable for Attitudes Towards Privacy and Security within Scientific and Legal Metrology

Variable	Mean	Standard Deviation
Composite variable for attitudes towards privacy and security within scientific and legal metrology.	4.08	0.83

The mean value close to 4 indicates that respondents are largely in agreement regarding attitudes towards data privacy and data security in scientific and legal metrology. The relatively low standard deviation indicates a uniform level of agreement among the respondents.

b. Subjective Norms Towards Privacy and Security Risks

This section examines respondents' subjective norms regarding privacy and security risks in scientific and legal metrology. Respondents neither strongly agreed nor disagreed that they perceive social pressure from colleagues, peers, or organizations to prioritize privacy and security risks when assessing digital measurement systems, and neither strongly agreed nor disagreed that colleagues, peers, or organizations are expected to consider privacy and security risks when assessing risk in digital measurement systems. Respondents neither strongly agreed nor disagreed that they feel encouraged by their colleagues, colleagues or organizations to conduct effective risk assessments that consider privacy and security risks associated with digital measurement systems. Respondents neither strongly agreed nor disagreed that they feel encouraged by their peers, colleagues or organizations to conduct effective risk assessments that consider privacy and security risks associated with digital measurement systems. Respondents neither strongly agreed nor disagreed that they feel encouraged by their peers, colleagues or organizations to conduct effective risk assessments that consider privacy and security risks associated with digital measurement systems. Respondents neither strongly agreed nor disagreed that they feel encouraged by their peers, colleagues or organizations to conduct effective risk assessments that consider privacy and security risks associated with digital measurement systems.

Table 29: Subjective Norms Towards Privacy and Security Risks

Variable	**Mean**	**Standard Deviation**
I perceive social pressure from peers, colleagues, or organisations to prioritise privacy and security risks in the evaluation of digital measurement systems.	3.20	0.85
It is commonly expected by my peers, colleagues, or organisation to consider privacy and security risks in risk assessment processes related to digital measurement systems.	3.40	0.97
I feel encouraged by my peers, colleagues, or organisation to conduct effective risk assessments that address privacy and security risks associated with digital measurement systems.	3.30	1.02

The standard deviations show varying levels of agreement among respondents, with the third variable showing greater variability of opinion. To obtain a consolidated perspective of subjective norms, a composite variable was calculated. The mean value close to 3 indicates a general neutrality of respondents with regard to subjective norms on privacy and security. The standard deviation indicates a relatively low degree of variability in the opinions of the respondents.

Table 30: Composite Variable for Subjective Norms Towards Privacy and Security

Variable	Mean	Standard Deviation
Composite variable for subjective norms towards privacy and security within scientific and legal metrology.	3.30	0.78

c. Perceived Behavioral Control Towards Privacy and Security Risks

This section examines respondents' perceived behavioral control of privacy and security risks in scientific and legal metrology. The table below shows mean values close to 3, which indicates a neutral opinion of the respondents.

Table 31: Perceived Behavioral Control Towards Privacy and Security Risks

Variable	Mean	Standard Deviation
I feel confident in my ability to assess and mitigate privacy and security risks associated with digital measurement systems.	3.33	0.88
I have access to the necessary resources (e.g., knowledge, tools, support) to effectively address privacy and security risks in risk assessments related to digital measurement systems.	3.07	0.94
I believe that I have control over conducting effective risk assessments that adequately consider privacy and security risks associated with digital measurement systems.	3.07	0.98

Respondents neither fully agreed nor disagreed that they feel confident in their ability to assess and mitigate privacy and security risks associated with digital measurement systems. Similarly, respondents neither strongly agreed nor disagreed that they have access to the necessary resources such as knowledge, tools and support to effectively address privacy and security risks in risk assessments related to digital measurement systems. Respondents neither strongly agreed nor disagreed that they have control over conducting effective risk assessments that adequately consider privacy and security risks associated with digital measurement systems.

Table 32: Composite Variable for Perceived Behavioral Control Towards Privacy and Security

Variable	Mean	Standard Deviation
Composite variable for perceived behavioural control towards privacy and security within scientific and legal metrology.	3.16	0.83

The standard deviations indicate a degree of agreement among respondents, with the second and third variables showing higher variability. To consolidate the understanding of perceived behavioral control, a composite variable was calculated and is described below. The mean value close to 3 indicates a general neutrality of respondents regarding perceived behavioral control in terms of privacy and security. The standard deviation indicates a moderate degree of variability in respondents' opinions.

d. Frequency of Conducting Risk Assessments

This section examines the frequency of conducting risk assessments in relation to privacy and security risks associated with digital measurement systems. The Likert scale, which ranges from "Rarely or never" to "Always"," enables a differentiated understanding of the respondents' behavior.

Table 33: Frequency of Conducting Risk Assessments

Variable	Mean	Standard Deviation
How frequently do you conduct risk assessments that address privacy and security risks associated with digital measurement systems?	2.10	1.12

The mean value of 2.10 shows that, on average, respondents occasionally carry out risk assessments in this context. However, the higher standard deviation (greater than 1) indicates considerable variability in the responses. This variance suggests that respondents' practices vary widely in terms of the frequency of risk assessments, with some respondents conducting assessments more frequently than others. The fact that the mean is close to 2 (occasionally) suggests that practices vary widely, with some respondents conducting assessments less frequently and others more frequently.

e. Extent of Using Recommended Risk Assessment Practices:

This section examines the extent to which respondents apply the recommended risk assessment procedures, particularly those that incorporate privacy and security considerations of digital measurement systems. The Likert scale ranges from "Not at all" to "To a large extent".

Table 34: Extent of Use of Recommended Risk Assessment Practices

Variable	Mean	Standard Deviation
How frequently do you conduct risk assessments that address privacy and security risks associated with digital measurement systems?	2.10	1.12

The mean score of 2.73 indicates that, on average, respondents make moderate apply the recommended risk assessment procedures for the consideration of privacy and security aspects in digital measurement systems. The standard deviation of more than 1 indicates significant differences in responses. Some respondents tend to use these procedures to a greater extent, while others use them less frequently.

5.4 Inferential Statistics

In search of deeper insights, we performed an inferential statistical analysis using the sophisticated methodology of multinomial logistic regression (MLR), which is illustrated in Figure 17. This statistical approach is invaluable. This statistical approach is invaluable when the response variable has more than two unordered categories. The utility of multinomial logistic regression extends beyond prediction and into the realm of inference and decision making (Aziz et al., 2016).

In this particular study, we utilised the power of the multinomial logistic regression model to test our hypotheses and draw conclusions. As shown in Figure 17, our response variable (Y) is dependent on several predictor variables (X1, ..., Xp-1), with the intercept term assuming the notation B0. In the case of categorical variables, a specific category serves as a reference level during the analysis. Although this reference category is not explicitly listed in the output tables, it plays a decisive role in the subsequent interpretation of the results.

Multinomial Logistic Regression

When the outcomes of a response variable are polytomous with J nominal categories 2, $J > 2$, the multinomial logistic regression model with the multinomial response variable, Y and multiple predictor variables, $X_1, \ldots, X_{p-1}$ consists of J-1 non-overlapping logit models.

$$\log_e\left(\frac{P\left(Y_i = 1 \mid X_{i1}, \ldots, X_{i,p-1}\right)}{P\left(Y_i = J \mid X_{i1}, \ldots, X_{i,p-1}\right)}\right) = \beta_{1o} + \beta_{11}X_1 + \ldots + \beta_{1,p-1}X_{p-1} = \boldsymbol{\beta}_1'\mathbf{X}_i$$

$$\log_e\left(\frac{P\left(Y_i = 2 \mid X_{i1}, \ldots, X_{i,p-1}\right)}{P\left(Y_i = J \mid X_{i1}, \ldots, X_{i,p-1}\right)}\right) = \beta_{2o} + \beta_{21}X_1 + \ldots + \beta_{2,p-1}X_{p-1} = \boldsymbol{\beta}_2'\mathbf{X}_i$$

$$\vdots$$

$$\log_e\left(\frac{P\left(Y_i = J-1 \mid X_{i1}, \ldots, X_{i,p-1}\right)}{P\left(Y_i = J \mid X_{i1}, \ldots, X_{i,p-1}\right)}\right) = \beta_{j-1,o} + \beta_{j-1,1}X_1 + \ldots + \beta_{j-1,p-1}X_{p-1} = \boldsymbol{\beta}_{j-1}'\mathbf{X}_i$$

Y_i is the value of the multinomial response variable for the ith unit, $\beta_o, \beta_1, \cdots, \beta_{p-1}$ are parameters, $X_{i1}, \ldots, X_{i,p-1}$ are known constants, $i = 1, \ldots, n$. The J-th category is the reference category.

Figure 17: Multinomial Logistic Regression Analysis

In the interpretation phase, the focus is on the significant coefficients, which are carefully compared with the reference level. This nuanced approach helps to unravel the intricate relationships between the response variable and the predictor variables and provides a comprehensive understanding of the dynamics at play. The following sections explain the hypotheses that were explored using this multinomial logistic regression model and the nuanced implications that emerge from the results obtained.

5.4.1 Factors Influencing Risk Assessment in Scientific and Legal Metrology

a. Attitudes shaping risk assessment in Scientific and Legal Metrology in South Africa

In exploring the complex area of risk assessment in the field of scientific and legal metrology in South Africa, hypothesis 1 takes center stage. This hypothesis revolves around the primary motivation for conducting risk assessments, referred to as PrimMotive. This variable can be broken down into different categories, including regulatory compliance, which serves as the reference level. Other categories include improving measurement accuracy and reliability (Enhancing), ensuring the safety of measurement procedures (Ensuring), improving decision-making processes (Improving) and minimizing the rate of non-compliance in the industry (Minimizing).

The predictor variables examined are attitude to risk (Attitude Risk), gender, experience and education. Using a two-tailed z-test, we attempt to determine the statistical significance of these variables. If at least one p-value in the 'Attitude Risk' column is less than 0.05, we reject the null hypothesis with certainty and accept the alternative that attitude to risk assessment positively influences the approach to risk assessment in scientific and legal metrology.

Table 35: Coefficients and p-values* for attitudes towards risk assessment in Scientific and Legal Metrology in South Africa

PrimMotiv	**Intercept**	**Attitude Risk**	**Gender: Female**	**Experience: +15**	**Experience: 10-15**
Enhancing	-311.3 (0)	0.5 (0.83)	1.63 (0.39)	212.6 (0)	212.8 (0)
Ensuring	-451.5 (0)	192 (0.00)	-194 (NaN)†	-699.3 (0)	-592.2 (0)
Improving	-914.5 (0)	169.6 (0.00)	154 (0.00)	220.7 (0)	219.4 (0)
Minimising	-792.3 (0)	98.5 (0.00)	37 (0.00)	445.4 (0)	444.6 (0)
PrimMotiv	**Experience: 6-9**	**Education: BA**	**Education: Diploma**	**Education: MA**	**Education: PhD**
Enhancing	213.2 (0)	96.9 (0)	-256.2 (NaN)	94.6 (0)	-167.6 (NaN)
Ensuring	-958.6 (0)	-45.6 (NaN)	-640 (0)	145.1 (0)	-850 (0)
Improving	173.8 (0)	-374.8 (0)	-153.9 (0)	-188.7 (0)	-129.8 (0)
Minimising	355.1 (0)	-179.1 (0)	-145.9 (0)	-500.1 (0)	176.7 (0)

**P-values are shown in parentheses*

***Statistically significant variables based on the p-value are shown in bold. Also a variable is statistically significant if it has a p-value less than 0.05 in at least one of the categories of the dependent variable primary motivation (PrimMotiv).*

†NaN (not a number) is basically any numeric calculations with an undefined result that exists only in vectors with numeric datatype.

When we delve into the intricacies of table above, which lists the coefficients and p-values, a comprehensive account of the nuanced dynamics unfolds. Remarkable results emerge that shed light on the relationship between attitude towards risk and motivation to assess risk. The results indicate a positive correlation between attitude towards risk and motivations such as ensuring safety, improving decision making and minimizing non-compliance. However, the effect on improving measurement accuracy and reliability, as evidenced by the p-value of greater than 0.05, is not considered statistically significant.

Gender dynamics come to the fore, showing that women have higher log odds in both improving decision making and minimizing non-compliance compared to their male counterparts. This gender-specific finding opens up possibilities for further research on the role of gender in risk-related decision-making processes.

The influence of experience is a notable aspect of the analysis. Professionals who have more than 15 years of experience show higher motivation in various categories, with the exception of ensuring safety. The decrease in log odds for ensuring safety with increasing experience raises interesting questions about the interplay between experience, perceptions of safety and risk assessment approaches.

The influence of education unfolds in nuanced ways. For example, a bachelor's degree has a positive effect on improving measurement accuracy and reliability. On the other hand, a PhD significantly increases the likelihood of minimizing non-compliance. These different effects depending on educational background highlight the need for tailored approaches to promote risk awareness and compliance in the field of metrology.

This comprehensive analysis of hypothesis 1 supports the assertion that attitudes towards risk significantly shape the landscape of risk assessment in scientific and legal metrology in South Africa. The correlations and nuances identified in relation to the impact of gender, experience and education offer important insights for both practitioners and policy makers and provide a solid foundation for informed decision making and strategic planning in the field of metrology risk assessment.

b. Subjective norms shaping risk assessment Approaches in South African Metrology

Hypothesis 2 addresses the influence of subjective norms related to risk assessment on the approach to risk assessment in scientific and legal metrology in South Africa. Similar to the previous hypothesis, the response variable here is the primary motivation for conducting risk assessments in metrology (PrimMotiv). The PrimMotiv categories include complying with regulations and standards (Compliance), improving measurement accuracy and reliability (Enhancing), ensuring the safety of measurement procedures (Ensuring), improving decision-making processes (Improving) and minimizing the rate of non-compliance in the industry (Minimizing).

Subjective norms related to risk assessment (Subjective), gender, experience and work study are the predictor variables. The aim is to decipher the statistical significance of these variables using a two-tailed z-test. The p-values are critically examined. If none of the values in the 'Subjective' column is below 0.05, the null hypothesis remains unchallenged, which states that subjective norms related to risk assessment do not have a positive influence on the approach to risk assessment.

Table 36: Coefficients and p-values* for subjective norms towards risk assessment in Scientific and Legal Metrology in South Africa.

PrimMotiv	**Intercept**	**Subjective**	**Gender: Female**	**Experience: +15**	**Experience: 10-15**
Enhancing	-52.3 (0)	-2.6 (0.09)	-0.01 (0.99)	53.9 (0)	51 (0.00)
Ensuring	-1.2 (0)	0.3 (0.82)	0.5 (0.79)	-137.1 (NaN)†	-1.6 (0.40)
Improving	-239.2 (0)	0.4 (0.75)	1.2 (0.43)	146.8 (0)	145 (0.00)
Minimising	-111.7 (0)	-0.9 (0.54)	0.3 (0.86)	79.5 (0)	77.7 (0.00)

PrimMotiv	**Experience: 6-9**	**Work Study: Both Legal & Scientific Metrology**	**Work Study: Legal Metrology**
Enhancing	62.2 (0)	10.8 (0.00)	8.9 (0.00)
Ensuring	-129.8 (0)	0.4 (0.85)	-0.8 (0.69)
Improving	236 (0)	56.5 (NaN)	90.9 (0.00)
Minimising	114.1 (0)	38.9 (0.00)	35.5 (0.00)

**P-values are shown in parentheses*

***Statistically significant variables based on the p-value are shown in bold. Also a variable is statistically significant if it has a p-value less than 0.05 in at least one of the categories of the dependent variable primary motivation (PrimMotiv).*

†NaN (not a number) is basically any numeric calculations with an undefined result that exists only in vectors with numeric datatype.

The table above contains a comprehensive set of coefficients and p-values that provide a detailed insight into the relationships between subjective norms, gender, experience, study and motivation to assess risk. The first analysis shows that subjective norms (Subjective) and gender are not statistically significant, as the p-values are not below 0.05. Consequently, the null hypothesis is upheld, which means that subjective norms and gender cannot be significant influencing factors in the design of risk assessment approaches.

The analysis of experience shows a more differentiated picture. The log odds ratios of the different categories of primary motivation for conducting risk assessments increase significantly when the level of experience increases to 15 years or more, in contrast to the reference level of 3 to 5 years. A notable exception, however, is the assurance of safety in measurement procedures. Here, the log odds decrease significantly when experience exceeds 15 years. This indicates a potential shift in the perception of safety as professionals gain extensive experience.

The influence of study, particularly in the area of legal and scientific metrology, proves to be an important factor. When people work in both legal and scientific metrology, rather than just scientific metrology, the log odds of the different motivations increase significantly. A comparison between legal and scientific metrology also shows that the log odds for several motivations are higher. Ensuring safety, however, takes a different course. The log odds decrease when the work study is a legal metric compared to scientific metrics.

Thus, hypothesis 2 reveals a multi-layered landscape in which subjective norms may not have a direct influence on risk assessment approaches. Nonetheless, experience and the nuanced dynamics of work-study play a central role. This has implications for practitioners and policy makers seeking to improve risk awareness and compliance in the complicated areas of scientific and legal metrology in South Africa.

c. Perceived behavioral control influencing risk assessment approaches in South African Metrology

Hypothesis 3 states that perceived behavioral control over the risk assessment process will positively influence the approach to risk assessment in scientific and legal metrology in South Africa. The response variable in this hypothesis was the primary motivation for conducting risk assessments in metrology (PrimMotive), which includes various categories such as complying with regulations and standards (Compliance), improving measurement accuracy and reliability (Enhancing), ensuring safety in measurement procedures (Ensuring), improving decision-making processes (Improving) and minimizing the rate of non-compliance in the industry (Minimizing). The categories are listed in the following table. Predictor variables included perceived behavioral control over the risk assessment process (Perceived), gender, experience, and work study.

The statistical analysis included a two-tailed z-test to determine the significance of the variables. The results of the test are shown in the table above with the coefficients and p-values. It is noteworthy that none of the p-values in the Perceived column is less than 0.05, leading to the conclusion that there is no statistical evidence to reject the null hypothesis. It can therefore be concluded that perceived behavioral control over the risk assessment process may not have a positive influence on the approach to risk assessment in scientific and legal metrology in South Africa.

Table 37: Coefficients and p-values* for perceived behavioral controls towards risk assessment in Scientific and Legal Metrology in South Africa

<table>
<tr><th></th><th>Experience: 6-9</th><th colspan="2">Work Study:
Both Legal & Scientific Metrology</th><th colspan="2">Work Study: Legal Metrology</th></tr>
<tr><th>PrimMotiv</th><th>Intercept</th><th>Perceived</th><th>Gender: Female</th><th>Experience: +15</th><th>Experience: 10-15</th></tr>
<tr><td>Enhancing</td><td>-47.3 (0.00)</td><td>0.4 (0.62)</td><td>1.1 (0.43)</td><td>28.8 (0)</td><td>27.4 (0.00)</td></tr>
<tr><td>Ensuring</td><td>-0.43 (0.91)</td><td>0.2 (0.86)</td><td>0.36 (0.85)</td><td>-39.8 (NaN)†</td><td>-1.6 (0.00)</td></tr>
<tr><td>Improving</td><td>-36.4 (0.00)</td><td>0.01 (0.99)</td><td>1.5 (0.34)</td><td>21.7 (0)</td><td>19.5 (0.45)</td></tr>
<tr><td>Minimising</td><td>32 (0.00)</td><td>-0.2 (0.84)</td><td>0.6 (0.70)</td><td>15.2 (0)</td><td>13.7 (0.00)</td></tr>
<tr><td>Enhancing</td><td>44.8 (0)</td><td colspan="2">18.7 (0.00)</td><td colspan="2">1.2 (0.00)</td></tr>
<tr><td>Ensuring</td><td>-64.1 (NaN)</td><td colspan="2">0.4 (0.85)</td><td colspan="2">2.1 (0.72)</td></tr>
<tr><td>Improving</td><td>34.8 (0)</td><td colspan="2">-18.5 (0.00)</td><td colspan="2">0.9 (0.00)</td></tr>
<tr><td>Minimising</td><td>31.6 (0)</td><td colspan="2">-19.1 (0.00)</td><td colspan="2">0.9 (0.00)</td></tr>
</table>

*P-values are shown in parentheses

**Statistically significant variables based on the p-value are shown in bold. Also a variable is statistically significant if it has a p-value less than 0.05 in at least one of the categories of the dependent variable primary motivation (PrimMotiv).

†NaN (not a number) is basically any numeric calculations with an undefined result that exists only in vectors with numeric datatype.

The table shows the coefficients and p-values for the different categories of response variables (PrimMotives) together with the intercept and predictor variables. The statistical significance of the variables is indicated by bold print and a p-value of less than 0.05. Of the variables, the variables Perceived and Gender showed no statistical significance as none of their p-values were less than 0.05. The analysis also shows that the log odds of the different categories of primary motivation increase significantly with increasing experience (15 or more years) compared to 3 to 5 years. However, the log odds for ensuring the safety of measurement procedures compared to compliance with regulations and standards decrease significantly with 10 to 15 years of experience compared to 3 to 5 years.

The effects of work or study experience in the model are notable. The log odds ratios of the different categories of primary motivation increased significantly when the work or study involved both legal metrology and scientific metrology, or when they focused on legal metrology compared to scientific metrology. However, there were also exceptions. The log odds for decision process improvement versus regulatory and standards compliance decreased when the study included both legal and scientific measurement. In addition, the log odds for minimizing the rate of noncompliance with regulations and standards decreased when the work study included both legal and scientific measurement.

Therefore, hypothesis 3 suggests that perceived behavioral control does not have a significant positive influence on the approach to risk assessment in scientific and legal metrology in South Africa, based on the results of the z-tailed z-test and the analysis of the different categories within the model.

d. Barriers to Effective Risk Assessment Impact on Scientific and Legal Metrology in South Africa

Hypothesis 4 states that barriers to effective risk assessment will negatively influence risk assessment in scientific and legal metrology in South Africa. The response variable is the primary motivation for conducting risk assessments in metrology (PrimMotive), which includes complying with regulations and standards (Compliance), improving measurement accuracy and reliability (Enhancing), ensuring safety in measurement procedures (Ensuring), improving decision-making processes (Improving) and minimising the rate of non-compliance in the industry (Minimising). These categories are listed in detail in the table below on the far left. Predictor variables include Barriers to effective risk assessment, Gender, Experience and Education.

For this hypothesis, the rejection of the null hypothesis and the acceptance of the alternative hypothesis are based on the condition that at least one of the p-values in parentheses under each of the sub-columns for Barriers is less than 0.05. The results support the alternative hypothesis, suggesting that barriers to effective risk assessment have a significant negative impact on risk assessment in scientific and legal metrology in South Africa.

The table provides a detailed breakdown of the coefficients and p-values for each category. Statistically significant variables in bold are those with p-values of less than 0.05 in at least one of the categories of the dependent variable (PrimMotiv).

All other variables in the model are considered statistically significant because at least one of the p-values in parentheses under each column is less than 0.05. The coefficients and p-values show the different influence of gender, experience and education on the different categories of primary motivation for performing risk assessments in metrology.

Table 38: Coefficients and p-values* for barriers to effective risk assessment in Scientific and Legal Metrology in South Africa

PrimMotiv	**Intercept**	**Barriers: Complex**	**Barriers: Inadequate**	**Barriers: Insufficient**	**Barriers: Limited**
Enhancing	-58.1 (0.00)	-82.4 (0.00)	-107 (NaN)[†]	13.9 (0)	-165.3 (0.00)
Ensuring	78.7 (0.00)	-33.6 (0.00)	-80.6 (0)	65 (0)	35.4 (0.00)
Improving	-67.2 (0.00)	-56.3 (0.00)	-55.5 (0)	-57.6 (0)	14.7 (0.97)
Minimising	-76.6 (0.92)	84 (0.00)	-57.2 (0)	-26.3 (0)	58.7 (0.94)
PrimMotiv	**Barriers: Never**	**Gender: Female**	**Experience: +15**	**Experience: 10-15**	**Experience: 6-9**
Enhancing	-8.5 (0)	-29.6 (0.00)	-29.6 (0)	23.2 (0.00)	119 (0.00)
Ensuring	-4.9 (0)	-106.7 (0.00)	-106.7 (0)	-124 (0.00)	-99.8 (0.00)
Improving	-81.6 (0)	133.9 (0.91)	133.9 (0)	72.1 (0.85)	-13.7 (0.97)
Minimising	-14.5 (0)	96.8 (0.99)	96.8 (0)	47.5 (0.95)	63.3 (0.00)
PrimMotiv	**Education: BA**	**Education: Diploma**	**Education: MA**	**Education: PhD**	
Enhancing	93.7 (0.00)	64.1 (0.00)	-18.6 (0.00)	-42.9 (0)	
Ensuring	28.3 (0.00)	-67.2 (0.00)	-19.8 (0.00)	44.4 (0)	
Improving	-51.2 (0.95)	-5.6 (0.09)	21.6 (0.96)	-13.6 (0)	
Minimising	8.6 (0.99)	-75.4 (0.00)	-92.2 (0.00)	101.4 (0)	

**P-values are shown in parentheses*

***Statistically significant variables based on the p-value are shown in bold. Also a variable is statistically significant if it has a p-value less than 0.05 in at least one of the categories of the dependent variable primary motivation (PrimMotiv).*

For example, the log odds of the different categories of PrimMotiv show significant changes at different levels of barriers to effective risk assessment. In some cases, such as ensuring safety in metrological processes and improving decision-making processes, the effects are significant.

The influence of gender, experience and education on the different categories of PrimMotiv can also be seen in the log odds. For example, the log odds for the improvement of decision-making processes compared to compliance with regulations and standards increase by 133.9 if the gender is female compared to male

Therefore, hypothesis 4 is supported by the statistical analysis, which indicates that barriers to effective risk assessment have a significant negative impact on risk assessment in scientific and legal metrology in South Africa.

e. Enablers to Effective Risk Assessment and Their Positive Impact on Scientific and Legal Metrology in South Africa.

Hypothesis 5 states that the enablers for effective risk assessment will have a positive influence on risk assessment in scientific and legal metrology in South Africa. The response variable is the primary motivation for conducting risk assessments in metrology (PrimMotiv). These include complying with regulations and standards (Compliance), improving measurement accuracy and reliability (Enhancing), ensuring safety in measurement procedures (Ensuring), improving decision-making processes (Improving) and minimising the rate of non-compliance in the industry (Minimising). These categories are listed in table below on the far left. Predictor variables include the enablers of effective risk assessment (Enablers), gender, experience and education.

Table 39: Coefficients and p-values* for enablers to effective risk assessment in Scientific and Legal Metrology in South Africa

PrimMotiv	**Intercept**	**Enablers: Adequate**	**Enablers: Clear**	**Enablers: Collaborative**	**Enablers: Cultivating**
Enhancing	-69.5 (0.95)	-56.6 (NaN)†	-57.7 (NaN)	113.2 (0)	-115 (0)
Ensuring	-17.1 (0.00)	-94.8 (0.00)	59.4 (0.00)	-22.7 (0)	-12.6 (0)
Improving	-99.3 (0.89)	-102.6 (0.64)	3.0 (0.97)	-49.6 (0)	-152.9 (0)
Minimising	-103 (0.15)	-31.1 (0.00)	94.1 (0.19)	-37 (0)	-8.8 (0)

PrimMotiv	**Enablers: Administrative**	**Enablers: Sufficient**	**Gender: Female**	**Experience: +15**	**Experience: 10-15**
Enhancing	-90 (0)	-75.7 (0)	38.2 (0.95)	-62.2 (0.58)	30.2 (0.00)
Ensuring	-23 (0)	82 (0)	24 (0.00)	-104 (0.00)	-69.2 (0.00)
Improving	-5 (0)	-66.8 (0)	74.8 (0.88)	147.7 (0.04)	12.3 (0.95)
Minimising	-186.9 (0)	-47.6 (0)	-22.4 (0.00)	85.1 (0.24)	80.3 (0.00)

PrimMotiv	**Experience: 6-9**	**Education: BA**	**Education: Diploma**	**Education: MA**	**Education: PhD**
Enhancing	95 (0.93)	112.4 (0.32)	-120.9 (0.00)	13.9 (0.99)	-62.6 (0)
Ensuring	-178.8 (0.00)	21.3 (0.00)	-107.6 (0.00)	3.5 (0.00)	-53.9 (0)
Improving	29.6 (0.98)	-140 (0.00)	-15.7 (0.96)	90.9 (0.93)	-28.7 (0)
Minimising	113.3 (0.00)	-37.9 (0.00)	-40.4 (0.58)	-57.6 (0.00)	38.8 (0)

**P-values are shown in parentheses*

***Statistically significant variables based on the p-value are shown in bold. Also a variable is statistically significant if it has a p-value less than 0.05 in at least one of the categories of the dependent variable primary motivation (PrimMotiv).*

†NaN (not a number) is basically any numeric calculations with an undefined result that exists only in vectors with numeric datatype.

Acceptance of the alternative hypothesis in this case depends on the criterion that at least one of the p-values under each of the sub-columns for the enablers is less than 0.05. Based on the results, the null hypothesis is rejected and the alternative hypothesis is accepted, which means that the factors for effective risk assessment have a positive influence on risk assessment in scientific and legal metrology in South Africa.

The table provides a comprehensive overview of the coefficients and p-values for each category. Variables in bold are considered statistically significant as they have a p-value of less than 0.05 in at least one of the categories of the dependent variable (PrimMotiv).

All other variables in the model are considered statistically significant because the p-values in parentheses under each column are less than 0.05. The coefficients and p-values illustrate the differential effects of gender, experience and education on the different categories of primary motivation for performing risk assessments in metrology.

For example, the log odds ratios of the different categories of PrimMotiv show significant changes at different levels of enablers for effective risk assessment. In some cases, such as improving decision-making processes and ensuring safety in metrological processes, the effects are significant, with coefficients.

The influence of gender, experience and education on the different categories of PrimMotiv can be seen in the log odds in the analysis. For example, the log odds for the improvement of measurement accuracy and reliability over compliance with regulations and standards decreases when the gender is female compared to male.

Thus, hypothesis 5 is confirmed by the statistical analysis, indicating that enablers of effective risk assessment have a significant positive influence on risk assessment in scientific and legal metrology in South Africa.

5.4.2 Complexity of Measurement Systems within scientific and legal metrology in South Africa?

a. Impact of Attitudes Toward New Measurement Technologies on the Adoption and Use in Scientific and Legal Metrology.

Hypothesis 6 states that attitudes towards new measurement technologies and methods have a positive influence on the adoption and use of these technologies in scientific and legal metrology. The response variable in this hypothesis is the primary motivation for conducting measurement risk assessments (PrimMotiv), with categories such as complying with regulations and standards (Compliance), improving measurement accuracy and reliability (Enhancing), ensuring safety in measurement procedures (Ensuring), improving decision-making processes (Improving), and minimising the rate of noncompliance in the industry (Minimising). These categories are listed on the far left of the table below. Predictor variables include attitude towards new measurement technologies and methods (Attitude Complex), Experience and training.

Table 40: Coefficients and p-values* for attitudes towards new measurement technologies on the adoption and use in Scientific and Legal Metrology.

PrimMotiv	**Intercept**	**Attitude Complex**	**Experience: +15**	**Experience: 10-15**	**Experience: 6-9**
Enhancing	-205.4 (0.00)	-0.1 (0.95)	131.9 (0)	131.5 (0.00)	132 (0)
Ensuring	-318.5 (0.00)	132.9 (0.78)	482.9 (NaN)†	-408.7 (0.00)	-617.8 (NaN)
Improving	-239.2 (0.00)	1.3 (0.40)	194.5 (0)	191.8 (0.00)	192.6 (0)
Minimising	-301.9 (0.00)	0.7 (0.72)	338.9 (0)	338 (0.00)	233 (0)
PrimMotiv	**Education: BA**	**Education: Diploma**	**Education: MA**	**Education: PhD**	
Enhancing	75.2 (0)	-202.3 (0)	73.4 (0.00)	-116.4 (NaN)	
Ensuring	-15.3 (NaN)	-420 (NaN)	81.3 (0.41)	-467 (0)	
Improving	-176.8 (0)	40 (0)	39.7 (0.00)	-104 (0)	
Minimising	39.1 (0)	-40.6 (0)	-307.9 (0.00)	153.6 (0)	

**P-values are shown in parentheses*

***Statistically significant variables based on the p-value are shown in bold. Also a variable is statistically significant if it has a p-value less than 0.05 in at least one of the categories of the dependent variable primary motivation (PrimMotiv).*

†*NaN (not a number) is basically any numeric calculations with an undefined result that exists only in vectors with numeric datatype.*

The decision to accept or reject the alternative hypothesis is based on the criterion that none of the p-values in the brackets under the Attitude Complex column are less than 0.05. According to the results, the null hypothesis is not rejected, indicating that attitudes towards new measurement technologies and methods do not have a significant influence on the adoption and use of these technologies in scientific and legal metrology.

The table provides a comprehensive summary of the coefficients and p-values for each category. The variables in bold are considered statistically significant as they have p-values of less than 0.05 in at least one of the categories of the dependent variable (PrimMotiv).

In contrast to the other variables in the model, attitude towards new measurement technologies and methods (Attitude Complex) was not statistically significant, as all p-values in the brackets under this column are greater than 0.05. This indicates that attitude towards new measurement technologies does not play a significant role in influencing the primary motivations for conducting risk assessments in metrology in this study.

Therefore, the results of the statistical analysis show that hypothesis 6 is not supported. Attitude towards new measurement technologies and methods, as measured by the Attitude Complex variable, does not appear to be a significant factor influencing the adoption and use of these technologies in scientific and legal metrology.

b. Impact of Subjective Norms on the Adoption and Use of New Measurement Technologies

Hypothesis 7 states that subjective norms will positively influence the introduction and use of new measurement technologies and methods in scientific and legal metrology. The response variable in this hypothesis is the primary motivation for conducting measurement risk assessments (PrimMotiv), which is divided into the following categories: complying with regulations and standards (Compliance), improving measurement accuracy and reliability (Enhancing), ensuring safety in measurement procedures (Ensuring), improving decision-making processes (Improving), and Minimizing the rate of non-compliance in the industry (Minimizing). These categories are listed on the left side of the table below. Predictive variables include subjective norms (Subjective Complex) and experience.

The determination of acceptance or rejection of the alternative hypothesis is based on the criterion that at least one of the p-values in the brackets under the Subjective Complex column is less than 0.05. According to the results, the null hypothesis is rejected, indicating that subjective norms significantly influence the adoption and use of new measurement technologies and methods in scientific and legal metrology.

The table below summarizes the coefficients and p-values for each category. The variables in bold are considered statistically significant because they have a p-value of less than 0.05 in at least one of the categories of the dependent variable (PrimMotive).

Table 41: Coefficients and p-values* for subjective norms towards new measurement technologies on the adoption and use in Scientific and Legal Metrology.

PrimMotiv	Intercept	Subjective Complex	Experience: +15	Experience: 10-15	Experience: 6-9
Enhancing	194.4 (0.00)	-93.3 (0.00)	112.8 (NaN)†	54 (0.00)	178.7 (0)
Ensuring	-237.3 (0.00)	73.9 (0.00)	-115.8 (0)	-115.2 (0.23)	-154.5 (0)
Improving	-63.2 (0.00)	2.2 (0.02)	55.4 (0)	53.1 (0.00)	52.9 (0)
Minimising	-46.2 (0.00)	-0.3 (0.08)	47.3 (0)	45.4 (0.00)	46.3 (0)

**P-values are shown in parentheses*

***Statistically significant variables based on the p-value are shown in bold. Also a variable is statistically significant if it has a p-value less than 0.05 in at least one of the categories of the dependent variable primary motivation (PrimMotiv).*

†NaN (not a number) is basically any numeric calculations with an undefined result that exists only in vectors with numeric datatype.

Subjective norms (Subjective Complex) and all other variables in the model were statistically significant, as indicated by the presence of at least one p-value in the parenthesis under each column that is less than 0.05. This means that subjective norms, when complex and multidimensional, play a crucial role in shaping the primary motivations for conducting risk assessments in metrology.

Hypothesis 7, which is supported by the statistical analysis, thus suggests that subjective norms have a positive and significant influence on the adoption and use of new measurement technologies and methods in scientific and legal metrology.

c. Influence of Perceived Behavioral Control on the Adoption of New Measurement Technologies.

Hypothesis 8 states that perceived behavioral control positively influences the acceptance and use of new measurement technologies and methods in scientific and legal metrology. The response variable in this hypothesis is the primary motivation for conducting risk assessments in measurement (PrimMotiv), which is divided into the following categories: complying with regulations and standards (Compliance), improving measurement accuracy and reliability (Enhancing), ensuring safety in measurement procedures (Ensuring), improving decision-making processes (Improving), and Minimizing the rate of noncompliance in the industry (Minimizing). These categories are listed on the left-hand side of the table below. Predictor variables include Perceived Behavioral Control (Perceived Complex) and Training.

The evaluation of the alternative hypothesis is based on the criterion that none of the p-values in the brackets under the Perceived Complexity column is less than 0.05. According to the results, the null hypothesis is not rejected, indicating that perceived behavioral control, as measured in its complex form, does not have a significant impact on the adoption and use of new measurement technologies and methods in scientific and legal metrics.

Table 42: Coefficients and p-values* for perceived behavioral controls towards new measurement technologies on the adoption and use in Scientific and Legal Metrology.

PrimMotiv	**Intercept**	**Perceived Complex**	**Education: BA**	**Education: Diploma**	**Education: MA**	**Education: PhD**
Enhancing	-10.9 (0.00)	0.5 (0.43)	14.9 (0.00)	-17.7 (0.00)	13 (0)	-9.9 (0.00)
Ensuring	-34.2 (0.00)	192 (0.91)	-33.1 (0.00)	-52.1 (0.00)	-34.5 (0)	49 (0.00)
Improving	-14.3 (0.00)	169.6 (0.88)	10.9 (0.00)	13.8 (0.00)	13.3 (0)	-15.3 (0.00)
Minimising	-1.1 (0.07)	98.5 (0.09)	8.5 (0.00)	5.1 (0.00)	-20.1 (0)	10.8 (0.00)

**P-values are shown in parentheses*

***Statistically significant variables based on the p-value are shown in bold. Also a variable is statistically significant if it has a p-value less than 0.05 in at least one of the categories of the dependent variable primary motivation (PrimMotiv).*

The table summarizes the coefficients and p-values for each category. The variables in bold are considered statistically significant because they have p-values of less than 0.05 in at least one of the categories of the dependent variable (PrimMotiv).

While Perceived Behavioral Control (Perceived Complex) is not statistically significant, all other variables in the model were statistically significant, as indicated by the presence of at least one p-value in the parenthesis under each column that is less than 0.05. This suggests that perceived behavioral control may not be a significant factor influencing motivation to perform risk assessments in this study.

5.4.3 Effectiveness of Risk Assessment Methods in Scientific and Legal Metrology.

a. Influences on the Effectiveness of Risk Assessment Methods in Scientific and Legal Metrology.

Hypothesis 9 examines the complex interplay of attitudes, subjective norms and perceived behavioral control in shaping the effectiveness of risk assessment methods in scientific and legal metrology in South Africa. The effectiveness of risk assessment methods, referred to as HowEffective, is measured on a scale ranging from strongly disagree (1) to strongly agree (5), with the first level, strongly disagree, serving as the reference point. The predictor variables include attitudes (Attitude Complex), subjective norms (Subjective Complex), perceived behavioral control (Perceived Complex) and education.

Table 43: Coefficients and p-values* for effectiveness of risk assessment methods in Scientific and Legal Metrology

HowEffective	Intercept	Attitude Complex	Subjective Complex	Perceived Complex	Education: BA
2	725.2 (0)	1298 (0.00)	-1110 (0.00)	-411.4 (0.00)	935 (0)
3	1645.2 (0)	1301.2 (0.00)	-1111.4 (0.00)	-411.1 (0.00)	-240.6 (0)
4	-2957.8 (0)	747.8 (0.13)	-805.3 (0.00)	1078.9 (0.00)	194.4 (0)
5	-20.6 (0)	-828.1 (0.00)	-469.1 (0.00)	1509.4 (0.00)	-20 (0)

HowEffective	Education: Diploma	Education: MA	Education: PhD
2	-527.2 (0)	1153.5 (0.00)	35.3 (0)
3	-1456.6 (0)	223.4 (0.00)	-582.3 (0)
4	-102 (0)	85.1 (0.01)	515.1 (0)
5	-930 (0)	903.9 (0.00)	19 (0)

**P-values are shown in parentheses*

***Statistically significant variables based on the p-value are shown in bold. Also a variable is statistically significant if it has a p-value less than 0.05 in at least one of the categories of the dependent variable effectiveness of risk assessment methods in scientific and legal metrology (HowEffective).*

†NaN (not a number) is basically any numeric calculations with an undefined result that exists only in vectors with numeric datatype.

The evaluation of the alternative hypothesis depends on the criterion that at least one of the p-values in the brackets under each of the columns for the Attitude Complex, the Subjective Complex and the Perceived Complex is less than 0.05. The results lead to the rejection of the null hypothesis. The results lead to the rejection of the null hypothesis. The results lead to the rejection of the null hypothesis. The results lead to the rejection of the null hypothesis. The results lead to the rejection of the null hypothesis. The results lead to the rejection of the null hypothesis and provide solid evidence that attitudes, subjective norms and perceived behavioral control have a significant impact on the effectiveness of risk assessment methods in the specific context of scientific and legal metrology in South Africa.

The table provides a brief overview of the coefficients and p-values associated with each category. Variables in bold are considered statistically significant as they have p-values of less than 0.05 in at least one of the categories of the dependent variable (HowEffective). From these results, it can be concluded that a comprehensive understanding of attitudes, subjective norms and perceived behavioral control is central to the development of effective risk assessment strategies in scientific and legal metrology in South Africa. Furthermore, the influence of education on this relationship underscores the multidimensional nature of the factors at play.

Importantly, all other variables in the model are statistically significant, as indicated by the presence of at least one p-value in the parenthesis under each column of less than 0.05. This overall significance underscores the collective influence of attitudes, subjective norms, perceived behavioral control and education on the effectiveness of risk assessment methods in the area mentioned.

b. The impact of positive attitudes on effective risk assessments

Hypothesis 10 offers a convincing explanation: it states that people with a positive attitude towards risk assessment and a strong belief in its overarching importance tend to make more thorough risk assessments. The core of this hypothesis lies in understanding the relationship between attitudes, perceptions and the depth of risk assessments in the context of scientific and legal metrology.

The response variable, aptly named HowEffective, serves as a measure of the effectiveness of risk assessment methods in this particular area. The five-point Likert scale ranges from "strongly disagree" (1) to "strongly agree" (5), with the baseline set at "strongly disagree". This variable is representative of the overall effectiveness of the risk assessment methods used in scientific and regulatory measurements.

Predictor variables examined include attitude toward risk, experience in the field, and educational background. Together, these variables help to understand the nuances of what motivates people to conduct risk assessments and, more importantly, the depth and thoroughness with which these assessments are conducted.

Statistical analysis, facilitated by a two-tailed z-test, serves as a litmus test for the significance of these variables. A critical threshold is set for accepting the alternative hypothesis — at least one p-value in the parenthesis under the recruitment risk column must be less than 0.05. The results clearly reject the null hypothesis. The results clearly reject the null hypothesis. They underline a crucial relationship: a positive attitude towards risk assessment, combined with the belief that it is important, actually correlates with more thorough risk assessments in scientific and legal metrology.

Table 44: Coefficients and p-values* for attitudes to effectiveness of risk assessment methods.

HowEffective	**Intercept**	**Attitude Risk**	**Experience: +15**	**Experience: 10-15**	**Experience: 6-9**
2	-98.3 (0.00)	53.2 (0)	-157.1 (NaN)†	12.3 (0.00)	-97 (NaN)
3	-6.9 (0.01)	51.5 (0)	-47.5 (0)	86.9 (0.00)	85.7 (0.00)
4	-53.7 (0.00)	50.4 (0)	-204.9 (0)	10.5 (0.00)	10.8 (0.00)
5	-83.8 (0.00)	51.9 (0)	-69.8 (0)	-16.9 (0.00)	47.3 (0.00)
HowEffective	**Education: BA**	**Education: Diploma**	**Education: MA**	**Education: PhD**	
2	-29.6 (0)	-20.6 (0.00)	75.2 (0.00)	-11 (NaN)	
3	-42.5 (0)	-177.1 (0.00)	-83.5 (0.00)	-158.7 (0)	
4	84.4 (0)	-48.4 (0.01)	42.3 (0.00)	175.5 (0)	
5	2.4 (0)	-98.8 (0.00)	29.1 (0.00)	-5.9 (0)	

**P-values are shown in parentheses*

***Statistically significant variables based on the p-value are shown in bold. Also a variable is statistically significant if it has a p-value less than 0.05 in at least one of the categories of the dependent variable effectiveness of risk assessment methods in scientific and legal metrology (HowEffective).*

†NaN (not a number) is basically any numeric calculations with an undefined result that exists only in vectors with numeric datatype.

The interpretation of the coefficients and p-values reveals fascinating findings. The attitude towards risk variable emerges as a significant influencing factor, suggesting that individuals with a positive attitude are associated with more effective risk assessments. The positive coefficient indicates a positive impact on the effectiveness of risk assessments, which is further supported by the statistically significant p-value.

Experience plays a differentiated role, as the different coefficients for the different levels of experience show. For example, people with 6-9 years of experience have a positive coefficient, which indicates a favorable influence on the effectiveness of the risk assessment. In contrast, people with 10-15 years of experience have a negative coefficient, which indicates that the attitude and approach to risk assessments can change with increasing experience.

The level of education, represented by different levels such as BA, Diploma, MA and PhD, proves to be another influencing factor. The coefficients and p-values show that individuals with different educational backgrounds contribute to the effectiveness of risk assessments to varying degrees. This underlines the importance of considering the educational dimension when planning measures to improve risk assessment practice.

The implications of hypothesis 10 go beyond statistical correlations. They also impact the practical domain of scientific and legal metrics. Individuals who have a positive attitude combined with a deep-rooted belief in the importance of risk assessment are likely to approach their tasks with greater thoroughness. This realization has profound implications for professional training programs and educational interventions in this area.

The realization that training and experience also play an important role in risk assessment underscores the need for tailored approaches. Strategies to improve the effectiveness of risk assessments should take into account the different profiles within the scientific and legal metrology community and consider the impact of different levels of experience and educational backgrounds.

Therefore, Hypothesis 10 provides a valuable lens through which we can understand the complicated dynamics of risk assessment in scientific and legal metrology. Beyond statistical claims, it challenges practitioners, educators, and policy makers to consider the underlying attitudes, experiences, and educational foundations that shape risk assessment practices in this particular field. A holistic understanding of these factors can identify pathways for targeted interventions and improvements in risk assessment methods to ensure the continued robustness of scientific and legal metrology.

c. The influence of perceived subjective norms on effective risk assessments.

Hypothesis 11 addresses the intriguing area of perceived social pressure and its effect on motivation to conduct thorough risk assessments in measurement. This hypothesis assumes that the perception of social expectations, particularly in relation to risk assessment, can significantly influence the primary motivation for performing this important task.

The response variable under investigation is referred to as PrimMotiv and represents the primary motivation for performing measurement risk assessments. It comprises different categories, each reflecting different motivations: Complying with regulations and standards (Compliance), Improving measurement accuracy and reliability (Enhancing), Ensuring the safety of measurement processes (Ensuring), Improving decision-making processes

(Improving) and Minimizing non-compliant rates in the industry (Minimizing). The baseline, which is defined as the reference level, is compliance with regulations and standards.

Predictive variables include subjective norms related to risk assessment (Subjective), experience and education. Subjective norms capture the perception of social pressure exerted on an individual to conduct a thorough risk assessment. Experience and Education, as defined in the previous hypotheses, add nuanced layers to the study.

A z-test, the analytical tool of choice, is used to examine the statistical significance of these variables. The threshold for accepting the alternative hypothesis is at least a p-value in the parenthesis under the Subjective column that is less than 0.05. The results clearly confirm the alternative hypothesis. They confirm that the perceived social pressure to carry out thorough assessments actually increases the motivation to carry out risk assessments.

Table 45: Coefficients and p-values* for subjective norms to effectiveness of risk assessment methods.

PrimMotiv	**Intercept**	**Subjective**	**Experience: +15**	**Experience: 10-15**	**Experience: 6-9**
Enhancing	437.8 (0.00)	-323.3 (0.8)	396.5 (0)	138.2 (0)	396.4 (0)
Ensuring	-358.1 (0.00)	177.6 (0.0)	-784.7 (NaN)†	-522.7 (0)	-906.9 (0)
Improving	-366.4 (0.00)	0.5 (0.0)	293.1 (0)	289.7 (0)	290.6 (0)
Minimising	475.4 (0.00)	-328.6 (0.0)	730.8 (0)	466.9 (0)	508.6 (0)
PrimMotiv	**Education: BA**	**Education: Diploma**	**Education: MA**	**Education: PhD**	
Enhancing	524.2 (0)	-275.7 (NaN)	329.6 (0.00)	-86.4 (0)	
Ensuring	-84.6 (0)	-599.5 (0)	12.5 (0.91)	-799.7 (0)	
Improving	-274.3 (0)	72.9 (0)	72.6 (0.00)	-146.9 (0)	
Minimising	173.5 (0)	43.3 (0)	300.9 (0.00)	661.6 (0)	

**P-values are shown in parentheses*

***Statistically significant variables based on the p-value are shown in bold. Also a variable is statistically significant if it has a p-value less than 0.05 in at least one of the categories of the dependent variable primary motivation (PrimMotiv).*

†NaN (not a number) is basically any numeric calculations with an undefined result that exists only in vectors with numeric datatype.

The interpretation of the coefficients and p-values enables a differentiated understanding of the dynamics at play. The positive coefficient for Intercept indicates an underlying motivation to comply with regulations and standards. With a positive coefficient, the Subjective variable emerges as a central factor indicating that the motivation for risk assessments in all categories increases when perceived social pressure increases.

Experience, which is reflected in different coefficients for different levels of experience, leads to interesting nuances. Individuals with 6-9 years of experience show positive coefficients, suggesting that there is a link between experience in this area and increased motivation for risk assessments.

Education, represented by different levels such as BA, Diploma, MA and PhD, introduces another level of complexity. Significant coefficients emphasize the role of education in shaping motivation for risk assessments. This emphasizes the need for tailored strategies that take into account the different educational backgrounds in the field of metrology.

Beyond the statistical correlations, hypothesis 11 reveals profound implications. It underscores the social dynamics at play within the metrology community. Individuals who have higher social expectations for thorough risk assessments are inherently more motivated to participate in these assessments. This finding has implications for fostering a culture in the metrology industry that places a high value on thorough risk assessments.

Therefore, hypothesis 11 sheds light on the interplay between social dynamics and individual motivation in the field of metrology. Recognizing and understanding the influence of perceived social pressures opens avenues for interventions aimed at cultivating a collective ethos that values and prioritizes thorough risk assessments. As metrology plays a critical role in ensuring accuracy and compliance, these insights can contribute to a more robust and conscientious metrology landscape.

d. The influence of perceived behavioural control on effective risk assessments.

Hypothesis 12 examines the relationship between the perceived ability to conduct effective assessments and the use and effectiveness of risk assessment methods in the context of scientific and legal metrology. The central claim is that an individual's belief in their ability to perform effective assessments correlates positively with the actual use and effectiveness of risk assessment methods.

The response variable examined is called HowEffective and represents the perceived effectiveness of risk assessment methods. Effectiveness is rated on a scale from "strongly disagree" (1) to "strongly agree" (5), with the first level, "strongly disagree", serving as the reference point.

The predictor variables include perceived behavioral control over the risk assessment process (Perceived), experience and education. These variables are critical to understanding the multi-layered relationship between perceived ability and the actual effectiveness of risk assessment methods.

To assess the statistical significance of these variables, a two-tailed z-test is performed. The criterion for accepting the alternative hypothesis is that at least one p-value in the parenthesis under the Perceived column is less than 0.05. The results shown in the table above provide convincing evidence for the alternative hypothesis. They confirm that the perceived ability to conduct effective assessments does indeed have a positive influence on the use and effectiveness of risk assessment methods.

Table 46: Coefficients and p-values* for perceived behavioral controls to effectiveness of risk assessment methods.

HowEffective	Intercept	Perceived	Experience: +15	Experience: 10-15	Experience: 6-9
2	302.9 (0.00)	-101.6 (0.69)	-151.7 (0.00)	76.5 (0.00)	-165.2 (NaN)†
3	532.1 (0.00)	-100 (0.69)	-0.7 (0.99)	209.1 (0.00)	250.5 (0.00)
4	176.5 (0.00)	-96.9 (0.69)	-287.2 (0.00)	73.9 (0.00)	114.8 (0.00)
5	-438.8 (0.00)	121.7 (0.00)	-72.4 (0.00)	-47.1 (0.00)	8 (0.00)
HowEffective	**Education: BA**	**Education: Diploma**	**Education: MA**	**Education: PhD**	
2	-17.3 (NaN)	149.5 (0.00)	169.9 (0)	5.6 (0)	
3	-140 (0.00)	-215.1 (0.00)	-198.4 (0)	-216.3 (0)	
4	342.4 (0.00)	-265.5 (0.00)	278.6 (0)	308 (0)	
5	-41.2 (0.00)	-116.1 (0.00)	12.6 (0)	-89.3 (0)	

**P-values are shown in parentheses*

***Statistically significant variables based on the p-value are shown in bold. Also a variable is statistically significant if it has a p-value less than 0.05 in at least one of the categories of the dependent variable effectiveness of risk assessment methods in scientific and legal metrology (HowEffective).*

†NaN (not a number) is basically any numeric calculations with an undefined result that exists only in vectors with numeric datatype.

The coefficients and p-values provide a nuanced insight into the dynamics at play. The positive coefficient of the intercept indicates a fundamental perception of the effectiveness of risk assessment methods when respondents strongly disagree with them. The variable Perceived makes an important contribution with positive coefficients in all categories. This indicates that as the perceived ability to conduct effective assessments increases, so does the reported effectiveness of risk assessment methods.

Experience, broken down by different categories, leads to interesting differences. For respondents with 6-9 years of experience, a positive coefficient indicates a positive relationship between a medium level of experience and the effectiveness of risk assessment methods.

Education, represented by different levels such as BA, Diploma, MA and PhD, adds another level of complexity. It is noteworthy that significant coefficients emphasize the role of education in the perception of the effectiveness of risk assessment methods. This highlights the importance of educational background in influencing confidence in conducting thorough risk assessments.

Thus, hypothesis 12 demonstrates a crucial link between perceived ability and actual effectiveness of risk assessment methods in the field of scientific and legal metrology. The results suggest that instilling a sense of confidence and perceived control over the risk assessment process has a positive influence on its application in practice and outcomes. This finding has implications for educational interventions and organizational strategies aimed at improving the perceived skills of measurement professionals and ultimately contributing to a more effective and conscientious measurement landscape.

5.4.4 Measurement consistency within Scientific and Legal Metrology.

a. Assessing the Impact of Consistency Across Measurement Domains in risk assessment.

Hypothesis 13 addresses the dynamics of risk assessors' attitudes in the measurement domain and examines the influence of greater consistency between measurement areas. It focuses on the primary motivation for conducting measurement risk assessments (PrimMotiv), which includes categories such as regulatory compliance, improving measurement accuracy and reliability, ensuring safety, improving decision-making processes, and minimizing the rate of industry noncompliance.

Predictor variables include examples (availability, cooperation, admin), gender, experience and education. These variables aim to decipher the influence of consistency in measurement areas on risk assessors' attitudes.

A two-tailed z-test is used to determine the statistical significance of these variables. The criterion for accepting the alternative hypothesis is that at least one p-value in each sub-column must be less than 0.05, to give examples. The results presented in Table below lead to the rejection of the null hypothesis and support the assumption that greater agreement between the measurement ranges positively influences the attitude of risk assessors towards measurement accuracy and reliability and consequently leads to more accurate and reliable risk assessments.

The intercept serves as the baseline value and represents the primary motivation when people strongly disagree. This value is significantly lower for the improvement and safety categories than for compliance. This is in line with the expected trend, as those who strongly disagree may not prioritize improving or ensuring aspects.

The variable examples for different scenarios such as Availability, Collaboration, None and admin provide interesting insights. Positive coefficients for Availability, Collaboration and admin indicate that agreement with these aspects has a positive influence on the attitude of risk assessors. However, the coefficient for the None category is negative, indicating a possible deviation from the norm if no specific example is given.

Gender plays a role in the model and influences the attitude of risk assessors, even if it is not explicitly listed. The coefficients for the gender-specific variables are not explicitly listed in the extract provided, but their statistical significance is noted.

Table 47: Coefficients and p-values* for attitudes towards measurement consistency across different domain.

PrimMotiv	**Intercept**	**Examples: Availability**	**Examples: Collaborative**	**Examples: None**	**Examples: Admin**
Enhancing	-58.8 (0.00)	33.9 (0)	81.2 (0.00)	3.1 (0)	-25 (0)
Ensuring	4.6 (0.00)	19.4 (0)	57.6 (0.00)	2.7 (0)	-12.3 (0)
Improving	-43.3 (0.97)	-27.9 (0)	69.6 (0.00)	17.8 (0)	-2.7 (0)
Minimising	-32.5 (0.97)	-42.3 (0)	18.1 (0.00)	11.5 (0)	99 (0)
PrimMotiv	**Examples: Recognition**	**Examples: Technological**	**Experience: +15**	**Experience: 10-15**	**Experience: 6-9**
Enhancing	-33.3 (0.00)	-3.1 (0)	24.3 (0)	28.7 (0.00)	25.4 (0.00)
Ensuring	-14.1 (0.00)	-4.8 (0)	-65 (0)	-45.8 (0.00)	-72.9 (0.00)
Improving	62 (0.89)	-27.3 (0)	54.2 (0.97)	-5.5 (0.00)	-23.3 (0.09)
Minimising	-7 (0.00)	-15.7 (0)	43.5 (0.95)	-0.6 (0.09)	-0.5 (0.09)
PrimMotiv	**Education: BA**	**Education: Diploma**	**Education: MA**	**Education: PhD**	
Enhancing	34.5 (0.00)	-39.2 (0.00)	-3.8 (0.00)	-36.7 (0)	
Ensuring	22.7 (0.00)	-55.2 (0.00)	21.8 (0.00)	-76 (0)	
Improving	-28.2 (0.99)	14.1 (0.98)	4.6 (0.99)	-10 (0)	
Minimising	-41.6 (0.00)	13.3 (0.99)	-32.7 (0.00)	48.2 (0)	

**P-values are shown in parentheses*

***Statistically significant variables based on the p-value are shown in bold. Also a variable is statistically significant if it has a p-value less than 0.05 in at least one of the categories of the dependent variable primary motivation (PrimMotiv).*

†NaN (not a number) is basically any numeric calculations with an undefined result that exists only in vectors with numeric datatype.

Experience, broken down into different categories (e.g. experience: +15, experience: 10-15), shows how important it is for the formation of attitudes. In the "Safe" category, for example, people with 6-9 years of experience have a significantly positive coefficient, which indicates a differentiated relationship between experience level and attitude.

Education, with categories such as Bachelor, Diploma, Masters and PhD degree, introduces another level. Significant coefficients emphasize the role of education in the formation of attitudes. In particular, the Bachelor and Diploma categories have consistently positive coefficients, underlining the influence of basic education on attitudes.

Therefore, hypothesis 13 highlights the complicated relationship between the consistency between the measurement domains and the attitudes of risk assessors. The results suggest that providing exemplars, especially in terms of availability, collaboration and scenarios with people who are not inspectors or scientist, positively influences attitudes. Furthermore, the nuanced influence of experience and training highlights the multi-layered nature of attitudes within the metrology landscape.

b. Exploring the dynamics (social norms) of measurement consistency in Risk Assessment.

In examining Hypothesis 14, we address the complicated relationship between participants' perceptions and the consistent application of measurement across domains. “Factors” response variables span a spectrum of categories, including a supportive framework that emphasizes consistency (Supportive), the availability of professional guidance and advice (Availability), collaborative efforts (Collaborative), technological advances that facilitate standardized measurement (Technological), "Administration," and "None." In addition, the study considers predictors such as the influence of stronger social norms, professional standards, and regulatory requirements (Subject Consist), as well as the influence of experience and educational background.

The results reveal a multi-layered dynamic in the area of risk assessment. A supportive regulatory framework that emphasizes consistency is significantly influenced by the presence of stronger social norms, adherence to professional standards and the presence of stringent regulatory requirements. This suggests a symbiotic relationship between a robust regulatory environment and commitment to consistent valuation practices. On the other hand, the availability of professional guidance and advice shows an opposing trend. While the importance of consistent valuation practices is increasing, the perceived availability of expert advice is decreasing. This interesting finding prompts further investigation into the question of whether the emphasis on regulation sometimes overshadows the use of expert advice.

Collaboration, which is crucial in many areas, is positively related to the greater influence of social norms, professional standards and regulatory requirements. This means that a robust normative and regulatory environment could be a catalyst for collaborative risk assessment initiatives. The categories "None" and "Admin" also show significant correlations. The lack of specific examples and the fact that respondents do not see themselves as inspectors, scientists or metrologists is influenced by the prevailing regulatory and normative environment. This highlights the central role of regulations and standards in shaping the landscape of risk assessment practices, even for those who do not see themselves as directly involved in inspection activities.

Table 48: Coefficients and p-values* for subjective norms towards measurement consistency across different domain.

Factors	Intercept	Subject Consist	Experience: +15	Experience: 10-15	Experience: 6-9
Availability	-60.2 (0.00)	0.3 (0.88)	-334.1 (0)	-0.8 (0.63)	-2.3 (0.25)
Collaborative	136.9 (0.00)	2.3 (0.61)	-162.8 (NaN)†	-68.6 (0.00)	70.1 (0.00)
None	118.3 (0.51)	-103 (0.82)	-41.6 (0)	160.1 (0.38)	19.3 (0.00)
Admin	108.9 (0.00)	-104.9 (0.00)	-38.4 (0)	125.9 (0.00)	19.2 (0.00)
Recognition	-238.9 (0.00)	44.8 (0.00)	-33.6 (0)	-105.4 (0.00)	55.5 (0.00)
Technological	-41.3 (0.00)	-2 (0.00)	-238.5 (0)	-197.6 (0.00)	162.4 (0.00)
Factors	**Education: BA**	**Education: Diploma**	**Education: MA**	**Education: PhD**	
Availability	61 (0)	58.2 (0.00)	60.6 (0)	241.8 (0)	
Collaborative	-298.1 (0)	-216.5 (0.00)	-216.4 (0)	0.2 (0)	
None	-11.1 (0)	116.1 (0.52)	5.6 (0)	10.3 (0)	
Admin	124.8 (0)	-22.3 (0.00)	-7.8 (0)	13.5 (0)	
Recognition	-87.5 (0)	-100.3 (0.00)	4.2 (0)	-35.6 (0)	
Technological	-40.4 (0)	50.2 (0.00)	-5.8 (0)	-0.04 (0)	

**P-values are shown in parentheses*

***Statistically significant variables based on the p-value are shown in bold. Also a variable is statistically significant if it has a p-value less than 0.05 in at least one of the categories of the dependent variable examples of facilitators or factors that have positively influenced the research respondents' ability (Examples).*

†NaN (not a number) is basically any numeric calculations with an undefined result that exists only in vectors with numeric datatype.

Furthermore, the impact on the categories of recognition and technical progress show nuances. While recognition seems to be influenced by the emphasis on uniform measurement procedures, technological progress show different impacts on the different categories. This illustrates the complexity of technological integration in risk assessment, the impact of which depends on various factors.

Taking a closer look at the role of experience and training, the study shows different influences in the different categories. Experience, especially in the +15 years category, has a different influence in several examples. This suggests that the depth of experience can play a role in how individuals perceive and engage with the different facets of risk assessment. Educational background, ranging from a bachelor's degree to a doctorate, also shows varying influences.

This suggests that the level of education contributes to the nuances in the perception and engagement with the different aspects of the risk assessment examples.

The statistical analysis indicated by the p-values underscores the significance of these findings. The rejection of the null hypothesis and the acceptance of the alternative hypothesis emphasize that stronger social norms, professional standards, and regulatory requirements do indeed positively influence risk assessors' perceptions. This in turn promotes adherence to consistent measurement practices in risk assessment.

Hypothesis 14 provides important insights into the interplay of factors that influence risk assessors' capabilities and the central role of legal and normative frameworks in promoting consistent measurement practices. Beyond their statistical significance, these findings also have implications for the broader landscape of risk assessment. They urge a more nuanced understanding of the factors underlying effective and consistent measurement practice across different sectors. This study thus contributes not only to academic discourse but also to the practical improvement of risk assessment methods in different professional settings.

c. Impact of Oversight and Resources (Perceived behavioural controls) on measurement consistency across different domains.

In the area of risk assessment, hypothesis 15 aims to unravel the complicated relationship between perceptions of supervision, availability of resources and confidence of risk assessors. The response variable, referred to as Enablers, includes a number of categories, including a supportive legal framework that values consistency (Supportive), the availability of expert guidance and advice (Availability), collaborative efforts (Collaborative), technological advances that facilitate standardized measurement (Technological), "Administration" and "None". The study also considers predictor variables such as the influence of stronger social norms, professional standards and legal requirements that prescribe consistent measurement practices (Subject Consist), as well as the influence of experience and training.

The z-test, a statistical tool used in this study, aims to identify the variables that significantly influence the skills of risk assessors. The results, shown in the table below, illustrate the coefficients and p-values in the different categories and provide insight into the nuanced dynamics at play.

The results show that a supportive regulatory framework that emphasizes consistency (Supportive) serves as a critical reference point. This category, which represents a robust regulatory environment, significantly influences the confidence of risk assessors. The positive coefficient suggests that a supportive regulatory environment strengthens confidence in conducting risk assessments.

Table 49: Coefficients and p-values* for perceived behavioral controls towards measurement consistency across different domain.

Enablers	**Intercept**	**Subject Consist**	**Experience: +15**	**Experience: 10-15**	**Experience: 6-9**
Availability	-239.4 (0.00)	0.2 (0.90)	-97.8 (0)	184.5 (0.00)	185.2 (0.00)
Collaborative	-85.5 (0.00)	-1.5 (0.78)	168.1 (0)	167.9 (0.00)	-319.1 (0.00)
None	218.5 (0.14)	-206.1 (0.73)	-52.4 (0)	311.7 (0.04)	32.4 (0.00)
Admin	176.2 (0.00)	-192.8 (0.00)	-28.5 (0)	216.9 (0.00)	59.8 (0.00)
Regular	-214.6 (0.00)	-1.2 (0.61)	407.5 (0)	241.3 (0.00)	51 (0.00)
Training	-190.2 (0.00)	0.2 (0.92)	-361.5 (0)	-378.8 (0.00)	0.2 (0.00)

Enablers	**Education: BA**	**Education: Diploma**	**Education: MA**	**Education: PhD**
Availability	-159.6 (0)	52.6 (0.00)	53.6 (0)	-100.6 (0)
Collaborative	-213.7 (0)	-77.1 (0.00)	-141.4 (NaN)	568.4 (0)
None	-58.9 (0)	-278.1 (0.06)	-0.6 (0)	12.1 (0)
Admin	215.5 (0)	-52.7 (0.00)	6.8 (0)	16.7 (0)
Regular	-187.6 (0)	-326.5 (0.00)	-22.1 (0)	495.1 (0)
Training	190 (0)	-163.1 (0.00)	189.7 (0)	-147.5 (0)

**P-values are shown in parentheses*

***Statistically significant variables based on the p-value are shown in bold. Also a variable is statistically significant if it has a p-value less than 0.05 in at least one of the categories of the dependent variable examples of facilitators or factors that have positively influenced the research respondents' ability (Examples).*

[†]*NaN (not a number) is basically any numeric calculations with an undefined result that exists only in vectors with numeric datatype.*

Similarly, the availability of technical guidance and advice (availability) is a critical factor. While the coefficient is not statistically significant, suggesting a nuanced relationship, the negative sign suggests a potential trade-off between regulatory focus and perceived availability of expert advice. Collective effort show a positive relationship with risk assessor confidence, highlighting the importance of collective effort in promoting risk assessor confidence.

Technological progress (Technological) show an interesting pattern. While the coefficient is negative, indicating a potential challenge in the seamless integration of technology, it is not statistically significant. This suggests that technological progress does not have a significantly impact on the confidence of risk assessors.

The "Administration" and "None" categories also provide valuable insights. The negative coefficients emphasize the importance of the regulatory and normative framework even for those who do not consider themselves to be inspectors. This suggests a far-reaching influence of regulations and standards on the confidence of people who are indirectly involved in inspection activities.

When examining the influence of experience and training, the study shows different effects. The +15 years of experience category shows a positive correlation, suggesting that extensive experience has a positive influence on confidence in risk assessments. Education also shows varying effects at different levels, underlining the role of educational background on the confidence of risk assessors.

The statistical significance indicated by the p-values supports the hypothesis. The rejection of the null hypothesis and the acceptance of the alternative hypothesis make it clear that increased awareness of monitoring and resources, especially those that emphasize consistency between measurement domains, positively influences risk assessors' confidence. This in turn leads to more accurate and reliable risk assessments.

Thus, hypothesis 15 provides valuable insights into the factors that increase risk assessors' confidence in their role. It emphasizes the central role of supervision, availability of resources and the broader regulatory and normative environment in shaping risk assessors' confidence. Beyond statistical significance, these findings have practical implications for the refinement of risk assessment methodologies and the promotion of a more confident cadre of risk assessors across all sectors.

5.4.5 Privacy and Security Risks of Digital Measurement Systems.

a. The Influence of Attitudes Towards Privacy and Security Risks.

Hypothesis 16 addresses the relationship between attitudes towards privacy and security risks associated with digital measurement systems and the likelihood of conducting effective risk assessments. The response variable labeled Enablers includes a number of categories: Availability of comprehensive risk assessment tools and methods (Availability), Sufficient training and education on risk assessment practices (Sufficient), Clear direction and support from senior management and regulators (Clear), cultivation a culture of security and risk awareness within the organization (Cultivating), collaboration and knowledge sharing among stakeholders (Collaborative), Adequate allocation of resources to risk assessment activities (Adequate), and "Admin".

The z-test, a statistical tool used in this study, is used to determine which variables have a significantly impact on the ability to conduct effective risk assessments. The results shown in the table below provide information on the coefficients and p-values in the different categories and illustrate the complex dynamics at play.

Table 50: Coefficients and p-values*for attitudes towards privacy and risks within South African metrology's landscape.

Enablers	**Intercept**	**Attitudes Privacy**	**Experience: +15**	**Experience: 10-15**	**Experience: 6-9**
Adequate	-105.7 (0.56)	66.1 (0.92)	-361 (0)	-342.5 (0)	-405.5 (0)
Clear	-216.9 (0.00)	92.4 (0.58)	-475.3 (0)	-583.6 (0)	-769.9 (0)
Collaborative	262.7 (0.00)	-292.8 (0.00)	29.5 (0)	499.4 (0)	-5.4 (0)
Cultivating	-158.3 (0.00)	-13.3 (0.00)	35.5 (0)	5.6 (0)	74.2 (0)
Not an inspector	-95.1 (0.00)	-118.1 (0.00)	-46.4 (0)	444.9 (0)	-51.2 (0)
Sufficient	-197.8 (0.00)	19 (0.00)	-322 (0)	-79.7 (0)	-99.9 (0)
Enablers	**Education: BA**	**Education: Diploma**	**Education: MA**	**Education: PhD**	
Adequate	113.1 (0.00)	221.7 (0.00)	-140.3 (0)	-175.6 (0.07)	
Clear	137 (0.00)	381 (0.00)	-156.8 (0)	-253.6 (0.00)	
Collaborative	-241.3 (0.00)	117.5 (0.00)	410.5 (0)	-15.2 (0.00)	
Cultivating	-126 (0.00)	1.8 (0.00)	149.6 (0)	-155.1 (0.00)	
Not an inspector	5.5 (0.00)	-58.2 (0.00)	11.1 (0)	-40 (0.00)	
Sufficient	-174.5 (0.00)	-174.5 (0.00)	-193.2 (0)	-436.4 (0.00)	

**P-values are shown in parentheses*

***Statistically significant variables based on the p-value are shown in bold. Also a variable is statistically significant if it has a p-value less than 0.05 in at least one of the categories of the dependent variable enablers to effective risk assessment (Enablers).*

†NaN (not a number) is basically any numeric calculations with an undefined result that exists only in vectors with numeric datatype.

The results show that attitudes towards privacy and security risks (Attitudes Privacy) play a central role in shaping effective risk assessments. The positive coefficient suggests that individuals and organizations with positive attitude towards privacy and security risks are more likely to conduct effective risk assessments. This highlights the importance of attitude and perception in approaching the challenges of digital measurement systems and emphasizes that a positive attitude towards the associated risks acts as a catalyst for effective risk assessment practices.

Among the various categories, the category "Clear" guidance and support from management and regulators stands out as a statistically significant factor. The positive coefficient indicates that the likelihood of conducting effective risk assessments increases when there is clear guidance and support. This highlights the organizational and managerial dimension in which a supportive structure and leadership play a critical role in enabling effective risk assessment practices.

The "cultivation" of a culture of safety and risk awareness within the organization also proves to be an important factor. The negative coefficient suggests an interesting relationship, possibly indicating that risk perception decreases when the organization places more emphasis on cultivating a culture of safety, which has a positive impact on effective risk assessment.

Educational background, another group of predictor variables, shows different effects. Education at different levels (BA, Diploma, MA, PhD) shows different influences in the different categories, highlighting the multi-faceted nature of the relationship between education and effective risk assessment.

The statistical significance, indicated by the p-values, supports the hypothesis. The rejection of the null hypothesis and acceptance of the alternative hypothesis emphasize that attitudes towards privacy and security risks play a critical role in determining the effectiveness of risk assessments. These findings have implications for organizations seeking to improve their risk assessment practices. They suggest that promoting a positive attitude towards risk in digital measurement systems is a fundamental step.

Therefore, Hypothesis 16 provides valuable insights into the psychological and organizational aspects that underlie effective risk assessment. It highlights the intricate interplay between attitudes, organizational culture and educational background that influences the likelihood of conducting robust risk assessments. Beyond statistical significance, these findings offer practical implications for organizations seeking to improve their risk assessment capabilities in the dynamic landscape of digital measurement systems.

b. Perceived behavioral control and effective risk assessment towards privacy and security risks.

Hypothesis 17 examines the relationship between perceived behavioral control and effective risk assessment. It examines whether individuals and organizations that have a higher level of perceived control in assessing and mitigating privacy and security risks associated with digital measurement systems are more likely to perform effective risk assessment. The response variable, enablers of effective risk assessment (enablers), includes several categories such as the availability of comprehensive risk assessment tools and methods, sufficient training, clear guidance, collaborative efforts, adequate resource allocation, and others. Predictor variables include, in particular, perceived behavioral control (subject privacy), experience, and training.

To assess the statistical significance of these variables, the two-tailed z-test was performed. The results, which are presented in Table 4.57, show the coefficients and p-values for each category under enablers, the intercept and the predictor variables. An important criterion for significance is that at least one of the p-values in the Subject Privacy column must be less than 0.05. The results lead to the rejection of the null hypothesis and support the alternative hypothesis that companies with higher perceived behavioral control are more likely to conduct effective risk assessments.

Table 51: Coefficients and p-values*for perceived behavioral control towards privacy and risks within South African metrology's landscape

Enablers	**Intercept**	**Subject Privacy**	**Experience: +15**	**Experience: 10-15**	**Experience: 6-9**
Adequate	-368.9 (0.00)	116.2 (0.00)	-49.7 (0)	-86 (NaN)	-232.9 (NaN)
Clear	-0.8 (0.00)	15 (0.00)	-180.8 (NaN)[†]	-273.4 (0.00)	-322.4 (0)
Collaborative	-72.7 (0.00)	-0.1 (0.00)	-5.9 (0)	26 (0.00)	-23.4 (0)
Cultivating	-15.4 (0.00)	-54.1 (0.00)	3.8 (0)	-29.3 (0.00)	105.9 (0)
Admin	-272.3 (0.38)	67 (0.94)	87.7 (0)	88.3 (0.00)	-122 (0)
Sufficient	117.4 (0.00)	2.6 (0.25)	-133.6 (0)	-39.7 (0.00)	-45.5 (0)

Enablers	**Education: BA**	**Education: Diploma**	**Education: MA**	**Education: PhD**
Adequate	50 (0.00)	53.8 (NaN)	-96.1 (NaN)	-92.8 (NaN)
Clear	53 (0.00)	200 (0)	-49.8 (0)	-134.1 (NaN)
Collaborative	-140 (0.00)	49.5 (0)	48.3 (0)	48.3 (0)
Cultivating	-42.4 (0.00)	-0.2 (0)	107.5 (0)	107.5 (0)
Admin	1.5 (0.99)	-82.2 (0)	-136.9 (0)	-136.9 (0)
Sufficient	-83.1 (0.00)	-83.1 (0)	-82.4 (0)	-82.4 (0)

*P-values are shown in parentheses

**Statistically significant variables based on the p-value are shown in bold. Also a variable is statistically significant if it has a p-value less than 0.05 in at least one of the categories of the dependent variable enablers to effective risk assessment (Enablers).

[†]NaN (not a number) is basically any numeric calculations with an undefined result that exists only in vectors with numeric datatype.

The intercept, privacy issue, experience categories and education levels are systematically presented and provide a comprehensive overview of the statistical significance of each variable. The coefficients indicate the strength and direction of the relationship, while the p-values determine their statistical significance. Variables with p-values of less than 0.05 are marked as statistically significant, which makes it easier to interpret the results.

These results are important for both the theory and practice of risk assessment. The finding that perceived behavioral control plays a central role in shaping effective risk assessment practices suggests that interventions or training programs aimed at improving this perception could positively influence risk management outcomes. Furthermore, the identification of significant variables within experience and training provides insight into the factors that contribute to effective risk assessment in specific occupational and educational contexts.

It is worth noting that certain variables labeled as NaN (no number) indicate undefined results in numerical calculations. Such cases require further investigation and clarification, possibly due to specific conditions in the data set.

Thus, hypothesis 17 illustrates the importance of perceived behavioral control in the field of digital measurement systems and risk assessment. The statistically significant relationships uncovered in this analysis provide valuable insights for the broader discourse on risk management practices.

c. Social Pressure and Effective Risk Assessment towards privacy and security risks.

Hypothesis 18 addresses the impact of social pressure on effective risk assessment and examines whether individuals and organizations that perceive social pressure to prioritize other aspects of digital measurement systems (e.g., cost, efficiency) over privacy and security risks are less likely to perform effective risk assessment. The response variable, enablers for effective risk assessment (enablers), includes categories such as the availability of risk assessment tools, training, clear guidance, collaborative efforts, resource allocation and not being an inspector. The availability of comprehensive risk assessment tools and methods is set as a reference value. The predictor variables also include perceived social pressure (Perceived Behav), experience and training.

A two-tailed z-test was performed to determine the statistical significance of these variables. The results, listed in Table 4.58, show the coefficients and p-values for each category under enablers, the intercept and the predictor variables. A critical criterion for significance is that at least one of the p-values in the Perceived Behavior column must be less than .05. The results lead to the rejection of the null hypothesis and support the alternative hypothesis that organizations that perceive social pressure to prioritize other issues over privacy and security risks are less likely to conduct effective risk assessment.

The intercept, perceived behavior, experience categories and education levels are systematically presented and provide a comprehensive overview of the statistical significance of each variable. The coefficients indicate the strength and direction of the relationship, while the p-values determine their statistical significance. Variables with p-values of less than 0.05 are marked as statistically significant, which makes it easier to interpret the results.

Table 52: Coefficients and p-values*for social norms towards privacy and risks within South African metrology's landscape

Enablers	Intercept	Perceived Behav	Experience: +15	Experience: 10-15	Experience: 6-9
Adequate	-2733.8 (0)	1095.6 (0)	-1603.9 (0)	-832.7 (0)	-1926.9 (0)
Clear	-432.4 (0)	281.8 (0)	-1801.8 (0)	-2156.4 (0)	-3065.4 (0)
Collaborative	-1205 (0)	305.2 (0)	-142.3 (0)	623.3 (0)	-86.4 (0)
Cultivating	-416.7 (0)	-354.3 (0)	32.5 (0)	2.8 (0)	1348.2 (0)
Not an inspector	-2317.4 (0)	699.7 (0)	-764 (0)	486.2 (0)	-660 (0)
Sufficient	676.4 (0)	309.2 (0)	-1474.3 (0)	-577.5 (0)	-1156.1 (0)

Enablers	Education: BA	Education: Diploma	Education: MA	Education: PhD
Adequate	144.1 (0)	-1.4 (0.00)	-589.9 (0)	-1483.7 (NaN)
Clear	826.4 (0)	1790.6 (0.00)	-64.4 (0)	-1362.8 (0)
Collaborative	-1017.4 (0)	2.3 (0.04)	-111.9 (0)	-21.1 (0)
Cultivating	-196.1 (0)	5.1 (0.00)	131.6 (0)	-295.1 (0)
Not an inspector	123.7 (0)	-798.8 (0.00)	-986.5 (0)	-528.2 (0)
Sufficient	-734.8 (0)	-689.4 (0.00)	-802.2 (0)	-2072.7 (0)

*P-values are shown in parentheses

**Statistically significant variables based on the p-value are shown in bold. Also a variable is statistically significant if it has a p-value less than 0.05 in at least one of the categories of the dependent variable enablers to effective risk assessment (Enablers).

†NaN (not a number) is basically any numeric calculations with an undefined result that exists only in vectors with numeric datatype.

These results have implications for understanding the dynamics that influence effective risk assessment practices. The significant influence of perceived social pressure suggests that interventions or strategies to mitigate this pressure could positively influence risk management outcomes. Furthermore, the identification of significant variables within experience and education provides insight into the nuanced factors that contribute to effective risk assessment in different occupational and educational contexts.

It is important to note that certain variables labeled as NaN (no number) indicate undefined results in numerical calculations. These cases require further investigation and clarification, which may be due to specific conditions in the dataset.

Thus, Hypothesis 18 contributes to our understanding of the social dynamics affecting risk assessment and highlights the importance of mitigating external pressures for effective risk management.

5.5 Conclusion

This chapter looks at comprehensive data analysis techniques aimed at generating meaningful insights that are critical to decision-making. It begins with descriptive statistics and provides a basic overview of the characteristics of the data set. The subsequent hypothesis testing, which is presented in the tables for hypotheses 1 to 18, focuses on statistical significance, which is crucial for accepting or rejection of the formulated hypotheses.

These results are of great benefit to both science and practice. However, it is important to recognize the limitations of data analysis. The chapter concludes by emphasizing the need for nuanced interpretation and the understanding that statistical significance is not synonymous with causality. This data-driven presentation forms the basis for the subsequent discussions and contributes to a better understanding of the research topic in the following sections.

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter encapsulates the culmination of the research study, providing a comprehensive overview of the findings and their implications. The following sections delineate the conclusions drawn from the study, assess the fulfillment of the study's objectives, and present recommendations derived from the research.

In pursuit of the research objectives, the study employed quantitative research methodologies, utilizing a 5-point Likert scale administered through questionnaires. The collected data were meticulously compiled and analyzed using statistical software and Excel spreadsheets to derive meaningful insights.The research study, outlined in Chapter 1, articulated three overarching objectives.

Research Aim:

1. Examine critical factors influencing risk assessment, encompassing equipment, measurement methods, environmental considerations, and regulatory requirements.
2. Investigate the pivotal role played by national and international metrology organizations and legal regulations in shaping risk assessment processes.
3. Emphasize the pivotal role of accurate measurement in fostering fairness, safety, and security across diverse industries.
4. Support informed decision-making within the realms of scientific and legal metrology

Research objectives:

The specific objectives were:

1. Identify key factors influencing the approach to risk assessment in scientific and legal metrology in South Africa.
2. Evaluate the efficacy of existing risk assessment practices in the same context.
3. Propose recommendations aimed at enhancing risk assessment practices, with a focus on elevating the accuracy and reliability of measurements in the field.

6.2 Fulfillment of Research Objectives:

6.2.1 Identification of key factors influencing risk assessment in scientific and legal metrology in South Africa:

The first research objective was to uncover and identify key factors that influence the approach to risk assessment in scientific and legal metrology in South Africa. The study took a comprehensive approach and examined various dimensions that contribute to the complex landscape of risk assessment.

One important factor examined in the study was "attitudes towards privacy and security risks" (Hypothesis 16). The study found that individual and organizational attitudes play a central role in shaping effective risk assessments in the field of metrology. The positive coefficient for attitudes towards privacy and security risks suggests that organizations with positive attitudes are more likely to conduct thorough and effective risk assessments. This finding highlights the importance of psychological and perceptual aspects in addressing the challenges posed by digital measurement systems.

In addition, the study identified "Clear" guidance and support from management and regulators as a statistically significant factor among the various categories considered. The positive coefficient in this category indicates that a supportive organizational structure in conjunction with leadership significantly increases the likelihood of conducting effective risk assessments. This finding underscores the critical role of management in fostering an environment conducive to sound risk assessment.

The study also sheds light on the impact of cultivating a culture of safety and risk awareness within an organization. The negative coefficient in this category indicates an interesting relationship, suggesting that a greater emphasis on cultivating a culture of safety can lead to a decrease in perceived risk. This nuanced result highlights the intricate balance required in organizational cultures where an emphasis on safety should complement, not hinder, effective risk assessment practices.

Educational background proved to be another influential factor, with different levels (BA, Diploma, MA, PhD) showing different influences in different categories. This illustrates the multifaceted nature of the relationship between education and effective risk assessment.

Thus, it can be said that the first research objective was achieved. The study provides valuable insights into the psychological, organizational and educational dimensions that influence the approach to risk assessment in scientific and legal metrology in South Africa. The findings not only contribute to the academic understanding of risk assessment, but also offer practical implications for organizations seeking to improve their risk assessment practices in the dynamic landscape of digital measurement systems.

6.2.2 Evaluating the effectiveness of existing risk assessment practices in scientific and legal metrology in South Africa:

The second research objective was to assess the effectiveness of current risk assessment practices in scientific and legal metrology in South Africa. The study rigorously examined different variables to assess the effectiveness of existing approaches.

The hypothesis (Hypothesis 17) which addresses the relationship between "Perceived Behavioral Control" and effective risk assessment provided crucial insights into the dynamics at play. The positive correlation between higher levels of perceived behavioral control and the likelihood of conducting effective risk assessments suggests a central role for this factor. Individuals and organizations that have a strong sense of control in assessing and mitigating privacy and security risks associated with digital measurement systems are more likely to perform effective risk assessments. This highlights the importance of interventions or training programs aimed at improving perceived behavioral control as a potential catalyst for improved risk management outcomes.

The results regarding experience and education levels added depth to the assessment. Experience levels, ranging from 6-9 years to over 15 years, showed different effects on the effectiveness of risk assessment. Educational background at different levels (BA, Diploma, MA, PhD) also showed different influences. These results illustrate the differentiated nature of risk assessment in specific occupational and educational contexts.

However, it is important to consider the cases labeled NaN (not a number), which indicate undefined results in numerical calculations. These cases require further investigation, possibly due to specific conditions in the data set. These anomalies highlight the need for a comprehensive understanding of the dataset and possible outliers that could influence the evaluation of the effectiveness of the risk assessment.

Therefore, the second research objective was successfully addressed and provides a nuanced understanding of the effectiveness of existing risk assessment practices in scientific and legal metrology in South Africa. The findings provide actionable insights for intervention and improvement, particularly to improve perceived behavioral control, experience and educational background to increase the overall effectiveness of risk assessment processes.

6.3 Recommendations for improving risk assessment practices in scientific and legal metrology in South Africa:

The third research objective was to propose recommendations to improve risk assessment practices in the field of scientific and legal metrology in South Africa. Based on the comprehensive analyzes of the study, the proposed recommendations aim to improve the accuracy and reliability of measurements.

6.3.1 Promote a positive attitude towards privacy and security risks:

The results of the study (Hypothesis 16) highlight the central role of attitudes towards privacy and security risks in the design of effective risk assessments. Organizations should promote a positive attitude towards these risks, as this is a fundamental step in ensuring sound risk assessment practices. Initiatives such as awareness programs and training could help to instill this positive attitude.

6.3.2 Clear guidance and support from management:

The category "Clear" guidance and support from management and regulators was found to be a statistically significant factor. It is therefore recommended that organizations establish clear structures and management support for risk assessment. This includes developing comprehensive risk assessment tools, providing sufficient training and ensuring adequate resource allocation.

6.3.3 Cultivate a culture of safety and risk awareness:

The negative coefficient in the "Cultivate" category indicates an interesting relationship between risk perception and organizational focus on cultivating a culture of safety. A delicate balance is required here. While fostering a safety culture is critical, organizations need to ensure that risk awareness is not inadvertently compromised as a result. A balanced approach would mean combining safety culture with a continued emphasis on the importance of risk assessment.

6.3.4 Tailored educational programs:

The varying influence of educational background (BA, Diploma, MA, PhD) on risk assessment practice necessitates tailored training programs. Training initiatives should take into account the different influences of different educational levels and ensure that they address the specific challenges associated with each category.

6.3.5 Mitigating perceived social pressure:

Hypothesis 18 highlights the negative impact of perceived social pressure on effective risk assessment. Strategies to mitigate these pressures, such as clear communication about the importance of privacy and security over other considerations such as cost and efficiency, can improve risk assessment outcomes.

Therefore, the third research objective was achieved by making a series of targeted recommendations. These recommendations are based on the empirical findings of the study and provide practical guidance for scientific and statutory metrology organizations in South Africa to increase the accuracy and reliability of measurements through improved risk assessment practices.

6.4 Possible future research

The comprehensive study of risk assessment in scientific and legal metrology in South Africa has laid the foundation for several compelling avenues for future research. First, the integration of new technologies, such as artificial intelligence and blockchain, into risk assessment should be explored in depth. Understanding the impact of these technologies on risk perception and risk management is critical to adapting methodologies to the evolving landscape of measurement systems. In addition, a cross-cultural examination of risk assessment practices can shed light on how cultural nuances influence attitudes towards privacy, security and risk. Expanding the geographic scope of the study for comparative analysis with other regions would enrich our understanding of broader cultural influences.

We recommend longitudinal studies to track the dynamic nature of risk landscapes over time. This approach can uncover adaptation strategies and highlight areas that require ongoing attention in the face of changing technologies, regulations, and organizational structures. In addition, interdisciplinary collaboration between metrologists, lawyers, psychologists and technologists can lead to a holistic understanding of risk assessment that combines the technical and human-centered aspects. Examining the direct impact of sound risk assessment practices on the establishment and maintenance of measurement standards is critical, emphasizing how effective risk management contributes to the reliability and accuracy of measurements.

Exploring public perceptions is an important extension of the current study, incorporating not only the perspective of companies but also that of the public. By understanding how the public's attitudes match or diverge with corporate attitudes towards privacy and security, we can create a more comprehensive framework for risk assessment. In addition, collaborative efforts within the metrology community to develop standardized metrics for risk assessment can facilitate benchmarking and comparison of practices between organizations, fostering a community of practice.

6.5 Limitations of the study

Although the study has made an important contribution, it is important to recognize its limitations. The study focused on the South African context and generalization of the findings to other regions should be done with caution due to possible differences in cultural, legal and organizational context. In addition, the use of self-reporting carries the possibility of response bias. Future research could benefit from other methods of data collection to increase validity.

The cross-sectional design of the study provides a snapshot of risk assessment practices, but a longitudinal approach could provide a more nuanced understanding of changes over time. Certain variables labeled as NaN (no number) require further investigation to clarify their undefined results in the numerical calculations, indicating potential complexities in the dataset.

6.6 Conclusion

This chapter has highlighted the findings, implications and future directions of the study on risk assessment in scientific and legal metrology in South Africa. The research objectives have been achieved by uncovering the key factors influencing risk assessment approaches, evaluating existing practices and making recommendations for improvement. The study's contributions provide a solid foundation for future research and encourage further investigation in the areas of technological integration, cross-cultural perspectives, longitudinal analysis, interdisciplinary approaches, public perception and standardized metrics for risk assessment. The journey through this chapter sets the stage for a better understanding of the dynamics of risk assessment in the complicated field of metrology.

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ANNEXURE A1: QUANTITATIVE RESEARCH INSTRUMENT

FACTORS INFLUENCING THE APPROACH TO RISK ASSESSMENT IN SCIENTIFIC AND LEGAL METROLOGY IN SOUTH AFRICA

MASTERS OF BUSINESS ADMINISTRATION

UNIVERSITY OF THE WITWATERSRAND

Dear colleagues

You are cordially invited to participate in a research study entitled "Factors Influencing the Approach to Risk Assessment in Scientific and Legal Metrology in South Africa" This study is part of an MBA research project at the University of the Witwatersrand.

Your invaluable insights as a participant are critical to the successful completion of this study. We greatly appreciate your participation and assure you that we will treat your responses with the utmost confidentiality. Your anonymity is fully guaranteed and you will not be asked to give your name at any point during the process.

Two different methods are used to collect the required data: filling out a questionnaire and a personal interview. For your convenience and to protect your privacy, questionnaires and data collection forms for statistical analysis will be sent via email. In addition, selected forms will be given to you during a personal interview.

As an expression of gratitude, the results of this survey will be shared with the University of the Witwatersrand and potentially published in a reputable journal. If you have any questions or need further information, please do not hesitate to contact us. Your active participation and insights will help improve our understanding of this important topic. We are grateful to you for accepting this invitation. Your contribution to this research project is of great value.

Regards

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1. Demographic Information

1.1 What is your gender:

☐Male ☐Female ☐ Prefer not to say

1.2 What is Highest Level of Education Completed:

☐High School Diploma or Equivalent ☐Bachelor ☐Masters ☐ PhD

1.3 Field of Work/Study:

☐Scientific Metrology ☐Legal Metrology ☐Both Scientific and Legal Metrology

1.4 Years of Experience in Metrology:

☐0-2 ☐3-5 ☐6-9 ☐ 3-5 ☐10-15 ☐+15

1.5 Have you received any training or education specifically related to risk assessment in metrology?

☒Yes ☐No

1.6 How frequently do you perform risk assessments in your metrology work?

☐Daily ☐Weekly ☐ Monthly ☐Occasionally ☐Rarely

1.7 What is your primary motivation for conducting risk assessments in metrology? (Select all that apply)

☐ Compliance with regulations and standards
☐ Enhancing measurement accuracy and reliability
☐ Ensuring safety in metrology processes
☐ Minimizing non-compliant rate in the industry
☐ Improving decision-making processes within your organisation

2. What are the Factors Influencing Risk Assessment in Scientific and Legal Metrology?

This section examines the factors that influence risk assessment in scientific and legal metrology. It explores participants' attitudes, subjective norms, perceived behavioral control, and barriers/enablers related to risk assessment. By understanding these factors, we can enhance the effectiveness of risk assessment practices in ensuring measurement accuracy, reliability, and overall safety:

2.1 Attitudes Toward Risk Assessment

Please indicate your level of agreement with the following statements:

2.1.1 Risk assessment is an important part of scientific and legal metrology.

☐ Strongly Disagree ☐Disagree ☐Neutral ☐Agree ☐Strongly Agree

2.1.2 Risk assessment contributes to ensuring measurement accuracy and reliability.

☐ Strongly Disagree ☐Disagree ☐Neutral ☐Agree ☐Strongly Agree

2.1.3 Risk assessment enhances decision-making processes in scientific and legal metrology.

☐ Strongly Disagree ☐Disagree ☐Neutral ☐Agree ☐Strongly Agree

2.1.4 Risk assessment improves overall safety in scientific and legal metrology.

☐ Strongly Disagree ☐Disagree ☐Neutral ☐Agree ☐Strongly Agree

2.1.5 Risk assessment provides valuable insights into non-compliant rate of product in the local market.

☐ Strongly Disagree ☐Disagree ☐Neutral ☐Agree ☐Strongly Agree

2.2 Subjective Norms Related to Risk Assessment

Please indicate your level of agreement with the following statements:

2.2.1 My colleagues in scientific and legal metrology expect me to conduct risk assessments.

☐ Strongly Disagree ☐Disagree ☐Neutral ☐Agree ☐Strongly Agree

2.2.2 My supervisors in scientific and legal metrology emphasize the importance of risk assessment.

☐ Strongly Disagree ☐Disagree ☐Neutral ☐Agree ☐Strongly Agree

2.2.3 Regulations and policies in scientific and legal metrology require me to conduct risk assessments.

☐ Strongly Disagree ☐Disagree ☐Neutral ☐Agree ☐Strongly Agree

2.2.4 There is a social or personal expectation within the scientific and legal metrology community to perform risk assessments.

☐ Strongly Disagree ☐Disagree ☐Neutral ☐Agree ☐Strongly Agree

2.2.5 Risk assessment is considered a professional norm in scientific and legal metrology.

☐ Strongly Disagree ☐Disagree ☐Neutral ☐Agree ☐Strongly Agree

2.3 Perceived Behavioral Control

Please indicate your level of agreement with the following statements:

2.3.1 I have the knowledge and skills required to conduct risk assessments.

☐ Strongly Disagree ☐Disagree ☐Neutral ☐Agree ☐Strongly Agree

2.3.2 I have access to the necessary resources (e.g., time, equipment) to conduct risk assessments.

☐ Strongly Disagree ☐Disagree ☐Neutral ☐Agree ☐Strongly Agree

2.3.3 Conducting risk assessments is within my control.

☐ Strongly Disagree ☐Disagree ☐Neutral ☐Agree ☐Strongly Agree

2.3.4 I feel confident in my ability to effectively perform risk assessments.

☐ Strongly Disagree ☐Disagree ☐Neutral ☐Agree ☐Strongly Agree

2.3.5 I believe I have sufficient authority to make decisions based on risk assessment outcomes.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

2.4 Barriers to Effective Risk Assessment within Scientific and Legal Metrology

2.4.1 What are the major barriers you have encountered when conducting risk assessments in scientific and legal metrology? Please select the most applicable option(s) from the following:

☐ Lack of adequate resources (e.g., time, equipment)

☐ Insufficient training or knowledge in risk assessment methodologies

☐ Limited awareness or understanding of the importance of risk assessment

☐ Inadequate support or commitment from management

☐ Complex regulatory requirements or lack of clear guidelines

☐ Other (please specify)

2.5 Enablers to Effective Risk Assessment Risk Assessment within Scientific and Legal Metrology

2.5.1 What factors enable or support effective risk assessment in scientific and legal metrology? Please select the most applicable option(s) from the following:

☐ Availability of comprehensive risk assessment tools and methodologies

☐ Sufficient training and education on risk assessment practices

☐ Clear guidance and support from management and regulatory bodies

☐ Cultivating a culture of safety and risk awareness within the organization

☐ Collaborative efforts and knowledge sharing among stakeholders

☐ Adequate allocation of resources for risk assessment activities

☐ Other (please specify)

3. How has the increasing complexity of measurement systems affected risk assessment in scientific and legal metrology in South Africa

This section focuses on understanding how the increasing complexity of measurement systems affects risk assessment within the field of legal and scientific metrology. It explores participants' attitudes, subjective norms, perceived behavioral control, and challenges associated with measurement system complexity. By examining these aspects, we can gain insights into the risks and uncertainties introduced by complex measurement systems and identify strategies to improve risk assessment practices in this evolving landscape.

3.1 Attitudes towards complexity of measurements systems

Please indicate your agreement with the following statements:

3.1.1 I believe that new measurement technologies and methods enhance accuracy and reliability in scientific and legal metrology

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

3.1.2 I perceive new measurement technologies and methods as beneficial for risk assessment in scientific and legal metrology.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

3.1.3 I consider new measurement technologies and methods as reliable tools for measurement in scientific and legal metrology.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

3.1.4 I think that new measurement technologies and methods are necessary to keep up with evolving measurement requirements.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

3.2 Subjective Norms towards complexity of measurements systems

Please indicate your agreement with the following statements:

3.2.1 My colleagues and peers in scientific and legal metrology expect me to adopt and use new measurement technologies and methods.

☒ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

3.2.2 There is an implicit expectation from regulatory bodies to adopt and use new measurement technologies and methods.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

3.2.3 I feel pressure from the industry to adopt and use new measurement technologies and methods.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

3.3 Perceived Behavioral Control towards complexity of measurements systems

Please indicate your agreement with the following statements:

3.3.1 I feel confident in my ability to successfully adopt and use new measurement technologies and methods.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

3.3.2 I believe I have the necessary knowledge and skills to effectively utilize new measurement technologies and methods.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

3.3.3 I have access to the resources (e.g., time, equipment) required to adopt and use new measurement technologies and methods.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

3.4 Section 4: Guided Questions

3.4.1 How do you perceive the challenges associated with the increasing complexity of measurement systems in scientific and legal metrology? Please select the most applicable option(s) from the following:

☐ Difficulties in understanding and implementing complex measurement technologies
☐ Increased time and effort required for risk assessment due to system complexity
☐ Challenges in identifying and assessing risks associated with complex measurement systems
☐ Impacts on the accuracy and reliability of measurement results
☐ Other (please specify)

3.4.2 In your opinion, what are the main risks and uncertainties introduced by complex measurement systems? Please select the most applicable option(s) from the following:

☐ Potential errors and inaccuracies in measurements
☐ Difficulty in identifying and mitigating system failures or malfunctions
☐ Increased vulnerability to external factors or interferences
☐ Challenges in ensuring traceability and comparability of measurements
☐ Other (please specify)

3.4.3 Are there any specific barriers or difficulties you have encountered in adopting and using new measurement technologies and methods in your work? Please select the most applicable option(s) from the following:

☐ Lack of training and knowledge on new measurement technologies and methods
☐ Insufficient resources or funding for implementing complex measurement systems
☐ Resistance to change from stakeholders or colleagues
☐ Compatibility issues with existing systems or infrastructure
☐ Other (please specify)

4. What risk assessment methods are currently used for scientific and legal metrology in South Africa, and how effective are they in identifying and mitigating potential risks?

This section examines the effectiveness of current risk assessment methods in South African metrology. It assesses participants' attitudes, norms, behavioral control, and the actual effectiveness of existing methods. The goal is to identify strengths, weaknesses, and opportunities for improving risk assessment practices in South African metrology.

4.1 Attitudes towards current risk assessment methods within scientific and legal metrology

Please indicate your level of agreement with the following statements

4.1.1 Risk assessment is an important part of my job in scientific and legal metrology.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

4.1.2 I believe that conducting thorough risk assessments is necessary to ensure the accuracy and reliability of measurements.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

4.1.3 I enjoy conducting risk assessments in scientific and legal metrology.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

4.1.4 I believe that risk assessment methods currently used in South African metrology are effective in identifying potential risks.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

4.2 Subjective Norms towards current risk assessment methods within scientific and legal metrology

Please indicate your level of agreement with the following statements:

4.2.1 My colleagues place great importance on conducting thorough risk assessments in our work.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

4.2.2 Stakeholders expect me to conduct thorough risk assessments in scientific and legal metrology.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

4.2.3 I feel motivated to conduct thorough risk assessments due to the perceived social pressure from my professional network.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

4.3 Perceived Behavioral Control towards current risk assessment methods within scientific and legal metrology

Please indicate your level of agreement with the following statements:

4.3.1 I feel confident in my ability to conduct thorough risk assessments.

☒ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

4.3.2 I have the necessary knowledge and skills to effectively assess potential risks in scientific and legal metrology.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

4.3.3 I have access to the resources (e.g., time, tools, information) required to conduct effective risk assessments.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

4.4 Effectiveness of Risk Assessment Methods within Scientific and Legal Metrology

Please answer the following questions based on your experience with risk assessment methods in scientific and legal metrology in South Africa.

4.4.1 how effective do you find the current risk assessment methods in identifying potential risks or non compliant products?

☐ Ineffective ☐ Somewhat effective ☐ Moderately effective ☐ Quite Effective ☐ Highly Effective

4.4.2 How frequently do you encounter potential risks related to non-compliance with regulations or standards during your measurements in scientific and legal metrology?

☐ rarely ☐ Occasionally ☐ Sometimes ☐ Often ☐ Very Oftern

5. How has the need for consistency across measurement domains impacted risk assessment in scientific and legal metrology in South Africa?

This section investigates how the need for consistency across measurement domains has influenced risk assessment in scientific and legal metrology in South Africa. It consists of four subsections: attitudes, subjective norms, perceived behavioral control, and barriers and facilitators.

5.1 Attitudes towards measurement consistency within Scientific and Legal Metrology

Please indicate your level of agreement with the following statements:

5.1.1 Measurement accuracy is crucial for reliable risk assessments.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

5.1.2 Consistency in measurement practices across domains enhances the accuracy and reliability of risk assessments.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

5.1.3 Inconsistent measurement practices in different domains undermine the validity and credibility of risk assessments.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

5.2 Subjective Norms towards measurement consistency within Scientific and Legal Metrology

Please indicate your level of agreement with the following statements:

5.2.1 There are established norms or standards that mandate consistent measurement practices in risk assessment across different domains.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

5.2.2 Compliance with consistent measurement practices is important for maintaining professional standards in risk assessment.

☒ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

5.2.3 Regulatory requirements emphasize the importance of consistency in measurement practices across domains.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

5.3 Perceived Behavioral Control towards measurement consistency within Scientific and Legal Metrology

Please indicate your level of agreement with the following statements:

5.3.1 I feel confident in my ability to ensure consistent measurement practices across different domains in risk assessment.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

5.3.2 I have the necessary resources (e.g., tools, training, guidance) to ensure consistency in measurement practices across domains in risk assessment.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

5.3.3 I have control over ensuring consistency in measurement practices across different domains in risk assessment.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

5.4 Barriers to ensuring consistency in risk assessment across different measurement domains.

5.4.1 What are the primary challenges you encounter when striving to ensure consistent measurement practices across different risk assessment domains? Please select the most applicable option(s) or provide specific examples if not listed.

☐ Lack of standardized guidelines or protocols
☐ Limited communication and coordination among different domains
☐ Inadequate resources or budget constraints
☐ Differing interpretations of regulations or standards
☐ Resistance to change from stakeholders
☐ Other (please specify): ________________

5.5 Facilitators to ensuring consistency in risk assessment across different measurement domains.

5.5.1 In your experience, what resources, tools, or policies have you found most helpful in promoting and ensuring consistent measurement practices across risk assessment domains? Please select the most applicable option(s) or provide specific examples if not listed.

☐ Clear and comprehensive guidelines or protocols
☐ Training programs and educational initiatives
☐ Availability of standardized measurement instruments
☐ Regular quality assurance and auditing processes
☐ Collaborative platforms or forums for sharing best practices
☐ Other (please specify): ________________

5.5.2 Can you share any examples of facilitators or factors that have positively influenced your ability to maintain consistency in measurement practices across different domains in risk assessment? Please select the most applicable option(s) or provide specific examples if not listed.

☐ Supportive regulatory framework emphasizing consistency
☐ Availability of expert guidance and consultation
☐ Collaborative efforts among stakeholders and organizations
☐ Technological advancements facilitating standardized measurements
☐ Recognition and incentives for maintaining consistency
☐ Other (please specify): ________________

6. What privacy and security risks are associated with digital measurement systems in South Africa, and how are they considered in risk assessment?

This section examines privacy and security risks of digital measurement systems in South Africa. It assesses participants' attitudes, norms, and control in addressing these risks, as well as effective risk assessment practices.

6.1 Attitudes towards privacy and security within Scientific and Legal Metrology

Please indicate your level of agreement with the following statements:

6.1.1 I believe that privacy and security risks associated with digital measurement systems can significantly impact the accuracy and reliability of risk assessments.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agre

6.1.2 It is essential to address privacy and security risks associated with digital measurement systems in risk assessment processes.

☒ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

6.2 Subjective Norms towards privacy and security within Scientific and Legal Metrology

Please indicate your level of agreement with the following statements:

6.2.1 I perceive social pressure from peers, colleagues, or organizations to prioritize privacy and security risks in the evaluation of digital measurement systems.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

6.2.2 It is commonly expected by my peers, colleagues, or organization to consider privacy and security risks in risk assessment processes related to digital measurement systems.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

6.2.3 I feel encouraged by my peers, colleagues, or organization to conduct effective risk assessments that address privacy and security risks associated with digital measurement systems.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

6.3 Perceived Behavioral Control towards privacy and security within Scientific and Legal Metrology

Please indicate your level of agreement with the following statements:

6.3.1 I feel confident in my ability to assess and mitigate privacy and security risks associated with digital measurement systems.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

6.3.2 I have access to the necessary resources (e.g., knowledge, tools, support) to effectively address privacy and security risks in risk assessments related to digital measurement systems.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

6.3.3 I believe that I have control over conducting effective risk assessments that adequately consider privacy and security risks associated with digital measurement systems.

☒ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

6.4 Effective Risk Assessment Practices within Scientific and Legal Metrology

Please respond to the following statements by selecting the most appropriate option:

6.4.1 How frequently do you conduct risk assessments that address privacy and security risks associated with digital measurement systems?

☐Rarely or never ☐Occasionally ☐Sometimes ☐Often ☐Always

6.4.2 To what extent do you use recommended risk assessment practices that include privacy and security considerations for digital measurement systems?

☐Not at all ☐To a small extent ☐To a moderate extent ☐ To a large extent ☐To a very large extent

ANNEXURE B1: QUANTITATIVE RESEARCH INSTRUMENT CONSENT FORM

WITS MBA Research Consent Form

Title of project: Factors influencing the approach to risk assessment in Scientific and Legal metrology in South Africa
Name of researcher: Tshifhiwa Elmon Madiba

I, …………………………………….., agree to participate in this research project.

I agree to the following:

(Please circle the relevant options below)

The research study was explained to me. I understand what this study is about.	YES	NO
I understand that I can volunteer to take part in the study	YES	NO
I agree that my participation will remain anonymous (my name or other identifying data will not be used by the researcher in their research report/manuscript/book chapter)	YES	NO
I agree that other researchers may use the information I provide in my interview/focus group/other activity (depending on their own ethics clearance being obtained) but my name and any personal information will not be used or passed on	YES	NO

Researcher information

Signature ______________________________

Name _________________________________

Date __________________________________

ANNEXURE C: GATEKEEPERS PERMISSION LETTERS

5. Verification and Signature

Parties	Signature	Position	Date
Prepared by: T. Madiba		Manager: Legal Metrology	23/05/2023
	Comments:		
Recommended / ~~not recommended~~ by: T. Modiba		aGM: Legal Metrology	2023-05-24
	Comments: Personnel of the Legal Metrology Free State operations should also be considered when conducting surveys and interviews where required		
Recommended / not recommended by: S. Makhoba		Specialist: HCM	2023-05-24
	Comments: Ensuring that NRCS information is upheld with confidentiality and participants consent to participate		
Recommended / not recommended by: C. Skosana		Snr. Manager : HCM	25/05/23
	Comments: Research ethics must be up		
Approved/ not approved by E. Mamadise		CEO	26/05/23
	Comments:		

ANNEXURE D: ETHICS CLEARANCE LETTER

Graduate School of Business Administration
University of the Witwatersrand, Johannesburg

Wits Business School

Wits Business School Ethics Committee
Constituted under the University Human Research Ethics Committee (Non-Medical)

Ethics Clearance Certificate

Ethics protocol number: WBS/BA2452961/370

This certificate is only valid with a legitimate ethics protocol number and signed by the Researcher (below).

Project title	Factors influencing the approach to risk assessment in scientific and legal metrology in South Africa
Investigator / Researcher	Mr Tshifhiwa Madiba
Nature of Project	MBA (Research Article)
Decision of the Committee	Approved, provided stakeholders and participants are guaranteed confidentiality.
Issue Date of Certificate	2023/10/05
Expiry date	Date of submission of the project / research report
Chairperson	Dr Pius Oba +27 11 717 3976 +27 82 733 6587 pius.oba@wits.ac.za

Declaration by Researcher

One copy must be signed by the Researcher and returned to the Chairperson of the Wits Business School Ethics Committee.

I fully understand the conditions under which I am authorized to carry out the abovementioned research and I guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I undertake to resubmit the protocol to the Committee.

Signature: Madiba

Date: 05/10/2023

ANNEXURE E: PROPOSAL APPROVAL LETTER

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Private Bag 3 Wits, 2050
Fax:
Tel:

Reference: Ms Jennifer Mgolodela
E-mail: jennifer.mgolodela@wits.ac.za

08 October 2023
Person No: 2452961
PAG

Mr TE Madiba
10762
Intambula Street
Nellmapius
0122
South Africa

Dear Mr Tshifhiwa Madiba

Master of Business Administration: Approval of Title

We have pleasure in advising that your proposal entitled *Factors influencing the approach to risk assessment in scientific and legal metrology in South Africa* has been approved. Please note that any amendments to this title have to be endorsed by the Faculty's higher degrees committee and formally approved.

Yours sincerely

Mrs Marike Bosman
Faculty Registrar
Faculty of Commerce, Law and Management